

UNIT IV

NATURAL HAZARDS AND DISASTERS: CAUSES, CONSEQUENCES AND MANAGEMENT

This unit deals with

- *Floods and droughts*
- *Earthquakes and tsunami*
- *Cyclones*
- *Landslides*

NATURAL HAZARDS AND DISASTERS

You might have read about tsunami or seen the images of horror on television set immediately after it happened. You may also be aware of the severe earthquake in Kashmir on both sides of the Line of Control (LOC). The damage caused to human life and properties during these episodes has moved us all. What are these as phenomena and how they are caused? How can we save ourselves? These are some questions which come to our minds. This chapter will attempt to analyse some of these questions.

Change is the law of nature. It is a continuous process that goes on uninterruptedly involving phenomena, big and small, material and non-material that make our physical and socio-cultural environment. It is a process present everywhere with variations in terms of magnitude, intensity and scale. Change can be a gradual or slow process like the evolution of landforms and organisms and it can be as sudden and swift as volcanic eruptions, tsunamis, earthquakes and lightening, etc. Similarly, it may remain confined to a smaller area occurring within a few seconds like hailstorms, tornadoes and dust storms, and it can also have global dimensions such as global warming and depletion of the ozone layer.

Besides these, changes have different meanings for different people. It depends upon the perspective one takes while trying to understand them. From the perspective of nature, changes are value-neutral (these are neither good nor bad). But from the human perspective, these are value-loaded. There are some changes that are desirable and good like

the change of seasons, ripening of fruits, while there are others like earthquakes, floods and wars that are considered bad and undesirable.

Observe the environment you live in and prepare a list of changes, which take place over a long period of time and those, which take place within a short period of time. Do you know why some changes are considered good and others bad? Prepare a list of changes, which you notice in your daily life and give reasons why some of these are considered good and others bad.

In this chapter, we will read about some of these changes, which are considered bad and have haunted humankind for a long time.

Disasters in general and natural disasters in particular, are some such changes that are always disliked and feared by humankind.

What is a Disaster?

“Disaster is an undesirable occurrence resulting from forces that are largely outside human control, strikes quickly with little or no warning, which causes or threatens serious disruption of life and property including death and injury to a large number of people, and requires therefore, mobilisation of efforts in excess of that which are normally provided by statutory emergency services”.

For a long time, geographical literature viewed disasters as a consequence of natural forces; and human beings were treated as innocent and helpless victims in front of the mighty forces of nature. But natural forces are

not the only causes of disasters. Disasters are also caused by some human activities. There are some activities carried by human beings that are directly responsible for disasters. Bhopal Gas tragedy, Chernobyl nuclear disaster, wars, release of CFCs (Chlorofluorocarbons) and increase of green house gases, environmental pollutions like noise, air, water and soil are some of the disasters which are caused directly by human actions. There are some other activities of human beings that accelerate or intensify disasters indirectly. Landslides and floods due to deforestation, unscientific land use and construction activities in fragile areas are some of the disasters that are the results of indirect human actions. Can you identify some other human activities going on in and around your neighbourhood and schools that can lead to disasters in the near future? Can you suggest some measures to prevent it? It is a common experience that human-made disasters have increased both in their numbers and magnitudes over the years and concerted efforts are on at various levels to prevent and minimise their occurrences. Though the success has been only nominal so far, it is possible to prevent some of these disasters created by human actions. As opposed to this, very little is possible to prevent natural disasters; therefore, the best way out is to emphasise on natural disaster mitigation and management. Establishment of National Institute of Disaster Management, India, Earth Summit at Rio de Janeiro, Brazil, 1992 and the World Conference on Disaster Management in May 1994 at Yokohama, Japan, etc. are some of the concrete steps towards this direction initiated at different levels.

Most often it is observed that scholars use disasters and natural hazards as interchangeable. Both are related phenomena, yet quite distinct from each other. Hence, it is necessary to distinguish between the two.

Natural Hazards are elements of circumstances in the Natural environment that have the potential to cause harm to people or property or both. These may be swift or permanent aspects of the respective environmental settings like currents in the oceans, steep slope and unstable structural

features in the Himalayas or extreme climatic conditions in deserts or glaciated areas.

As compared to natural hazards, *natural disasters are relatively sudden and cause large scale, widespread death, loss of property and disturbance to social systems and life over which people have a little or no control.* Thus, any event can be classed as disaster when the magnitude of destruction and damage caused by it is very high.

Generally, disasters are generalised experiences of people the world over, and no two disasters are similar and comparable to each other. Every disaster is unique in terms of the local socio-environmental factors that control it, the social response it generates, and the way each social group negotiates with it. However, the opinion mentioned above is indicative of three important things. Firstly, the magnitude, intensity, frequency and damages caused by natural disasters have increased over the years. Secondly, there is a growing concern among people the world over to deal with the menace created by these so that the loss of human life and property can be minimised. And finally, significant changes have taken place in the pattern of natural disasters over the years.

There has also been a change in the perception of natural disasters and hazards. Previously, hazards and disasters were seen as two closely associated and interrelated phenomena, i.e. areas prone to natural hazards, were more vulnerable to disasters. Hence, people avoided tampering with the delicate balance that existed in a given ecosystem. People avoided intensification of their activities in such areas and that is how disasters were less damaging. Technological power has given large capacity to human intervention in nature. Consequently, now, human beings tend to intensify their activities into disaster prone areas increasing their vulnerability to disasters. Colonisation of flood plains of most of the rivers and development of large cities and port-towns like – Mumbai and Chennai along the coast, and touching the shore due to high land values, make them vulnerable to the occurrence of cyclones, hurricanes and tsunamis.

These observations can also be corroborated by the data given in Table 7.1 showing the magnitude of deaths caused by twelve serious natural disasters in the past sixty years in different countries of the world.

It is evident from the table that natural disasters have caused widespread loss of life and property. Conceted efforts are on at various levels to take appropriate measures to deal with the situation. It is also being felt that the damages caused by natural disasters have global repercussions that are beyond the means and capabilities of individual nation-states to cope up with. Hence, this issue was raised at the U.N. General Assembly in 1989 and it was finally formalised at the *World Conference on Disaster Management* in May 1994 at Yokohama, Japan. This was subsequently called the *Yokohama Strategy and Plan of Action for a Safer World*.

CLASSIFICATION OF NATURAL DISASTERS

Human beings the world over have experienced disasters and have faced and lived with them. Now people are becoming aware and various steps have been initiated at different levels for mitigating the effects of disasters. Identification and classification of disasters is being considered as an effective and scientific step to deal promptly and efficiently with the disasters. Broadly, natural disasters can be classified under four categories (See Table 7.2).

India is one of those countries which has experienced most of the natural disasters mentioned in Table 7.2. Every year it loses thousands of lives and property worth millions of rupees due to these natural calamities. In the following section, some of

Table 7.1 : Top Twelve Natural Disasters Since 1948

Year	Location	Type	Deaths
1948	The Soviet Union (now Russia)	Earthquakes	110,000
1949	China	Floods	57,000
1954	China	Floods	30,000
1965	East Pakistan (now Bangladesh)	Tropical Cyclones	36,000
1968	Iran	Earthquakes	30,000
1970	Peru	Earthquakes	66,794
1970	East Pakistan (now Bangladesh)	Tropical Cyclones	500,000
1971	India	Tropical Cyclones	30,000
1976	China	Earthquakes	700,000
1990	Iran	Earthquakes	50,000
2004	Indonesia, Sri Lanka, India, etc.	Tsunamis	500,000*
2005	Pakistan, India	Earthquakes	70,000*

Source : United Nations Environmental Programme (UNEP), 1991

*News Report from National Institute for Disaster Management, Government of India, New Delhi

Table 7.2 : Classification of Natural Disasters

Atmospheric	Terrestrial	Aquatic	Biological
Blizzards	Earthquakes	Floods	Plants and Animals as colonisers (Locusts, etc.).
Thunderstorms	Volcanic Eruptions	Tidal Waves	Insects infestation— fungal, bacterial and viral diseases such as bird flu, dengue, etc.
Lightning	Landslides	Ocean Currents	
Tornadoes	Avalanches	Storm Surge	
Tropical Cyclone	Subsidence	Tsunami	
Drought	Soil Erosion		
Hailstorm			
Frost, Heat Wave or Loo.Cold Waves, etc.			

Yokohama Strategy and International Decade for Natural Disaster Reduction (IDNDR)
Yokohama Strategy and Plan of Action for a Safer World

All the member states of the United Nations and other states met at the **World Conference on Natural Disaster Reduction** in the city of Yokohama from May 23rd-27th 1994. It acknowledged that the impact of natural disasters in terms of human and economic losses has risen in recent years, and society, in general, has become vulnerable to natural disasters. It also accepted that these disasters affected the poor and disadvantaged groups the worst, particularly in the developing countries, which are ill-equipped to cope with them. Hence, the conference adopted the Yokohama strategy as a guide to rest of the decade and beyond, to mitigate the losses due to these disasters.

The resolution of the World Conference on Natural Disasters Reduction is as mentioned below:

- (i) It will note that each country has the sovereign responsibility to protect its citizens from natural disasters;
- (ii) It will give priority attention to the developing countries, particularly the least developed, land-locked countries and small-island developing states;
- (iii) It will develop and strengthen national capacities and capabilities and, where appropriate, national legislation for natural and other disaster prevention, mitigation and preparedness, including the mobilisation of non-governmental organisations and participation of local communities;
- (iv) It will promote and strengthen sub-regional, regional and international cooperation in activities to prevent, reduce and mitigate natural and other disasters, with particular emphasis on:
 - (a) human and institutional capacity-building and strengthening;
 - (b) technology sharing: the collection, the dissemination and utilisation of information; and
 - (c) mobilisation of resources.

It also declared the decade 1990-2000 as the *International Decade for Natural Disaster Reduction (IDNDR)*.

the highly devastating natural disasters have been discussed, particularly in the context of India.

NATURAL DISASTERS AND HAZARDS IN INDIA

It was discussed in one of the previous chapters that India is vast and diverse in terms of its physical and socio-cultural attributes. It is largely due to its vast geographical area, environmental diversities and cultural pluralities that scholars often described it using two meaningful adjectives like the 'Indian-subcontinent' and the 'land of unity in diversity'. Its vastness in terms of natural attributes combined with its prolonged colonial past, continuing various forms of social discriminations and also equally large population have enhanced its vulnerability to natural disasters. These observations can also be illustrated by focussing on some of the major natural disasters in India.

Earthquakes

Earthquakes are by far the most unpredictable and highly destructive of all the natural disasters. You have already learnt the causes

of earthquakes in your book *Fundamentals of Physical Geography* (NCERT, 2006). Earthquakes that are of tectonic origin have proved to be the most devastating and their area of influence is also quite large. These earthquakes result from a series of earth movements brought about by a sudden release of energy during the tectonic activities in the earth's crust. As compared to these, the earthquakes associated with volcanic eruption, rock fall, landslides, subsidence, particularly in the mining areas, impounding of dams and reservoirs, etc. have limited area of influence and the scale of damage.

It was mentioned in Chapter 2 of the book that the Indian plate is moving at a speed of one centimetre per year towards the north and northeastern direction and this movement of plates is being constantly obstructed by the Eurasian plate from the north. As a result of this, both the plates are said to be locked with each other resulting in accumulation of energy at different points of time. Excessive accumulation of energy results in building up of stress, which ultimately leads to the breaking up of the lock and the sudden release of energy causes

earthquakes along the Himalayan arch. Some of the most vulnerable states are Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and the Darjiling and subdivision of West Bengal and all the seven states of the northeast.



Figure 7.1 : A Damaged Building Due to an Earthquake

Apart from these regions, the central-western parts of India, particularly Gujarat (in 1819, 1956 and 2001) and Maharashtra (in 1967 and 1993) have also experienced some severe earthquakes. Earth scientists have found it difficult to explain the occurrence of earthquakes in one of the oldest, most stable and mature landmass of Peninsular block for a long time. Recently, some earth scientists have come up with a theory of emergence of a fault line and energy build-up along the fault line represented by the river Bhima (Krishna) near Latur and Osmanabad (Maharashtra) and the possible breaking down of the Indian plate (Figure 7.2).

National Geophysical Laboratory, Geological Survey of India, Department of Meteorology, Government of India, along with the recently formed *National Institute of Disaster Management*, have made an intensive analysis of more than 1,200 earthquakes that have occurred in India in different years in the past, and based on these, they divided India into the following five earthquake zones:

- (i) Very high damage risk zone
- (ii) High damage risk zone
- (iii) Moderate damage risk zone
- (iv) Low damage risk zone
- (v) Very low damage risk zone.

Out of these, the first two zones had experienced some of the most devastating earthquakes in India. As shown in the Figure 7.2,

areas vulnerable to these earthquakes are the North-east states, areas to the north of Darbhanga and Araria along the Indo-Nepal border in Bihar, Uttarakhand, Western Himachal Pradesh (around Dharamshala) and Kashmir Valley in the Himalayan region and the Kuchchh (Gujarat). These are included in the Very High Damage Risk Zone. Similarly, the remaining parts of Jammu and Kashmir, Himachal Pradesh, Northern parts of Punjab, Eastern parts of Haryana, Delhi, Western Uttar Pradesh, and Northern Bihar fall under the High Damage Risk Zone. Remaining parts of the country fall under moderate to very Low Damage Risk Zone. Most of the areas that can be considered safe are from the stable landmass covered under the Deccan plateau.

Socio-Environmental Consequences of Earthquakes

The idea of an earthquake is often associated with fear and horror due to the scale, magnitude and suddenness at which it spreads disasters on the surface of the earth without discrimination. It becomes a calamity when it strikes the areas of high density of population. It not only damages and destroys the settlements, infrastructure, transport and communication network, industries and other developmental activities but also robs the population of their material and socio-cultural gains that they have preserved over generations. It renders them homeless, which puts an extra-pressure and stress, particularly on the weak economy of the developing countries.

Effects of Earthquakes

Earthquakes have all encompassing disastrous effects on the area of their occurrence. Some of the important ones are listed in Table 7.3.

Table 7.3 : Effects of Earthquakes		
<i>On Ground</i>	<i>On Manmade Structures</i>	<i>On Water</i>
Fissures Settlements	Cracking Slidings	Waves Hydro-Dynamic Pressure Tsunami
Landslides Liquefaction Earth Pressure Possible Chain-effects	Overturning Buckling Collapse	Possible Chain-effects

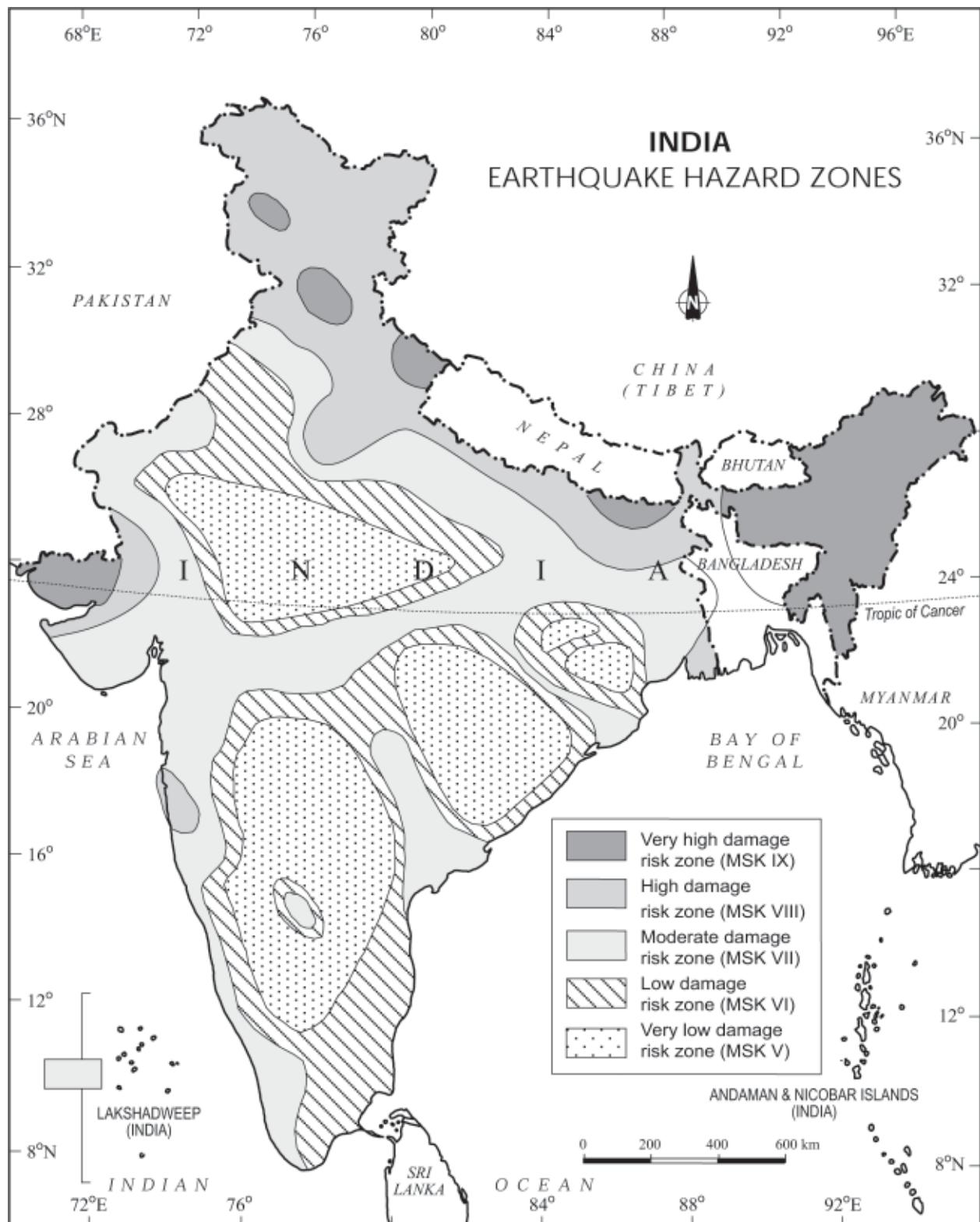


Figure 7.2 : India: Earthquake Hazard Zones

Apart from these, earthquakes also have some serious and far-reaching environmental consequences. Surface seismic waves produce fissures on the upper layers of the earth's crust through which water and other volatile materials gush out, inundating the neighbouring areas. Earthquakes are also responsible for landslides and often these cause obstructions in the flow of rivers and channels resulting in the formation of reservoirs. Sometimes, rivers also change their course causing floods and other calamities in the affected areas.

Earthquake Hazard Mitigation

Unlike other disasters, the damages caused by earthquakes are more devastating. Since it also destroys most of the transport and communication links, providing timely relief to the victims becomes difficult. It is not possible to prevent the occurrence of an earthquake; hence, the next best option is to emphasis on disaster preparedness and mitigation rather than curative measures such as:

- (i) Establishing earthquake monitoring centres (seismological centres) for regular monitoring and fast dissemination of information among the people in the vulnerable areas. Use of Geographical Positioning System (GPS) can be of great help in monitoring the movement of tectonic plates.
- (ii) Preparing a vulnerability map of the country and dissemination of vulnerability risk information among the people and educating them about the ways and means minimising the adverse impacts of disasters.
- (iii) Modifying the house types and building designs in the vulnerable areas and discouraging construction of high-rise buildings, large industrial establishments and big urban centres in such areas.
- (iv) Finally, making it mandatory to adopt earthquake-resistant designs and use light materials in major construction activities in the vulnerable areas.

Tsunami

Earthquakes and volcanic eruptions that cause the sea-floor to move abruptly resulting in sudden displacement of ocean water in the form of high vertical waves are called *tsunamis* (harbour waves) or seismic sea waves. Normally, the seismic waves cause only one instantaneous vertical wave; but, after the initial disturbance, a series of afterwaves are created in the water that oscillate between high crest and low trough in order to restore the water level.

The speed of wave in the ocean depends upon the depth of water. It is more in the shallow water than in the ocean deep. As a result of this, the impact of *tsunami* is less over the ocean and more near the coast where they cause large-scale devastations. Therefore, a ship at sea is not much affected by *tsunami* and it is difficult to detect a *tsunami* in the deeper parts of sea. It is so because over deep water the *tsunami* has very long wave-length and limited wave-height. Thus, a *tsunami* wave raises the ship only a metre or two and each rise and fall takes several minutes. As opposed to this, when a *tsunami* enters shallow water, its wave-length gets reduced and the period remains unchanged, which increases the wave-height. Sometimes, this height can be up to 15m or more, which causes large-scale destructions along the shores. Thus, these are also called *Shallow Water Waves*. *Tsunamis* are frequently observed along the Pacific ring of fire, particularly along the coast of Alaska, Japan, Philippines, and other islands of South-east Asia, Indonesia, Malaysia, Myanmar, Sri Lanka, and India etc.

After reaching the coast, the *tsunami* waves release enormous energy stored in them and water flows turbulently onto the land destroying port-cities and towns, structures, buildings and other settlements. Since the coastal areas are densely populated the world over, and these are also centres of intense human activity, the loss of life and property is likely to be much higher by a *tsunami* as compared to other natural hazards in the coastal areas. The extent of devastation caused by *tsunami* can be assessed through the

visuals on Banda Ache (Indonesia) presented in the book *Practical Work in Geography - Part I* (NCERT, 2006).

Unlike other natural hazards, the mitigation of hazards created by tsunami is difficult, mainly because of the fact that losses are on a much larger scale.



Figure 7.3 : Tsunami Affected Area

It is beyond the capacity of individual state or government to mitigate the damage. Hence, combined efforts at the international levels are the possible ways of dealing with these disasters as has been in the case of the tsunami that occurred on 26th December 2004 in which more than 300,000 people lost their lives. India has volunteered to join the *International Tsunami Warning System* after the December 2004 tsunami disaster.

Tropical Cyclone

Tropical cyclones are intense low-pressure areas confined to the area lying between 30° N and 30° S latitudes, in the atmosphere around which high velocity winds blow. Horizontally, it extends up to 500-1,000 km and vertically from surface to 12-14 km. A tropical cyclone or hurricane is like a heat engine that is energised by the release of latent heat on account of the condensation of moisture that the wind gathers after moving over the oceans and seas.

There are differences of opinion among scientists about the exact mechanism of a tropical cyclone. However, some initial conditions for the emergence of a tropical cyclone are:

- (i) Large and continuous supply of warm and moist air that can release enormous latent heat.
- (ii) Strong Coriolis force that can prevent filling of low pressure at the centre (absence of Coriolis force near the equator prohibits the formation of tropical cyclone between 0° - 5° latitude).
- (iii) Unstable condition through the troposphere that creates local disturbances around which a cyclone develops.
- (iv) Finally, absence of strong vertical wind wedge, which disturbs the vertical transport of latent heat.

Structure of Tropical Cyclone

Tropical cyclones are characterised by large pressure gradients. The centre of the cyclone is mostly a warm and low-pressure, cloudless core known as *eye of the storm*. Generally, the isobars are closely placed to each other showing high-pressure gradients. Normally, it varies between 14-17mb/100 km, but sometimes it can be as high as 60mb/100km. Expansion of the wind belt is about 10-150 km from the centre.

Spatio-temporal Distribution of Tropical Cyclone in India

Owing to its Peninsular shape surrounded by the Bay of Bengal in the east and the Arabian Sea in the west, the tropical cyclones in India also originate in these two important locations. Though most of the cyclones originate between 10° - 15° north latitudes during the monsoon season, yet in case of the Bay of Bengal, cyclones mostly develop during the months of October and November. Here, they originate between 16° - 2° N latitudes and to the west of 92° E. By July the place of origin of these storms shifts to around 18° N latitude and west of 90° E near the Sunderban Delta. Table 7.4 and Figure 7.4 show the frequency and tracks of time of cyclonic storms in India.

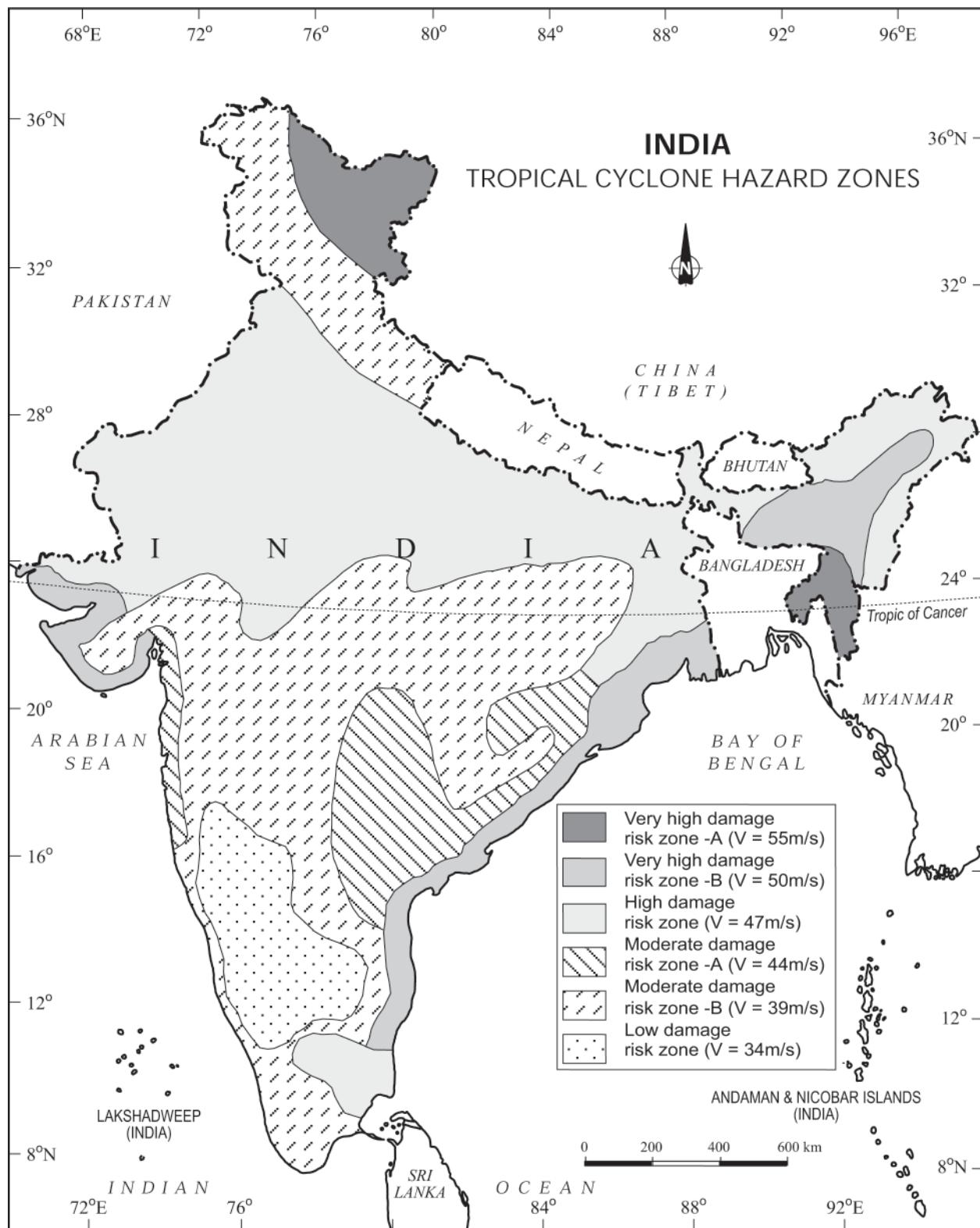


Figure 7.4 : Tropical Cyclone Hazard Zones

Months	<i>Bay of Bengal Sea</i>	<i>Arabian</i>
January	4 (1.3) *	2 (2.4)
February	1 (0.3)	0 (0.0)
March	4 (1.30)	0 (0.0)
April	18 (5.7)	5 (6.1)
May	28 (8.9)	13 (15.9)
June	34 (10.8)	13 (15.9)
July	38 (12.1)	3 (3.7)
August	25 (8.0)	1 (1.2)
September	27 (8.6)	4 (4.8)
October	53 (16.9)	17 (20.7)
November	56 (17.8)	21 (25.6)
December	26 (8.3)	3 (3.7)
Total	314 (100)	82 (100)

*Data in the brackets are in percentage to total number of storms taking place in a year

Consequences of Tropical Cyclones

It was mentioned that the energy to the tropical cyclone comes from the latent heat released by the warm moist air. Hence, with the increase in distance from the sea, the force of the cyclone decreases. In India, the force of the cyclone decreases with increase in distance from the Bay of Bengal and the Arabian Sea. So, the coastal areas are often struck by severe cyclonic storms with an average velocity of 180 km/h. Often, this results in abnormal rise in the sea level known as *Storm Surge*.

A surge is generated due to interaction of air, sea and land. The cyclone provides the driving force in the form of very high horizontal pressure-gradient and very strong surface winds. The sea water flows across the coast along with strong winds and heavy downpour.

This results in inundation of human settlements, agricultural fields, damaging crops and destruction of structures created by human beings.

Floods

You read in newspapers and watch images of floods on televisions occurring in some regions during rainy seasons. Inundation of land and human settlements by the rise of water in the channels and its spill-over presents the condition of flooding. Unlike other natural

disasters, the causes of floods are well-established. Floods are relatively slow in occurrences and often, occur in well-identified regions and within expected time in a year. Floods occur commonly when water in the form of surface run-off exceeds the carrying capacity of the river channels and streams and flows into the neighbouring low-lying flood plains. At times, this even goes beyond the capacity of lakes and other inland water bodies in which they flow. Floods can also be caused due to a storm surge (in the coastal areas), high intensity rainfall for a considerably longer time period, melting of ice and snow, reduction in the infiltration rate and presence of eroded material in the water due to higher rate of soil erosion. Though floods occur frequently over wide geographical area having disastrous ramifications in many parts of the world, floods in the South, Southeast and East Asian countries, particularly in China, India and Bangladesh, are frequent and equally disastrous.

Once again, unlike other natural disasters, human beings play an important role in the genesis as well as spread of floods. Indiscriminate deforestation, unscientific agricultural practices, disturbances along the natural drainage channels and colonisation of flood-plains and river-beds are some of the human activities that play an important role in increasing the intensity, magnitude and gravity of floods.



Figure 7.5 : Brahmaputra During Flood

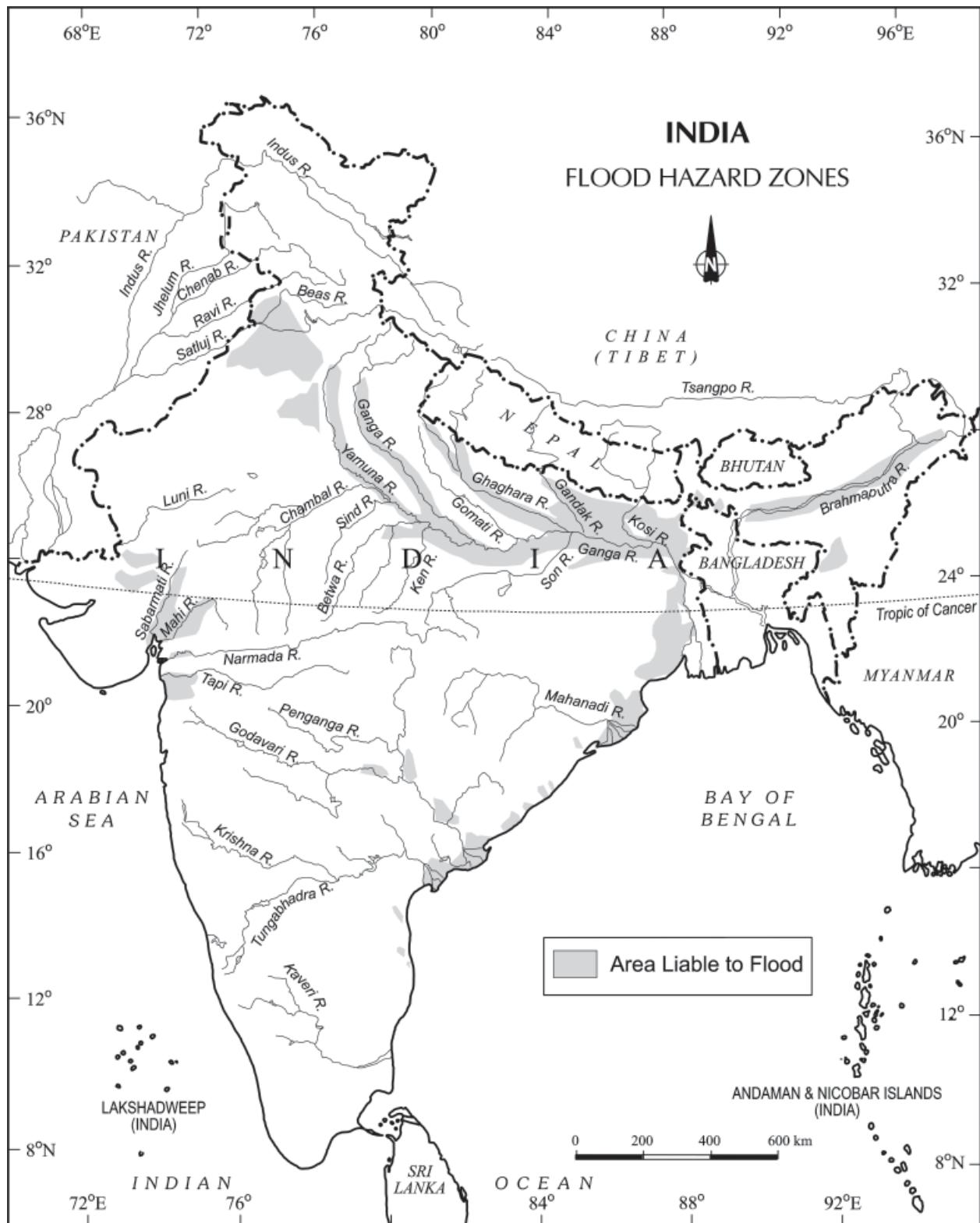


Figure 7.6 : Flood Hazard Zones

Various states of India face heavy loss of lives and property due to recurrent floods. *Rashtriya Barh Ayog* (National Flood Commission) identified 40 million hectares of land as flood-prone in India. The Figure 7.6 shows the flood-affected areas in India. Assam, West Bengal and Bihar are among the high flood-prone states of India. Apart from these, most of the rivers in the northern states like Punjab and Uttar Pradesh, are also vulnerable to occasional floods. It has been noticed that states like Rajasthan, Gujarat, Haryana and Punjab are also getting inundated in recent decades due to flash floods. This is partly because of the pattern of the monsoon and partly because of blocking of most of the streams and river channels by human activities. Sometimes, Tamil Nadu experiences flooding during November-January due to the retreating monsoon.

Consequence and Control of Floods

Frequent inundation of agricultural land and human settlement, particularly in Assam, West Bengal, Bihar and Eastern Uttar Pradesh (flooding rivers), coastal areas of Orissa, Andhra Pradesh, Tamil Nadu and Gujarat (cyclone) and Punjab, Rajasthan, Northern Gujarat and Haryana (flash floods) have serious consequences on the national economy and society. Floods do not only destroy valuable crops every year but these also damage physical infrastructure such as roads, rails, bridges and human settlements. Millions of people are rendered homeless and are also washed down along with their cattle in the floods. Spread of diseases like cholera, gastro-enteritis, hepatitis and other water-borne diseases spread in the flood-affected areas. However, floods also make a few positive contributions. Every year, floods deposit fertile silt over agricultural fields which is good for the crops. Majuli (Assam), the largest riverine island in the world, is the best example of good paddy crops after the annual floods in Brahmaputra. But these are insignificant benefits in comparison to the grave losses.

The Government of India as well as the state governments are well aware of the menace created by floods every year. How do these

governments generally respond to the floods? Construction of flood protection embankments in the flood-prone areas, construction of dams, afforestation and discouraging major construction activities in the upper reaches of most of the flood-creating rivers, etc. are some steps that need to be taken up on urgent basis. Removal of human encroachment from the river channels and depopulating the flood plains can be the other steps. This is particularly true in western and northern parts of the country which experience *flash-floods*. Cyclone centres may provide relief in coastal areas which are hit by a storm surge.

Droughts

The term 'drought' is applied to an extended period when there is a shortage of water availability due to inadequate precipitation, excessive rate of evaporation and over-utilisation of water from the reservoirs and other storages, including the ground water.

Drought is a complex phenomenon as it involves elements of meteorology like precipitation, evaporation, evapotranspiration, ground water, soil moisture, storage and surface run-off, agricultural practices, particularly the types of crops grown, socio-economic practices and ecological conditions.

Types of Droughts

Meteorological Drought : It is a situation when there is a prolonged period of inadequate rainfall marked with mal-distribution of the same over time and space.

Agricultural Drought : It is also known as soil moisture drought, characterised by low soil moisture that is necessary to support the crops, thereby resulting in crop failures. Moreover, if an area has more than 30 per cent of its gross cropped area under irrigation, the area is excluded from the drought-prone category.

Hydrological Drought : It results when the availability of water in different storages and reservoirs like aquifers, lakes, reservoirs, etc. falls below what the precipitation can replenish.

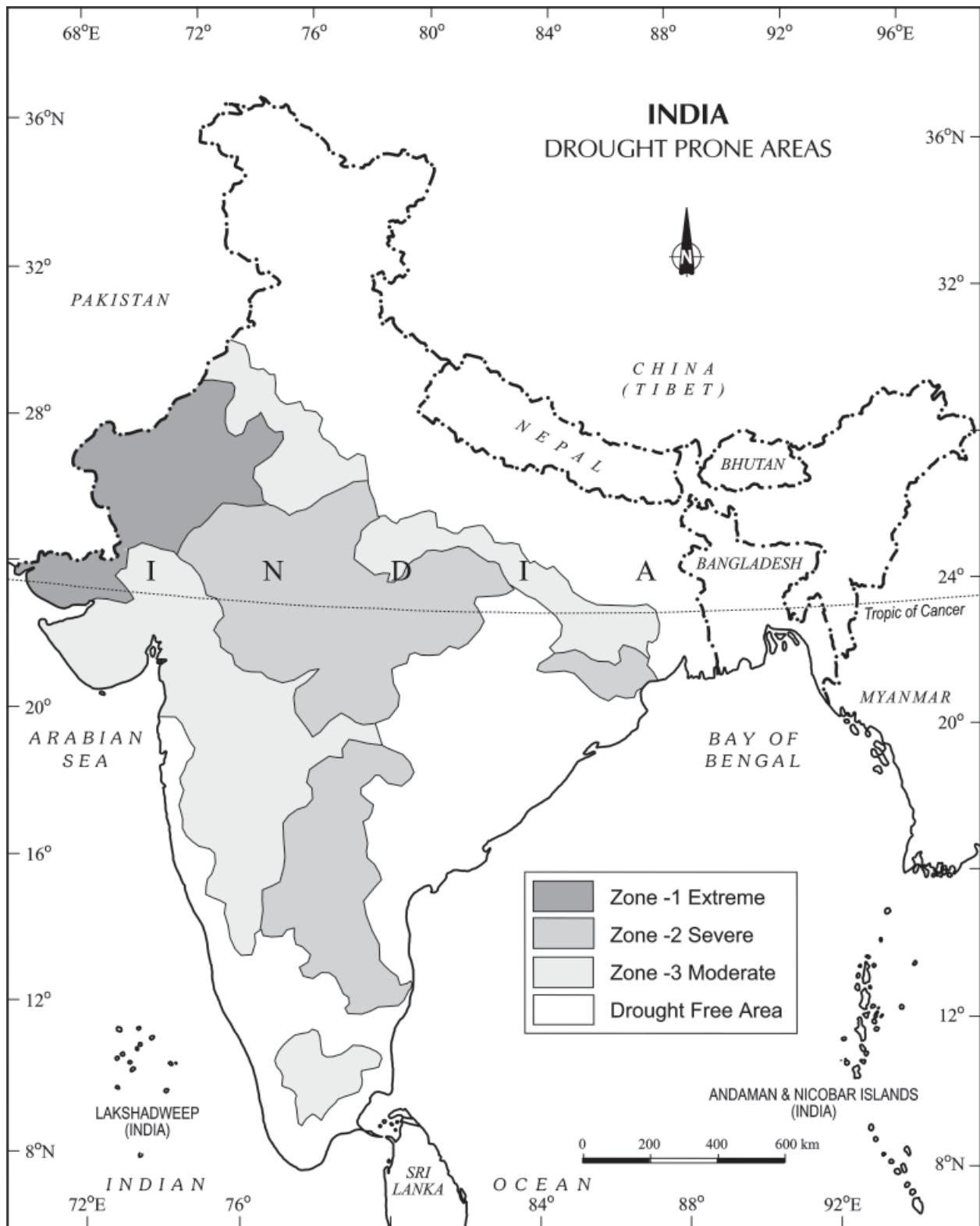
**Figure 7.8 : Drought Prone Areas**



Figure 7.7 : Drought

Ecological Drought : When the productivity of a natural ecosystem fails due to shortage of water and as a consequence of ecological distress, damages are induced in the ecosystem.

Various parts of India experience these droughts recurrently which result in some serious socio-economic and ecological problems.

Drought Prone Areas in India

Indian agriculture has been heavily dependent on the monsoon rainfall. Droughts and floods are the two accompanying features of Indian climate. According to some estimates, nearly 19 per cent of the total geographical area of the country and 12 per cent of its total population suffer due to drought every year. About 30 per cent of the country's total area is identified as drought prone affecting around 50 million people. It is a common experience that while some parts of the country reel under floods, there are regions that face severe drought during the same period. Moreover, it is also a common sight to witness that one region suffers due to floods in one season and experiences drought in the other. This is mainly because of the large-scale variations and unpredictability in the behaviour of the monsoon in India. Thus, droughts are widespread and common phenomena in most parts of the country, but these are most recurrent and severe in some and not so in others. On the basis of severity of droughts, India can be divided into the following regions:

Extreme Drought Affected Areas : It is evident from the Figure 7.8 that most parts of Rajasthan, particularly areas to the west of the Aravali hills, i.e. Marusthal and Kachchh regions of Gujarat fall in this category. Included here are also the districts like Jaisalmer and Barmer from the Indian desert that receive less than 90 mm average annual rainfall.

Severe Drought Prone Area : Parts of eastern Rajasthan, most parts of Madhya Pradesh, eastern parts of Maharashtra, interior parts of Andhra Pradesh and Karnataka Plateau, northern parts of interior Tamil Nadu and southern parts of Jharkhand and interior Orissa are included in this category.

Moderate Drought Affected Area : Northern parts of Rajasthan, Haryana, southern districts of Uttar Pradesh, the remaining parts of Gujarat, Maharashtra except Konkan, Jharkhand and Coimbatore plateau of Tamil Nadu and interior Karnataka are included in this category. The remaining parts of India can be considered either free or less prone to the drought.

Consequences of Drought

Droughts have cascading effects on various other aspects of environment and society. Crop failure leading to scarcity of food grains (*akal*), fodder (*trinkal*), inadequate rainfall, resulting in shortage of water (*jalkal*), and often shortage in all the three (*trikal*) is most devastating. Large-scale death of cattle and other animals, migration of humans and livestock are the most common sight to be seen in the drought-affected areas. Scarcity of water compels people to consume contaminated water resulting in spread of many waterborne diseases like gastro-enteritis, cholera, hepatitis, etc.

Droughts have both immediate as well as long-term disastrous consequences on the social and physical environments. Consequently, planning for drought has to take both aspects into consideration. Provision for the distribution of safe drinking water, medicines for the victims and availability of fodder and water for the cattle and shifting of the people and their livestock

to safer places, etc. are some steps that need to be taken immediately. Identification of ground water potential in the form of aquifers, transfer of river water from the surplus to the deficit areas, and particularly planning for inter-linking of rivers and construction of reservoirs and dams, etc. should be given a serious thought. Remote sensing and satellite imageries can be useful in identifying the possible river-basins that can be inter-linked and in identifying the ground water potential.

Dissemination of knowledge about drought-resistant crops and proper training to practise the same can be some of the long-term measures that will be helpful in drought-mitigation. Rainwater harvesting can also be an effective method in minimising the effects of drought.

Observe the methods adopted for roof-top rainwater harvesting in your locality and suggest measures to make it more effective.

Landslides

Have you ever read about the blocking of roads to Srinagar or disruption of rail services by stones falling on the Konkan Railway track? It happens due to landslide, which is the rapid sliding of large mass of bedrocks. Disasters due to landslides, are in general, far less dramatic than due to earthquakes, volcanic eruptions, tsunamis and cyclones but their impact on the natural environment and national economy is in no way less severe. Unlike other disasters that are sudden, unpredictable and are largely controlled by macro or regional factors, landslides are largely controlled by highly localised factors. Hence, gathering information and monitoring the possibilities of landslide is not only difficult but also immensely cost-intensive.

It is always difficult to define in a precise statement and generalise the occurrence and behaviour of a landslide. However, on the basis of past experiences, frequency and certain causal relationships with the controlling factors like geology, geomorphic agents, slope, land-use, vegetation cover and

human activities, India has been divided into a number of zones.

Landslide Vulnerability Zones

Very High Vulnerability Zone : Highly unstable, relatively young mountainous areas in the Himalayas and Andaman and Nicobar, high rainfall regions with steep slopes in the Western Ghats and Nilgiris, the north-eastern regions, along with areas that experience frequent ground-shaking due to earthquakes, etc. and areas of intense human activities, particularly those related to construction of roads, dams, etc. are included in this zone.

High Vulnerability Zone : Areas that have almost similar conditions to those included in the very high vulnerability zone are also included in this category. The only difference between these two is the combination, intensity and frequency of the controlling factors. All the Himalayan states and the states from the north-eastern regions except the plains of Assam are included in the high vulnerability zones.

Moderate to Low Vulnerability Zone : Areas that receive less precipitation such as Trans-Himalayan areas of Ladakh and Spiti (Himachal Pradesh), undulated yet stable relief and low precipitation areas in the Aravali, rain shadow areas in the Western and Eastern Ghats and Deccan plateau also experience occasional landslides. Landslides due to mining and

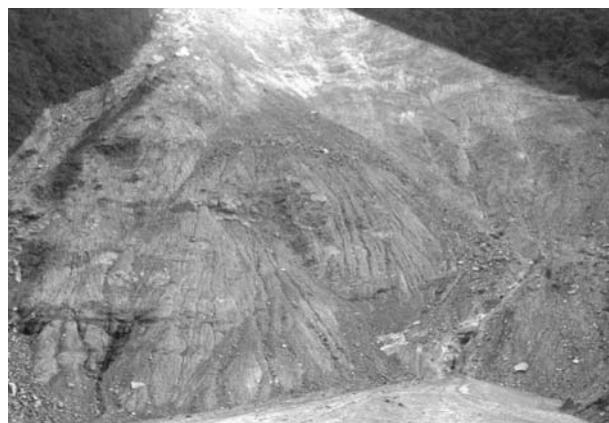


Figure 7.9 : Landslide

subsidence are most common in states like Jharkhand, Orissa, Chhattisgarh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Goa and Kerala.

Other Areas : The remaining parts of India, particularly states like Rajasthan, Haryana, Uttar Pradesh, Bihar, West Bengal (except district Darjiling), Assam (except district Karbi Anglong) and Coastal regions of the southern States are safe as far as landslides are concerned.

Consequences of Landslides

Landslides have relatively small and localised area of direct influence, but roadblock, destruction of railway lines and channel-blocking due to rock-falls have far-reaching consequences. Diversion of river courses due to landslides can also lead to flood and loss of life and property. It also makes spatial interaction difficult, risky as well as a costly affair, which, in turn, adversely affects the developmental activities in these areas.

Mitigation

It is always advisable to adopt area-specific measures to deal with landslides. Restriction on the construction and other developmental activities such as roads and dams, limiting agriculture to valleys and areas with moderate slopes, and control on the development of large settlements in the high vulnerability zones, should be enforced. This should be supplemented by some positive actions like promoting large-scale afforestation programmes and construction of bunds to reduce the flow of water. Terrace farming should be encouraged in the northeastern hill states where *Jhumming* (Slash and Burn/Shifting Cultivation) is still prevalent.

DISASTER MANAGEMENT

Disasters due to cyclones, unlike the ones caused by earthquakes, tsunamis and volcanic eruptions are more predictable in terms of the time and place of their occurrences. Moreover, with the help of development of techniques to monitor the behaviour of cyclones, their intensity, direction and magnitude, it has become possible to manage the cyclonic hazard

to some extent. Construction of cyclone-shelters, embankments, dykes, reservoirs and afforestation to reduce the speed of the winds are some of the steps that can help in minimising the damages. However, increase in the loss of life and property in countries like India, Bangladesh, Myanmar, etc. in successive storms is largely due to high vulnerability of their population residing in the coastal areas.

Disaster Management Bill, 2005

The Disaster Management Bill, 2005, defines disaster as a catastrophe, mishap, calamity or grave occurrence affecting any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, environment, and is of such nature or magnitude as to be beyond the coping capacity of the community of the affected area.

CONCLUSION

On the basis of the above discussion, it can be concluded that disasters can be natural or the results of human activities, and all hazards need not turn into disasters since it is difficult to eliminate disasters, particularly natural disasters. Then the next best option is mitigation and preparedness. There are three stages involved in disaster mitigation and management:

- (i) Pre-disaster management involves generating data and information about the disasters, preparing vulnerability zoning maps and spreading awareness among the people about these. Apart from these, disaster planning, preparedness and preventive measures are other steps that need to be taken in the vulnerable areas.
- (ii) During disasters, rescue and relief operations such as evacuation, construction of shelters and relief camps, supplying of water, food, clothing and medical aids etc. should be done on an emergency basis.
- (iii) Post-disaster operations should involve rehabilitation and recovery of victims. It

should also concentrate on capacity-building in order to cope up with future disasters, if any.

These measures have special significance to a country like India, which has about two-third of its geographical area and equal

proportion of its population, vulnerable to disasters. Introduction of the Disaster Management Bill, 2005 and establishment of National Institute of Disaster Management are some examples of the positive steps taken by the Government of India.

EXERCISES

1. Choose the right answer from the four alternatives given below.
 - (i) Which one of the following states of India experiences floods frequently?

(a) Bihar	(c) Assam
(b) West Bengal	(d) Uttar Pradesh
 - (ii) In which one of the following districts of Uttarakhand did Malpa Landslide disaster take place?

(a) Bageshwar	(c) Almora
(b) Champawat	(d) Pithoragarh
 - (iii) Which one of the following states receives floods in the winter months?

(a) Assam	(c) Kerala
(b) West Bengal	(d) Tamil Nadu
 - (iv) In which of the following rivers is the Majuli River Island situated?

(a) Ganga	(c) Godavari
(b) Brahmaputra	(d) Indus
 - (v) Under which type of natural hazards do blizzards come?

(a) Atmospheric	(c) Terrestrial
(b) Aquatic	(d) Biological
2. Answer the following questions in less than 30 words.
 - (i) When can a hazard become a disaster?
 - (ii) Why are there more earthquakes in the Himalayas and in the north-eastern region of India?
 - (iii) What are the basic requirements for the formation of a cyclone?
 - (iv) How are the floods in Eastern India different from the ones in Western India?
 - (v) Why are there more droughts in Central and Western India?
3. Answer the following questions in not more than 125 words.
 - (i) Identify the Landslide-prone regions of India and suggest some measures to mitigate the disasters caused by these.
 - (ii) What is vulnerability? Divide India into natural disaster vulnerability zones based on droughts and suggest some mitigation measures.
 - (v) When can developmental activities become the cause of disasters?

Project/Activity

Prepare a project report on any one of the topics given below.

- | | |
|-----------------------------------|--|
| (i) Malpa Landslide | (v) Tehri Dam/Sardar Sarovar |
| (ii) Tsunami | (vi) Bhuj/Latur Earthquakes |
| (iii) Orissa and Gujarat Cyclones | (vii) Life in a delta/riverine island |
| (iv) Inter-linking of rivers | (viii) Prepare a model of rooftop rainwater harvesting |

APPENDIX



STATES, THEIR CAPITALS, NUMBER OF DISTRICTS, AREA AND POPULATION

Sl. No.	State	Capital	No. of Districts	Area in sq. km	Population
1.	Andhra Pradesh	Hyderabad	23	2,75,060	7,57,27,541
2.	Arunachal Pradesh	Itanagar	14	83,743	10,91,117
3.	Assam	Dispur	23	78,438	2,66,38,407
4.	Bihar	Patna	37	94,163	8,28,78,796
5.	Chhattisgarh	Raipur	16	1,36,034	2,07,95,956
6.	Goa	Panji	02	3,702	13,43,998
7.	Gujarat	Gandhi Nagar	25	1,96,024	5,05,96,992
8.	Haryana	Chandigarh	19	44,212	2,10,82,982
9.	Himachal Pradesh	Shimla	12	55,673	60,77,248
10.	Jammu and Kashmir	Srinagar	14	2,22,236	1,00,69,917
11.	Jharkhand	Ranchi	18	79,714	2,69,09,428
12.	Karnataka	Bangalore	27	1,91,791	5,27,83,958
13.	Kerala	Tiruvananantapuram	14	38,863	3,18,38,619
14.	Madhya Pradesh	Bhopal	45	3,08,000	6,03,85,118
15.	Maharashtra	Mumbai	35	3,07,713	9,67,52,247
16.	Manipur	Imphal	9	22,327	23,88,634
17.	Meghalaya	Shillong	7	22,327	23,06,069
18.	Mizoram	Aizawl	8	21,081	8,91,058
19.	Nagaland	Kohima	8	16,579	19,88,636
20.	Orissa	Bhubaneshwar	30	1,55,707	3,67,06,920
21.	Punjab	Chandigarh	17	50,362	2,42,89,296
22.	Rajasthan	Jaipur	32	3,42,239	5,64,73,122
23.	Sikkim	Gangtok	04	7,096	5,40,493
24.	Tamil Nadu	Chennai	29	1,30,058	6,21,10,839
25.	Tripura	Agartala	04	10,49,169	31,91,168
26.	Uttaranchal	Dehra Dun	13	53,484	84,79,562
27.	Uttar Pradesh	Lucknow	70	2,38,566	16,60,52,859
28.	West Bengal	Kolkata	18	88,752	8,02,21,171

APPENDIX**UNION TERRITORIES, THEIR CAPITALS, AREA AND POPULATION**

Sl. No.	Union Territories	Capital	Area	Population
1.	Andaman and Nicobar Islands	Port Blair	8,249	3,56,152
2.	Chandigarh	Chandigarh	114	9,00,914
3.	Dadra and Nagar Haveli	Silvassa	491	2,20,490
4.	Daman and Diu	Daman	112	1,58,204
5.	NCT Delhi	* Delhi	1483	1,38,00000
6.	Lakshadweep	Kavaratti	32	60,595
7.	Pondicherry	**Pondicherry	492	9,73,829

Note : * Delhi has the status of National Capital Territory with a Legislative Assembly

** Pondicherry also has a Legislative Assembly

Source : *India-2005, A Reference Annual*, Publications Division, Ministry of Information and Broadcasting

APPENDIX



IMPORTANT RIVER BASINS

Rivers	Length (in km)	Catchment Area (sq. km) Potential Discharge in the River (km ³)	Average Annual Flow Excluding the Groundwater (km ³)	Estimated Utilisable
Indus (in India)	1,114	321,289	73.31	46.0
Ganga (in India)	2,525	861,452	525.02	250.0
Brahmaputra (in India)	916	194,413		
Barak and others		41,723		
Flowing to Meghna				
Sabarmati	371	21,674	3.81	1.99
Mahi	585	34,842	11.02	3.10
Narmada	1,312	98,796	45.64	34.30
Tapti	724	65,145	14.88	14.50
Brahmani and Baitarni	799+365	39,033+12,789	28.48	18.30
Mahanadi	851	141,589	66.88	49.99
Godavari	1,465	312,812	110.54	76.30
Krishna	1,401	258,948	78.12	58.00
Penner	597	55,213	6.32	6.86
Kaveri	800	81,155	21.36	19.00
Suvarnarekha	395	19,296	12.37	6.81
Total		2,528,084	1,869.35	690.31
{ Medium river basins flowing towards the east and west directions		248,505	255.02	59.03
Total		2,776,589	2,124.37	749.34

APPENDIX
IV
STATE/UNION TERRITORY WISE FOREST COVER

State/UT	Geographic Area	Forest Cover			
		Dense	Open	Total	Percent
Andhra Pradesh	275,069	25,827	18,810	44,637	16.23
Arunachal Pradesh	83,743	53,932	14,113	68,045	81.25
Assam	78,438	15,830	11,884	27,714	35.33
Bihar	94,163	3,372	2,348	5,720	6.07
Chhattisgarh	135,191	37,880	18,568	56,448	41.75
Delhi	1,483	38	73	111	7.51
Goa	3,702	1,785	310	2,095	56.59
Gujarat	196,022	8,673	6,479	15,152	7.73
Haryana	44,212	1,139	615	1,754	3.97
Himachal Pradesh	55,673	10,429	3,931	14,360	25.79
Jammu & Kashmir	222,236	11,848	9,389	21,237	9.56
Jharkhand	79,714	11,787	10,850	22,637	28.40
Karnataka	191,791	26,156	10,835	36,991	19.29
Kerala	38,863	11,772	3,788	15,560	40.04
Madhya Pradesh	308,245	44,384	32,881	77,265	25.07
Maharashtra	307,713	30,894	16,588	47,482	15.43
Manipur	22,327	5,710	11,216	16,926	75.81
Meghalaya	22,429	5,681	9,903	15,584	69.48
Mizoram	21,081	8,936	8,558	17,494	82.98
Nagaland	16,579	5,393	7,952	13,345	80.49
Orissa	155,707	27,972	20,866	48,838	31.36
Punjab	50,362	1,549	883	2,432	4.83
Rajasthan	342,239	6,322	10,045	16,367	4.78
Sikkim	7,096	2,391	802	3,193	45.00
Tamilnadu	130,058	12,499	8,983	21,482	16.52
Tripura	10,486	3,463	3,602	7,065	67.38
Uttar Pradesh	240,928	8,965	4,781	13,746	5.71
Uttaranchal	53,483	19,023	4,915	23,938	44.76
West Bengal	88,752	6,346	4,347	10,693	12.05
Andaman & Nicobar	8,249	6,593	337	6,930	84.01
Chandigarh	114	5	4	9	7.51
Dadra & Nagar Haveli	491	151	68	219	44.60
Daman & Diu	112	2	4	6	5.53
Lakshadweep	32	27	0	27	85.91
Pondicherry	480	35	1	36	7.45
Total	3,287,263	416,809	258,729	675,538	20.55

Source : State Forest Report, 2001

APPENDIX



NATIONAL PARKS OF INDIA

<i>State/UT</i>	<i>Area of State</i>	<i>National Parks (km²)</i>	<i>Area Covered (km²)</i>	<i>% of State Area</i>
Andhra Pradesh	275,068	4	373.23	0.14
Arunachal Pradesh	83,743	2	2290.82	2.74
Assam	78,438	5	1968.60	2.51
Bihar	94,163	1	335.65	0.36
Chhattisgarh	135,194	3	2929.50	2.17
Goa	3,702	1	107.00	2.89
Gujarat	196,024	4	480.11	0.24
Haryana	442,122	2	117.13	0.26
Himachal Pradesh	55,673	2	1429.40	2.57
Jammu and Kashmir	222,235	4	4680.25	2.11
Jharkhand	79,714	1	231.67	0.29
Karnataka	191,791	5	2435.14	1.27
Kerala	38,863	4	549.34	1.41
Madhya Pradesh	308,252	9	3656.36	1.19
Maharashtra	307,690	5	955.93	0.31
Manipur	22,327	1	40.00	0.18
Meghalaya	22,429	2	267.48	1.19
Mizoram	21,081	2	250.00	1.19
Nagaland	16,579	1	202.02	1.22
Orissa	155,707	2	990.70	0.64
Punjab	50,362	0	0.00	0.00
Rajasthan	342,239	5	4122.33	1.20
Sikkim	7,096	1	1784.00	25.14
Tamil Nadu	130,058	5	307.84	0.24
Tripura	10,486	0	0.00	0.00
Uttar Pradesh	240,926	1	490.00	0.20
Uttaranchal	53,485	6	4725.00	7.62
West Bengal	88,752	5	1693.25	1.91
Union Territories				
Andaman and Nicobar	8,249	9	1156.91	14.02
Chandigarh	114	0	0.00	0.00
Dadra and Nagar Haveli	491	0	0.00	0.00
Daman & Diu	112	0	0.00	0.00
Delhi	1,483	0	0.00	0.00
Lakshadweep	32	0	0.00	0.00
Pondicherry	493	0	0.00	0.00
India	3,287,263	92	38,569.66	1.17

Source: State Forest Report, 2001

GLOSSARY

Alluvial Plain : A level tract of land made up of alluvium or fine rock material brought down by a river.

Archipelago : A group of islands that lie in fairly close proximity.

Arid : Denoting any climate or region in which the rainfall is insufficient or barely sufficient to support vegetation.

Backwater : A stretch of water that has become bypassed by the main flow of a stream, although still joined to it. It has a very low rate of flow.

Bedrock : The solid rock lying beneath soil and weathered material.

Biosphere Reserve : These are multi-purpose protected areas, where every plant and animal size is to be protected in its natural habitat. Its major objectives are : (i) to conserve and maintain diversity and integrity of the natural heritage in its full form, i.e. physical environment, the flora and the fauna; (ii) to promote research on ecological conservation and other aspects of environment at preservation; (iii) to provide facilities for education, awareness and explaining.

Bunding : The practice of constructing embankments of earth or stone for conserving water and soil to increase crop production.

Calcareous : Composed of or containing a high proportion of calcium carbonate.

Catchment Area : The area drained by a major river and its tributaries.

Climate : The average weather conditions of a sizeable area of the earth's surface over a period of time (usually spread over a span of at least 30 years).

Coast : The boundary between land and sea. It includes the strip of land that borders the sea shore.

Coastal Plain : It is a flat low lying land between the coast and higher ground inland.

Conservation : The protection of natural environment and natural resources for the future. It includes the management of minerals, landscape, soil and forests to prevent their destruction and over exploitation.

Coral : It is a small calcium secreting marine polyp that occurs in colonies, mainly in warm shallow sea water. It forms the coral reefs.

Depression : In meteorology; it denotes an area of relatively low atmospheric pressure, which is found mainly in temperate regions. It is also used as synonym for temperate cyclones.

Estuary : The tidal mouth of a river where fresh and saline water get mixed.

Fauna : The animal life of a given area or time.

Fold : A bend in rock strata resulting from compression of an area of the earth's crust.

Glacier : A mass of snow and ice that moves slowly away from its place of accumulation carving gradually a broad and steepsided valley on its way.

Gneiss : A coarse grained metamorphic rock with a banded structure. It is formed by the large scale application of heat and pressure associated with mountain building and volcanic activity.

Gorge : A deep valley with steep and rocky side walls.

Gully Erosion : It is the erosion of the soil and rock by the concentration of runoff into gullies.

Humus : The dead organic content of the soil.

Island : A mass of land that is surrounded by water and is smaller than a continent.

Jet Stream : A very strong and steady westerly wind blowing just below the tropopause.

Lake : A body of water that lives in a hollow in the earth's surface and is entirely surrounded by land.

Landslide : A form of mass movement in which rock and debris moves rapidly downslope under the influence of gravity as a result of failure along a shear plane.

Meander : A pronounced curve or loop in the course of a river channel.

Monsoon : A complete reversal of winds over a large area leading to a change of seasons.

National Park : A National park is an area which is strictly reserved for the protection of the wildlife and where activities such as forestry, grazing or cultivation are not allowed.

Pass : A route through a mountain range which follows the line of a col or a gap.

Peninsula : A piece of land jutting out into the sea.

Plain : An extensive area of flat or gently undulating land.

Plateau : An extensive elevated area of relatively flat land.

Playa : The low flat central area of a basin of inland drainage. Playas occur in areas of low rainfall.

Protected Forest : An area notified under the provisions of Indian Forest Act or the State Forest Acts having limited degree of protection. In Protected Forests, all activities are permitted unless prohibited.

Rapids : A stretch of swift flowing water where a river bed suddenly becomes steeper due to the presence of hard rocks.

Reserved Forest : An area notified under the provisions of Indian Forest Act or the State Forest Acts having full degree of protection. In Reserved Forests, all activities are prohibited unless permitted.

Sanctuary : A sanctuary is an area, which is reserved for the conservation of animals only and operations such as harvesting of timber, collection of minor forest products are allowed so long as they do not affect the animals adversely.

Soil Profile : It is the vertical section of soil from the ground surface to the parent rock.

Subcontinent : A big geographical unit which stands out distinctly from the rest of the continent.

Terai : A belt of marshy ground and vegetation on the lower parts of the alluvial fans.

Tectonic : Forces originating within the earth and responsible for bringing widespread changes in the landform features.

Unclassed Forest : An area recorded as forest but not included in reserved or protected forest category. Ownership status of such forests varies from state to state.

8

Winds, Storms and Cyclones

Orissa was hit by a cyclone with wind speed of 200 km/h on 18 October 1999. The cyclone smashed 45,000 houses making 7,00,000 people homeless. On 29 October the same year, a second cyclone with wind speed of 260 km/h hit Orissa again. It was accompanied by water waves about 9 m high. Thousands of people lost their lives. Property worth crores of rupees was destroyed. The cyclone affected agriculture, transport, communication, and electricity supply.

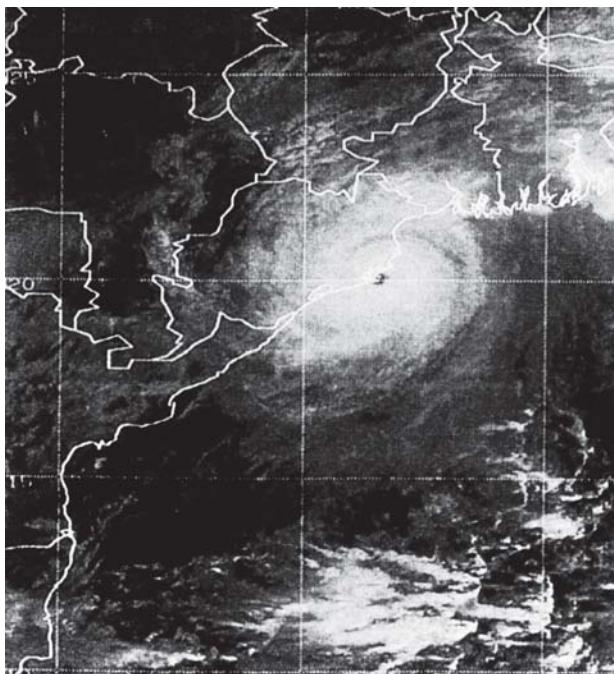


Fig. 8.1 Image taken by a satellite of a cyclone approaching the coast of Orissa

Courtesy: India Meteorological Department,
New Delhi

But, what are cyclones? How are they formed? Why are they so destructive? In this chapter we shall seek answers to some of these questions.

We begin with some activities involving air. These activities will clarify some basic features concerning a cyclone. Before we begin, remember that the moving air is called the **wind**.

8.1 AIR EXERTS PRESSURE

Activity 8.1

Whenever an activity involves heating, be very careful. It is advised that such activities are performed in the presence of an elderly person from your family. Or, carry out these activities in the presence of your teacher.

You need to boil water in the following activity.

Take a tin can with a lid. Fill it approximately half with water. Heat the can on a candle flame till the water boils. Let the water boil for a few minutes. Blow out the candle. Immediately put the lid tightly on the can. Be careful in handling the hot can. Put the can carefully in a shallow metallic vessel or a washbasin. Pour fresh water over the can. What happens to the shape of the can?



Fig. 8.2 Can with hot water being cooled

Can you guess why the shape of the can gets distorted?

If you cannot get a tin can, take a soft plastic bottle. Fill it with hot water. Empty the bottle and immediately cap it tightly. Place the bottle under running water.

Recall now some of your experiences.

When you fly a kite, does the wind coming from your back help?

If you are in a boat, is it easier to row it if there is wind coming from behind you?

Do you find it difficult to ride a bicycle against the direction of the wind?

You know that we have to fill air into the bicycle tube to keep it tight. Also, you know that a bicycle tube overfilled with air may burst. What is the air doing inside the tube?

Discuss with your friends how the air in the bicycle tube keeps it in shape.

All these experiences show that the air exerts pressure. It is due to this pressure that the leaves of trees, banners, or flags flutter when the wind

is blowing. You can list some more experiences which show that the air has pressure.

Let us now try to explain why the can (or the bottle) gets distorted. As water is poured over the can, some steam in the can condenses into water, reducing the amount of air inside. The pressure of air inside the can decreases than the pressure exerted by the air from outside the can. As a result the can gets compressed.

This activity again confirms that air exerts pressure.

8.2 HIGH SPEED WINDS ARE ACCOMPANIED BY REDUCED AIR PRESSURE

Activity 8.2



Fig. 8.3 Blowing into the bottle

Crumple a small piece of paper into a ball of size smaller than the mouth of an empty bottle. Hold the empty bottle on its side and place the paper ball just inside its mouth. Now try to blow on the ball to force it into the bottle. Try the activity with bottles of different sizes. Challenge your friends if they can force

the paper ball in by blowing into the bottle.

Paheli and Boojho are thinking about the following question:

Why is it difficult to force the paper ball into the bottle?

Activity 8.3

Blow the balloons

Take two balloons of approximately equal size. Put a little water into the



Fig. 8.4 Blowing between the balloons

balloons. Blow up both the balloons and tie each one to a string. Hang the balloons 8–10 cm apart on a cycle spoke or a stick. Blow in the space between the balloons.

What did you expect? What happens?

Try different ways of blowing on the balloons to see what happens.

Activity 8.4

Can you blow and lift?

Hold a strip of paper, 20 cm long and 3 cm wide, between your thumb and forefinger as shown in the Fig. 8.5. Now blow over the paper.

Paheli thinks that the strip will be lifted up. Boojho thinks that the strip will bend down.

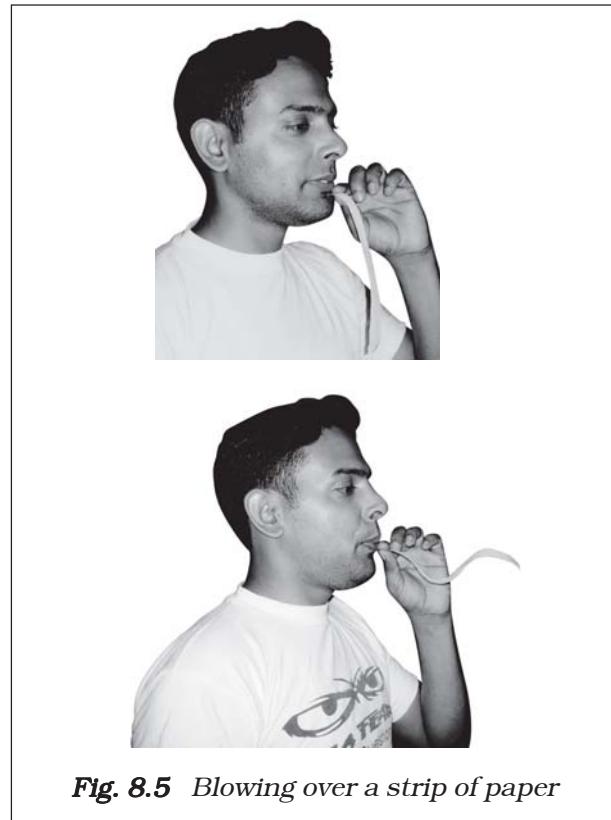


Fig. 8.5 Blowing over a strip of paper

What do you think will happen to the paper?

Let us try to understand the observations in Activities 8.2, 8.3 and 8.4.

Were the observations along the lines you thought? Do you get the feeling that the increased wind speed is accompanied by a reduced air pressure?

When we blow into the mouth of the bottle, the air near the mouth has higher speed. This decreases the pressure there. The air pressure inside the bottle is higher than near the mouth. The air inside the bottle pushes the ball out.

In Activity 8.3 you saw that when you blew between the balloons, they moved

towards each other. How could this happen? This could happen if the pressure of air between the balloons were somehow reduced. The pressure outside the balloons would then push them towards each other.

In Activity 8.4 you saw that when you blew over the paper strip, it went upwards. Again, this could happen if blowing over the paper reduced the air pressure above the strip.

We see that the **increased wind speed is, indeed, accompanied by a reduced air pressure**.

Can you imagine what would happen if high-speed winds blew over the roofs of buildings? If the roofs were weak, they could be lifted and blown away. If you have any such experience, share it with your friends.

Let us try to understand how winds are produced, how they bring rain and how they can be destructive sometimes.

You already know that when air moves, it is called wind. **Air moves from**

the region where the air pressure is high to the region where the pressure is low. The greater the difference in pressure, the faster the air moves. But how are the pressure differences created in nature? Is the difference in temperature involved? The following activities will help you to understand this.

8.3 AIR EXPANDS ON HEATING

Activity 8.5

Take a boiling tube. Stretch a balloon tightly over the neck of the tube. You can use a tape to make it tight. Pour some hot water in a beaker. Insert the boiling tube with the balloon in the hot water. Observe for 2–3 minutes for any change in shape of the balloon. Take the tube out, let it cool down to the room temperature. Take some ice-cold water in another beaker and place the tube with the balloon in cold water for 2–3 minutes. Observe the change in the shape of the balloon.

Think and try to answer:

What makes the balloon inflated when the boiling tube is placed in hot water?

Why is the same balloon deflated when the tube is kept in cold water?

Can we infer from the first observation that air expands on heating? Can you now state what happens to the air in the boiling tube when it cools down?



Balloon tied over the neck of the boiling tube

Boiling tube immersed in hot water

Boiling tube immersed in ice-cold water

Fig. 8.6 The shape of the balloon in hot and cold water

The next activity is very interesting. This will make you understand more about hot air.

Activity 8.6

Take two paper bags or empty paper cups of the same size. Hang the two bags in

CAUTION

Handle the burning candle carefully.

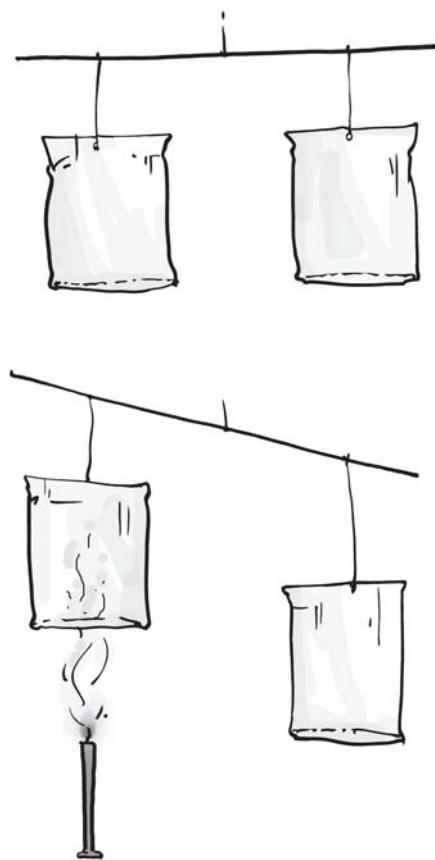


Fig. 8.7 Hot air rising up

the inverted position on the two ends of a metal or wooden stick.

Tie a piece of thread in the middle of the stick. Hold the stick by the thread (Fig. 8.7) as in a balance. Put a burning

candle below one of the bags as shown in the figure. Observe what happens.

Why is the balance of the bags disturbed?

Does this activity indicate that warm air rises up? As the warm air rises up, it pushes the bag above the candle. Does the disturbance of the balance suggest that the warm air is lighter than the cold air?

Can you now explain why smoke always rises up?

Also, it is important to remember that on heating the air expands and occupies more space. When the same thing occupies more space, it becomes lighter. **The warm air is, therefore, lighter than the cold air.** That is the reason that the smoke goes up.

In nature there are several situations, where warm air rises at a place. The air pressure at that place is lowered. The cold air from the surrounding areas rushes in to fill its place. This sets up convection in air, as you learnt in Chapter 4.

8.4 WIND CURRENTS ARE GENERATED DUE TO UNEVEN HEATING ON THE EARTH

These situations are:

(a) Uneven heating between the equator and the poles

You might have learnt in Geography that regions close to the equator get maximum heat from the Sun. The air in these regions gets warm. The warm air rises, and the cooler air from the

regions in the 0–30 degrees latitude belt on either side of the equator moves in. These winds blow from the north and the south towards the equator. At the poles, the air is colder than that at latitudes about 60 degrees. The warm air at these latitudes rises up and the cold wind from the polar regions rushes in, to take its place. In this way, wind circulation is set up from the poles to the warmer latitudes, as shown in Fig. 8.8.



Fig. 8.8 The wind flow pattern because of uneven heating on the earth



I wonder why the winds shown in the figure are not in the exact north-south direction.

The winds would have flown in the north-south direction from north to south, or from south to north. A change in direction is however, caused by the rotation of the earth.

(b) Uneven heating of land and water

You have read about the sea breeze and the land breeze in Chapter 4.

In summer, near the equator the land warms up faster and most of the time the temperature of the land is higher than that of water in the oceans. The air over the land gets heated and rises. This causes the winds to flow from the oceans towards the land. These are monsoon winds (Fig. 8.9).

The word monsoon is derived from the Arabic word 'mausam', which means 'season'.

In winter, the direction of the wind flow gets reversed; it flows from the land to the ocean (Fig. 8.10).



The winds from the oceans carry water and bring rain. It is a part of the water cycle.

The monsoon winds carry water and it rains.

Clouds bring rain and give us happiness. Farmers in our country depend mainly on rains for their harvests. There are many folk songs associated with clouds and rain. Sing and enjoy with your friends, if you know such a song. Here is one for you.

Roaring clouds across the sky
 Tell us that monsoon's here
 Dark and floating clouds then pour
 Raindrops every where.
 Clouds make lightning flash overhead
 And irrigate fields with rain
 Clouds make earth, its fragrance spread
 When wet with drops of rain.
 Rising from the ocean vast
 Clouds fill up with rain
 Rain to ocean, back at last
 To mingle with ocean again!

JULY — $\frac{0.5 \text{ Km.}}{1,600 \text{ Ft.}}$ a.s.l.

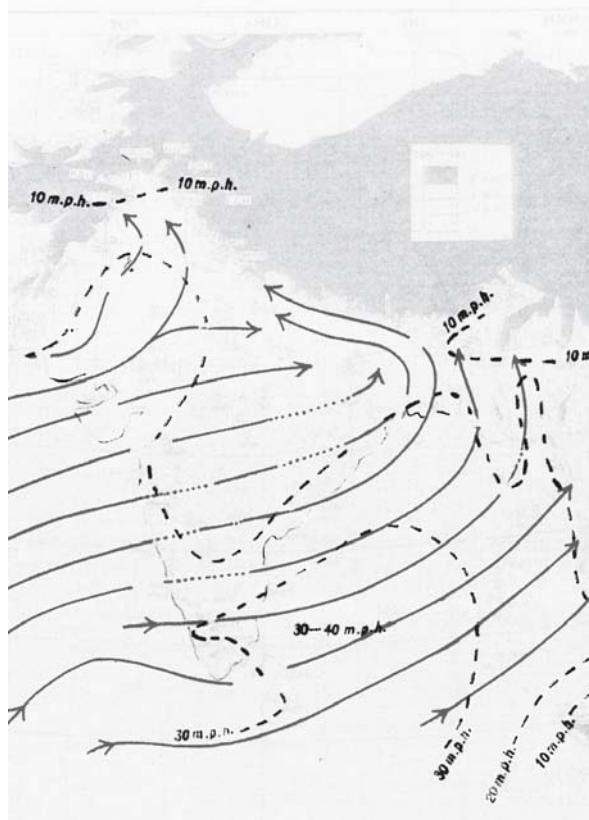


Fig. 8.9 Uneven heating of land especially the Rajasthan desert generates monsoon winds from **southwest** direction in **summer**. These winds carry lots of water from the Indian Ocean.

However, it is not always a happy ending. Rains often create problems.

Can you list some of the problems?

You can discuss the causes and solutions of the problems with your teacher and parents.

In nature itself there are certain situations that can sometimes create disasters and pose threat to humans, animals and plant life.

Let's study two such situations — **thunderstorms** and **cyclones**.

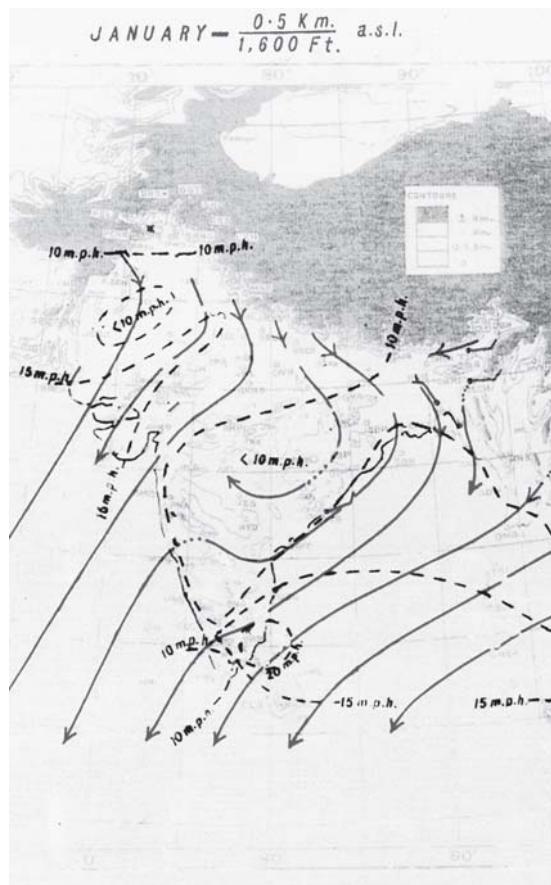


Fig. 8.10 Uneven heating of land and water in **winter** generate winds from the **northwest** colder land. These colder winds carry little water, hence bring small amount of rain in winter.

Courtesy: India Meteorological Department, New Delhi

8.5 THUNDERSTORMS AND CYCLONES

Thunderstorms develop in hot, humid tropical areas like India very frequently. The rising temperatures produce strong upward rising winds. These winds carry water droplets upwards, where they freeze, and fall down again. The swift movement of the falling water droplets along with the rising air create lightning and sound. It is this event that we call a **thunderstorm**. You will read about lightning in higher classes.

If a storm is accompanied by lightning, we must take the following precautions:

- Do not take shelter under an isolated tree. If you are in a forest take shelter under a small tree. Do not lie on the ground.
- Do not take shelter under an umbrella with a metallic end.
- Do not sit near a window. Open garages, storage sheds, metal sheds are not safe places to take shelter.
- A car or a bus is a safe place to take shelter.
- If you are in water, get out and go inside a building.

How a thunderstorm becomes a cyclone

You know that water requires heat when it changes from liquid to vapour state. Does the water give back heat when vapour condenses into liquid? Can you recall any experience to support this?

Structure of a cyclone

The centre of a cyclone is a calm area. It is called the **eye** of the storm. A large cyclone is a violently rotating mass of air in the atmosphere, 10 to 15 km high. The diameter of the eye varies from 10 to 30 km (Fig. 8.11). It is a region free of clouds and has light winds. Around this calm and clear eye (Fig. 8.12), there is a cloud region of about 150 km in size. In this region there are high-speed winds (150–250 km/h) and thick clouds with heavy rain. Away from this region the wind speed gradually decreases. The formation of a cyclone is a very complex process. A model is shown in Fig. 8.11.

Before cloud formation, water takes up heat from the atmosphere to change into vapour. When water vapour changes back to liquid form as raindrops, this heat is released to the atmosphere. The heat released to the atmosphere warms the air around. The air tends to rise and causes a drop in pressure. More air rushes to the centre of the storm. This cycle is repeated. The chain of events ends with the formation of a very low-pressure system with very high-speed winds revolving around it. It is this weather condition that we call a **cyclone**. Factors like wind speed, wind direction, temperature and humidity contribute to the development of cyclones.

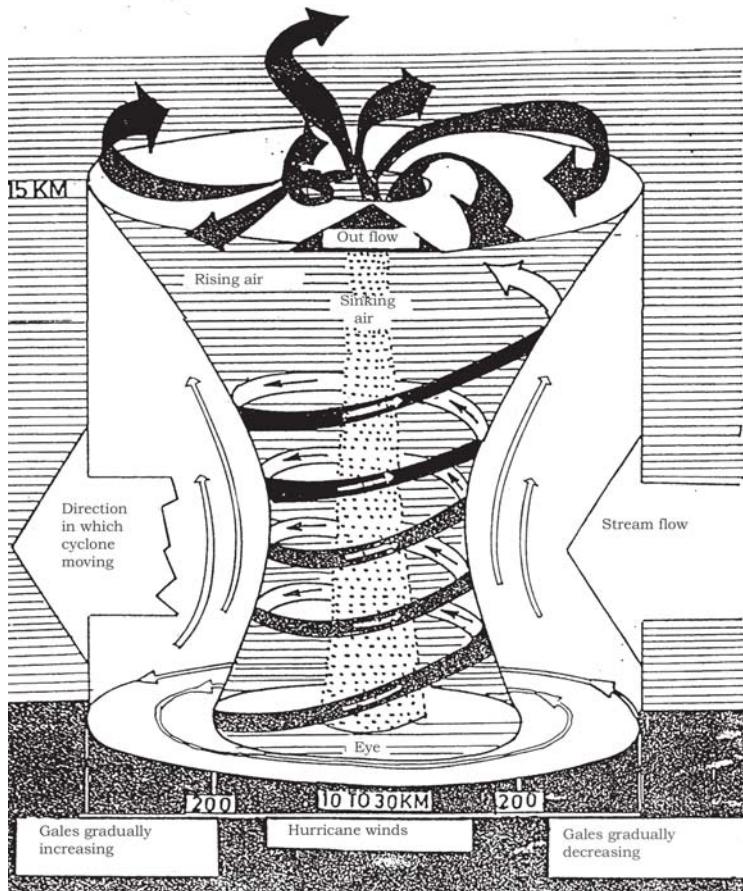


Fig. 8.11 Formation of a cyclone

Courtesy: India Meteorological Department, New Delhi

8.6 DESTRUCTION CAUSED BY CYCLONES

Cyclones can be very destructive. Strong winds push water towards the shore even if the storm is hundreds of kilometres away. These are the first indications of an approaching cyclone. The water waves produced by the wind are so powerful that a person cannot overcome them.

The low pressure in the eye lifts water surface in the centre. The rising water may be as high as 3–12 metres

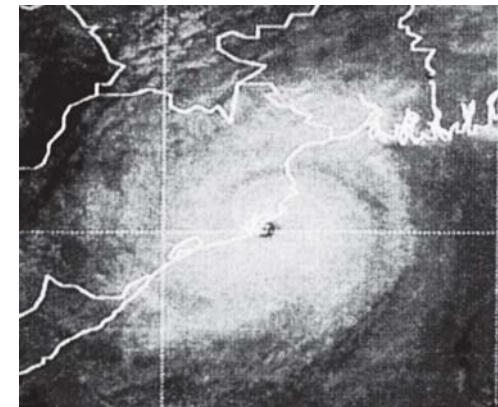


Fig. 8.12 The image of the 'eye' of a cyclone



Fig. 8.13 Rising water caused by a cyclone.

(Fig. 8.13). It appears like a water-wall moving towards the shore. As a result, the seawater enters the low-lying coastal areas, causing severe loss of life and property. It also reduces the fertility of the soil.

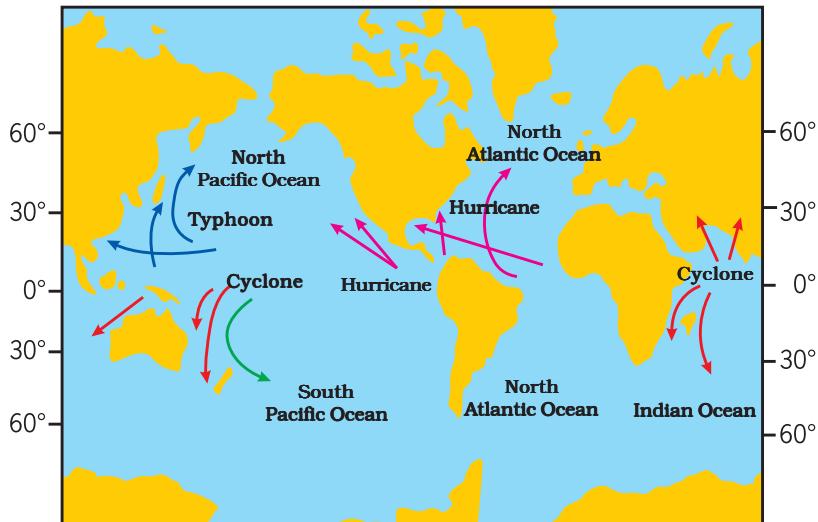
Continuous heavy rainfall may further worsen the flood situation.

High-speed winds accompanying a cyclone can damage houses, telephones and other communication systems, trees, etc., causing tremendous loss of life and property.

A cyclone is known by different names in different parts of the world. It is called a '**hurricane**' in the American continent. In Philippines and Japan it is called a '**typhoon**' (Fig. 8.14).

Fig. 8.14 Regions near the equator where cyclones form.

Cyclones are worldwide phenomena.



The diameter of a tornado can be as small as a metre and as large as a km, or even wider. The funnel of a tornado sucks dust, debris and everything near it at the base (due to low pressure) and throws them out near the top. Here are a few accounts of the survivors of tornados—(from Discovery channel's "Young Discovery Series").

"I saw the cloud coming and tried to take shelter inside. But as soon as I reached for the doorknob, the house took off into the sky. I was not hurt at all."

"After the storm we had to clean the debris from the wheat fields. We picked up splintered boards and tree branches as well as dead chickens with their feathers blown off and rabbits looked like they had been skinned."

A tornado shelter is a room situated deep inside or underground having no windows. Or otherwise it is better to shut windows and take shelter under a table, workbench, where debris cannot reach. One has to bow down on knees protecting head and neck using arms (Fig. 8.15).



Fig. 8.15 Protecting from a tornado

Tornadoes: In our country they are not very frequent. A tornado is a dark funnel shaped cloud that reaches from the sky to the ground (Fig. 8.16). Most of the tornadoes are weak. A violent tornado can travel at speeds of about 300 km/h. Tornadoes may form within cyclones.

The whole coastline of India is vulnerable to cyclones, particularly the east coast. The west coast of India is less vulnerable to cyclonic storms both in terms of intensity and frequency of the cyclones.

8.7 EFFECTIVE SAFETY MEASURES

- A cyclone forecast and warning service.
- Rapid communication of warnings to the



Fig. 8.16 Image of a tornado

[National Severe Storm Laboratory (NSSL)]
Courtesy: India Meteorological Department,
New Delhi

We have learnt that all storms are low-pressure systems. Wind speed plays an important role in the formation of storms. It is, therefore, important to measure the wind speed. The instrument that measures the wind speed is called an anemometer.

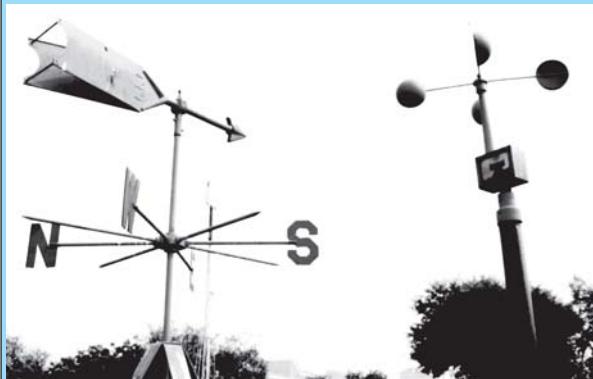


Fig. 8.17 An anemometer for measuring the speed of wind

Courtesy: India Meteorological Department,
New Delhi

Government agencies, the ports, fishermen, ships and to the general public.

- Construction of cyclone shelters in the cyclone prone areas, and Administrative arrangements for moving people fast to safer places.

Action on the part of the people

- We should not ignore the warnings issued by the meteorological department through TV, radio, or newspapers.
- We should —
 - make necessary arrangements to shift the essential household goods, domestic animals and vehicles, etc. to safer places;
 - avoid driving on roads through standing water, as floods may have damaged the roads; and
 - keep ready the phone numbers of all emergency services like police, fire brigade, and medical centres.

Some other precautions, if you are staying in a cyclone hit area —

- Do not drink water that could be contaminated. Always store drinking water for emergencies.
- Do not touch wet switches and fallen power lines.
- Do not go out just for the sake of fun.
- Do not pressurise the rescue force by making undue demands.
- Cooperate and help your neighbours and friends.

8.8 ADVANCED TECHNOLOGY HAS HELPED

These days we are better protected. In the early part of the last century, coastal

residents may have had less than a day to prepare or evacuate their homes from an oncoming cyclone. The world today is very different. Thanks to satellites and radars, a **Cyclone alert** or **Cyclone watch** is issued 48 hours in advance of any

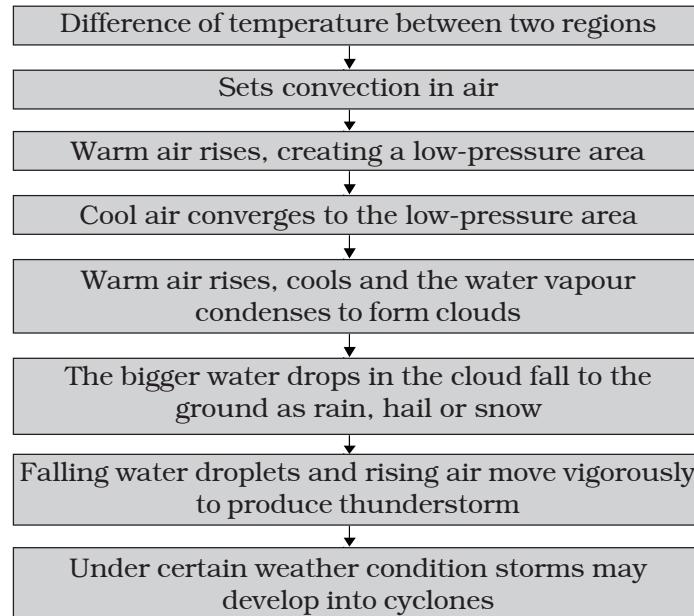
expected storm and a **Cyclone warning** is issued 24 hrs in advance. The message is broadcast every hour or half hour when a cyclone is nearer the coast. Several national and international organisations cooperate to monitor the cyclone-related disasters.

Keywords

Anemometer	Low pressure	Tornado
Cyclone	Monsoon winds	Typhoon
Hurricane	Pressure	Wind flow pattern
Lightning	Thunderstorms	

What you have learnt

- Air around us exerts pressure.
- Air expands on heating and contracts on cooling.
- Warm air rises up, whereas comparatively cooler air tends to sink towards the earth's surface.
- As warm air rises, air pressure at that place is reduced and the cooler air moves to that place.
- The moving air is called wind.
- Uneven heating on the earth is the main cause of wind movements.
- Winds carrying water vapour bring rain.
- High-speed winds and air pressure difference can cause cyclones.
- It has become easier to monitor cyclones with the help of advance technology like satellites and radars.
- Self-help is the best help. Therefore it is better to plan in advance and be ready with defence against any approaching cyclone.
- The following flow chart will help you to understand the phenomena that lead to the formation of clouds and falling of rain and creation of storms and cyclones:



Exercises

1. Fill the missing word in the blank spaces in the following statements:
 - (a) Wind is _____ air.
 - (b) Winds are generated due to _____ heating on the earth.
 - (c) Near the earth's surface _____ air rises up whereas _____ air comes down.
 - (d) Air moves from a region of _____ pressure to a region of _____ pressure.
2. Suggest two methods to find out wind direction at a given place.
3. State two experiences that made you think that air exerts pressure (other than those given in the text).
4. You want to buy a house. Would you like to buy a house having windows but no ventilators? Explain your answer.
5. Explain why holes are made in hanging banners and hoardings.
6. How will you help your neighbours in case cyclone approaches your village/town?
7. What planning is required in advance to deal with the situation created by a cyclone?
8. Which one of the following place is unlikely to be affected by a cyclone.

(i) Chennai	(ii) Mangaluru (Mangalore)
-------------	----------------------------

(iii) Amritsar

(iv) Puri

9. Which of the statements given below is correct?

- (i) In winter the winds flow from the land to the ocean.
- (ii) In summer the winds flow from the land towards the ocean.
- (iii) A cyclone is formed by a very high-pressure system with very high-speed winds revolving around it.
- (iv) The coastline of India is not vulnerable to cyclones.

Extended Learning — Activities and Projects

1. You can perform the Activity 8.5 in the chapter slightly differently at home. Use two plastic bottles of the same size. Stretch one balloon on the neck of each bottle. Keep one bottle in the sun and the other in the shade. Record your observations. Compare these observations and the result with those of Activity 8.5.
2. You can make your own anemometer.

Collect the following items:

4 small paper cups (used ice cream cups), 2 strips of cardboard (20cm long and 2cm wide), gum, stapler, a sketch pen and a sharpened pencil with eraser at one end.

Take a scale; draw crosses on the cardboard strips as shown in the Fig. 8.18. This will give you the centres of the strips.

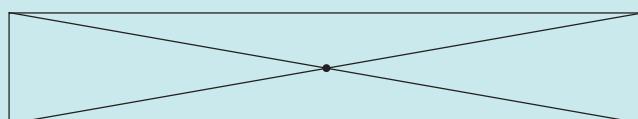


Fig. 8.18 Finding centre of the strips

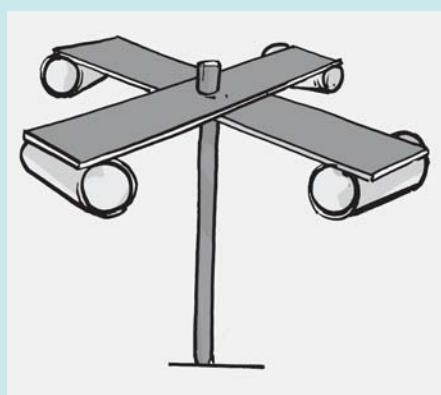


Fig. 8.19 A model of an anemometer

Fix the strips at the centre, putting one over the other so that they make a plus (+) sign. Now fix the cups at the ends of the strips. Colour the outer surface of one cup with a marker or a sketch pen. All the 4 cups should face in the same direction.

Push a pin through the centre of the strips and attach the strips and the cups to the eraser of the pencil. Check that the strips rotate freely when you blow on the cups. Your anemometer is ready. Counting the number of rotations per minute will give you an estimate of the speed of the wind. To observe the changes in the wind speed, use it at different places and different times of the day.

If you do not have a pencil with attached eraser you can use the tip of a ball pen. The only condition is that the strips should rotate freely.

Remember that this anemometer will indicate only speed changes. It will not give you the actual wind speed.

3. Collect articles and photographs from newspapers and magazines about storms and cyclones. Make a story on the basis of what you learnt in this chapter and the matter collected by you.
4. Suppose you are a member of a committee, which is responsible for creating **development plan** of a coastal state. Prepare a short speech indicating the measures to be taken to reduce the suffering of the people caused by cyclones.
5. Interview eyewitness to collect the actual experience of people affected by a cyclone.
6. Take an aluminium tube about 15 cm long and 1 to 1.5 cm in diameter. Cut slice of a medium-sized potato about 2 cm thick. Insert the tube in the slice, press it, and rotate it 2–3 times. Remove the tube. You will find a piece of potato fixed in the tube like a piston head. Repeat the same process with the other end of the tube. Now you have the tube with both ends closed by potato pieces with an air column in between. Take a pencil with one end unsharpened. Place this end at one of the pieces of potato. Press it suddenly to push the potato piece in the tube. Observe what happens. The activity shows rather dramatically how increased air pressure can push things.

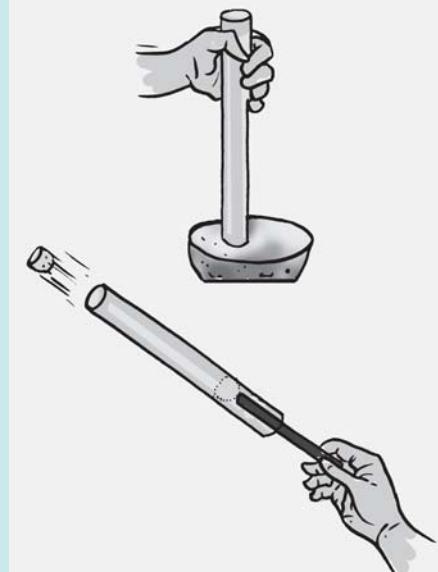


Fig. 8.20

CAUTION: When you perform this activity, make sure that nobody is standing in front of the tube.

You can read more on the related topics on the following websites:

<http://www.imd.gov.in/>

<http://library.thinkquest.org/10136/>

www.bom.gov.au/lam/students_teachers/cycmod.shtml

www.chunder.com/ski/lightanim.html

Did you know?

A bolt of lightning travels at a speed of more than 400,000 km/h. It can heat the air around it to a temperature which is more than 4 times the temperature of the surface of the sun. That is what makes lightning so dangerous.

CHAPTER 15

SOME NATURAL PHENOMENA

In Class VII you read about winds, storms and cyclones. You learnt that cyclones can cause a lot of damage to human life and property. You also learnt that we can protect ourselves from these destructive phenomena to some extent. In this chapter we shall discuss two other destructive natural phenomena. These are lightning and earthquakes. We shall also discuss what steps we can take to minimise destruction caused by these phenomena.

15.1 Lightning

You might have seen sparks on a electric pole when wires become loose. This phenomenon is quite common when a wind is blowing and shacking the wires. You might also have seen sparks when a plug is loose in its socket. Lightning is also an electric spark, but on a huge scale.

In ancient times people did not understand the cause of these sparks. They were, therefore, afraid of lightning and thought that the wrath of gods was visiting them. Now, of course, we understand that lightning is caused by the accumulation of charges in the clouds. We need not be afraid of lightning, but we have to take

precautions to protect ourselves from the deadly sparks.

The Sparks that the Greeks Knew About

The ancient Greeks knew as early as 600 B.C. that when amber (amber is a kind of resin) was rubbed with fur, it attracted light objects such as hair. You might have seen that when you take off woollen or polyester clothes, your hair stands on ends. If you take off these clothes in the dark, you see even a spark and hear crackling sound. In 1752 Benjamin Franklin, an American scientist, showed that lightning and the spark from your clothes are essentially the same phenomena. However, this realisation took 2000 years.

I wonder why they took so many years to realise the similarity.



Scientific discoveries are a result of hardwork by many people. It can sometime takes a long time.

We shall now study some properties of electric charges. We shall also see how they are related to the lightning in the sky.

Let us perform some activities to understand the nature of electric charges. But recall first what you might have played as a game. When you rub a plastic scale on your dry hair, the scale can attract very small pieces of paper.

15.2 Charging by rubbing

Activity 15.1

Take a used ballpen refill and rub it vigorously with a piece of polythene. Bring it close to small pieces of paper. Take care not to touch the rubbed end of the refill with your hand or with a metallic object. Repeat the activity with small pieces of dry leaf, husk and mustard seeds. Record your observations.

When a plastic refill is rubbed with polythene, it acquires a small electric charge. Similarly, when a plastic comb is rubbed with dry hair, it acquires a small charge. These objects are called **charged objects**. In the process of charging the refill and the plastic comb, polythene and hair also get charged.

Let's try to charge some other objects that are familiar to you.

Activity 15.2

Collect the objects and the materials listed in Table 15.1. Try to charge each by rubbing with the materials mentioned in the Table. Record your findings. You can add more items to the Table.

Table 15.1

Objects rubbed	Materials used for rubbing	Attracts/does not attract pieces of paper	Charged/not charged
Refill	Polythene, woollen cloth		
Balloon	Polythene, woollen cloth, dry hair		
Eraser	Wool		
Steel spoon	Polythene, woollen cloth		

15.3 Types of Charges and their Interaction

We will select some objects from Table 15.1 for the next activity.

Activity 15.3

- a)** Inflate two balloons. Hang them in such a way that they do not touch each other (Fig. 15.1). Rub both the balloons with a woollen cloth and release them. What do you observe?

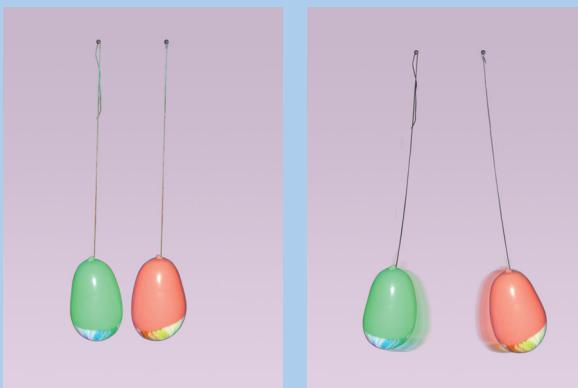


Fig. 15.1 : Like charges repel each other

Now let us repeat this activity with the used pen refills. Rub one refill with polythene. Place it carefully in a glass tumbler using the tumbler as a stand (Fig. 15.2). Rub the other



Fig. 15.2 : Interaction between like charges

refill also with polythene. Bring it close to the charged refill. Be careful not to touch the charged end with your hand. Is there any effect on the refill in the tumbler? Do the two attract each other, or repel each other?

In this activity we have brought close together the charged objects that were made of the same material. What happens if two charged objects made of different materials are brought close to each other? Let's find out.

- b)** Rub a refill and place it gently in a glass tumbler as before (Fig. 15.3). Bring an inflated charged balloon near the refill and observe.



Fig. 15.3 : Unlike charges attract each other

Let's summarise the observations:

A charged balloon repelled a charged balloon.

A charged refill repelled a charged refill.

But a charged balloon attracted a charged refill.

Does it indicate that the charge on the balloon is of a different kind from the charge on the refill? Can we say then, that there are two kinds of

charges? Can we also say that the charges of the same kind repel each other, while charges of different kind attract each other?

It is a convention to call the charge acquired by a glass rod when it is rubbed with silk as positive. The other kind of charge is said to be negative.

It is observed that when a charged glass rod is brought near a charged plastic straw rubbed with polythene there is attraction between the two.

What do you think would be the kind of charge on the plastic straw? Your guess, that the plastic straw would carry a negative charge is correct.

The electrical charges generated by rubbing are static. They do not move by themselves. When charges move, they constitute an electric current. You have been reading about electric current since Class VI. The current in a circuit which makes a bulb glow, or the current that makes a wire hot, is nothing but a motion of charges.

15.4 Transfer of Charge

Activity 15.4

Take an empty jam bottle. Take a piece of cardboard slightly bigger in size than the mouth of the bottle. Pierce a hole in it so that a metal paper clip could be inserted. Open out paper clip as shown in Fig. 15.4. Cut two strips of aluminium foil about $4\text{ cm} \times 1\text{ cm}$ each. Hang them on the paper clip as shown. Insert the paper clip in the cardboard lid so that it is perpendicular to it (Fig. 15.4). Charge a refill and touch it

with the end of the paper clip. Observe what happens. Is there any effect on the foil strips? Do they repel each other or attract each other? Touch now, other charged bodies with the end of the paper clip. Do foil strips behave in the same way in all cases? Can this apparatus be used to detect whether a body is charged or not? Can you explain why the foil strips repel each other?



Fig 15.4 : A simple electroscope

The aluminium foil strips receive the same charge from the charged refill through the paper clip (remember that metals are good conductors of electricity). The strips carrying similar charges repel each other and they become wide open. Such a device can be used to test whether an object is carrying charge or not. This device is known as **electroscope**.

Thus, we find that electrical charge can be transferred from a charged object to another through a metal conductor.

Touch the end of the paper clip gently with hand and you will find a change in

the foil strips. They come back to their original state. Repeat charging of foil strips and touching the paper clip. Every time you will find that the foil strips collapse as soon as you touch the paperclip with hand. Why does it happen? The reason is that the foil strips lose charge to the earth through your body. We say that the foil strips are **discharged**. The process of transferring of charge from a charged object to the earth is called **earthing**.

Earthing is provided in buildings to protect us from electrical shocks due to any leakage of electrical current.

15.5 The Story of Lightning

It is now possible to explain lightning in terms of the charges produced by rubbing.

You learnt in Class VII that during the development of a thunderstorm, the air currents move upward while the water droplets move downward. These vigorous movements cause separation of charges. By a process, not yet completely understood, the positive charges collect near the upper edges of the clouds and the negative charges accumulate near the lower edges. There is accumulation of positive charges near the ground also. When the magnitude of the accumulated charges becomes very large, the air which is normally a poor conductor of electricity, is no longer able to resist their flow. Negative and positive charges meet, producing streaks of bright light and sound. We see streaks as lightning (Fig. 15.5). The process is called an electric discharge.

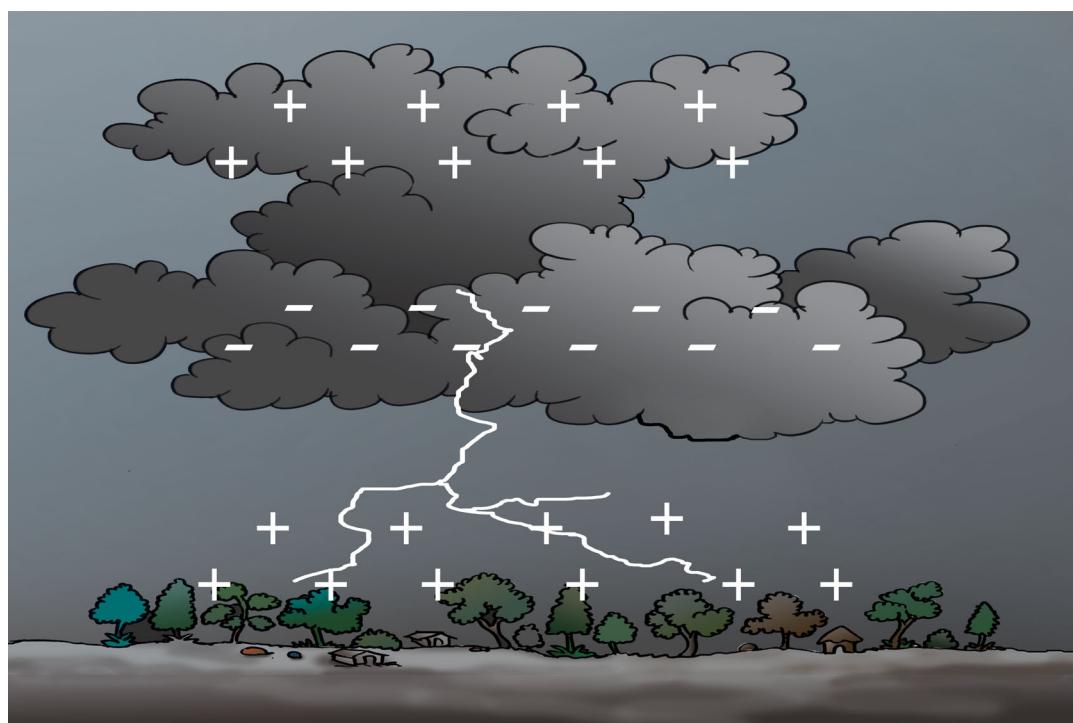


Fig 15.5 : Accumulation of charges leading to lightning.

The process of electric discharge can occur between two or more clouds, or between clouds and the earth. Today we need not get frightened by lightning like the ancient people did. Now we understand the basic phenomenon. Scientists are trying hard to improve our understanding. However, lightning strike could destroy life and property. It is, therefore, necessary to take measures to protect ourselves.

15.6 Lightning Safety

During lightning and thunderstorm no open place is safe.

- ⦿ Hearing thunder is an alert to rush to a safer place.
- ⦿ After hearing the last thunder, wait for some time before coming out of the safe place.

Finding a safe place

A house or a building is a safe place.

If you are travelling by car or by bus, you are safe inside with windows and doors of the vehicle shut.

Do's and Don'ts during a Thunder-storm

Outside

Open vehicles, like motorbikes, tractors, construction machinery, open cars are not safe. Open fields, tall trees, shelters in parks, elevated places do not protect us from lightning strokes.

Carrying umbrella is not a good idea at all during thunderstorms.

If in a forest, take shelter under shorter trees.

If no shelter is available and you are in an open field, stay far away from all trees. Stay away from poles or other

metal objects. Do not lie on the ground. Instead, squat low on the ground. Place your hands on your knees with your head between the hands (Fig. 15.6). This position will make you the smallest target to be struck.



Fig. 15.6 : Safe position during lightning

Inside the house

Lightning can strike telephone cords, electrical wires and metal pipes (Do you remember, lightning is an electrical discharge?). During a thunderstorm contact with these should be avoided. It is safer to use mobile phones and cordless phones. However, it is not wise to call up a person who is receiving your phone through a wired phone.

Bathing should be avoided during thunderstorms to avoid contact with running water.

Electrical appliances like computers, TVs, etc., should be unplugged. Electrical lights can remain on. They do not cause any harm.

Lightning Conductors

Lightning Conductor is a device used to protect buildings from the effect of lightning. A metallic rod, taller than the building, is installed in the walls of the building during its construction. One end of the rod is kept out in the air and the other is buried deep in the ground (Fig. 15.7). The rod provides easy route for the transfer of electric charge to the ground.

The metal columns used during construction, electrical wires and water pipes in the buildings also protect us to an extent. But do not touch them during a thunderstorm.

15.7 Earthquakes

You just learnt about thunderstorm and lightning. In Class VII you learnt about cyclones. These natural phenomena can cause large scale destruction of human life and property. Fortunately, these phenomena can be predicted to some extent. The weather department can warn about a thunderstorm developing in some area.

If a thunderstorm occurs there is always a possibility of lightning and cyclones accompanying it. So, we get time to take measures to protect ourselves from the damage caused by these phenomena.

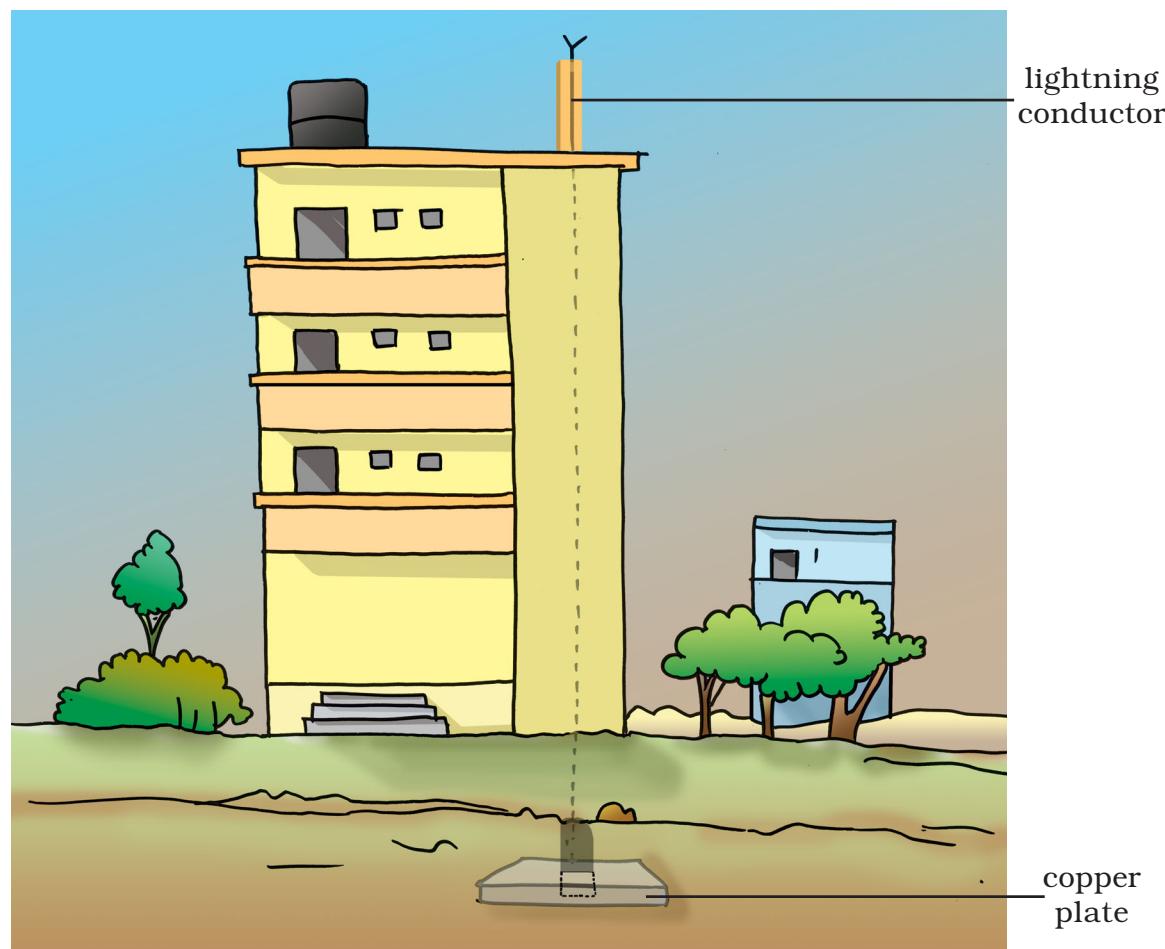


Fig. 15.7 : Lightning conductor

There is, however, one natural phenomenon which we are not yet able to predict. It is an earthquake. It can cause damage to human life and property on a huge scale.

A major earthquake occurred in India on 8th October 2005 in Uri and Tangdhar towns of North Kashmir (Fig. 15.8). Before that a major earthquake occurred on 26th January 2001 in Bhuj District of Gujarat.

Activity 15.5

Ask your parents about the huge damages to life and property caused by these earthquakes. Collect a few pictures showing the damage

caused by these earthquakes from newspapers and magazines of those days. Prepare a short report on the suffering of the people during the earthquakes.

What is an earthquake? What happens when it occurs? What can we do to minimise its effects? These are some of the questions which we shall discuss below.

What is an Earthquake?

An earthquake is a sudden shaking or trembling of the earth lasting for a very short time. It is caused by a disturbance deep inside the earth's crust.



Fig. 15.8 : Kashmir earthquake

Earthquakes occur all the time, all over the earth. They are not even noticed. Major earthquakes are much less frequent. They can cause immense damage to buildings, bridges, dams and people. There can be a great loss to life and property. The earthquakes can cause floods, landslides and tsunamis. A major tsunami occurred in the Indian Ocean on 26th December 2004. All the coastal areas around the ocean suffered huge losses.

Activity 15.6

Take an outline map of the world. Locate the eastern coast and Andaman and Nicobar Islands in India. Mark other countries around the Indian Ocean which could have suffered damage. Collect accounts of the devastation caused by the tsunami in India from your parents, or other elders in the family or in the neighbourhood.

What Causes an Earthquake?



My grandmother told me that the earth is balanced on the horn of a bull and when the bull shifts it to the other horn, an earthquake takes place. How could it be true?

In ancient times, people did not know the true cause of earthquakes. Their ideas were, therefore, expressed in mythical stories such as the one told by Boojho's grandmother. Similar myths were prevalent in other parts of the world.

What could cause a disturbance inside the earth?



Now we know that the tremors are caused by the disturbance deep down inside the uppermost layer of the earth called the crust (Fig. 15.9).

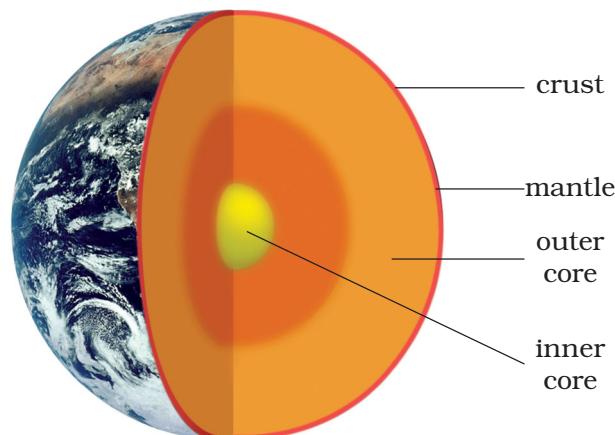


Fig. 15.9 : Structure of the earth

The outermost layer of the earth is not in one piece. It is fragmented. Each fragment is called a plate (Fig. 15.10). These plates are in continual motion. When they brush past one another, or

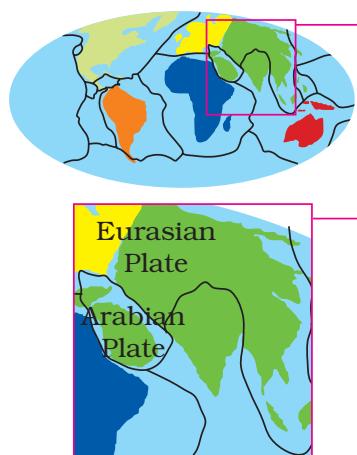


Fig. 15.10 : Earth plates

a plate goes under another due to collision (Fig. 15.11), they cause disturbance in the earth's crust. It is this disturbance that shows up as an earthquake on the surface of the earth.

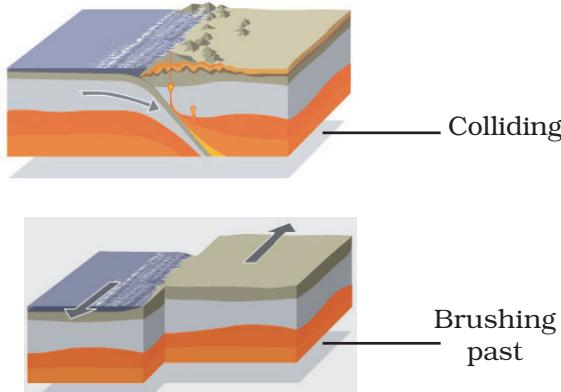


Fig. 15.11 : Movements of earth's plates



If scientists know so much about earthquakes, can they also predict when and where the next one will strike?

Although, we know for sure what causes an earthquake, it is not yet possible to predict when and where the next earthquake might occur.



I read somewhere that underground explosions could also cause tremors.

Tremors on the earth can also be caused when a volcano erupts, or a meteor hits the earth, or an underground nuclear explosion is

carried out. However, most earthquakes are caused by the movement of earth's plates.

Since earthquakes are caused by the movement of plates, the boundaries of the plates are the weak zones where earthquakes are more likely to occur. The weak zones are also known as **seismic** or **fault zones**. In India, the areas most threatened are Kashmir, Western and Central Himalayas, the whole of North-East, Rann of Kutch, Rajasthan and the Indo - Gangetic Plane. Some areas of South India also fall in the danger zone (Fig. 15.12).

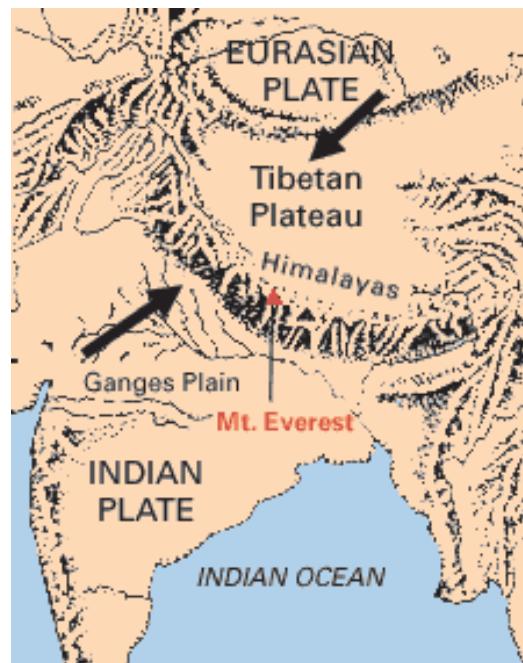


Fig. 15.12 : Movements of Indian earth's plate

The power of an earthquake is expressed in terms of a magnitude on a scale called **Richter scale**. Really destructive earthquakes have magnitudes higher than 7 on the Richter scale. Both Bhuj and Kashmir earthquakes had magnitudes greater than 7.5.

The tremors produce waves on the surface of the earth. These are called seismic waves. The waves are recorded by an instrument called the **seismograph** (Fig. 15.13). The instrument is simply a vibrating rod, or a pendulum, which starts vibrating when tremors occur. A pen is attached to the vibrating system. The pen records the seismic waves on a paper which moves under it. By studying these waves, scientists can construct a complete map of the earthquake, as shown in Fig. 15.14. They can also estimate its power to cause destruction.

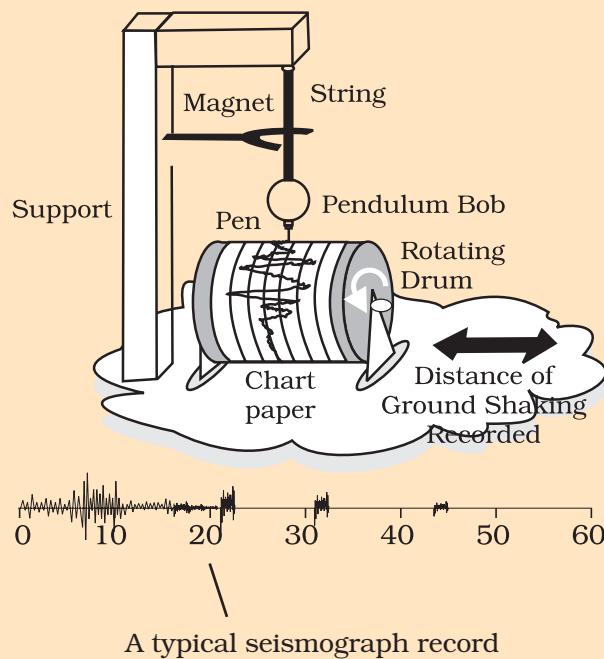


Fig. 15.13 : A seismograph

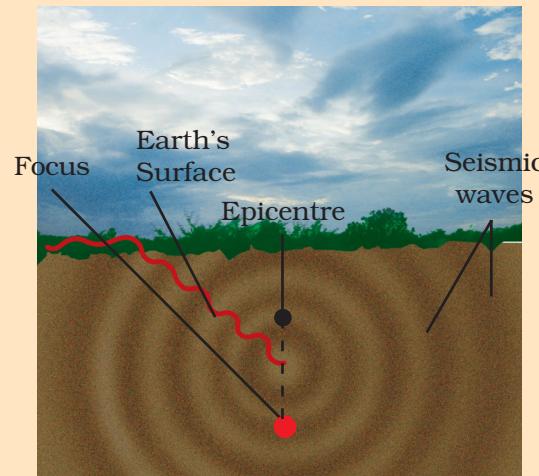


Fig. 15.14 : Map of the earthquake

Like many other scales in science (decibel is another example), Richter scale is not linear. This means that an earthquake of magnitude 6 does not have one and half times the destructive energy of an earthquake of magnitude 4. In fact, an increase of 2 in magnitude means 1000 times more destructive energy. For example, an earthquake of magnitude 6 has thousand times more destructive energy than an earthquake of magnitude 4.

Protection against Earthquakes

We know from the earlier pages that earthquakes cannot be predicted. We have also seen that they can be highly destructive. It is, therefore, important that we take necessary precautions to protect ourselves all the time. People living in seismic zones, where the earthquakes are more likely to occur,

have to be specially prepared. First of all, the buildings in these zones should be designed so that they can withstand major tremors. Modern building technology can make it possible.

It is advisable to make the structure simple so that it is 'Quake Safe'.

- Consult qualified architects and structural engineers.

- In highly seismic areas, the use of mud or timber is better than the heavy construction material. Keep roofs as light as possible. In case the structure falls, the damage will not be heavy.
- It is better if the cupboards and shelves are fixed to the walls, so that they do not fall easily.
- Be careful where you hang wall clocks, photo-frames, water heaters etc., so that in the event of an earthquake, they do not fall on people.
- Since some buildings may catch fire due to an earthquake, it is necessary that all buildings, especially tall buildings, have fire fighting equipment in working order.

The Central Building Research Institute, Roorkee, has developed knowhow to make quake proof houses.

In the event that an earthquake does strike, take the following steps to protect yourself:

1. If you are at home:

- Take shelter under a table and stay there till shaking stops.
- Stay away from tall and heavy objects that may fall on you.
- If you are in bed, do not get up. Protect your head with a pillow.

2. If you are outdoors:

- Find a clear spot, away from buildings, trees and overhead power lines. Drop to the ground.
- If you are in a car or a bus, do not come out. Ask the driver to drive slowly to a clear spot. Do not come out till the tremors stop.

KEYWORDS**CRUST****DISCHARGE****EARTH'S PLATES****EARTHQUAKE****ELECTROSCOPE****LIGHTNING****LIGHTNING****CONDUCTOR****NEGATIVE CHARGE****POSITIVE CHARGE****RICHTER SCALE****SEISMOGRAPH****THUNDER****THUNDERSTORM****TRANSFER OF
CHARGE****TSUNAMI****TREMOR****WHAT YOU HAVE LEARNT**

- ⌚ Some objects can be charged by rubbing with other objects.
- ⌚ There are two kinds of charges — positive charge and negative charge
- ⌚ Like charges repel and unlike charges attract each other.
- ⌚ The electrical charges produced by rubbing are called static charges.
- ⌚ When charges move, they constitute an electric current.
- ⌚ An electroscope may be used to detect whether a body is charged or not.
- ⌚ The process of transfer of charge from a charged object to the earth is called earthing.
- ⌚ The process of electric discharge between clouds and the earth or between different clouds causes lightning.
- ⌚ Lightning strike could destroy life and property.
- ⌚ Lightning conductors can protect buildings from the effects of lightning.
- ⌚ An earthquake is a sudden shaking or trembling of the earth.
- ⌚ Earthquake is caused by a disturbance deep inside the earth's crust.
- ⌚ It is not possible to predict the occurrence of an earthquake.
- ⌚ Earthquakes tend to occur at the boundaries of earth's plates. These boundaries are known as fault zones.
- ⌚ Destructive energy of an earthquake is measured on the Richter scale. The earthquake measuring 7 or more on Richter scale can cause severe damage to life and property.
- ⌚ We should take necessary precautions to protect ourselves from earthquakes.

Exercises

Select the correct option in Questions 1 and 2.

1. Which of the following cannot be charged easily by friction?
 - (a) A plastic scale
 - (b) A copper rod
 - (c) An inflated balloon
 - (d) A woollen cloth.
2. When a glass rod is rubbed with a piece of silk cloth the rod
 - (a) and the cloth both acquire positive charge.
 - (b) becomes positively charged while the cloth has a negative charge.
 - (c) and the cloth both acquire negative charge.
 - (d) becomes negatively charged while the cloth has a positive charge.
3. Write T against true and F against false in the following statements:
 - (a) Like charges attract each other (T/F)
 - (b) A charged glass rod attract a charged plastic straw (T/F)
 - (c) Lightning conductor cannot protect a building from lightning (T/F)
 - (d) Earthquakes can be predicted in advance (T/F)
4. Sometime, a crackling sound is heard while taking off sweater during winters. Explain.
5. Explain why a charged body loses its charge if we touch it with our hand.
6. Name the scale on which the destructive energy of an earthquake is measured. An earthquake measures 3 on this scale. Would it be recorded by a seismograph? Is it likely to cause much damage?
7. Suggest three measures to protect ourselves from lightning.
8. Explain why a charged balloon is repelled by another charged balloon whereas an uncharged balloon is attracted by another charged balloon?
9. Describe with the help of a diagram an instrument which can be used to detect a charged body.
10. List three states in India where earthquakes are more likely to strike.
11. Suppose you are outside your home and an earthquake strikes. What precaution would you take to protect yourself?
12. The weather department has predicted that a thunderstorm is likely to occur on a certain day. Suppose you have to go out on that day. Would you carry an umbrella? Explain.

Extended Learning — Activities and Projects

1. Open a water tap. Adjust the flow so that it forms a thin stream. Charge a refill. Bring it near the water stream. Observe what happens. Write a short report on the activity.
2. Make your own charge detector. Take a paper strip roughly 10 cm × 3 cm. Give it a shape as shown in Fig. 15.15. Balance it on a needle. Bring a charged body near it. Observe what happens. Write a brief report, explaining its working.

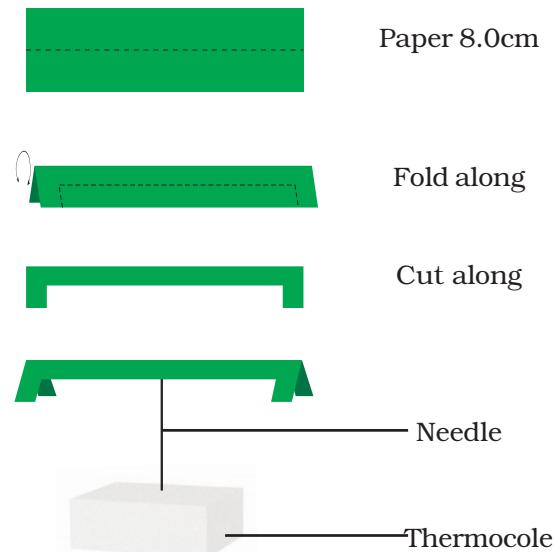


Fig. 15.15

3. This activity should be performed at night. Go to a room where there is a fluorescent tube light. Charge a balloon. Switch off the tube light so that the room is completely dark. Bring the charged balloon near the tubelight. You should see a faint glow. Move the balloon along the length of the tube and observe how glow changes.
Caution : Do not touch the metal parts of the tube or the wires connecting the tube with the mains.
4. Find out if there is an organisation in your area which provides relief to those suffering from natural disaster. Enquire about the type of help they render to the victims of earthquakes. Prepare a brief report on the problems of the earthquake victims.

For more information on these topics, visit:

- science.howstuffworks.com/lightning.htm
- science.howstuffworks.com/earthquake.htm
- www.enchantedlearning.com/subjects/astronomy/planets/earth/continents.shtml

UNIT I

GEOGRAPHY AS A DISCIPLINE

This unit deals with

- *Geography as an integrating discipline; as a science of spatial attributes*
- *Branches of geography; importance of physical geography*

C H A P T E R

1

GEOGRAPHY AS A DISCIPLINE

You have studied geography as one of the components of your social studies course upto the secondary stage. You are already aware of some of the phenomena of geographical nature in the world and its different parts. Now, you will study 'Geography' as an independent subject and learn about the physical environment of the earth, human activities and their interactive relationships. Therefore, a pertinent question you can ask at this stage is — Why should we study geography? We live on the surface of the earth. Our lives are affected by our surroundings in many ways. We depend on the resources to sustain ourselves in the surrounding areas. Primitive societies subsisted on 'natural means of subsistence', i.e. edible plants and animals. With the passage of time, we developed technologies and started producing our food using natural resources such as land, soil and water. We adjusted our food habits and clothing according to the prevailing weather conditions. There are variations in the natural resource base, technological development, adaptation with and modification of physical environment, social organisations and cultural development. As a student of geography, you should be curious to know about all the phenomena which vary over space. You learn about the diverse lands and people. You should also be interested in understanding the changes which have taken place over time. Geography equips you to appreciate diversity and investigate into the causes responsible for creating such variations over time and space. You will develop skills to understand the globe converted into maps and have a visual sense

of the earth's surface. The understanding and the skills obtained in modern scientific techniques such as GIS and *computer cartography* equip you to meaningfully contribute to the national endeavour for development.

Now the next question which you may like to ask is — What is geography? You know that earth is our home. It is also the home of many other creatures, big and small, which live on the earth and sustain. The earth's surface is not uniform. It has variations in its physical features. There are mountains, hills, valleys, plains, plateaus, oceans, lakes, deserts and wilderness. There are variations in its social and cultural features too. There are villages, cities, roads, railways, ports, markets and many other elements created by human beings across the entire period of their cultural development.

This variation provides a clue to the understanding of the relationship between the physical environment and social/cultural features. The physical environment has provided the stage, on which human societies enacted the drama of their creative skills with the tools and techniques which they invented and evolved in the process of their cultural development. Now, you should be able to attempt the answer of the question posed earlier as to "What is geography"? In very simple words, it can be said that geography is the description of the earth. The term *geography* was first coined by *Eratosthenese*, a Greek scholar (276-194 BC.). The word has been derived from two roots from Greek language *geo* (earth) and *graphos* (description).

Put together, they mean description of the earth. The earth has always been seen as the abode of human beings and thus, scholars defined geography as, "the description of the earth as the abode of human beings". You are aware of the fact that reality is always multifaceted and the 'earth' is also multi-dimensional, that is why many disciplines from natural sciences such as geology, pedology, oceanography, botany, zoology and meteorology and a number of sister disciplines in social sciences such as economics, history, sociology, political science, anthropology, etc. study different aspects of the earth's surface. Geography is different from other sciences in its subject matter and methodology but at the same time, it is closely related to other disciplines. Geography derives its data base from all the natural and social sciences and attempts their synthesis.

We have noted that there exist variations over the surface of the earth in its physical as well as cultural environment. A number of phenomena are similar and many are dissimilar. It was, therefore, logical to perceive geography as the study of *areal differentiation*. Thus, geography was perceived to study all those phenomena which vary over space. Geographers do not study only the variations in the phenomena over the earth's surface (space) but also study the associations with the other factors which cause these variations. For example, cropping patterns differ from region to region but this variation in cropping pattern, as a phenomenon, is related to variations in soils, climates, demands in the market, capacity of the farmer to invest and technological inputs available to her/him. Thus, the concern of geography is to find out the causal relationship between any two phenomena or between more than one phenomenon.

A geographer explains the phenomena in a frame of cause and effect relationship, as it does not only help in interpretation but also foresees the phenomena in future.

The geographical phenomena, both the physical and human, are not static but highly dynamic. They change over time as a result of the interactive processes between *ever*

changing earth and untiring and ever-active human beings. Primitive human societies were directly dependent on their immediate environment. Geography, thus, is concerned with the study of *Nature* and *Human* interactions as an integrated whole. 'Human' is an integral part of 'nature' and 'nature' has the imprints of 'human'. 'Nature' has influenced different aspects of human life. Its imprints can be noticed on food, clothing, shelter and occupation. Human beings have come to terms with nature through adaptation and modification. As you already know, the present society has passed the stage of primitive societies, which were directly dependent on their immediate physical environment for sustenance. Present societies have modified their natural environment by inventing and using technology and thus, have expanded the horizon of their operation by appropriating and utilising the resources provided by nature. With the gradual development of technology, human beings were able to loosen the shackles of their physical environment. Technology helped in reducing the harshness of labour, increased labour efficiency and provided leisure to human beings to attend to the higher needs of life. It also increased the scale of production and the mobility of labour.

The interaction between the physical environment and human beings has been very succinctly described by a poet in the following dialogue between 'human' and 'nature' (God). *You created the soil, I created the cup, you created night, I created the lamp. You created wilderness, hilly terrains and deserts; I created flower beds and gardens.* Human beings have claimed their contribution using natural resources. With the help of technology, human beings moved from the stage of necessity to a stage of freedom. They have put their imprints everywhere and created new possibilities in collaboration with nature. Thus, we now find *humanised nature* and *naturalised human beings* and geography studies this interactive relationship. The space got organised with the help of the means of transportation and communication network. The links (routes) and nodes (settlements of all types and hierarchies) integrated the space and

gradually, it got organised. As a social science discipline, geography studies the ‘spatial organisation’ and ‘spatial integration’.

Geography as a discipline is concerned with three sets of questions:

- (i) Some questions are related to the identification of the patterns of natural and cultural features as found over the surface of the earth. These are the questions about *what*?
- (ii) Some questions are related to the distribution of the natural and human/cultural features over the surface of the earth. These are the questions about *where*?

Taken together, both these questions take care of distributional and locational aspects of the natural and cultural features. These questions provided inventorised information of what features and where located. It was a very popular approach during the colonial period. These two questions did not make geography a scientific discipline till the third question was added. The third question is related to the explanation or the causal relationships between features and the processes and phenomena. This aspect of geography is related to the question, *why*?

Geography as a discipline is related to space and takes note of spatial characteristics and attributes. It studies the patterns of distribution, location and concentration of phenomena over space and interprets them providing explanations for these patterns. It takes note of the associations and inter-relationships between the phenomena over space and interprets them providing explanations for these patterns. It also takes note of the associations and inter-relationships between the phenomena resulting from the dynamic interaction between human beings and their physical environment.

GEOGRAPHY AS AN INTEGRATING DISCIPLINE

Geography is a discipline of synthesis. It attempts *spatial synthesis*, and history attempts *temporal synthesis*. Its approach is holistic in nature. It recognises the fact that the world is a system of interdependencies. The

present world is being perceived as a global village. The distances have been reduced by better means of transportation increasing accessibility. The audio-visual media and information technology have enriched the data base. Technology has provided better chances of monitoring natural phenomena as well as the economic and social parameters. Geography as an integrating discipline has interface with numerous natural and social sciences. All the sciences, whether natural or social, have one basic objective, of *understanding the reality*. Geography attempts to comprehend the associations of phenomena as related in sections of reality. Figure 1.1 shows the relationship of geography with other sciences. Every discipline, concerned with scientific knowledge is linked with geography as many of their elements vary over space. Geography helps in understanding the reality in totality in its spatial perspective. Geography, thus, not only takes note of the differences in the phenomena from place to place but integrates them holistically which may be different at other places. A geographer is required to have a broad understanding of all the related fields, to be able to logically integrate them. This integration can be understood with some examples. Geography influences historical events. Spatial distance itself has been a very potent factor to alter the course of history of the world. Spatial depth provided defence to many countries, particularly in the last century. In traditional warfare, countries with large size in area, gain time at the cost of space. The defence provided by oceanic expanse around the countries of the new world has protected them from wars being imposed on their soil. If we look at the historical events world over, each one of them can be interpreted geographically.

In India, Himalayas have acted as great barriers and provided protection but the passes provided routes to the migrants and invaders from Central Asia. The sea coast has encouraged contact with people from East and Southeast Asia, Europe and Africa. Navigation technology helped European countries to colonise a number of countries of Asia and Africa, including India as they got accessibility

through oceans. The geographical factors have modified the course of history in different parts of the world.

Every geographical phenomenon undergoes change through time and can be explained temporally. The changes in landforms, climate, vegetation, economic activities occupations and cultural developments have followed a definite historical course. Many geographical features result from the decision making process by different institutions at a particular point of time. It is possible to convert time in terms of space and space in terms of time. For example, it can be said that place A is 1,500 km from place B or alternately, it can also be said that place A is two hours away (if one travels by plane) or seventeen hours away (if one travels by a fast moving train). It is for this reason, time is an integral part of geographical studies as the fourth dimension. Please mention other three dimensions?

Figure 1.1 amply depicts the linkages of geography with different natural and social sciences. This linkage can be put under two segments.

Physical Geography and Natural Sciences

All the branches of physical geography, as shown in Figure 1.1, have interface with natural sciences. The traditional physical geography is linked with geology, meteorology, hydrology and pedology, and thus, geomorphology, climatology, oceanography and soil geography respectively have very close link with the natural sciences as these derive their data from these sciences. Bio-Geography is closely related to botany, zoology as well as ecology as human beings are located in different locational niche.

A geographer should have some proficiency in mathematics and art, particularly in drawing maps. Geography is very much linked with the study of astronomical locations and deals with latitudes and longitudes. The shape of the earth is *Geoid* but the basic tool of a geographer is a map which is two dimensional representation of the earth. The problem of converting geoids into two dimensions can be tackled by projections constructed graphically or mathematically. The cartographic and quantitative techniques require sufficient proficiency in mathematics, statistics and

econometrics. Maps are prepared through artistic imagination. Making sketches, mental maps and cartographic work require proficiency in arts.

Geography and Social Sciences

Each social science sketched in Figure 1.1 has interface with one branch of geography. The relationships between geography and history have already been outlined in detail. Every discipline has a philosophy which is the *raison d'être* for that discipline. Philosophy provides roots to a discipline and in the process of its evolution, it also experiences distinct historical processes. Thus, the history of geographical thought as mother branch of geography is included universally in its curricula. All the social science disciplines, viz. sociology, political science, economics and demography study different aspects of social reality. The branches of geography, viz. social, political, economic and population and settlements are closely linked with these disciplines as each one of them has spatial attributes. The core concern of political science is territory, people and sovereignty while political geography is also interested in the study of the state as a spatial unit as well as people and their political behaviour. Economics deals with basic attributes of the economy such as production, distribution, exchange and consumption. Each of these attributes also has spatial aspects and here comes the role of economic geography to study the spatial aspects of production, distribution, exchange and consumption. Likewise, *population geography* is closely linked with the discipline of *demography*.

The above discussion shows that geography has strong interface with natural and social sciences. It follows its own methodology of study which makes it distinct from others. It has osmotic relationship with other disciplines. While all the disciplines have their own individual scope, this individuality does not obstruct the flow of information as in case of all cells in the body that have individual identity separated by membranes but the flow of blood is not obstructed. Geographers use data obtained from sister disciplines and

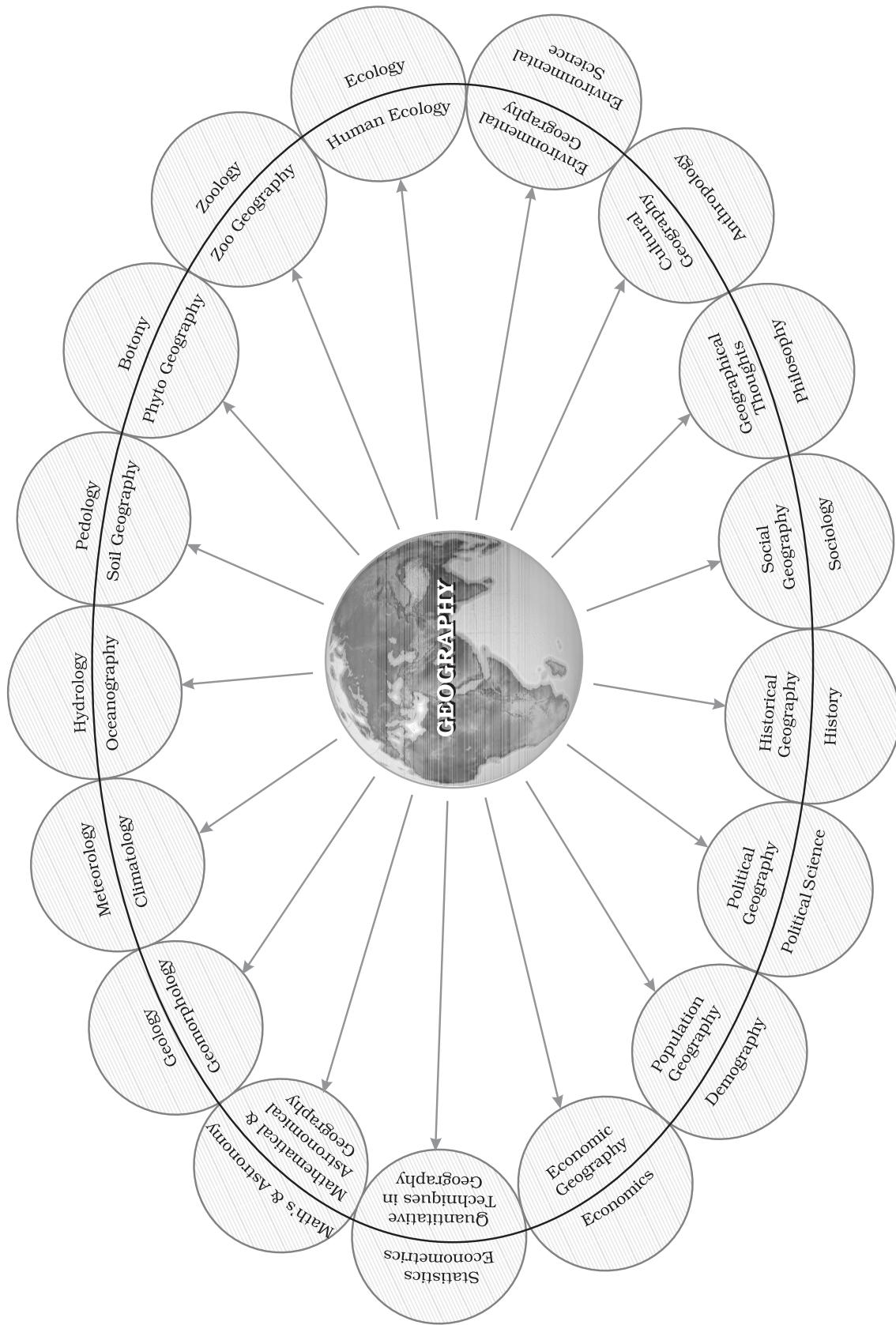


Figure 1.1 : Geography and its relation with other subjects

attempt synthesis over space. Maps are very effective tools of geographers in which the tabular data is converted into visual form to bring out the spatial pattern.

BRANCHES OF GEOGRAPHY

Please study Figure 1.1 for recapitulation. It has very clearly brought out that geography is an interdisciplinary subject of study. The study of every subject is done according to some approach. The major approaches to study geography have been (i) Systematic and (ii) Regional. The systematic geography approach is the same as that of general geography. This approach was introduced by *Alexander Von Humboldt*, a German geographer (1769-1859) while regional geography approach was developed by another German geographer and a contemporary of Humboldt, *Karl Ritter* (1779-1859).

In systematic approach (Figure 1.2), a phenomenon is studied world over as a whole, and then the identification of typologies or spatial patterns is done. For example, if one is interested in studying natural vegetation, the study will be done at the world level as a first step. The typologies such as equatorial rain forests or softwood conical forests or monsoon forests, etc. will be identified, discussed and delimited. In the regional approach, the world is divided into regions at different hierarchical levels and then all the geographical phenomena in a particular region are studied. These regions may be natural, political or designated region. The phenomena in a region are studied in a holistic manner searching for unity in diversity.

Dualism is one of the main characteristics of geography which got introduced from the very beginning. This dualism depended on the aspect emphasised in the study. Earlier scholars laid emphasis on physical geography. But human beings are an integral part of the earth's surface. They are part and parcel of nature. They also have contributed through their cultural development. Thus developed human geography with emphasis on human activities.

BRANCHES OF GEOGRAPHY (BASED ON SYSTEMATIC APPROACH)

1. Physical Geography

- (i) *Geomorphology* is devoted to the study of landforms, their evolution and related processes.
- (ii) *Climatology* encompasses the study of structure of atmosphere and elements of weather and climates and climatic types and regions.
- (iii) *Hydrology* studies the realm of water over the surface of the earth including oceans, lakes, rivers and other water bodies and its effect on different life forms including human life and their activities.
- (iv) *Soil Geography* is devoted to study the processes of soil formation, soil types, their fertility status, distribution and use.

2. Human Geography

- (i) *Social/Cultural Geography* encompasses the study of society and its spatial dynamics as well as the cultural elements contributed by the society.
- (ii) *Population and Settlement Geography* (Rural and Urban). It studies population growth, distribution, density, sex ratio, migration and occupational structure etc. Settlement geography studies the characteristics of rural and urban settlements.
- (iii) *Economic Geography* studies economic activities of the people including agriculture, industry, tourism, trade, and transport, infrastructure and services, etc.
- (iv) *Historical Geography* studies the historical processes through which the space gets organised. Every region has undergone some historical experiences before attaining the present day status. The geographical features also experience temporal changes and these form the concerns of historical geography.

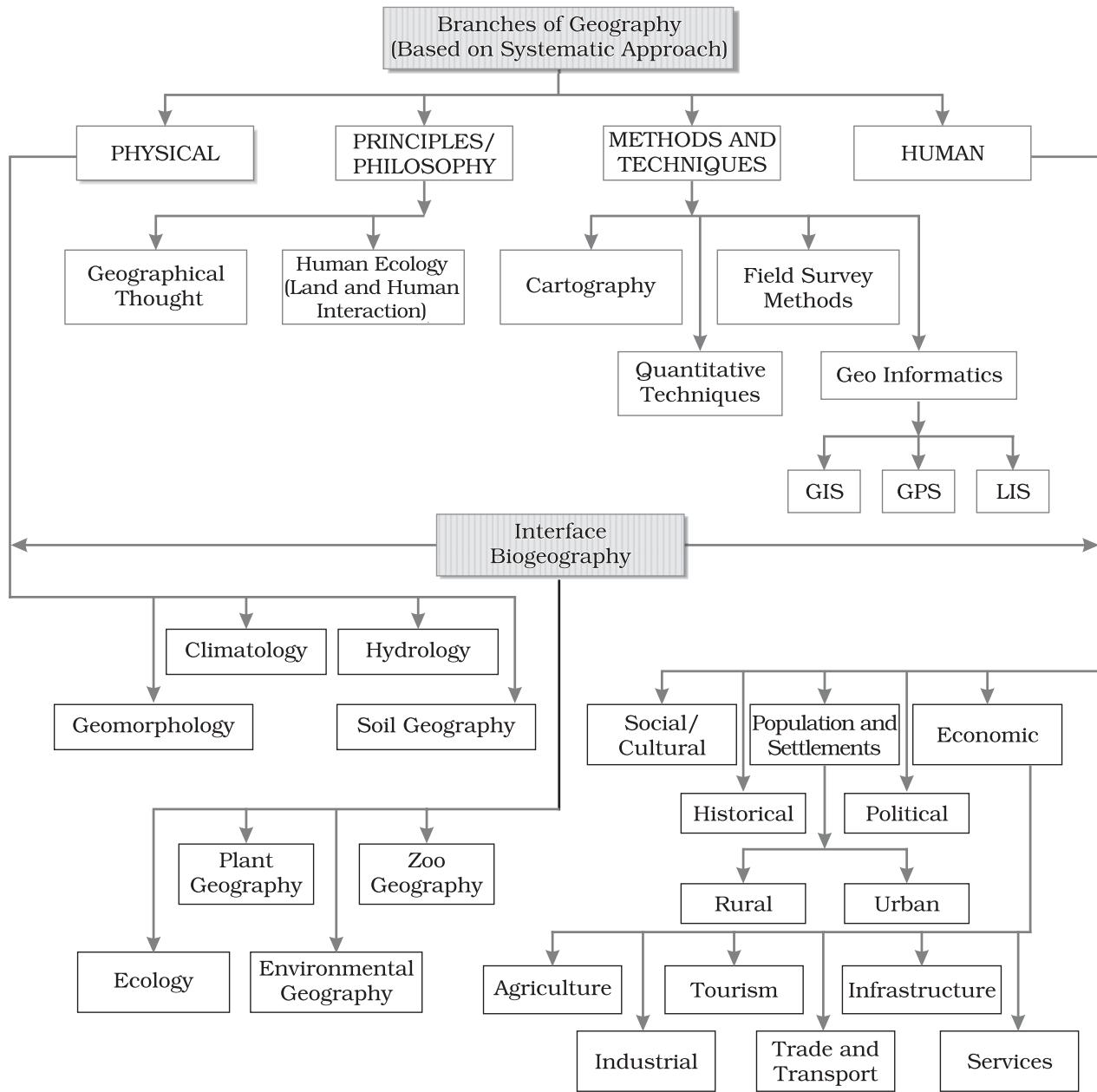


Figure 1.2 : Branches of geography based on systematic approach

- (v) *Political Geography* looks at the space from the angle of political events and studies boundaries, space relations between neighbouring political units, delimitation of constituencies, election scenario and develops theoretical framework to understand the political behaviour of the population.

3. Biogeography

The interface between physical geography and human geography has led to the development of Biogeography which includes:

- (i) *Plant Geography* which studies the spatial pattern of natural vegetation in their habitats.

- (ii) *Zoo Geography* which studies the spatial patterns and geographic characteristics of animals and their habitats.
- (iii) *Ecology /Ecosystem* deals with the scientific study of the habitats characteristic of species.
- (iv) *Environmental Geography* concerns world over leading to the realisation of environmental problems such as land gradation, pollution and concerns for conservation has resulted in the introduction of this new branch in geography.

BRANCHES OF GEOGRAPHY BASED ON REGIONAL APPROACH (FIGURE 1.3)

1. Regional Studies/Area Studies

Comprising *Macro*, *Meso* and *Micro* Regional Studies

2. Regional Planning

Comprising Country/Rural and Town/Urban Planning

3. Regional Development

4. Regional Analysis

There are two aspects which are common to every discipline, these are:

- (i) Philosophy
 - (a) Geographical Thought
 - (b) Land and Human Interaction/Human Ecology
- (ii) Methods and Techniques
 - (a) Cartography including Computer Cartography
 - (b) Quantitative Techniques/Statistical Techniques

- (c) Field Survey Methods
- (d) Geo-informatics comprising techniques such as Remote Sensing, GIS, GPS, etc.

The above classification gives a comprehensive format of the branches of geography. Generally geography curricula is taught and learnt in this format but this format is not static. Any discipline is bound to grow with new ideas, problems, methods and techniques. For example, what was once manual cartography has now been transformed into computer cartography. Technology has enabled scholars to handle large quantum of data. The internet provides extensive information. Thus, the capacity to attempt analysis has increased tremendously. GIS has further opened vistas of knowledge. GPS has become a handy tool to find out exact locations. Technologies have enhanced the capacity of attempting synthesis with sound theoretical understanding.

You will learn some preliminary aspects of these techniques in your book, *Practical work in Geography – Part I* (NCERT, 2006). You will continue to improve upon your skills and learn about their application.

PHYSICAL GEOGRAPHY AND ITS IMPORTANCE

This chapter appears in the book entitled *Fundamentals of Physical Geography*. The contents of the book clearly reflect its scope. It is therefore, appropriate to know the importance of this branch of geography.

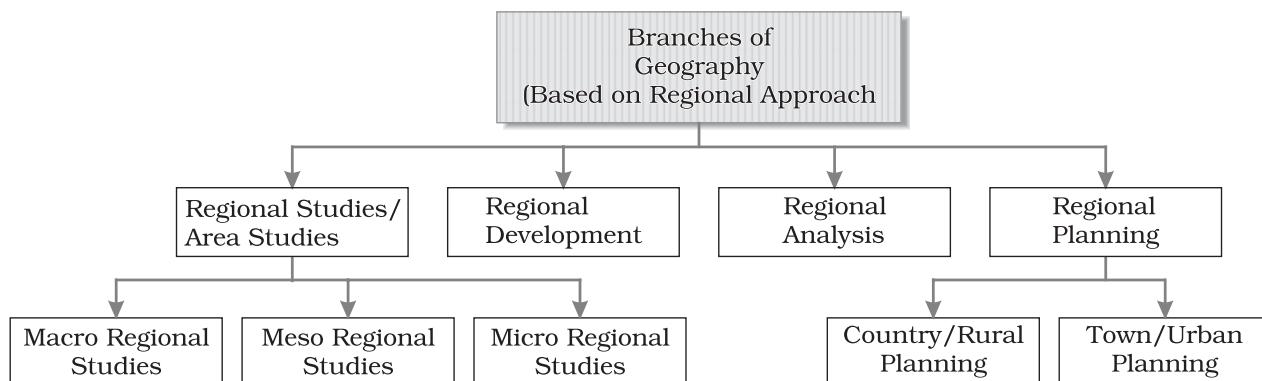


Figure 1.3 : Branches of geography based on regional approach

Physical geography includes the study of lithosphere (landforms, drainage, relief and physiography), atmosphere (its composition, structure, elements and controls of weather and climate; temperature, pressure, winds, precipitation, climatic types, etc.), hydrosphere (oceans, seas, lakes and associated features with water realm) and biosphere (life forms including human being and macro-organism and their sustaining mechanism, viz. food chain, ecological parameters and ecological balance). Soils are formed through the process of *pedogenesis* and depend upon the parent rocks, climate, biological activity and time. Time provides maturity to soils and helps in the development of soil profiles. Each element is important for human beings. Landforms provide the base on which human activities are located. The plains are utilised for agriculture. Plateaus provide forests and minerals. Mountains provide pastures, forests, tourist spots and are sources of rivers providing water to lowlands. Climate influences our house types, clothing and food habits. The climate has a profound effect on vegetation, cropping pattern, livestock farming and some industries, etc. Human beings have developed technologies which modify climatic elements in a restricted space such as air conditioners and coolers. Temperature and precipitation ensure the density of forests and quality of grassland. In India, monsoonal rainfall sets the agriculture rhythm in motion. Precipitation recharges the *ground water aquifers* which later provides water for agriculture and domestic use. We study oceans which are the store house of resources. Besides fish and other

sea-food, oceans are rich in mineral resources. India has developed the technology for collecting manganese nodules from oceanic bed. Soils are renewable resources, which influence a number of economic activities such as agriculture. The fertility of the soil is both naturally determined and culturally induced. Soils also provide the basis for the biosphere accommodating plants, animals and micro organisms.

What is Geography?

Geography is concerned with the description and explanation of the areal differentiation of the earth's surface.

Richard Hartshorne

Geography studies the differences of phenomena usually related in different parts of the earth's surface.

Hettner

The study of physical geography is emerging as a discipline of evaluating and managing natural resources. In order to achieve this objective, it is essential to understand the intricate relationship between physical environment and human beings. Physical environment provides resources, and human beings utilise these resources and ensure their economic and cultural development. Accelerated pace of resource utilisation with the help of modern technology has created ecological imbalance in the world. Hence, a better understanding of physical environment is absolutely essential for sustainable development.

EXERCISES

1. Multiple choice questions.
 - (i) Which one of the following scholars coined the term 'Geography'?

(a) Herodotus	(c) Galileo
(b) Erathosthenese	(d) Aristotle
 - (ii) Which one of the following features can be termed as 'physical feature'?

(a) Port	(c) Plain
(b) Road	(d) Water park

- (iii) Make correct pairs from the following two columns and mark the correct option.

1. Meteorology	A. Population Geography
2. Demography	B. Soil Geography
3. Sociology	C. Climatology
4. Pedology	D. Social Geography

(a) 1B,2C,3A,4D (c) 1D,2B,3C,4A

(b) 1A,2D,3B,4C (d) 1C,2A,3D,4B

- (iv) Which one of the following questions is related to cause-effect relationship?

(a) Why (c) What

(b) Where (d) When

- (v) Which one of the following disciplines attempts temporal synthesis?

(a) Sociology (c) Anthropology

(b) Geography (d) History

2. Answer the following questions in about 30 words.

(i) What important cultural features do you observe while going to school? Are they similar or dissimilar? Should they be included in the study of geography or not? If yes, why?

(ii) You have seen a tennis ball, a cricket ball, an orange and a pumpkin. Which one amongst these resembles the shape of the earth? Why have you chosen this particular item to describe the shape of the earth?

(iii) Do you celebrate *Van Mahotsava* in your school? Why do we plant so many trees? How do the trees maintain ecological balance?

(iv) You have seen elephants, deer, earthworms, trees and grasses. Where do they live or grow? What is the name given to this sphere? Can you describe some of the important features of this sphere?

(v) How much time do you take to reach your school from your house? Had the school been located across the road from your house, how much time would you have taken to reach school? What is the effect of the distance between your residence and the school on the time taken in commuting? Can you convert time into space and vice versa?

3. Answer the following questions in about 150 words.

(i) You observe every day in your surroundings that there is variation in natural as well as cultural phenomena. All the trees are not of the same variety. All the birds and animals you see, are different. All these different elements are found on the earth. Can you now argue that geography is the study of "areal differentiation"?

(ii) You have already studied geography, history, civics and economics as parts of social studies. Attempt an integration of these disciplines highlighting their interface.

Project Work

Select forest as a natural resource.

- (i) Prepare a map of India showing the distribution of different types of forests.
- (ii) Write about the economic importance of forests for the country.
- (iii) Prepare a historical account of conservation of forests in India with focus on Chipko movements in Rajasthan and Uttarakhand.



GLOSSARY

Abiotic : Non-living thing. Usually refers to the physical and chemical components of an organism's *environment*.

Adiabatic Lapse Rate : The rate of change of temperature by an ascending or descending airmass. If no other non-adiabatic processes (i.e. no heat enters or leaves the system) occur (like condensation, evaporation and radiation), expansion causes the parcel of air to cool at a set rate of 0.98° per 100 m. The opposite occurs when a parcel of air descends in the atmosphere. The air in a descending parcel becomes compressed. Compression causes the temperature within the parcel to increase at a rate of 0.98° per 100 m.

Air Mass : A body of air whose temperature and humidity characteristics, acquired in source region, remain relatively constant over a horizontal distance of hundreds to thousands of km. Air masses develop their climatic characteristics by remaining stationary over a source region for a number of days. Air masses are classified according to their temperature and humidity characteristics.

Aphelion : It is the point in the Earth's orbit when it is farthest from the sun (152.5 million km). Aphelion occurs on the 3rd or 4th of July.

Asthenosphere : Zone in the Earth's *mantle* that exhibits plastic properties. Located below the *lithosphere* at between 100 and 200 km.

Atmospheric Pressure : Weight of the *atmosphere* on a surface. At *sea-level*, the average atmospheric pressure is 1013.25 mb. Pressure is measured by a device called a *barometer*.

Aurora : Multicoloured lights that appear in the upper *atmosphere (ionosphere)* over the polar regions and visible from locations in the middle and high latitudes. Caused by the interaction of *solar wind* with oxygen and nitrogen gas in the atmosphere. Aurora in the Northern Hemisphere are called *aurora borealis* and *aurora australis* in the Southern Hemisphere.

Bajada : Consecutive series of *alluvial fans* forming along the edge of a linear mountain range. Surface of this feature undulates in a rolling fashion as one moves from the centre of one alluvial fan to another. Normally occur in arid climates.

Batholith : A large mass of subsurface *intrusive igneous rock* that has its origins from *mantle magma*.

Big Bang : Theory about the origin of universe. It suggests that about 15 billion years ago all of the matter and energy in the *Universe* was concentrated into an area smaller than an atom. At this instant, matter, energy, space and time were not existant. Then suddenly with a bang, the Universe began to expand at an incredible rate and matter, energy, space and time came into being. As the Universe expanded, matter began to coalesce into gas clouds, and then stars and planets. Some scientists believe that this expansion is finite and will one day cease. After this point in time, the Universe will begin to collapse until a *Big Crunch* occurs.

Biodiversity : The *diversity* of different species (*species diversity*), genetic variability among individuals within each species (*genetic diversity*), and variety of ecosystems (*ecosystem diversity*).

Biomass : The weight of living tissues usually measured per unit area over a

particular time interval. Can include the dead parts of organisms like bark, hair, and nails.

Biome : Largest recognisable assemblage of *animals* and *plants* on the Earth. The distribution of the biomes is controlled mainly by climate.

Calcification : A dry environment soil-forming process that results in the accumulation of *calcium carbonate* in surface *soil* layers.

Caldera Volcano : Explosive type of *volcano* that leaves a large circular depression. Some of these depressions can be as large as 40 km in diameter. These volcanoes form when wet *granitic magma* quickly rises to the surface of the Earth.

Chlorofluorocarbons (CFCs) : Is an artificially created gas that has become concentrated in the Earth's *atmosphere*. This very strong *greenhouse* gas is released from aerosol sprays, refrigerants, and the production of fumes.

Cirrocumulus Clouds : Patchy white high altitude *cloud* composed of ice crystals. Found in an altitude range from 5,000 - 18,000 m.

Cirrostratus Clouds : High altitude sheet like *clouds* composed of ice crystals. These thin clouds often cover the entire sky. Found in an altitude range from 5,000 - 18,000 m.

Cold Front : A transition zone in the *atmosphere* where an advancing cold *air mass* displaces a warm air mass.

Continental Crust : *Granitic* portion of the Earth's *crust* that makes up the continents. Thickness of the continental crust varies between 20 - 75 km. See *sial layer*.

Coriolis Force : An apparent force due to the *Earth's rotation*. Causes moving objects to be deflected to the right in the Northern Hemisphere and to the left in the Southern hemisphere. Coriolis force does not exist on the equator. This force is responsible for the direction of flow in meteorological phenomena like *mid-latitude cyclones*, *hurricanes*, and *anticyclones*.

Cumulus Cloud : Large *clouds* with relatively flat bases. These are found in an altitude range from 300 - 2,000 m.

Cumulonimbus Cloud : A well developed vertical *cloud* that often has top shaped like an anvil. These clouds can extend in altitude from a few hundred m above the surface to more than 12,000 m.

Desert Pavement : A veneer of coarse particles left on the ground after the *erosion* of finer particles by *wind*.

Earthquake : A sudden motion or shaking in the Earth. The motion is caused by the quick release of slowly accumulated energy in the form of *seismic waves*.

Earthquake Focus : Point of stress release in an *earthquake* (also known as hypocentre).

Ebb Tide : Time during the *tidal period* when the *water* level in the sea is falling.

Ecosystem : A system consisting of biotic and abiotic components. Both these groups are interrelated and interacting.

El Nino : The name given to the occasional development of warm ocean surface waters along the coast of Ecuador and Peru. Recently this phenomenon has been used for forecasting of climatic conditions in different parts of the world. The El Nino normally occurs around Christmas and lasts usually for a few weeks to a few months.

Epicentre : A place on the surface of the earth located at the shortest distance from the focus of the earthquake, the point at which the seismic energy gets released.

Global Warming : Warming of the Earth's *average global temperature* because of an increase in the concentration of *greenhouse gases*.

Geomagnetism : A property of magnetically susceptible minerals to get aligned to the earth's magnetic field during the period of rock formation.

Geostrophic Wind : Horizontal wind in the upper atmosphere that moves parallel to isobars. Results from a balance between *pressure gradient force* and *Coriolis force*.

Greenhouse Effect : The greenhouse effect causes the *atmosphere* to trap more heat energy at the Earth's surface and within the atmosphere by absorbing and re-emitting longwave energy.

Greenhouse Gases : Gases responsible for the *greenhouse effect*. These gases include: *carbon dioxide* (CO_2); *methane* (CH_4); *nitrous oxide* (N_2O); *chlorofluorocarbons* (CFC); and *tropospheric ozone* (O_3).

Habitat : Location where a *plant* or *animal* lives.

Hail : It is a type of precipitation received in the form of ice pellets or hail stones. The size of hailstones can be between 5 and 190 mm in diameter.

Halocline : The distinct zone in the ocean below which the salinity increases sharply.

Hydration : A form of *chemical weathering* that involves the rigid attachment of H^+ and OH^- ions to the *atoms* and *molecules* of a *mineral*.

Hydrolysis : *Chemical weathering* process that involves the reaction between *mineral* ions and the ions of water (OH^- and H^+), and results in the decomposition of the *rock* surface by forming new compounds.

Infiltration : A portion of the precipitation which reaches the earth surface seeps into the ground in the permeable strata. This process is known as infiltration.

Insolation : Incoming solar radiation in short wave form.

Inter Tropical Convergence Zone (ITCZ) : Zone of *low atmospheric pressure* and ascending air located at or near the equator. Rising air currents are due to global wind *convergence* and *convection* from thermal heating.

Katabatic Wind : Any *wind* blowing down the slope of a mountain.

Land Breeze : Local *thermal circulation* pattern found at the interface between land and water. In this circulation system, surface winds blow from land to water during the night.

La Nina : Condition opposite of an *El Nino*. In a La Nina, the tropical Pacific *trade winds* become very strong and an abnormal accumulation of cold water occurs in the central and eastern Pacific Ocean.

Latent Heat : It is the energy required to change a substance to a higher state of matter (solid > liquid > gas). This same energy is released from the substance when the change of state is reversed (gas > liquid > solid).

Neap Tide : *Tide* that occurs every 14 - 15 days and coincides with the first and last quarter of the moon. This tide has a small tidal range because the *gravitational* forces of the moon and sun are perpendicular to each other.

Nimbostratus Clouds : Dark, gray low altitude *cloud* that produces continuous *precipitation* in the form of rain or snow. Found in an altitude range from the surface to 3,000 m.

Occluded Front : A transition zone in the *atmosphere* where an advancing cold *air mass* sandwiches a warm air mass between another cold air mass pushing the warm air into the upper atmosphere.

Ozone : Tri-atomic oxygen that exists in the earth's *atmosphere* as a gas. Ozone is highest in concentration in the *stratosphere* (10-50 km above the earth's surface) where it absorbs the sun's ultraviolet radiation. Stratospheric ozone is produced naturally and helps to protect life from the harmful effects of solar ultraviolet radiation.

Ozone Hole : It is a sharp seasonal decrease in stratospheric ozone concentration that occurs over Antarctica in the spring. First detected in the late 1970s, the ozone hole continues to appear as a result of complex chemical reaction in the atmosphere that involves CFCs.

Palaeomagnetism : The alignment in terms of inclination from horizon acquired by magnetically susceptible minerals in the rock during the period of their formation.

Photosynthesis : It is the chemical process where *plants* and some *bacteria* can capture and organically fix the energy of the *sun*.

Plate Tectonics : Theory suggesting that the earth's surface is composed of a number of *oceanic* and *continental plates*. Driven by convection currents in the *mantle*, these plates have the ability to slowly move across the earth's plastic *asthenosphere*.

Precipitation : Showering of the raindrops, snow or hailstones from the clouds onto the surface of the earth. Rainfall, snowfall, cloud burst and hailstones are forms of precipitation.

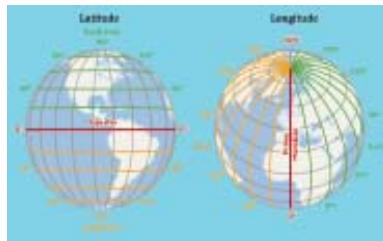
Runoff : It is the flow of water over land through different channels.

Solar Wind : Mass of ionised gas emitted to space by the *sun*. Plays a role in the formation of *auroras*.

Subsurface flow : It is the movement of water below the surface of the earth. After infiltration, the subsurface water returns to the surface through seepage into the streams or eventually goes into the ocean. The subsurface water flow is influenced by land slope, rainfall, intensity of groundwater extraction, etc.

Thermocline : Boundary in a body of water where the greatest vertical change in *temperature* occurs. This boundary is usually the transition zone between the layer of warm water near the surface that is mixed and the cold deep water layer.

2



GLOBE : LATITUDES AND LONGITUDES



Figure 2.1 : Globe



Let's Do

Take a big round potato or a ball. Taking a knitting needle pierce through it. It resembles the axis shown in a globe. You can now move the potato or the ball around this axis from left to right.

In the previous chapter, you have read that our planet earth is not a sphere. It is slightly flattened at the North and the South Poles and bulge in the middle. Can you imagine how it looks? You may look at a globe carefully in your classroom to get an idea. **Globe** is a true model (miniature form) of the earth (Figure 2.1).

Globes may be of varying size and type – big ones, which cannot be carried easily, small pocket globes, and globe-like balloons, which can be inflated and are handy and carried with ease. The globe is not fixed. It can be rotated the same way as a top spin or a potter's wheel is rotated. On the globe, countries, continents and oceans are shown in their correct size.

It is difficult to describe the location of a point on a sphere like the earth. Now the question arises as to how to locate a place on it? We need certain points of reference and lines to find out the location of places.

You will notice that a needle is fixed through the globe in a tilted manner, which is called its **axis**. Two points on the globe through which the needle passes are two poles – North Pole and South Pole. The globe can be moved around this needle from west to east just as the earth moves. But, remember there is a major difference. The real earth has no such needle. It moves around its axis, which is an imaginary line.

Another imaginary line running on the globe divides it into two equal parts. This line is known as the **equator**. The northern half of the earth is known as the Northern Hemisphere and the southern half is known as the Southern Hemisphere. They are both

equal halves. Therefore, the equator is an imaginary circular line and is a very important reference point to locate places on the earth. All parallel circles from the equator up to the poles are called **parallels of latitudes**. Latitudes are measured in degrees.

The equator represents the zero degree latitude. Since the distance from the equator to either of the poles is one-fourth of a circle round the earth, it will measure $\frac{1}{4}$ th of 360 degrees, i.e. 90° . Thus, 90° north latitude marks the North Pole and 90° south latitude marks the South Pole.

As such, all parallels north of the equator are called ‘north latitudes.’

Similarly all parallels south of the equator are called ‘south latitudes.’

The value of each latitude is, therefore, followed by either the word north or south. Generally, this is indicated by the letter ‘N’ or ‘S’. For example, both Chandrapur in Maharashtra (India) and Belo Horizonte in Brazil (South America) are located on parallels of about 20° latitude. But the former is 20° north of the equator and the latter is 20° south of it. We, therefore, say that Chandrapur is situated at 20° N latitude and Belo Horizonte is situated at 20° S latitude. We see in Figure 2.2 that as we move away from the equator, the size of the parallels of latitude decreases.

IMPORTANT PARALLELS OF LATITUDES

Besides the equator (0°), the North Pole (90° N) and the South Pole (90° S), there are four important parallels of latitudes—

(i) **Tropic of Cancer** ($23\frac{1}{2}^\circ$ N) in the Northern Hemisphere. (ii) **Tropic of Capricorn** ($23\frac{1}{2}^\circ$ S) in the Southern Hemisphere. (iii) **Arctic Circle** at $66\frac{1}{2}^\circ$ north of the equator. (iv) **Antarctic Circle** at $66\frac{1}{2}^\circ$ south of the equator.

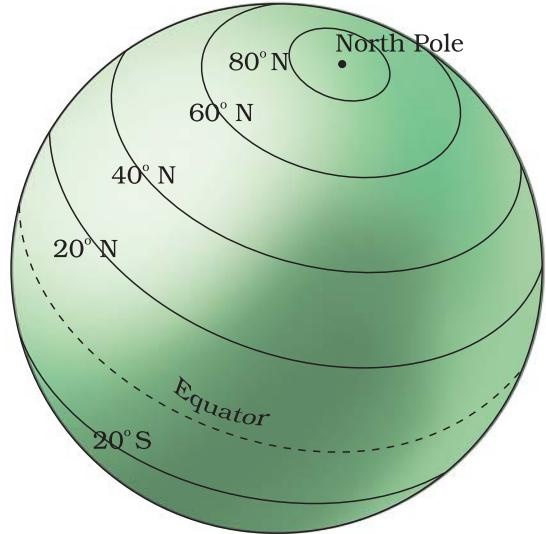


Figure 2.2 : Latitude



Do you know?

By measuring the angle of the Pole Star from your place, you can know the latitude of your place.

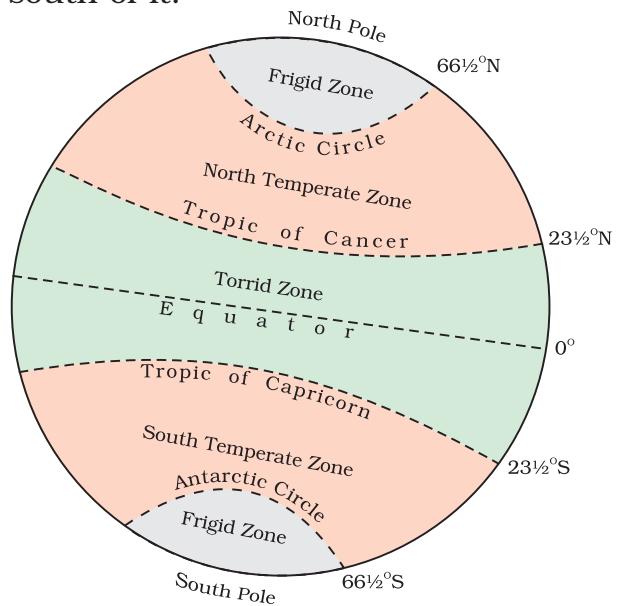


Figure 2.3 : Important Latitudes and Heat Zones

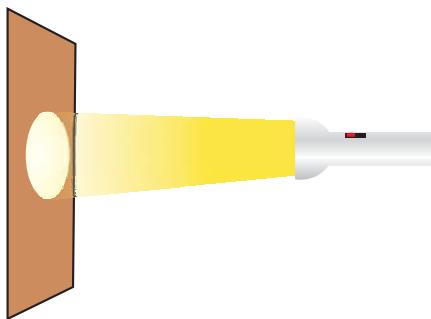


Figure 2.4 : (a)

Torch-light falling on a straight surface is bright and covers a smaller area.

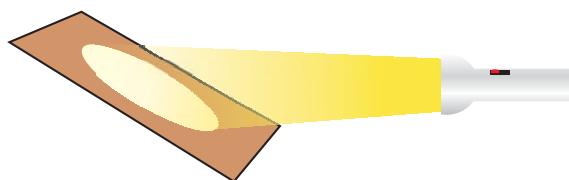


Figure 2.4 : (b)

Torch-light falling on a slanted surface is less bright but covers a bigger area.

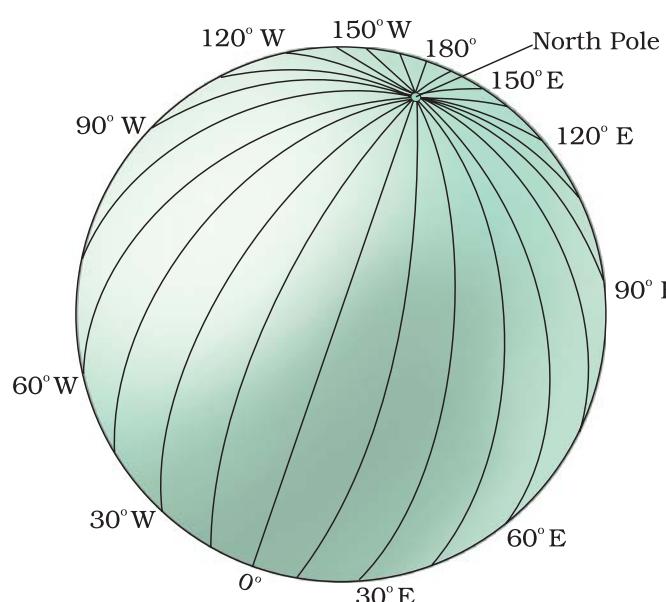


Figure 2.5 : Longitudes

HEAT ZONES OF THE EARTH

The mid-day sun is exactly overhead at least once a year on all latitudes in between the Tropic of Cancer and the Tropic of Capricorn. This area, therefore, receives the maximum heat and is called the **Torrid Zone**.

The mid-day sun never shines overhead on any latitude beyond the Tropic of Cancer and the Tropic of Capricorn. The angle of the sun's rays goes on decreasing towards the poles. As such, the areas bounded by 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, have moderate temperatures. These are, therefore, called **Temperate Zones**.

Areas lying between the Arctic Circle and the North Pole in the Northern Hemisphere and the Antarctic Circle and the South Pole in the Southern Hemisphere, are very cold. It is because here the sun does not rise much above the horizon. Therefore, its rays are always slanting. These are, therefore, called **Frigid Zones**.

WHAT ARE LONGITUDES?

To fix the position of a place, it is necessary to know something more than the latitude of that place. You can see, for example, that Hyderabad (in Pakistan) and Allahabad (in India) are situated on the same latitude (i.e., $25^{\circ}25'N$). Now, in order to locate them precisely, we must find out how far east or west these places are from a given line of reference running from the North Pole to the South Pole. These lines of references are called the meridians of longitude, and the

distances between them are measured in ‘degrees of longitude.’ Each degree is further divided into minutes, and minutes into seconds. They are semi-circles and the distance between them decreases steadily polewards until it becomes zero at the poles, where all the meridians meet.

Unlike parallels of latitude, all meridians are of equal length. Thus, it was difficult to number the meridians. Hence, all countries decided that the count should begin from the meridian which passed through Greenwich, where the British Royal Observatory is located. This meridian is called the **Prime Meridian**. Its value is 0° longitude and from it we count 180° eastward as well as 180° westward. The Prime Meridian divides the earth into two equal halves, the Eastern Hemisphere and the Western Hemisphere. Therefore, the longitude of a place is followed by the letter E for the east and W for the west. It is, however, interesting to note that 180° East and 180° West meridians are on the same line.

Now look at the grid of the parallels of latitude and meridians of longitude on the globe (Figure 2.6). You can locate any point on the globe very easily if you know its latitude and longitude. For example, Dhubri in Assam is situated at 26° N latitude and 90° E longitude. Find out the point where these two lines cut each other. That point will be the location of Dhubri.

To understand this clearly draw equidistant vertical and horizontal lines on a paper (Figure 2.7). Label the vertical rows with numbers and horizontal rows with letters, draw some small circles randomly on points where these horizontal and vertical lines intersect each other. Name these small circles as a, b, c, d and e.

Let vertical lines represent East Longitudes and horizontal lines as North Latitudes.

Now you will see that circle ‘a’ is located on B° N latitude and 1° E longitude.

Find out the location of other circles.

Let's Do

Draw a circle. Let the Prime meridian divide it into two equal halves. Colour and label the eastern hemisphere and the western hemisphere. Similarly draw another circle and let the equator divide it into two halves. Now colour the Northern hemisphere and Southern hemisphere.

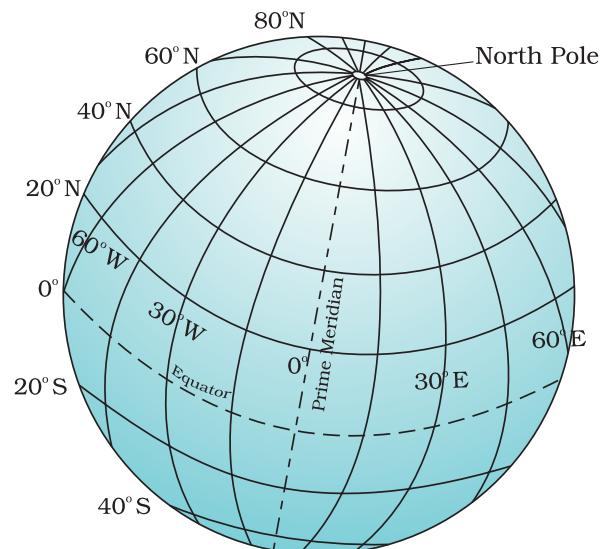


Figure 2.6 : Grid

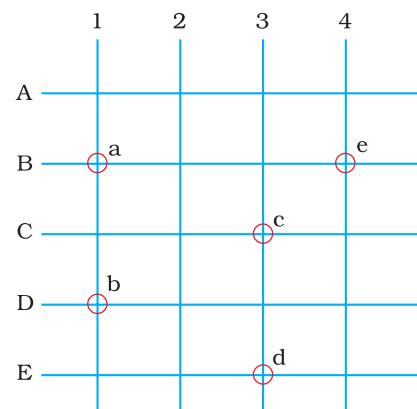


Figure 2.7

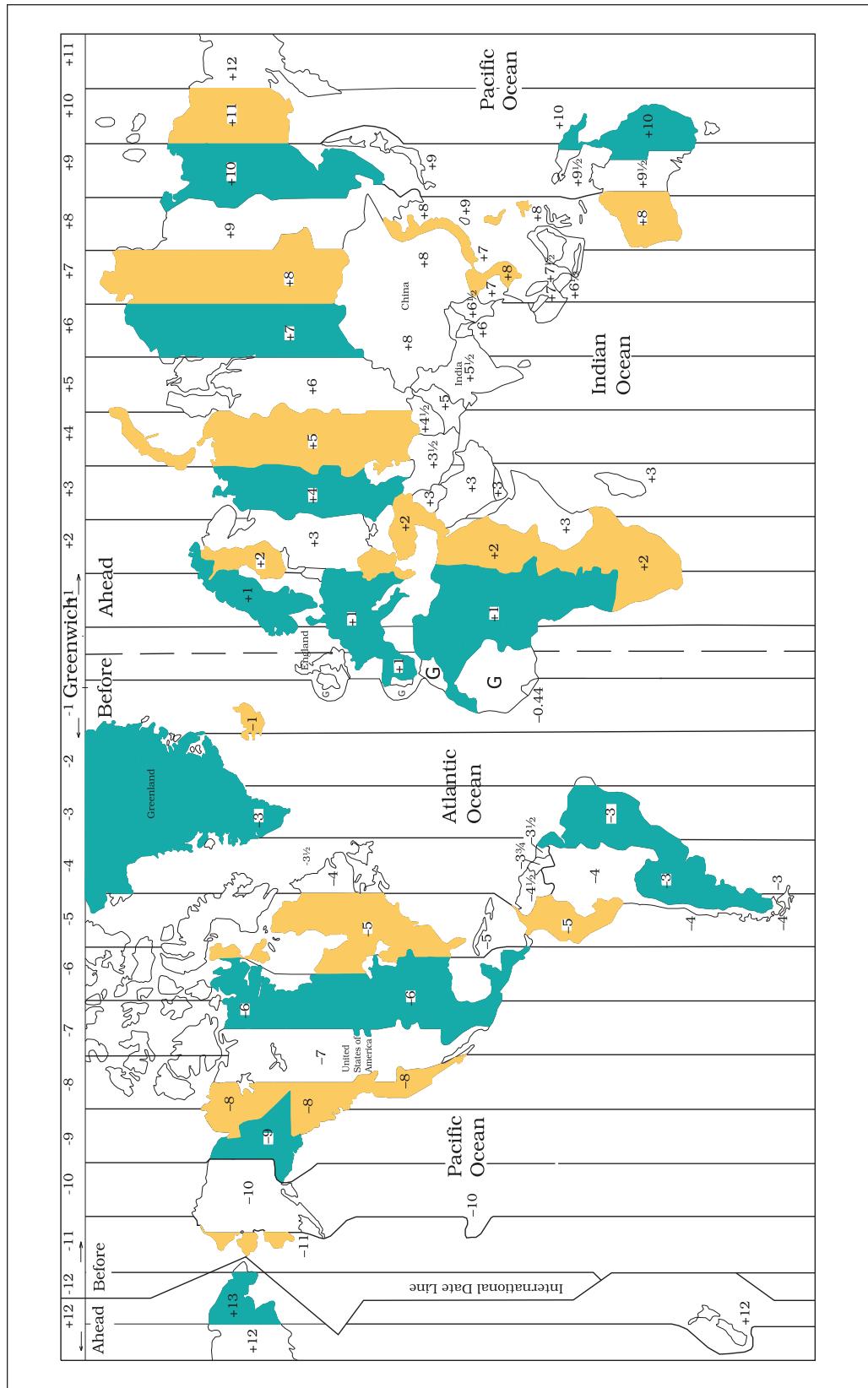


Figure 2.8 : Time zones of the World

LONGITUDE AND TIME

The best means of measuring time is by the movement of the earth, the moon and the planets. The sun regularly rises and sets every day, and naturally, it is the best time-keeper throughout the world. Local time can be reckoned by the shadow cast by the sun, which is the shortest at noon and longest at sunrise and sunset.

When the Prime Meridian of Greenwich has the sun at the highest point in the sky, all the places along this meridian will have mid-day or noon.

As the earth rotates from west to east, those places east of Greenwich will be ahead of Greenwich time and those to the west will be behind it (Figure 2.8). The rate of difference can be calculated as follows. The earth rotates 360° in about 24 hours, which means 15° an hour or 1° in four minutes. Thus, when it is 12 noon at Greenwich, the time at 15° east of Greenwich will be $15 \times 4 = 60$ minutes, i.e., 1 hour ahead of Greenwich time, which means 1 p.m. But at 15° west of Greenwich, the time will be behind Greenwich time by one hour, i.e., it will be 11.00 a.m. Similarly, at 180° , it will be midnight when it is 12 noon at Greenwich.

At any place a watch can be adjusted to read 12 o'clock when the sun is at the highest point in the sky, i.e., when it is mid-day. The time shown by such a watch will give the local time for that place. You can see that all the places on a given meridian of longitude have the same local time.

WHY DO WE HAVE STANDARD TIME?

The local time of places which are on different meridians are bound to differ. For example, it will be difficult to prepare a time-table for trains which cross several longitudes. In India, for instance, there will be a difference of about 1 hour and 45 minutes in the local times of Dwarka in Gujarat and Dibrugarh in Assam. It is, therefore, necessary to adopt the local time of some central meridian of a country as the standard time for the country. In India, the longitude of $82\frac{1}{2}^\circ$ E ($82^\circ 30'E$) is treated as the standard meridian. The local time at this meridian is taken as the standard time for the whole country. It is known as the Indian Standard Time (IST).

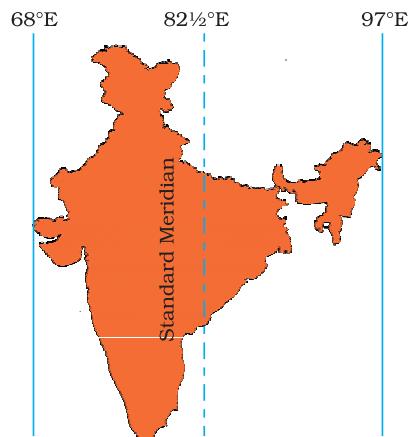


Figure 2.9 : Indian Standard Meridian

Kabeer lives in a small town near Bhopal. He tells his friend Alok that they will not be able to sleep tonight. A day and night cricket match between India and England had started at 2 p.m. in London. This means that the match would begin at 7.30 p.m. in India and finish well into the night. Do you know what is the time difference between India and England?

India located east of Greenwich at $82^{\circ}30'E$ is 5 hours and 30 minute ahead of GMT. So it will be 7:30 p.m. in India when its 2:00 p.m. noon in London.

Some countries have a great longitudinal extent and so they have adopted more than one standard time. For example, in Russia, there are as many as eleven standard times. The earth has been divided into twenty-four time zones of one hour each. Each zone thus covers 15° of longitude.

EXERCISES

1. Answer the following questions briefly.

- (a) What is the true shape of the earth?
- (b) What is a globe?
- (c) What is the latitudinal value of the Tropic of Cancer?
- (d) What are the three heat zones of the Earth?
- (e) What are parallels of latitude and meridians of longitude?
- (f) Why does the torrid zone receive maximum amount of heat?
- (g) Why is it 5.30 p.m. in India and 12.00 noon in London?

2. Tick the correct answers.

- (a) The value of the prime meridian is
 - (i) 90°
 - (ii) 0°
 - (iii) 60°
- (b) The frigid zone lies near
 - (i) the Poles
 - (ii) the Equator
 - (iii) the Tropic of Cancer
- (c) The total number of longitudes are
 - (i) 360
 - (ii) 180
 - (iii) 90
- (d) The Antarctic circle is located in
 - (i) the Northern hemisphere
 - (ii) the Southern hemisphere
 - (iii) the Eastern hemisphere
- (e) Grid is a network of
 - (i) parallels of latitudes and meridians of longitudes
 - (ii) the Tropic of Cancer and the Tropic of Capricorn
 - (iii) the North Pole and the South Pole

3. Fill in the blanks.

- The Tropic of Capricorn is located at _____.
- The Standard Meridian of India is _____.
- The 0° Meridian is also known as _____.
- The distance between the longitudes decreases towards _____.
- The Arctic Circle is located in the _____ hemisphere.



THINGS To Do

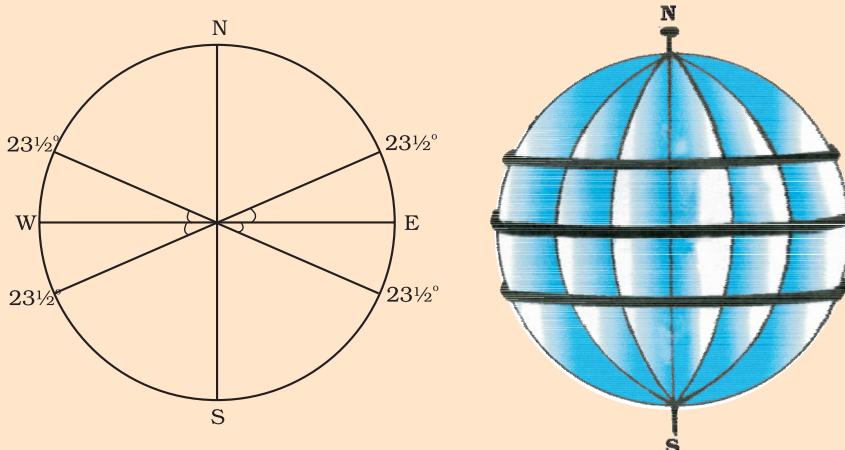
- Draw a diagram of the earth showing the earth's axis, the Equator, Tropics of Cancer and Capricorn, Arctic Circle and Antarctic Circle.



FOR FUN

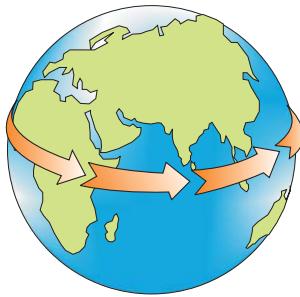
- Draw and cut out six circles of the same size (approx. 3 cm. radius) from cardboard. Mark diamettes (NS, EW) and $23\frac{1}{2}^{\circ}$ angles on each face of the circles as shown on the figure. Place the circle one on top of the other and stitch along the line NS. Now there are twelve semi-circles. Let one semi-circle represent 0° or Greenwich Meridian (Prime Meridian). The 6th semi-circle from it will be the 180° Meridian. Between the 0° and 180° there are 5 semi-circles on both sides which are West and East longitudes 30° apart. On two ends of the stapled line stick pins to represent the North and South Poles.

A rubber band around the model touching the EW points will represent the Equator. Two rubber bands touching the $23\frac{1}{2}^{\circ}$ points, South and North of the EW points will represent the tropics.



3

MOTIONS OF THE EARTH



Let's Do

Take a ball to represent the earth and a lighted candle to represent the sun. Mark a point on the ball to represent a town X. Place the ball in such a way that the town X is in darkness. Now rotate the ball from left to right. As you move the ball slightly, the town will have its sunrise. As the ball continues to move, the point X gradually gets away from the sun. This is sunset.

As you know that the earth has two types of motions, namely rotation and revolution. **Rotation** is the movement of the earth on its axis. The movement of the earth around the sun in a fixed path or orbit is called **Revolution**.

The axis of the earth which is an imaginary line, makes an angle of $66\frac{1}{2}^\circ$ with its **orbital plane**. The plane formed by the orbit is known as the orbital plane. The earth receives light from the sun. Due to the spherical shape of the earth, only half of it gets light from the sun at a time (Figure 3.2). The portion facing the sun experiences day while the other half away from the sun experiences night. The circle that divides the day from night on the globe is called the **circle of illumination**. This circle does not coincide with the axis as you see in the Figure 3.2. The earth takes about 24 hours to complete one rotation around its axis. The period of rotation is known as the *earthday*. This is the daily motion of the earth.

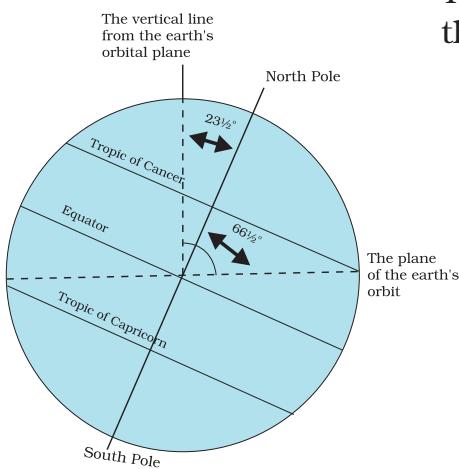


Figure 3.1 : Inclination of the Earth's axis and the orbital plane

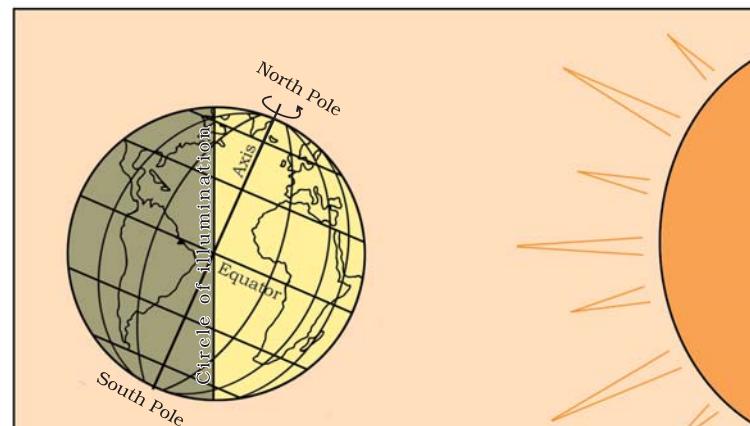


Figure 3.2 : Day and Night on the Earth due to rotation

What would happen if the earth did not rotate? The portion of the earth facing the sun would always experience day, thus bringing continuous warmth to the region. The other half would remain in darkness and be freezing cold all the time. Life would not have been possible in such extreme conditions.

REVOLUTION

The second motion of the earth around the sun in its orbit is called **revolution**. It takes $365\frac{1}{4}$ days (one year) to revolve around the sun. We consider a year as consisting of 365 days only and ignore six hours for the sake of convenience.

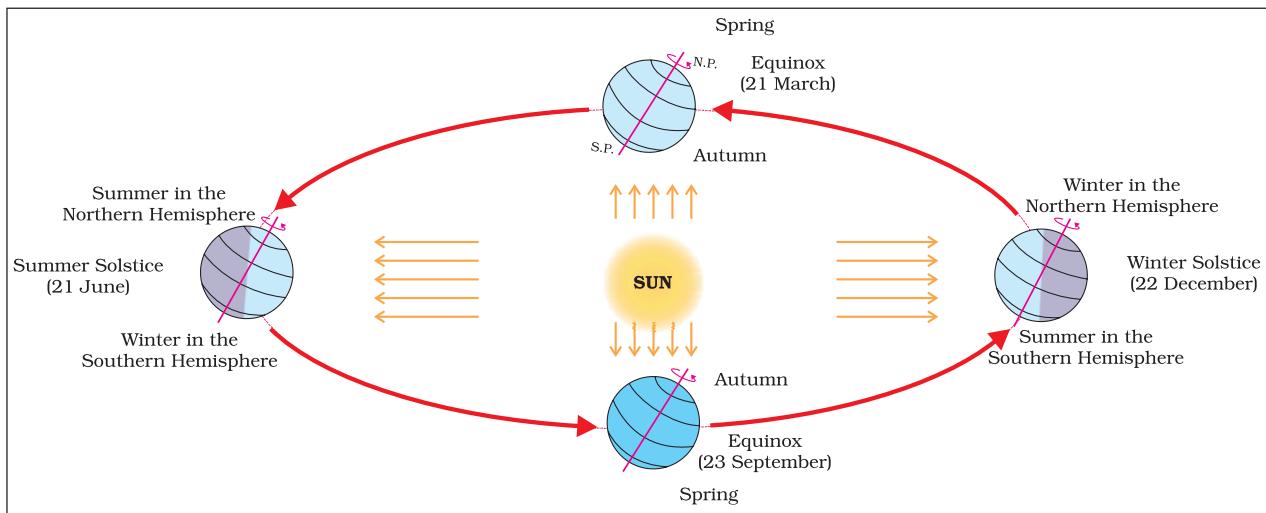


Figure 3.3 : Revolution of the Earth and Seasons

Six hours saved every year are added to make one day (24 hours) over a span of four years. This surplus day is added to the month of February. Thus every fourth year, February is of 29 days instead of 28 days. Such a year with 366 days is called a **leap year**. Find out when will the next leap year be?

From the Figure 3.3, it is clear that the earth is going around the sun in an **elliptical orbit**.

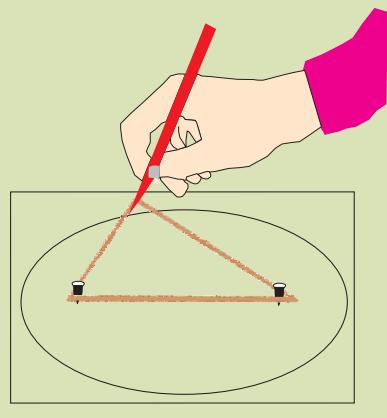
Notice that throughout its orbit, the earth is inclined in the same direction.

A year is usually divided into summer, winter, spring and autumn seasons. Seasons change due to the change in the position of the earth around the sun.

Let's Do



Do you know how to draw an ellipse? Take a pencil, two pins and a loop of thread. Now fix these pins on a paper as shown in the figure. Put the loop on the paper enclosing these two pins inside the loop. Now hold the pencil and draw the line keeping the thread tight and moving the pencil along it. The figure represents an ellipse.



Let's Do

To understand the earth's inclination in the same direction, draw a big ellipse on the ground and take a flag with a stick. Stand anywhere on the line of the ellipse. Point your flag to a fixed point far away like on a tree-top. Now move along the ellipse keeping your flag always pointing towards that fixed point. In this way, the axis of the earth remains inclined permanently in the same position. The revolution of the earth and the inclination of the earth's axis in a fixed direction cause seasons.

Look at the Figure 3.3. You will see that on 21st June, the Northern Hemisphere is tilted towards the sun. The rays of the sun fall directly on the Tropic of Cancer. As a result, these areas receive more heat. The areas near the poles receive less heat as the rays of the sun are slanting. The North Pole is inclined towards the sun and the places beyond the Arctic Circle experience continuous daylight for about six months. Since a large portion of the Northern Hemisphere is getting light from the sun, it is summer in the regions north of the equator. The longest day and the shortest night at these places occur on 21st June. At this time in the Southern Hemisphere all these conditions are reversed. It is winter season there. The nights are longer than the days. This position of the earth is called the **Summer Solstice**.

On 22nd December, the Tropic of Capricorn receives direct rays of the sun as the South Pole tilts towards it. As the sun's rays fall vertically at the Tropic of Capricorn ($23\frac{1}{2}$ ° S), a larger portion of the Southern Hemisphere gets light. Therefore, it is summer in the Southern Hemisphere with longer days and shorter nights. The reverse happens in the Northern Hemisphere. This position of the earth is called the **Winter Solstice**. Do you know that Christmas is celebrated in Australia in the summer season?

On 21st March and September 23rd, direct rays of the sun fall on the equator. At this position, neither of the poles is tilted towards the sun; so, the whole earth experiences equal days and equal nights. This is called an **equinox**.

On 23rd September, it is autumn season in the Northern Hemisphere and spring season in the Southern Hemisphere. The opposite is the case on 21st March,

when it is spring in the Northern Hemisphere and autumn in the Southern Hemisphere.

Thus, you find that there are days and nights and changes in the seasons because of the rotation and revolution of the earth respectively.

EXERCISES

1. Answer the following questions briefly.

- (a) What is the angle of inclination of the earth's axis with its orbital plane?
- (b) Define rotation and revolution.
- (c) What is a leap year?
- (d) Differentiate between the Summer and Winter Solstice.
- (e) What is an equinox?
- (f) Why does the Southern Hemisphere experience Winter and Summer Solstice in different times than that of the Northern Hemisphere?
- (g) Why do the poles experience about six months day and six months night?

2. Tick the correct answers.

- (a) The movement of the earth around the sun is known as
 - (i) Rotation
 - (ii) Revolution
 - (iii) Inclination
- (b) Direct rays of the sun fall on the equator on
 - (i) 21 March
 - (ii) 21 June
 - (iii) 22 December
- (c) Christmas is celebrated in summer in
 - (i) Japan
 - (ii) India
 - (iii) Australia
- (d) Cycle of the seasons is caused due to
 - (i) Rotation
 - (ii) Revolution
 - (iii) Gravitation

3. Fill in the blanks.

- (a) A leap year has _____ number of days.
- (b) The daily motion of the earth is _____.
- (c) The earth travels around the sun in _____ orbit.
- (d) The sun's rays fall vertically on the Tropic of _____ on 21st June.
- (e) Days are shorter during _____ season.

THINGS TO DO



1. Make a drawing to show the inclination of the earth.
2. Record the timings of sunrise and sunset at your place taking help from your local newspaper on the 21st of each month and answer the following :
 - (a) In which month are the days shortest?
 - (b) In which months are the days and nights nearly equal?

FOR FUN



1. Draw different shapes of ellipses by placing two pins nearer and farther using the same loop of thread. Notice when the ellipse becomes circular.
2. On any sunny day, take a straight stick that is one metre long. Find out a clean and level place on the ground. Place this stick into the ground where it casts a distinctive (sharp) shadow.

Step (1): Mark the tip of the shadow with a stone or a twig or by any other means. The first shadow mark is always towards the west. See after 15 minutes and mark the tip of the shadow again. By then it would have moved a few centimetres away. Now join the two points and you have an approximate east-west line.

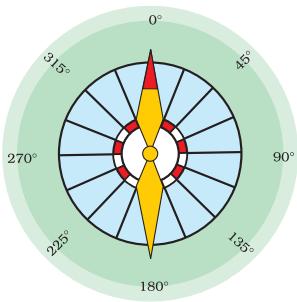
Step (2) : Stand with the first mark to your left and the second mark to your right you are now facing north. This fact is true everywhere on the earth because the earth rotates in west to east direction.

An alternative method is more accurate but requires more time. Set up your shadow stick and mark the first shadow in the morning. Use a piece of string to draw a clean arc through this mark around the stick. At mid-day, the shadow will shrink or disappear. In the afternoon, it will lengthen again and at the point where it touches the arc, make a second mark. Draw a line through the two marks to get an accurate east-west line.



4

MAPS



You have learnt in the previous chapter about the advantages of a globe. However, globe has limitations as well. A globe can be useful when we want to study the earth as a whole. But, when we want to study only a part of the earth, as about our country, states, districts, towns and villages, it is of little help. In such a situation we use maps. A **map** is a representation or a drawing of the earth's surface or a part of it drawn on a flat surface according to a scale. But it is impossible to flatten a round shape completely.

We find that maps are useful to us for various purposes. One map shows a small area and a few facts. Another map may contain as many facts as a big book. When many maps are put together we get an **Atlas**. Atlases are of various sizes, measurements drawn on different scales. Maps provide more information than a globe. They are of different types. Some of them are described below.

PHYSICAL MAPS

Maps showing natural features of the earth such as mountains, plateaus, plains, rivers, oceans etc. are called **physical or relief maps**.

POLITICAL MAPS

Maps showing cities, towns and villages, and different countries and states of the world with their boundaries are called **political maps**.

THEMATIC MAPS

Some maps focus on specific information; such as road

Let's Do

Take an old rubber ball and make any drawing all over it. You may also mark north pole and south pole on it. Now cut this ball with knife and try to flatten it. See how drawings are distorted.

maps, rainfall maps, maps showing distribution of forests, industries etc. are known as **thematic maps**. Suitable titles are given on the basis of information provided in these maps.

There are three **Components of Maps** – distance, direction and symbol.

DISTANCE

Maps are drawings, which reduce the entire world or a part of it to fit on a sheet of paper. Or we can say maps are drawn to reduced scales. But this reduction is done very carefully so that the distance between the places is real. It can only be possible when a small distance on paper represents a large distance on the ground. Therefore, a scale is chosen for this purpose. **Scale** is the ratio between the actual distance on the ground and the distance shown on the map. For example, the distance between your school and your home is 10 km. If you show this 10 km. distance by 2 cm on a map, it means, 1 cm on the map will show 5 km. on the ground. The scale of your drawing will be $1\text{cm} = 5\text{ km}$. Thus, scale is very important in any map. If you know the scale, you will be able to calculate the distance between any two places on a map.

When large areas like continents or countries are to be shown on a paper, then we use a small scale. For example 5 cm. on the map shows 500 km. of the ground. It is called a **small scale map**.

When a small area like your village or town is to be shown on paper, then we use a large scale that is 5 cm. on the map shows 500 metres only on the ground. It is called a **large scale map**.

Large scale maps give more information than small scale maps.

DIRECTION

Most maps contain an arrow marked with the letter 'N' at the upper right hand corner. This arrow shows the northern direction. It is called the north line. When you know the north, you can find out other directions, for example east, west and south. There are four major



Let's Do

Look at the Figure 4.1. There is a scale. It may be used for measuring distance between places. For example the distance between the well and the tree is 5 cm. It means that the actual distance is 50 metres. Now the distance between the PO (A) to Karim's house (E) is 12 cm. It means 120 metres on the ground but you can not fly like a bird directly from E to A. You will have to walk on the road. Let us measure the total walking distance from E to C, then C to M, M to B and B to A. Add all these distances. This will be the total walking distance from Karim's house to the post office.

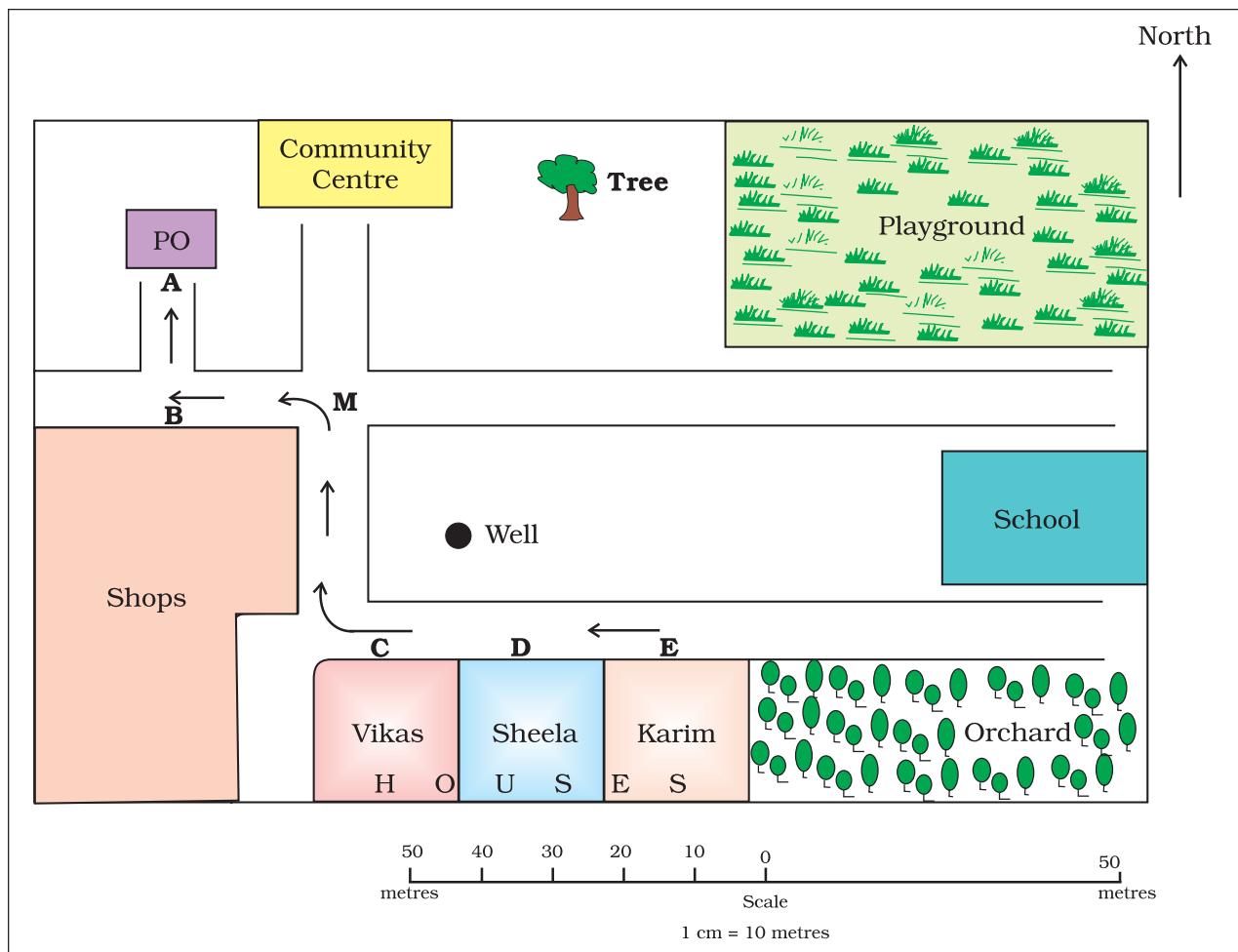


Figure 4.1 : Map of a village

directions, North, South, East and West {Figure 4.2 (a)}. They are called **cardinal points**. Other four intermediate directions are north-east (NE), south-east(SE), south-west (SW) and north-west (NW). We can locate any place more accurately with the help of these intermediate directions.

Find out the following directions from the Figure 4.1: (a) The direction of the Community Centre, the playground from Vikas's house (b) the direction of school from shops.

We can find out the direction of a place with the help of a compass. It is an instrument used to find out main directions. Its magnetic needle always points towards north-south direction {Figure 4.2 (b)}.

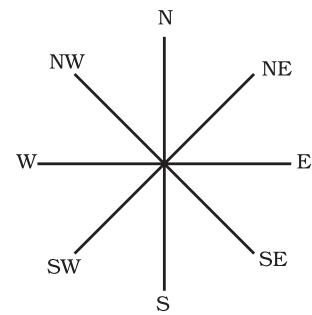


Figure 4.2 (a) : Cardinal Directions

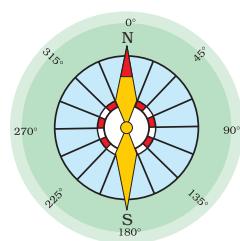


Figure 4.2 (b) : Compass

SYMBOLS

It is the third important component of a map. It is not possible to draw on a map the actual shape and size of different features such as buildings, roads, bridges, trees, railway lines or a well. So, they are shown by using certain letters, shades, colours, pictures and lines. These symbols give a lot of information in a limited space. With the use of these symbols, maps can be drawn easily and are simple to read. Even if you don't know the language of an area and therefore cannot ask someone for directions, you can collect information from maps with the help of these symbols. Maps have a universal language that can be understood by all. There is an international agreement regarding the use of these symbols. These are called **conventional symbols**. Some of the conventional symbols are shown in the Figure 4.3.

Railway Line : Broad gauge, Metre gauge,	
Railway station	
Roads : Metalled, Unmetalled	
Boundary : International, State, District,	
River, Well, Tank, Canal, Bridge	
Temple, Church, Mosque, Chhatri	
Post Office, Post & Telegraph Office, Police Station	
Settlement, Graveyard	
Trees, Grass	

Figure 4.3 : Conventional Symbols

Various colours are used for the same purpose. For example, generally blue is used for showing water bodies, brown for mountain, yellow for plateau and green is used for plains.

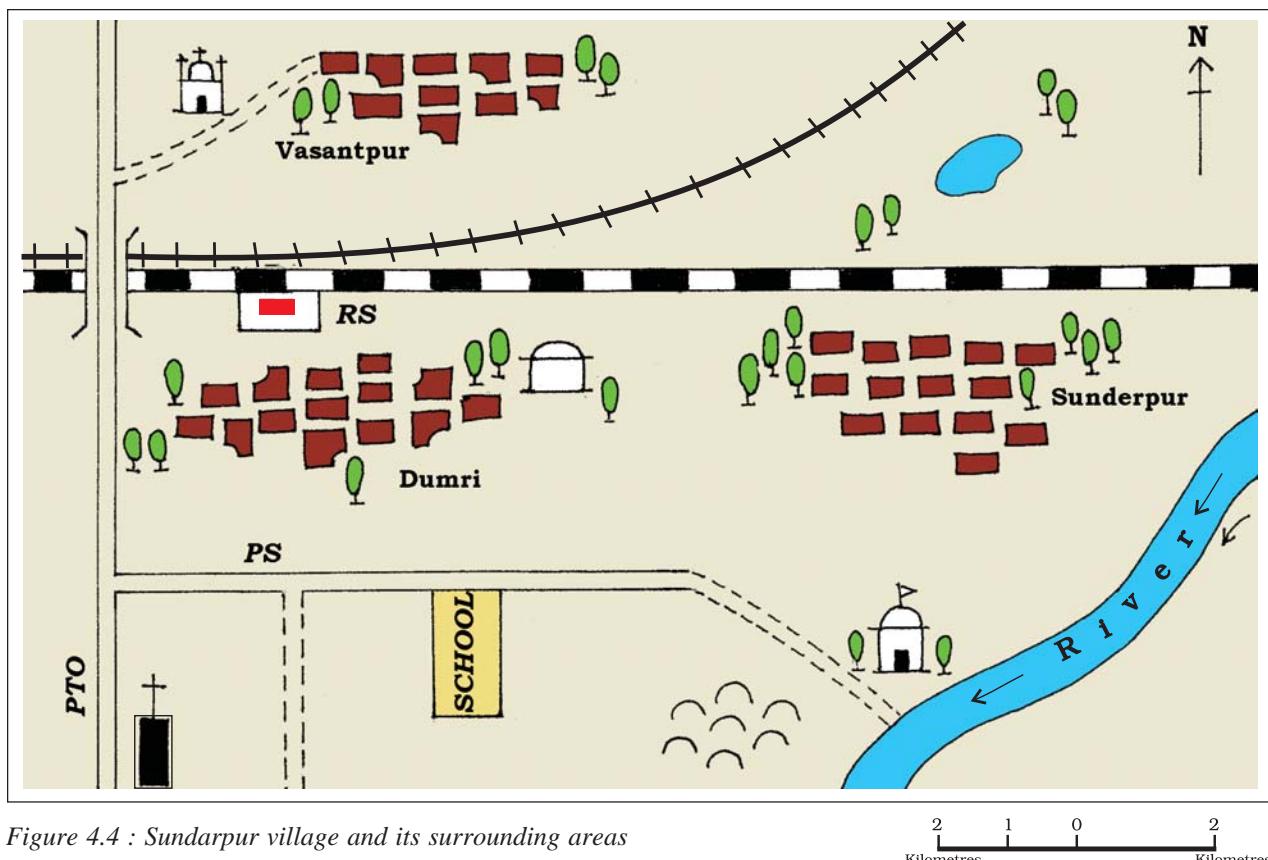


Figure 4.4 : Sundarpur village and its surrounding areas

2
Kilometres
1
0
2
Kilometres

SKETCH

A **sketch** is a drawing mainly based on memory and spot observation and not to scale. Sometimes a rough drawing is required of an area to tell where a particular place is located with respect to other places. Suppose, you want to go to your friend's house, but you don't know the way. Your friend may make a rough drawing to show the way to his house. Such a rough drawing is drawn without scale, and is called a *sketch map*.

PLAN

A **plan** is a drawing of a small area on a large scale. A large-scale map gives lot of information, but there are certain things which we may sometimes want to know for example the length and breadth of a room, which can't be shown in a map. At that time, we can refer drawings drawn to scale called a *plan*.

Look at the Figure 4.4 and find out :

- In which direction is the river flowing?
- What kind of road passes by the side of village Dumri?
- Sunderpur is situated on what type of railway line.
- The Police station is situated on which side of the railway bridge.
- On which side of the railway line do the following lie :
 - Chhatri
 - Church
 - Pond
 - Mosque
 - River
 - Post and Telegraph Office
 - Graveyard

EXERCISES

1. Answer the following questions briefly.

- (a) What are the three components of a map?
- (b) What are the four cardinal directions?
- (c) What do you mean by the term 'the scale of the map'?
- (d) How are maps more helpful than a globe?
- (e) Distinguish between a map and a plan.
- (f) Which map provides detailed information?
- (g) How do symbols help in reading maps?

2. Tick the correct answers.

- (a) Maps showing distribution of forests are
 - (i) Physical map
 - (ii) Thematic Map
 - (iii) Political map
- (b) The blue colour is used for showing
 - (i) Water bodies
 - (ii) Mountains
 - (iii) Plains
- (c) A compass is used –
 - (i) To show symbols
 - (ii) To find the main direction
 - (iii) To measure distance
- (d) A scale is necessary
 - (i) For a map
 - (ii) For a sketch
 - (iii) For symbols



THINGS To Do

1. Draw a plan of your classroom and show the teacher's table, blackboard, desks, door and windows.
2. Draw a sketch of your school and locate the following :
 - (a) the principal's room (b) your classroom
 - (c) the playground (d) the library
 - (e) some big trees (f) drinking water



FOR FUN

1. Make the plan (in the space given below) of a fun-park where you can enjoy several activities : for example swings, slides, see-saw, merry-go-round, boating, swimming, looking into funny mirrors, etc. or anything else that you can think of.



5



MAJOR DOMAINS OF THE EARTH

As you have read in the first chapter, the earth is the only planet which has life. Human beings can live here because the life sustaining elements of land, water and air are present on the earth.

The surface of the earth is a complex zone in which three main components of the environment meet, overlap and interact. The solid portion of the earth on which we live is called the **Lithosphere**. The gaseous layers that surround the earth, is the **Atmosphere**, where oxygen, nitrogen, carbondioxide and other gases are found. Water covers a very big area of the earth's surface and this area is called the **Hydrosphere**. The Hydrosphere comprises water in all its forms, that is, ice, water and water vapour.

The **Biosphere** is the narrow zone where we find land, water and air together, which contains all forms of life.



Word Origin

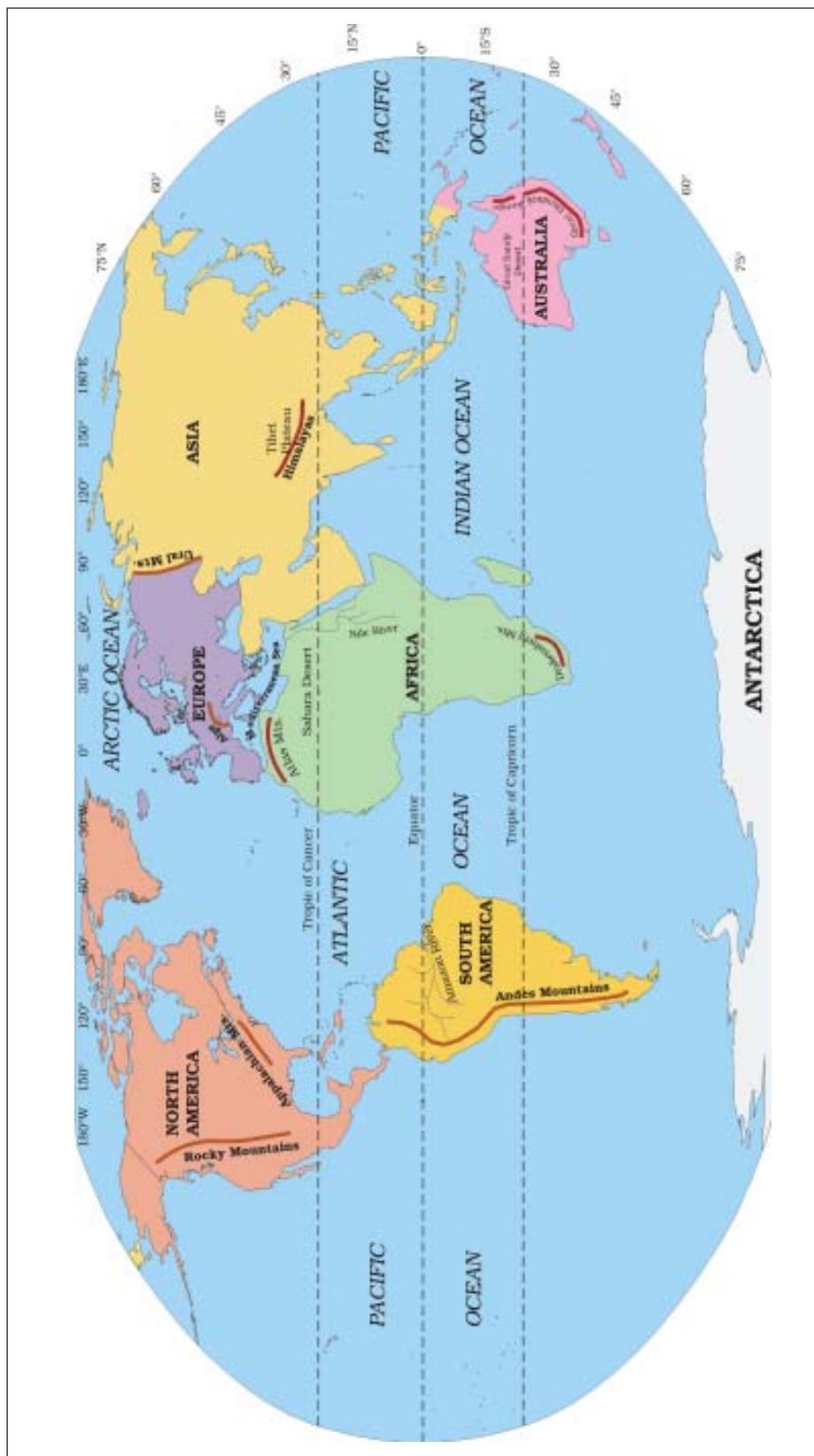
In Greek language,
Lithos means Stone;
Atmos means Vapour;
Hudor means Water;
and *Bios* means Life.
Can you make words using
the above?

LITHOSPHERE

The solid portion of the earth is called the *Lithosphere*. It comprises the rocks of the earth's crust and the thin layers of soil that contain nutrient elements which sustain organisms.

There are two main divisions of the earth's surface. The large landmasses are known as the **continents** and the huge water bodies are called the **ocean basins**. All the oceans of the world are connected with one another. Look at the map of the world (Figure 5.1). Are all the land masses connected with one another?

The level of seawater remains the same everywhere. Elevation of land is measured from the level of the sea, which is taken as zero.



MAJOR DOMAINS OF THE EARTH

Figure 5.1 : The World : Continents and Oceans



Do you know?

Edmund Hillary (Britain) and Tenzing Norgay Sherpa (India) were the first men to climb the highest mountain peak Mt. Everest on the planet earth on 29th May, 1953.

Junko Tabei (Japan) was the first woman to reach the summit on 16th May, 1975. The first Indian woman to climb the highest peak on 23rd May, 1984 was Bachendri Pal.

The highest mountain peak Mt. Everest is 8,848 metres above the sea level. The greatest depth of 11,022 metres is recorded at Mariana Trench in the Pacific Ocean. Could you imagine that depth of sea is much more than the highest point?

Continents

There are seven major continents. These are separated by large water bodies. These continents are – Asia, Europe, Africa, North America, South America, Australia and Antarctica. Look at the map of the world (Figure 5.1) and notice that the greater part of the land mass lies in the Northern Hemisphere.

Asia is the largest continent. It covers about one-third of the total land area of the earth. The continent lies in the Eastern Hemisphere. The Tropic of Cancer passes through this continent. Asia is separated from Europe by the Ural mountains on the west (Figure 5.1). The combined landmass of Europe and Asia is called the *Eurasia* (Europe + Asia).

Europe is much smaller than Asia. The continent lies to the west of Asia. The Arctic Circle passes through it. It is bound by water bodies on three sides. Look at the map of the world and locate it.

Africa is the second largest continent after Asia. The Equator or 0° latitude runs almost through the middle of the continent. A large part of Africa lies in the Northern Hemisphere. Look at the Figure 5.1; you will find that it is the only continent through which the Tropic of Cancer, the Equator and the Tropic of Capricorn pass.

The Sahara Desert, the world's largest hot desert, is located in Africa. The continent is bound on all sides by oceans and seas. Look at the world map (Figure 5.1). You will notice that the world's longest river the **Nile**, flows through Africa. Notice where the Equator, the Tropic of Cancer and the Tropic of Capricorn pass in the map of Africa.

North America is the third largest continent of the world. It is linked to South America by a very narrow strip of land called the Isthmus of Panama. The continent lies completely in the Northern and Western Hemisphere. Three oceans surround this continent. Can you name these oceans?

South America lies mostly in the Southern Hemisphere. Which two oceans surround it on the east and the west? The Andes, world's longest mountain range, runs through its length from north to south (Figure 5.1). South America has the world's largest river, the Amazon.

Australia is the smallest continent that lies entirely in the Southern Hemisphere. It is surrounded on all sides by the oceans and seas. It is called an *island continent*.

Antarctica, completely in the Southern Hemisphere, is a huge continent. It is larger than the combined area of Europe and Australia. The South Pole lies almost at the centre of this continent. As it is located in the South Polar Region, it is permanently covered with thick ice sheets. There are no permanent human settlements. Many countries have research stations in Antarctica. India also has research stations there. These are named as **Maitri** and **Dakshin Gangotri**.

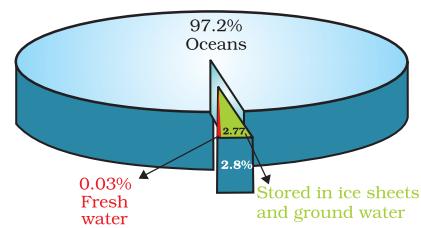
HYDROSPHERE

The earth is called the *blue planet*. More than 71 per cent of the earth is covered with water and 29 per cent is with land. Hydrosphere consists of water in all its forms. As running water in oceans and rivers and in lakes, ice in glaciers, underground water and the water vapour in atmosphere, all comprise the hydrosphere.

More than 97% of the Earth's water is found in the oceans and is too salty for human use. A large proportion of the rest of the water is in the form of icesheets and glaciers or under the ground and a very small percentage is available as fresh water for human



Figure 5.2 : Isthmus and Strait



use. Hence, despite being a ‘blue planet’ we face a shortage of water!!

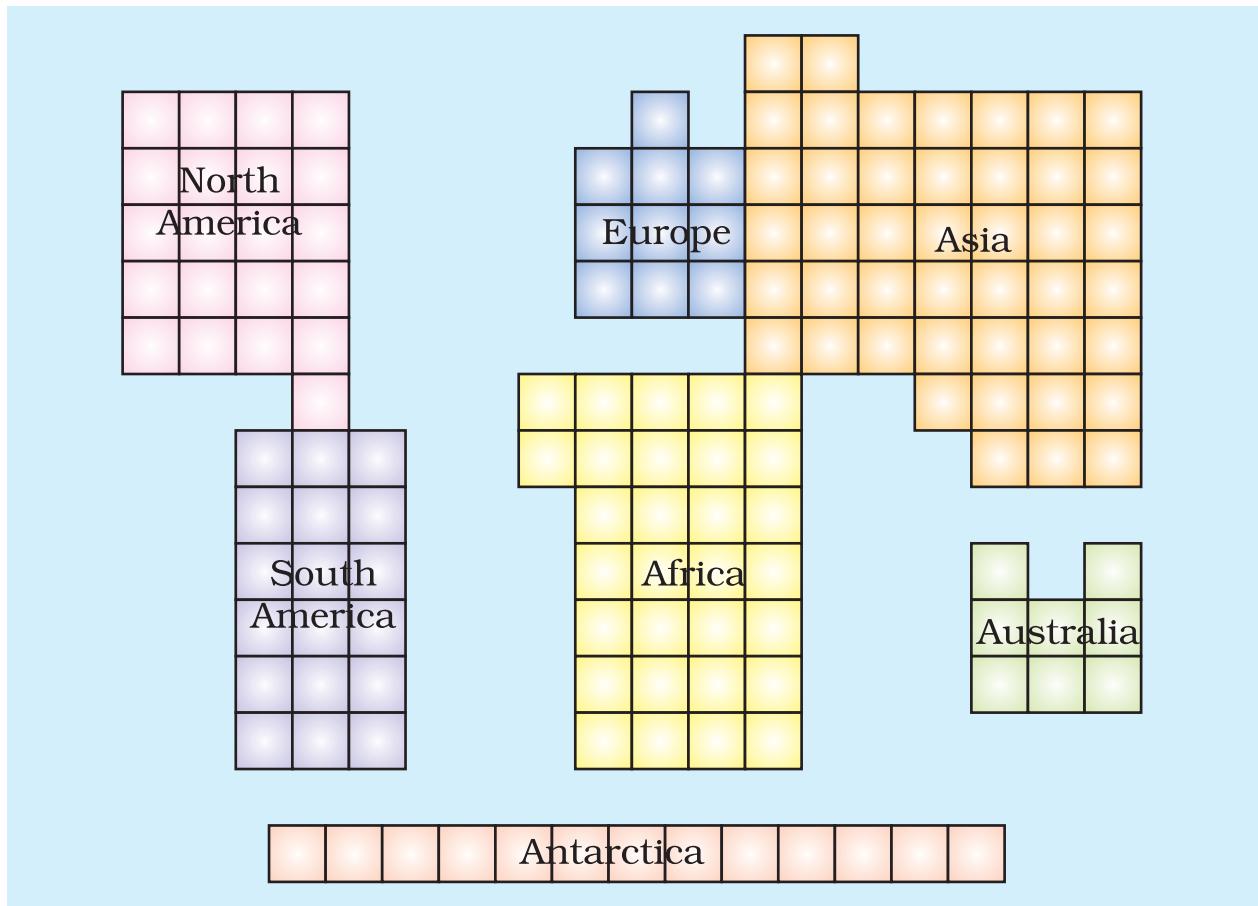


Figure 5.3 : Comparative size of the continents

Count the squares given in Figure 5.3 and answer the following :

(a) Name the largest and smallest continents; (b) Which is larger – North or South America?

Oceans

Oceans are the major part of hydrosphere. They are all interconnected.

The ocean waters are always moving. The three chief movements of ocean waters are the waves, the tides and the ocean currents. The four major oceans are the Pacific Ocean, the Atlantic Ocean, the Indian Ocean and the Arctic Ocean, in order of their size (Figure 5.1).

The Pacific Ocean is the largest ocean. It is spread over one-third of the earth. Mariana Trench, the deepest part of the earth, lies under the Pacific Ocean. The Pacific Ocean is circular in shape. Asia, Australia,

North and South Americas surround it. Look at the map and find out the location of the continents around the Pacific Ocean.

The Atlantic Ocean is the second largest Ocean in the world. It is 'S' shaped. It is flanked by the North and South Americas on the western side, and Europe and Africa on the eastern side. The coastline of Atlantic Ocean is highly *indented*. This irregular and indented coastline provides ideal location for natural harbours and ports. From the point of view of commerce, it is the busiest Ocean.

The Indian Ocean is the only ocean named after a country, that is, India. The shape of ocean is almost triangular. In the north, it is bound by Asia, in the west by Africa and in the east by Australia.

The Arctic Ocean is located within the Arctic Circle and surrounds the North Pole. It is connected with the Pacific Ocean by a narrow stretch of shallow water known as Bering strait. It is bound by northern coasts of North America and Eurasia.

ATMOSPHERE

The earth is surrounded by a layer of gas called the **atmosphere**. This thin blanket of air is an integral and important aspect of the planet. It provides us with the air we breathe and protects us from the harmful effects of sun's rays.

The atmosphere extends up to a height of about 1,600 kilometres. The atmosphere is divided into five layers based on composition, temperature and other properties. These layers starting from earth's surface are called the troposphere, the stratosphere, the mesosphere, the thermosphere and the exosphere.

The atmosphere is composed mainly of nitrogen and oxygen, which make up about 99 per cent of clean, dry air. Nitrogen 78 per cent, oxygen 21 per cent and other gases like carbondioxide, argon and others comprise 1 per cent by volume. Oxygen is the breath of life while nitrogen helps in the growth of living organisms. Carbon dioxide, though present in minute amount, is important as it absorbs heat radiated by the earth, thereby keeping the planet warm. It is also essential for the growth of plants.

The density of the atmosphere varies with height. It



Figure 5.4 : Layers of the Atmosphere



Figure 5.5 : A mountaineer

is maximum at the sea level and decreases rapidly as we go up. You know, the climbers experience problems in breathing due to this decrease in the density of air. They have to carry with them oxygen cylinders to be able to breathe at high altitudes. The temperature also decreases as we go upwards. The atmosphere exerts pressure on the earth. This varies from place to place. Some areas experience high pressure and some areas low pressure. Air moves from high pressure to low pressure. Moving air is known as wind.

BIOSPHERE – THE DOMAIN OF LIFE

The **biosphere** is the narrow zone of contact between the land, water and air. It is in this zone that life, that is unique to this planet, exists. There are several

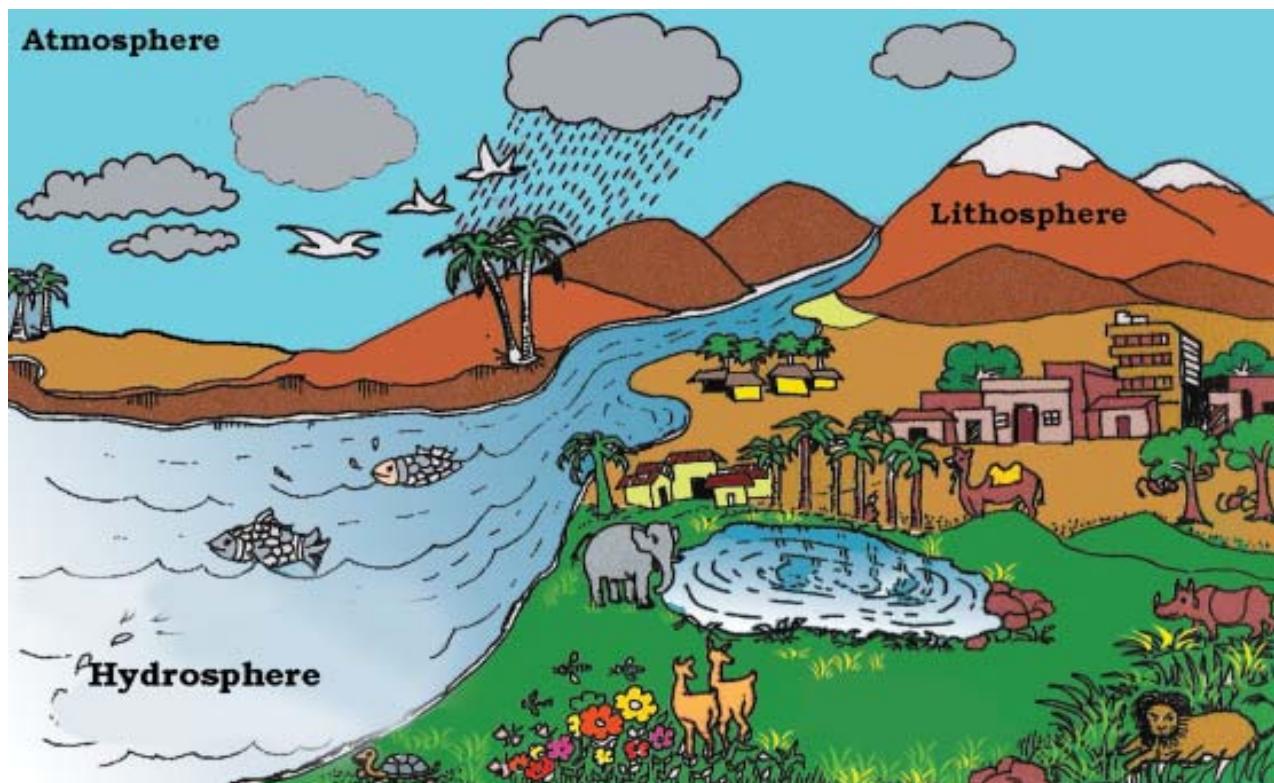


Figure 5.6 : The Biosphere

species of organisms that vary in size from microbes and bacteria to huge mammals. All the living organisms including humans are linked to each other and to the biosphere for survival.

The organisms in the biosphere may broadly be divided into the plant kingdom and the animal kingdom. The three domains of the earth interact with each other and affect each other in some way or the other. For example, cutting of forests for fulfilling our needs of wood, or clearing land for agriculture may lead to fast removal of soil from slopes. Similarly earth's surface may be changed due to natural calamities like earthquakes. For example, there could be submergence of land, as happened in the case of Tsunami recently. Parts of Andaman & Nicobar islands were submerged under water. Discharge of waste material into lakes and rivers makes the water unsuitable for human use. It also damages other forms of life.

Emission from industries, thermal power plants and vehicles, pollute the air. Carbon dioxide (CO_2) is an important constituent of air. But increase in the amount of CO_2 leads to increase in global temperatures. This is termed as global warming. There is thus, a need to limit the use of resources of the earth to maintain the balance of nature between the domains of the lithosphere, the atmosphere and the hydrosphere.

EXERCISES

1. Answer the following questions briefly.

- (a) What are the four major domains of the earth?
- (b) Name the major continents of the earth.
- (c) Name the two continents that lie entirely in the Southern Hemisphere.
- (d) Name the different layers of atmosphere.
- (e) Why is the earth called the 'blue planet'?
- (f) Why is the Northern Hemisphere called the Land Hemisphere?
- (g) Why is the Biosphere important for living organisms?

2. Tick the correct answers.

- (a) The mountain range that separates Europe from Asia is
 - (i) the Andes
 - (ii) the Himalayas
 - (iii) the Urals
- (b) The continent of North America is linked to South America by
 - (i) Isthmus
 - (ii) Strait
 - (iii) Canal
- (c) The major constituent of atmosphere by per cent is
 - (i) Nitrogen
 - (ii) Oxygen
 - (iii) Carbon dioxide
- (d) The domain of the earth consisting of solid rocks is
 - (i) the Atmosphere
 - (ii) the Hydrosphere
 - (iii) the Lithosphere
- (e) Which is the largest continent?
 - (i) Africa
 - (ii) Asia
 - (iii) Australia

3. Fill in the blanks.

- (a) The deepest point on the earth is _____ in the Pacific Ocean.
- (b) The _____ Ocean is named after a country.
- (c) The _____ is a narrow contact zone of land, water and air that supports life.
- (d) The continents of Europe and Asia together are known as _____.
- (e) The highest mountain peak on the earth is _____.



THINGS To Do

1. Cut the outline of the continents from an outline map of the world and arrange them according to their decreasing sizes.
2. Cut the outline of the continents from an outline map of the world and try to fit them together as a Jig-saw puzzle.
3. Collect pictures of expeditions to the Himalayas. Write about the kind of equipment carried by the climbers for protection against sunshine, temperature and the lack of air.

Map Skills

1. On the outline map of the world, mark the following :
Europe, Asia, Antarctica, South America, Australia, Indian Ocean, Pacific Ocean, Atlantic Ocean, Ural Mountains and Isthmus of Panama.



6



MAJOR LANDFORMS OF THE EARTH

You must have seen some of the landform features as shown in the Figure 6.1 below. You will notice that the surface of the earth is not the same everywhere. The earth has an infinite variety of landforms. Some parts of the lithosphere may be rugged and some flat.

These landforms are a result of two processes. You will be amazed to know that the ground you are standing on is slowly moving. Within the earth, a continuous movement is taking place. The first, or the **internal process** leads to the upliftment and sinking of the earth's surface at several places.

Do you know?
A hill is a land surface higher than the local area. Broadly, a steep hill with an elevation of more than 600 metres is termed as a mountain. Name some mountains with a height of more than 8,000 metres.

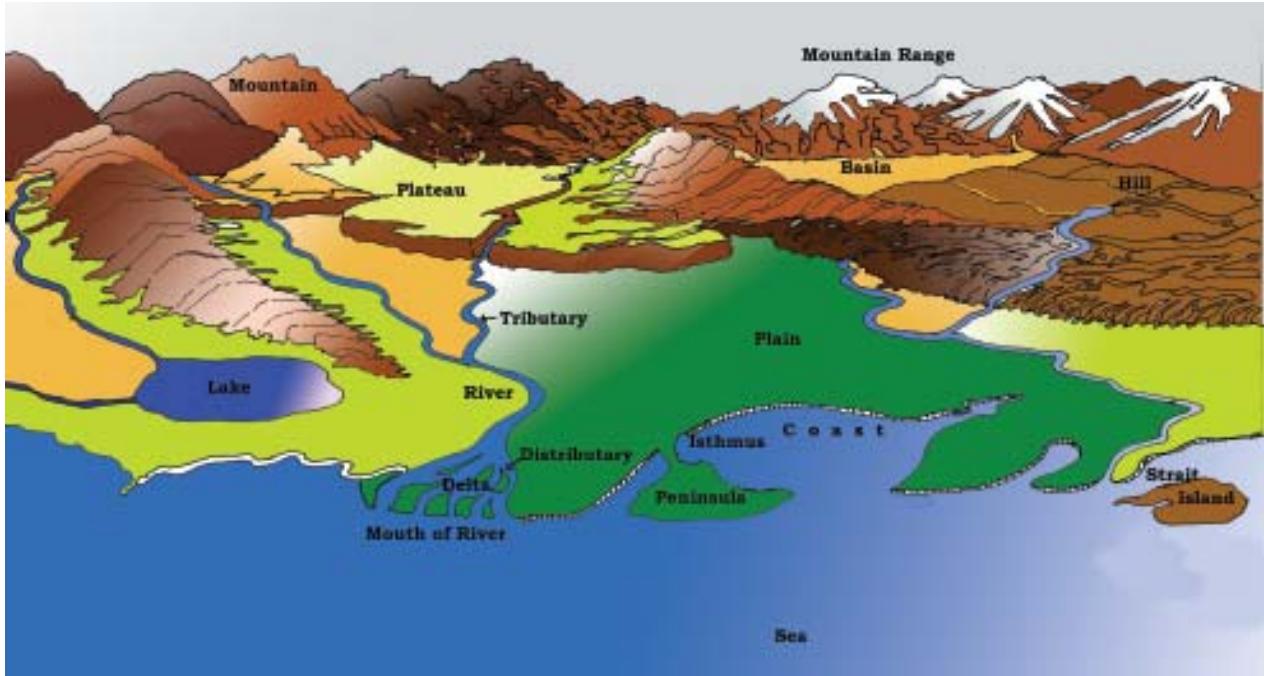


Figure 6.1 : Landforms

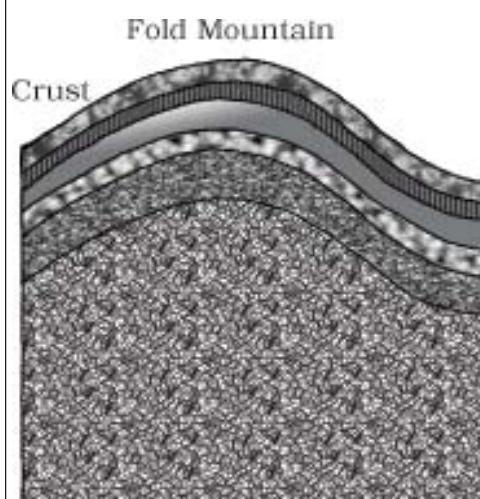


Let's Do

Making of a Mountain :

1. All you require is a pile of paper.
2. Put the papers on your table.
3. Push the papers from both sides by your hands.
4. The sheet will be folded and rise into a peak.
5. You have made a mountain!

In the same process our Himalayas and the Alps were formed!



The second, or the **external process** is the continuous wearing down and rebuilding of the land surface. The wearing away of the earth's surface is called **erosion**. The surface is being lowered by the process of erosion and rebuilt by the process of **deposition**. These two processes are carried out by running water, ice and wind. Broadly, we can group different landforms depending on elevation and slope as **mountains, plateaus and plains**.

MOUNTAINS

A **mountain** is any natural elevation of the earth surface. The mountains may have a small summit and a broad base. It is considerably higher than the surrounding area. Some mountains are even higher than the clouds. As you go higher, the climate becomes colder.

In some mountains, there are permanently frozen rivers of ice. They are called **glaciers**. There are some mountains you cannot see as they are under the sea. Because of harsh climate, less people live in the mountain areas. Since the slopes are steep, less land is available for farming.

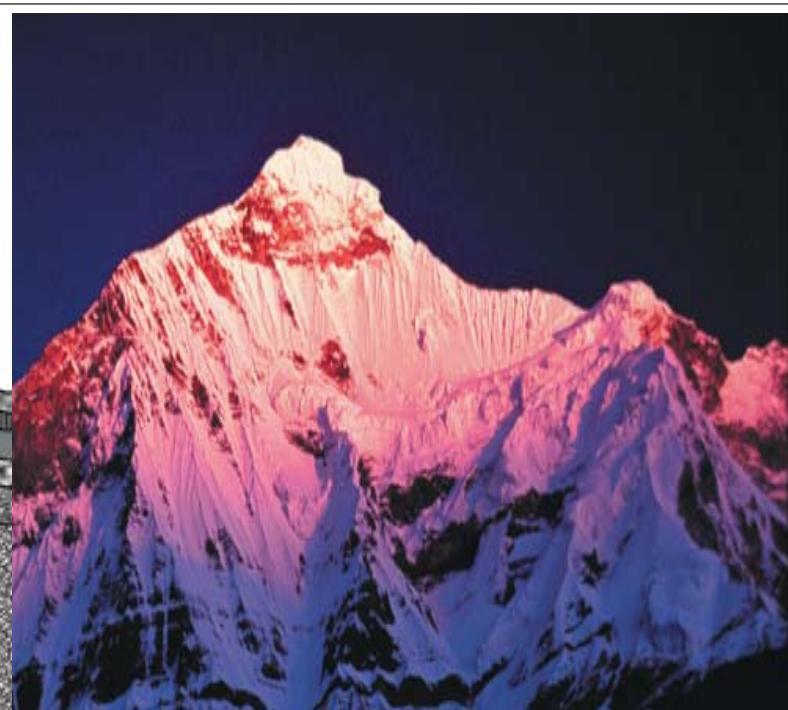


Figure 6.2 : Fold Mountains (Himalayas)

Mountains may be arranged in a line known as **range**. Many mountain systems consist of a series of parallel ranges extending over hundreds of kilometres. The Himalayas, the Alps and the Andes are mountain ranges of Asia, Europe and South America, respectively (Figure 5.1). Mountains vary in their heights and shape.

There are three types of mountains- **Fold Mountains, Block Mountains and the Volcanic Mountains**.

The Himalayan Mountains and the Alps are young fold mountains with rugged relief and high conical peaks. The Aravali range in India is one of the oldest fold mountain systems in the world. The range has considerably worn down due to the processes of erosion. The Appalachians in North America and the Ural mountains in Russia (Figure 5.1) have rounded features and low elevation. They are very old fold mountains.

Block Mountains are created when large areas are broken and displaced vertically. The uplifted blocks are termed as **horsts** and the lowered blocks are called **graben**. The Rhine valley and the Vosges mountain in Europe are examples of such mountain systems. Locate them on the world map in the atlas and find out some more examples of this type of landforms.

Volcanic mountains are formed due to **volcanic activity**. Mt.Kilimanjaro in Africa and Mt.Fujiyama in Japan are examples of such mountains.

Mountains are very useful. The mountains are a **storehouse** of water. Many rivers have their source in the **glaciers** in the mountains. Reservoirs are made and the water is harnessed for the use of people. Water from the mountains is also used for irrigation and generation of hydro-electricity. The **river valleys** and **terraces** are ideal for cultivation of crops. Mountains have a rich variety of **flora** and **fauna**. The forests provide fuel, fodder, shelter and other products like

Do you know?

Mauna Kea (Hawaii) in the Pacific Ocean is an undersea mountain. It is higher than Mount Everest being 10,205 metres high.

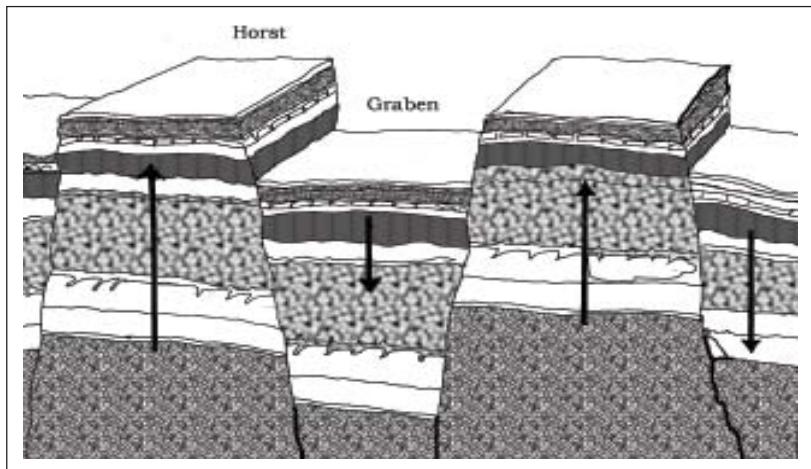


Figure 6.3 : A Block Mountain

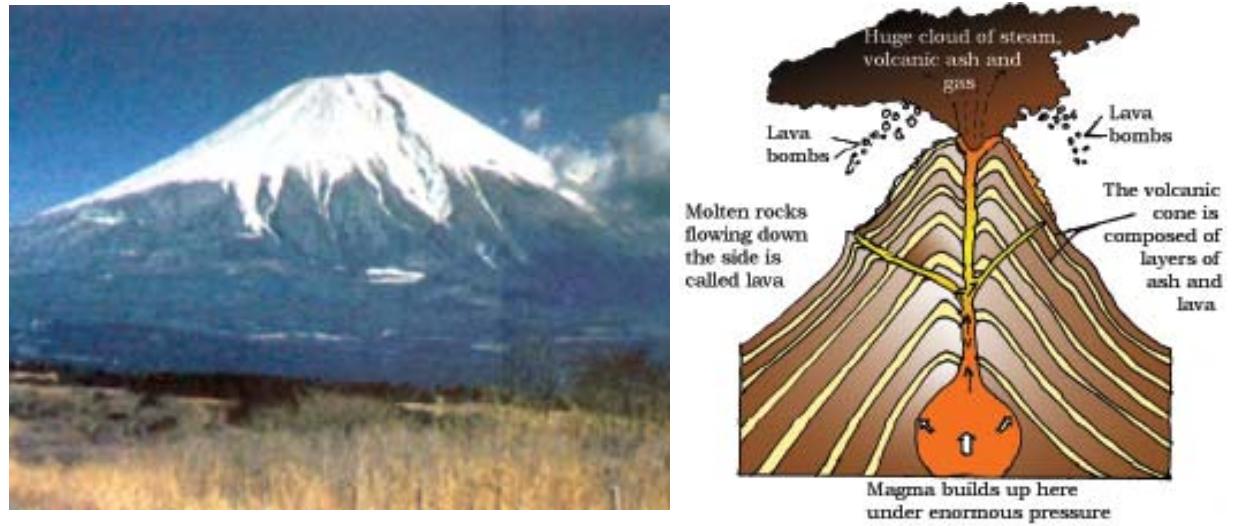


Figure 6.4 : Volcanic Mountain



Can you name this game?

gum, raisins, etc. Mountains provide an idyllic site for tourists. They visit the mountains for their scenic beauty. Several sports like paragliding, hang gliding, river rafting and skiing are popular in the mountains. Can you name some places in the Himalayas associated with these sports?

PLATEAUS



Figure 6.5 : Plateau

A plateau is an elevated flat land. It is a flat-topped **table land** standing above the surrounding area. A plateau may have one or more sides with steep slopes. The height of plateaus often varies from few hundred metres to several thousand metres. Plateaus, like mountains may be young or old. The Deccan plateau in India is one of the oldest plateaus. The East African Plateau in Kenya, Tanzania and Uganda and the Western plateau of Australia are other examples. The Tibet plateau (Figure 5.1, p.31) is the highest plateau in the world with a height of 4,000 to 6,000 metres above the mean sea level.

Plateaus are very useful because they are rich in mineral deposits. As a result, many of the mining areas in the world are located in the plateau areas. The

African plateau is famous for gold and diamond mining. In India huge reserves of iron, coal and manganese are found in the Chhotanagpur plateau.

In the plateau areas, there may be several waterfalls as the river falls from a great height. In India, the Hundru falls in the Chhotanagpur plateau on the river Subarnarekha and the Jog falls in Karnataka are examples of such waterfalls. The lava plateaus are rich in black soil that are fertile and good for cultivation. Many plateaus have scenic spots and are of great attraction to tourists.

PLAINS

Plains are large stretches of flat land. They are, generally, not more than 200 metres above mean sea level. Some plains are extremely level. Others may be slightly rolling and undulating. Most of the plains are formed by rivers and their tributaries. The rivers flow down the slopes of mountains and erode them. They carry forward the eroded material. Then they deposit their load consisting of stones, sand and silt along their courses and in their valleys. It is from these deposits that plains are formed.

Generally, plains are very fertile. Construction of transport network is easy. Thus, these plains are very thickly-populated regions of the world. Some of the largest plains made by the rivers are found in Asia and North America. For example, in Asia, these plains are formed by the Ganga and the Brahmaputra in India and the Yangtze in China.

Plains are the most useful areas for human habitation. There is great concentration of people as more flat land is available for building houses, as well as for cultivation.



Figure 6.6 : Plains

Because of fertile soils, the land is highly productive for cultivation. In India too, the Indo-Gangetic plains are the most densely populated regions of the country.

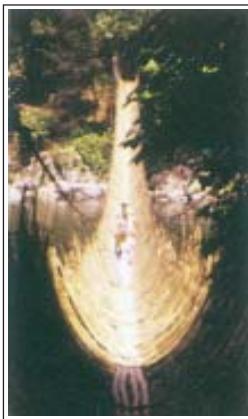


Figure 6.7 : Rope Bridge (Arunachal Pradesh)

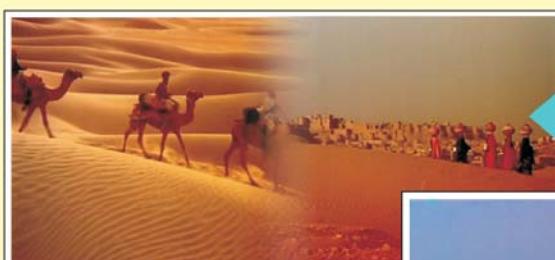
LANDFORMS AND THE PEOPLE

Humans have been living on different kinds of landforms in different ways. Life is difficult in mountainous areas. Plains provide much better conditions. It is easy to grow crops, build a house or a road in a plain than a mountain. Can you point out some differences in the ways people live on different kinds of landforms? Sometimes, natural calamities such as earthquakes, volcanic eruption, storms and floods cause widespread destruction. Huge loss of life and property takes place. By creative awareness about such incidences we may lower the risks.

You may find out from your own surroundings in how many ways we use the land and water. Quite often we use the land in a wasteful manner, for example constructing houses on a fertile land. Similarly we throw garbage on land or in water making them dirty. We should avoid using such important gifts of nature in a careless manner. The available land is not only for our use. It is our duty to leave the earth a better place for future generations as well.



Figure 6.8 : A polluted river



1. Look carefully at photograph nos. 1-10. Write one sentence about each of the photograph.
2. Name the landform features shown in the photograph nos. 1,2 and 7.
3. What appears to be the main use of this land? (Photograph no. 9)
4. What activities do you see in the photograph nos. 3,6,8 and 9.





5



6



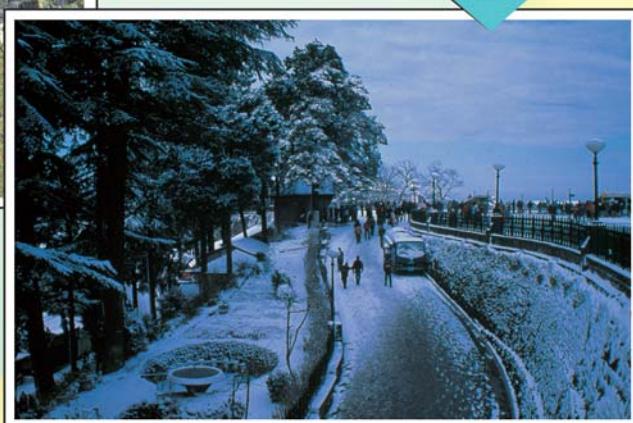
7



8



9



10

5. What type of houses do you see in photograph nos. 4 and 5.
6. Name the water sports/games shown in photograph nos. 3 & 8.
7. Name two means of transport shown in photograph nos. 1 and 10.

EXERCISES

1. Answer the following questions briefly.

- (a) What are the major landforms?
- (b) What is the difference between a mountain and a plateau?
- (c) What are the different types of mountains?
- (d) How are mountains useful to man?
- (e) How are plains formed?
- (f) Why are the river plains thickly populated?
- (g) Why are mountains thinly populated?

2. Tick the correct answers.

- (a) The mountains differ from the hills in terms of
 - (i) elevation
 - (ii) slope
 - (iii) aspect
- (b) Glaciers are found in
 - (i) the mountains
 - (ii) the plains
 - (iii) the plateaus
- (c) The Deccan Plateau is located in
 - (i) Kenya
 - (ii) Australia
 - (iii) India
- (d) The river Yangtze flows in
 - (i) the South America
 - (ii) Australia
 - (iii) China
- (e) An important mountain range of Europe is
 - (i) the Andes
 - (ii) the Alps
 - (iii) the Rockies

3. Fill in the blanks.

1. A _____ is an unbroken flat or a low-level land.
2. The Himalayas and the Alps are examples of _____ types of mountains.
3. _____ areas are rich in mineral deposits.
4. The _____ is a line of mountains.
5. The _____ areas are most productive for farming.



THINGS To Do

1. What kind of landforms are found in your state? Based on the reading of this chapter, say how they are of use to the people.

Map Skills

1. On an outline map of the world, mark the following :
 - (a) Mountain ranges: Himalayas, Rockies and Andes.
 - (b) Plateau : Tibet.



INTERIOR OF THE EARTH

What do you imagine about the nature of the earth? Do you imagine it to be a solid ball like cricket ball or a hollow ball with a thick cover of rocks i.e. lithosphere? Have you ever seen photographs or images of a volcanic eruption on the television screen? Can you recollect the emergence of hot molten lava, dust, smoke, fire and magma flowing out of the volcanic crater? The interior of the earth can be understood only by indirect evidences as neither any one has nor any one can reach the interior of the earth.

The configuration of the surface of the earth is largely a product of the processes operating in the interior of the earth. Exogenic as well as endogenic processes are constantly shaping the landscape. A proper understanding of the physiographic character of a region remains incomplete if the effects of endogenic processes are ignored. Human life is largely influenced by the physiography of the region. Therefore, it is necessary that one gets acquainted with the forces that influence landscape development. To understand why the earth shakes or how a tsunami wave is generated, it is necessary that we know certain details of the interior of the earth. In the previous chapter, you have noted that the earth-forming materials have been distributed in the form of layers from the crust to the core. It is interesting to know how scientists have gathered information about these layers and what are the characteristics of each of these layers. This is exactly what this chapter deals with.

SOURCES OF INFORMATION ABOUT THE INTERIOR

The earth's radius is 6,370 km. No one can reach the centre of the earth and make observations or collect samples of the material. Under such conditions, you may wonder how scientists tell us about the earth's interior and the type of materials that exist at such depths. Most of our knowledge about the interior of the earth is largely based on estimates and inferences. Yet, a part of the information is obtained through direct observations and analysis of materials.

Direct Sources

The most easily available solid earth material is surface rock or the rocks we get from mining areas. Gold mines in South Africa are as deep as 3 - 4 km. Going beyond this depth is not possible as it is very hot at this depth. Besides mining, scientists have taken up a number of projects to penetrate deeper depths to explore the conditions in the crustal portions. Scientists world over are working on two major projects such as "Deep Ocean Drilling Project" and "Integrated Ocean Drilling Project". The deepest drill at Kola, in Arctic Ocean, has so far reached a depth of 12 km. This and many deep drilling projects have provided large volume of information through the analysis of materials collected at different depths.

Volcanic eruption forms another source of obtaining direct information. As and when the molten material (magma) is thrown onto the surface of the earth, during volcanic eruption it becomes available for laboratory analysis. However, it is difficult to ascertain the depth of the source of such magma.

Indirect Sources

Analysis of properties of matter indirectly provides information about the interior. We know through the mining activity that temperature and pressure increase with the increasing distance from the surface towards the interior in deeper depths. Moreover, it is also known that the density of the material also increases with depth. It is possible to find the rate of change of these characteristics. Knowing the total thickness of the earth, scientists have estimated the values of temperature, pressure and the density of materials at different depths. The details of these characteristics with reference to each layer of the interior are discussed later in this chapter.

Another source of information are the meteors that at times reach the earth. However, it may be noted that the material that becomes available for analysis from meteors, is not from the interior of the earth. The material and the structure observed in the meteors are similar to that of the earth. They are solid bodies developed out of materials same as, or similar to, our planet. Hence, this becomes yet another source of information about the interior of the earth.

The other indirect sources include gravitation, magnetic field, and seismic activity. The gravitation force (g) is not the same at different latitudes on the surface. It is greater near the poles and less at the equator. This is because of the distance from the centre at the equator being greater than that at the poles. The gravity values also differ according to the mass of material. The uneven distribution of mass of material within the earth influences this value. The reading of the gravity at different places is influenced by many other factors. These readings differ from the expected values. Such a difference is called *gravity anomaly*. Gravity anomalies give us information about the distribution of mass of the material in the crust of the earth. Magnetic surveys also provide information about the distribution of magnetic materials in the crustal portion, and thus, provide information about the distribution of materials in this part. Seismic activity is one of the most important sources of

information about the interior of the earth. Hence, we shall discuss it in some detail.

Earthquake

The study of seismic waves provides a complete picture of the layered interior. An earthquake in simple words is shaking of the earth. It is a natural event. It is caused due to release of energy, which generates waves that travel in all directions.

Why does the earth shake?

The release of energy occurs along a fault. A fault is a sharp break in the crustal rocks. Rocks along a fault tend to move in opposite directions. As the overlying rock strata press them, the friction locks them together. However, their tendency to move apart at some point of time overcomes the friction. As a result, the blocks get deformed and eventually, they slide past one another abruptly. This causes a release of energy, and the energy waves travel in all directions. The point where the energy is released is called the *focus* of an earthquake, alternatively, it is called the *hypocentre*. The energy waves travelling in different directions reach the surface. The point on the surface, nearest to the focus, is called *epicentre*. It is the first one to experience the waves. It is a point directly above the focus.

Earthquake Waves

All natural earthquakes take place in the lithosphere. You will learn about different layers of the earth later in this chapter. It is sufficient to note here that the lithosphere refers to the portion of depth up to 200 km from the surface of the earth. An instrument called 'seismograph' records the waves reaching the surface. A curve of earthquake waves recorded on the seismograph is given in Figure 3.1. Note that the curve shows three distinct sections each representing different types of wave patterns. Earthquake waves are basically of two types — *body waves* and *surface waves*. Body waves are generated due to the release of energy at the focus and move in all directions travelling through the body of the earth. Hence, the name

body waves. The body waves interact with the surface rocks and generate new set of waves called surface waves. These waves move along the surface. The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities.

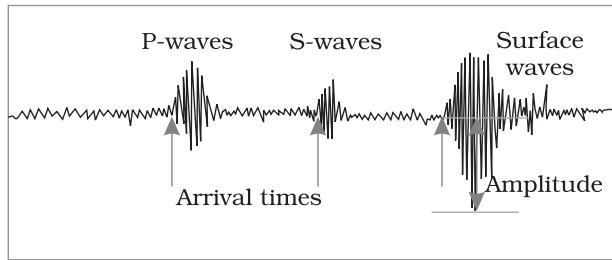


Figure 3.1 : Earthquake Waves

There are two types of body waves. They are called P and S-waves. P-waves move faster and are the first to arrive at the surface. These are also called 'primary waves'. The P-waves are similar to sound waves. They travel through gaseous, liquid and solid materials. S-waves arrive at the surface with some time lag. These are called secondary waves. An important fact about S-waves is that they can travel only through solid materials. This characteristic of the S-waves is quite important. It has helped scientists to understand the structure of the interior of the earth. Reflection causes waves to rebound whereas refraction makes waves move in different directions. The variations in the direction of waves are inferred with the help of their record on seismograph. The surface waves are the last to report on seismograph. These waves are more destructive. They cause displacement of rocks, and hence, the collapse of structures occurs.

Propagation of Earthquake Waves

Different types of earthquake waves travel in different manners. As they move or propagate, they cause vibration in the body of the rocks through which they pass. P-waves vibrate parallel to the direction of the wave. This exerts pressure on the material in the direction of the

propagation. As a result, it creates density differences in the material leading to stretching and squeezing of the material. Other three waves vibrate perpendicular to the direction of propagation. The direction of vibrations of S-waves is perpendicular to the wave direction in the vertical plane. Hence, they create troughs and crests in the material through which they pass. Surface waves are considered to be the most damaging waves.

Emergence of Shadow Zone

Earthquake waves get recorded in seismographs located at far off locations. However, there exist some specific areas where the waves are not reported. Such a zone is called the 'shadow zone'. The study of different events reveals that for each earthquake, there exists an altogether different shadow zone. Figure 3.2 (a) and (b) show the shadow zones of P and S-waves. It was observed that seismographs located at any distance within 105° from the epicentre, recorded the arrival of both P and S-waves. However, the seismographs located beyond 145° from epicentre, record the arrival of P-waves, but not that of S-waves. Thus, a zone between 105° and 145° from epicentre was identified as the shadow zone for both the types of waves. The entire zone beyond 105° does not receive S-waves. The shadow zone of S-wave is much larger than that of the P-waves. The shadow zone of P-waves appears as a band around the earth between 105° and 145° away from the epicentre. The shadow zone of S-waves is not only larger in extent but it is also a little over 40 per cent of the earth surface. You can draw the shadow zone for any earthquake provided you know the location of the epicentre. (See the activity box on page 28 to know how to locate the epicentre of a quake event).

Types of Earthquakes

- (i) The most common ones are the *tectonic* earthquakes. These are generated due to sliding of rocks along a fault plane.
- (ii) A special class of tectonic earthquake is sometimes recognised as *volcanic* earthquake. However, these are confined to areas of active volcanoes.

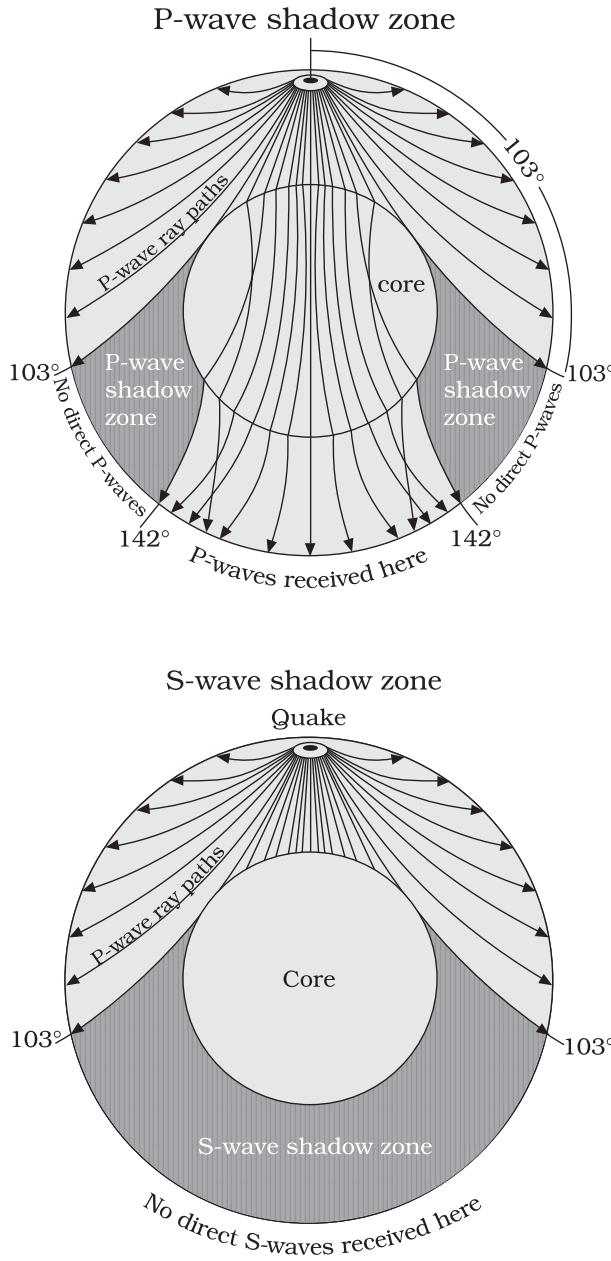


Figure 3.2 (a) and (b) : Earthquake Shadow Zones

- (iii) In the areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors. These are called *collapse* earthquakes.
- (iv) Ground shaking may also occur due to the explosion of chemical or nuclear devices. Such tremors are called *explosion* earthquakes.

- (v) The earthquakes that occur in the areas of large reservoirs are referred to as *reservoir induced* earthquakes.

Measuring Earthquakes

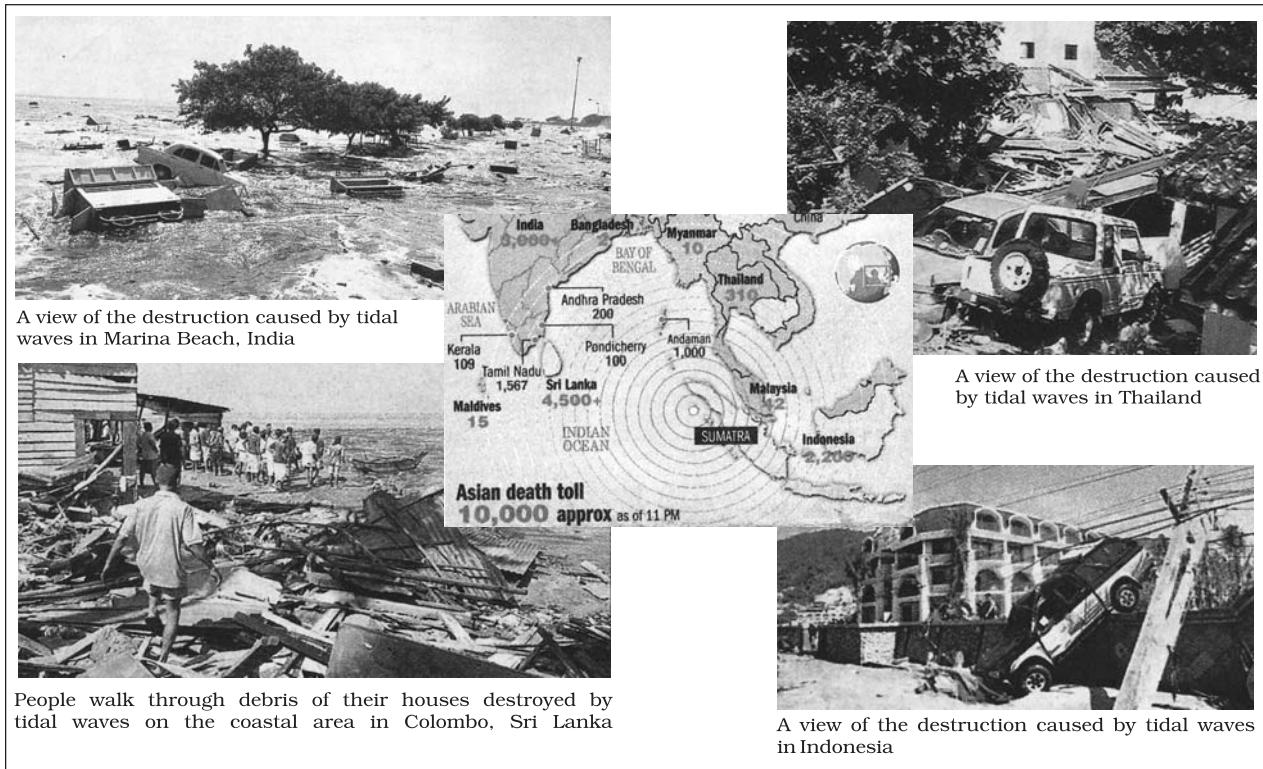
The earthquake events are scaled either according to the magnitude or intensity of the shock. The magnitude scale is known as the *Richter scale*. The magnitude relates to the energy released during the quake. The magnitude is expressed in absolute numbers, 0-10. The intensity scale is named after *Mercalli*, an Italian seismologist. The intensity scale takes into account the visible damage caused by the event. The range of intensity scale is from 1-12.

EFFECTS OF EARTHQUAKE

Earthquake is a natural hazard. The following are the immediate hazardous effects of earthquake:

- (i) Ground Shaking
- (ii) Differential ground settlement
- (iii) Land and mud slides
- (iv) Soil liquefaction
- (v) Ground lurching
- (vi) Avalanches
- (vii) Ground displacement
- (viii) Floods from dam and levee failures
- (ix) Fires
- (x) Structural collapse
- (xi) Falling objects
- (xii) Tsunami

The first six listed above have some bearings upon landforms, while others may be considered the effects causing immediate concern to the life and properties of people in the region. The effect of tsunami would occur only if the epicentre of the tremor is below oceanic waters and the magnitude is sufficiently high. *Tsunamis* are waves generated by the tremors and not an earthquake in itself. Though the actual quake activity lasts for a few seconds, its effects are devastating provided the magnitude of the quake is more than 5 on the Richter scale.



Frequency of Earthquake Occurrences

The earthquake is a natural hazard. If a tremor of high magnitude takes place, it can cause heavy damage to the life and property of people. However, not all the parts of the globe necessarily experience major shocks. We shall be discussing the distribution of earthquakes and volcanoes with some details in the next



A view of the damaged Aman Setu at the LOC in Uri, due to an earthquake

chapter. Note that the quakes of high magnitude, i.e. 8+ are quite rare; they occur once in 1-2 years whereas those of 'tiny' types occur almost every minute.

STRUCTURE OF THE EARTH

The Crust

It is the outermost solid part of the earth. It is brittle in nature. The thickness of the crust varies under the oceanic and continental areas. Oceanic crust is thinner as compared to the continental crust. The mean thickness of oceanic crust is 5 km whereas that of the continental is around 30 km. The continental crust is thicker in the areas of major mountain systems. It is as much as 70 km thick in the Himalayan region.

It is made up of heavier rocks having density of 3 g/cm^3 . This type of rock found in the oceanic crust is basalt. The mean density of material in oceanic crust is 2.7 g/cm^3 .

The Mantle

The portion of the interior beyond the crust is called the mantle. The mantle extends from Moho's discontinuity to a depth of 2,900 km. The upper portion of the mantle is called *asthenosphere*. The word *astheno* means weak. It is considered to be extending upto 400 km. It is the main source of magma that finds

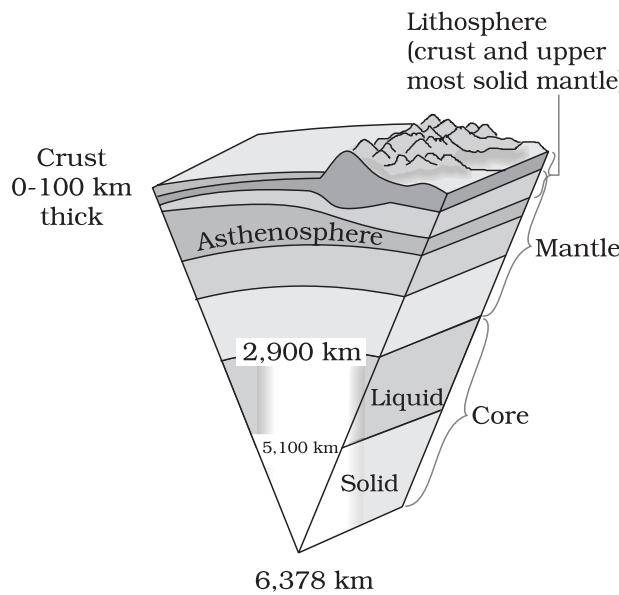


Figure 3.4 : The interior of the earth

its way to the surface during volcanic eruptions. It has a density higher than the crust's (3.4 g/cm^3). The crust and the uppermost part of the mantle are called lithosphere. Its thickness ranges from 10-200 km. The lower mantle extends beyond the asthenosphere. It is in solid state.

The Core

As indicated earlier, the earthquake wave velocities helped in understanding the existence of the core of the earth. The core-mantle boundary is located at the depth of 2,900 km. The outer core is in liquid state while the inner core is in solid state. The density of material at the mantle core boundary is around 5 g/cm^3 and at the centre of the earth at 6,300 km, the density value is around 13 g/cm^3 . The core is made up of very heavy material mostly constituted by nickel and iron. It is sometimes referred to as the *nife* layer.

VOLCANOES AND VOLCANIC LANDFORMS

You may have seen photographs or pictures of volcanoes on a number of occasions. A volcano is a place where gases, ashes and/or molten rock material – lava – escape to the ground. A volcano is called an active volcano if the materials mentioned are being released or have

been released out in the recent past. The layer below the solid crust is mantle. It has higher density than that of the crust. The mantle contains a weaker zone called *asthenosphere*. It is from this that the molten rock materials find their way to the surface. The material in the upper mantle portion is called *magma*. Once it starts moving towards the crust or it reaches the surface, it is referred to as *lava*. The material that reaches the ground includes lava flows, pyroclastic debris, volcanic bombs, ash and dust and gases such as nitrogen compounds, sulphur compounds and minor amounts of chlorene, hydrogen and argon.

Volcanoes

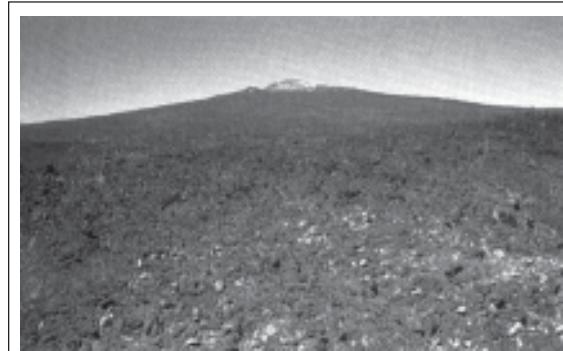
Volcanoes are classified on the basis of nature of eruption and the form developed at the surface. Major types of volcanoes are as follows:

Shield Volcanoes

Barring the basalt flows, the shield volcanoes are the largest of all the volcanoes on the earth. The Hawaiian volcanoes are the most famous



Shield Volcano



Cinder Cone

examples. These volcanoes are mostly made up of basalt, a type of lava that is very fluid when erupted. For this reason, these volcanoes are not steep. They become explosive if somehow water gets into the vent; otherwise, they are characterised by low-explosivity. The upcoming lava moves in the form of a fountain and throws out the cone at the top of the vent and develops into cinder cone.

Composite Volcanoes

These volcanoes are characterised by eruptions of cooler and more viscous lavas than basalt. These volcanoes often result in explosive eruptions. Along with lava, large quantities of pyroclastic material and ashes find their way to the ground. This material accumulates in the vicinity of the vent openings leading to formation of layers, and this makes the mounts appear as composite volcanoes.



Composite Volcano

Caldera

These are the most explosive of the earth's volcanoes. They are usually so explosive that when they erupt they tend to collapse on themselves rather than building any tall structure. The collapsed depressions are called *calderas*. Their explosiveness indicates that the magma chamber supplying the lava is not only huge but is also in close vicinity.

Flood Basalt Provinces

These volcanoes outpour highly fluid lava that flows for long distances. Some parts of the world are covered by thousands of sq. km of thick basalt lava flows. There can be a series of flows with some flows attaining thickness of

more than 50 m. Individual flows may extend for hundreds of km. The *Deccan Traps* from India, presently covering most of the Maharashtra plateau, are a much larger flood basalt province. It is believed that initially the trap formations covered a much larger area than the present.

Mid-Ocean Ridge Volcanoes

These volcanoes occur in the oceanic areas. There is a system of mid-ocean ridges more than 70,000 km long that stretches through all the ocean basins. The central portion of this ridge experiences frequent eruptions. We shall be discussing this in detail in the next chapter.

VOLCANIC LANDFORMS

Intrusive Forms

The lava that is released during volcanic eruptions on cooling develops into igneous rocks. The cooling may take place either on reaching the surface or also while the lava is still in the crustal portion. Depending on the location of the cooling of the lava, igneous rocks are classified as *volcanic rocks* (cooling at the surface) and *plutonic rocks* (cooling in the crust). The lava that cools within the crustal portions assumes different forms. These forms are called *intrusive forms*. Some of the forms are shown in Figure 3.5.

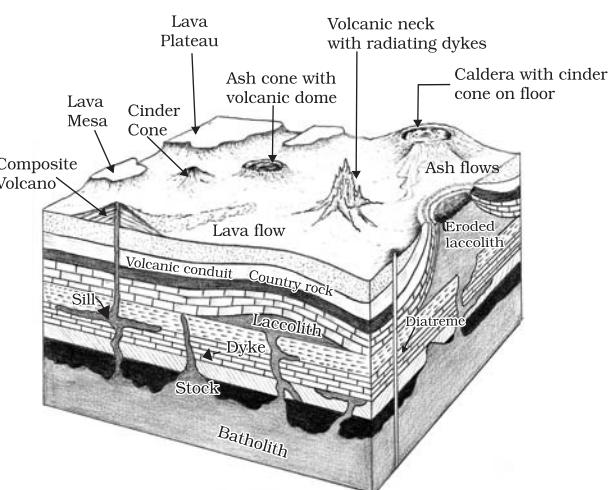


Figure 3.5 : Volcanic Landforms

Batholiths

A large body of magmatic material that cools in the deeper depth of the crust develops in the form of large domes. They appear on the surface only after the denudational processes remove the overlying materials. They cover large areas, and at times, assume depth that may be several km. These are granitic bodies. Batholiths are the cooled portion of magma chambers.

Lacoliths

These are large dome-shaped intrusive bodies with a level base and connected by a pipe-like

conduit from below. It resembles the surface volcanic domes of composite volcano, only these are located at deeper depths. It can be regarded as the localised source of lava that finds its way to the surface. The Karnataka plateau is spotted with domal hills of granite rocks. Most of these, now exfoliated, are examples of lacoliths or batholiths.

Lapolith, Phacolith and Sills

As and when the lava moves upwards, a portion of the same may tend to move in a horizontal direction wherever it finds a weak

Activity : Locating an Epicentre

For this you will need

Data from 3 seismograph stations about the time of arrival of P-waves, S-waves.

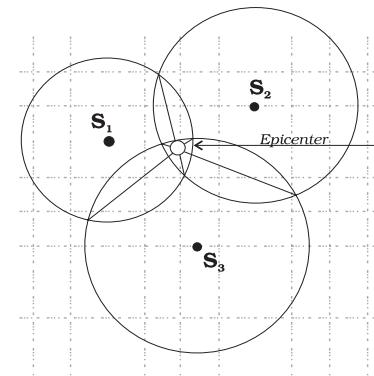
Procedure

1. Find the time of arrival of P and S-waves of the given quake for the three stations for which you have the data.
2. Compute the time lag between the arrival of P and S-waves for each station; it is called time lag. (Note that it is directly related to the distance of the seismograph from the focus.)
3. *A. Basic rule : For every second of time lag, the earthquake is roughly 8 km away from you.*
4. Using the rule quoted above, convert the time lag into distance (# seconds of time lag * 8) for each station.
5. On a map locate the seismograph stations.
6. Draw circles, taking the seismograph stations as the centre, with the radius equal to the distance you have calculated in the previous step. (Do not forget to convert distance as per the map scale.)
7. These circles will intersect each other in a point. This point is the location of the epicentre.

In normal practice, the epicentres are located using computer models. They take into account the structure of the earth's crust. The locations with accuracy within a few hundred metres can be achieved. The procedure outlined here is a much simplified version of what is normally done, although the principle is the same.

In the following diagram, the epicentre is located using this procedure. It also contains a table giving necessary data. Why don't you try for yourself?

Data										
Station	Arrival time of									
	P-waves			S-waves			Hour	Min.	Sec.	
S1	03	23	20	03	24	45				
S2	03	22	17	03	23	57				
S3	03	22	00	03	23	55				
Scale of the map 1cm = 40km										



plane. It may get rested in different forms. In case it develops into a saucer shape, concave to the sky body, it is called *lapolith*. A wavy mass of intrusive rocks, at times, is found at the base of synclines or at the top of anticline in folded igneous country. Such wavy materials have a definite conduit to source beneath in the form of magma chambers (subsequently developed as batholiths). These are called the phacoliths.

The near horizontal bodies of the intrusive igneous rocks are called *sill* or *sheet*, depending on the thickness of the material. The thinner ones are called sheets

while the thick horizontal deposits are called *sills*.

Dykes

When the lava makes its way through cracks and the fissures developed in the land, it solidifies almost perpendicular to the ground. It gets cooled in the same position to develop a wall-like structure. Such structures are called dykes. These are the most commonly found intrusive forms in the western Maharashtra area. These are considered the feeders for the eruptions that led to the development of the Deccan traps.

EXERCISES

1. Multiple choice questions.

- (i) Which one of the following earthquake waves is more destructive?
 - (a) P-waves
 - (c) Surface waves
 - (b) S-waves
 - (d) None of the above
- (ii) Which one of the following is a direct source of information about the interior of the earth?
 - (a) Earthquake waves
 - (c) Gravitational force
 - (b) Volcanoes
 - (d) Earth magnetism
- (iii) Which type of volcanic eruptions have caused Deccan Trap formations?
 - (a) Shield
 - (c) Composite
 - (b) Flood
 - (d) Caldera
- (iv) Which one of the following describes the lithosphere:
 - (a) upper and lower mantle
 - (c) crust and core
 - (b) crust and upper mantle
 - (d) mantle and core

2. Answer the following questions in about 30 words.

- (i) What are body waves?
- (ii) Name the direct sources of information about the interior of the earth.
- (iii) Why do earthquake waves develop shadow zone?
- (iv) Briefly explain the indirect sources of information of the interior of the earth other than those of seismic activity.

3. Answer the following questions in about 150 words.

- (i) What are the effects of propagation of earthquake waves on the rock mass through which they travel?
- (ii) What do you understand by intrusive forms? Briefly describe various intrusive forms.

C H A P T E R

4

DISTRIBUTION OF OCEANS AND CONTINENTS

In the previous chapter, you have studied the interior of the earth. You are already familiar with the world map. You know that continents cover 29 per cent of the surface of the earth and the remainder is under oceanic waters. The positions of the continents and the ocean bodies, as we see them in the map, have not been the same in the past. Moreover, it is now a well-accepted fact that oceans and continents will not continue to enjoy their present positions in times to come. If this is so, the question arises what were their positions in the past? Why and how do they change their positions? Even if it is true that the continents and oceans have changed and are changing their positions, you may wonder as to how scientists know this. How have they determined their earlier positions? You will find the answers to some of these and related questions in this chapter.

CONTINENTAL DRIFT

Observe the shape of the coastline of the Atlantic Ocean. You will be surprised by the symmetry of the coastlines on either side of the ocean. No wonder, many scientists thought of this similarity and considered the possibility of the two Americas, Europe and Africa, to be once joined together. From the known records of the history of science, it was *Abraham Ortelius*, a Dutch map maker, who first proposed such a possibility as early as 1596. *Antonio Pellegrini* drew a map showing the three continents together. However, it was *Alfred Wegener*—a German meteorologist who put forth a comprehensive argument in the form of “the continental drift

theory” in 1912. This was regarding the distribution of the oceans and the continents.

According to Wegener, all the continents formed a single continental mass, a mega ocean surrounded by the same. The super continent was named PANGAEA, which meant all earth. The mega-ocean was called PANTHALASSA, meaning all water. He argued that, around 200 million years ago, the super continent, Pangaea, began to split. Pangaea first broke into two large continental masses as Laurasia and Gondwanaland forming the northern and southern components respectively. Subsequently, Laurasia and Gondwanaland continued to break into various smaller continents that exist today. A variety of evidence was offered in support of the continental drift. Some of these are given below.

Evidence in Support of the Continental Drift

The Matching of Continents (Jig-Saw-Fit)

The shorelines of Africa and South America facing each other have a remarkable and unmistakable match. It may be noted that a map produced using a computer programme to find the best fit of the Atlantic margin was presented by Bullard in 1964. It proved to be quite perfect. The match was tried at 1,000-fathom line instead of the present shoreline.

Rocks of Same Age Across the Oceans

The radiometric dating methods developed in the recent period have facilitated correlating the rock formation from different continents across

the vast ocean. The belt of ancient rocks of 2,000 million years from Brazil coast matches with those from western Africa. The earliest marine deposits along the coastline of South America and Africa are of the Jurassic age. This suggests that the ocean did not exist prior to that time.

Tillite

It is the sedimentary rock formed out of deposits of glaciers. The Gondawana system of sediments from India is known to have its counter parts in six different landmasses of the Southern Hemisphere. At the base the system has thick tillite indicating extensive and prolonged glaciation. Counter parts of this succession are found in Africa, Falkland Island, Madagascar, Antarctica and Australia besides India. Overall resemblance of the Gondawana type sediments clearly demonstrates that these landmasses had remarkably similar histories. The glacial tillite provides unambiguous evidence of palaeoclimates and also of drifting of continents.

Placer Deposits

The occurrence of rich placer deposits of gold in the Ghana coast and the absolute absence of source rock in the region is an amazing fact. The gold bearing veins are in Brazil and it is obvious that the gold deposits of the Ghana are derived from the Brazil plateau when the two continents lay side by side.

Distribution of Fossils

When identical species of plants and animals adapted to living on land or in fresh water are found on either side of the marine barriers, a problem arises regarding accounting for such distribution. The observations that Lemurs occur in India, Madagascar and Africa led some to consider a contiguous landmass "Lemuria" linking these three landmasses. Mesosaurus was a small reptile adapted to shallow brackish water. The skeletons of these are found only in two localities : the Southern Cape province of South Africa and Iraver formations of Brazil. The two localities presently are 4,800 km apart with an ocean in between them.

Force for Drifting

Wegener suggested that the movement responsible for the drifting of the continents was caused by pole-fleeing force and tidal force. The polar-fleeing force relates to the rotation of the earth. You are aware of the fact that the earth is not a perfect sphere; it has a bulge at the equator. This bulge is due to the rotation of the earth. The second force that was suggested by Wegener—the tidal force—is due to the attraction of the moon and the sun that develops tides in oceanic waters. Wegener believed that these forces would become effective when applied over many million years. However, most of scholars considered these forces to be totally inadequate.

Post-Drift Studies

It is interesting to note that for continental drift, most of the evidence was collected from the continental areas in the form of distribution of flora and fauna or deposits like tillite. A number of discoveries during the post-war period added new information to geological literature. Particularly, the information collected from the ocean floor mapping provided new dimensions for the study of distribution of oceans and continents.

Convectional Current Theory

Arthur Holmes in 1930s discussed the possibility of convection currents operating in the mantle portion. These currents are generated due to radioactive elements causing thermal differences in the mantle portion. Holmes argued that there exists a system of such currents in the entire mantle portion. This was an attempt to provide an explanation to the issue of force, on the basis of which contemporary scientists discarded the continental drift theory.

Mapping of the Ocean Floor

Detailed research of the ocean configuration revealed that the ocean floor is not just a vast plain but it is full of relief. Expeditions to map the oceanic floor in the post-war period provided a detailed picture of the ocean relief and indicated the existence of submerged

mountain ranges as well as deep trenches, mostly located closer to the continent margins. The mid-oceanic ridges were found to be most active in terms of volcanic eruptions. The dating of the rocks from the oceanic crust revealed the fact that the latter is much younger than the continental areas. Rocks on either side of the crest of oceanic ridges and having equidistant locations from the crest were found to have remarkable similarities both in terms of their constituents and their age.

Ocean Floor Configuration

In this section we shall note a few things related to the ocean floor configuration that help us in the understanding of the distribution of continents and oceans. You will be studying the details of ocean floor relief in Chapter 13. The ocean floor may be segmented into three major divisions based on the depth as well as the forms of relief. These divisions are continental margins, deep-sea basins and mid-ocean ridges.

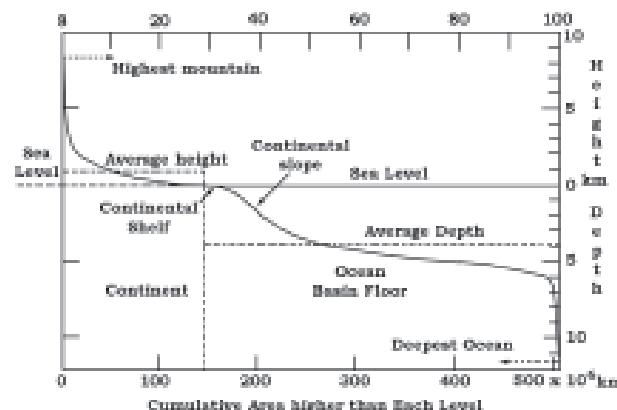


Figure 4.1 : Ocean Floor

Continental Margins

These form the transition between continental shores and deep-sea basins. They include continental shelf, continental slope, continental rise and deep-oceanic trenches. Of these, the deep-sea trenches are the areas which are of considerable interest in so far as the distribution of oceans and continents is concerned.

Abyssal Plains

These are extensive plains that lie between the continental margins and mid-oceanic ridges. The abyssal plains are the areas where the continental sediments that move beyond the margins get deposited.

Mid-Oceanic Ridges

This forms an interconnected chain of mountain system within the ocean. It is the longest mountain-chain on the surface of the earth though submerged under the oceanic waters. It is characterised by a central rift system at the crest, a fractionated plateau and flank zone all along its length. The rift system at the crest is the zone of intense volcanic activity. In the previous chapter, you have been introduced to this type of volcanoes as mid-oceanic volcanoes.

Distribution of Earthquakes and Volcanoes

Study the maps showing the distribution of seismic activity and volcanoes given in Figure 4.2. You will notice a line of dots in the central parts of the Atlantic Ocean almost parallel to the coastlines. It further extends into the Indian Ocean. It bifurcates a little south of the Indian subcontinent with one branch moving into East Africa and the other meeting a similar line from Myanmar to New Guiana. You will notice that this line of dots coincides with the mid-oceanic ridges. The shaded belt showing another area of concentration coincides with the Alpine-Himalayan system and the rim of the Pacific Ocean. In general, the foci of the earthquake in the areas of mid-oceanic ridges are at shallow depths whereas along the Alpine-Himalayan belt as well as the rim of the Pacific, the earthquakes are deep-seated ones. The map of volcanoes also shows a similar pattern. The rim of the Pacific is also called rim of fire due to the existence of active volcanoes in this area.

CONCEPT OF SEA FLOOR SPREADING

As mentioned above, the post-drift studies provided considerable information that was not

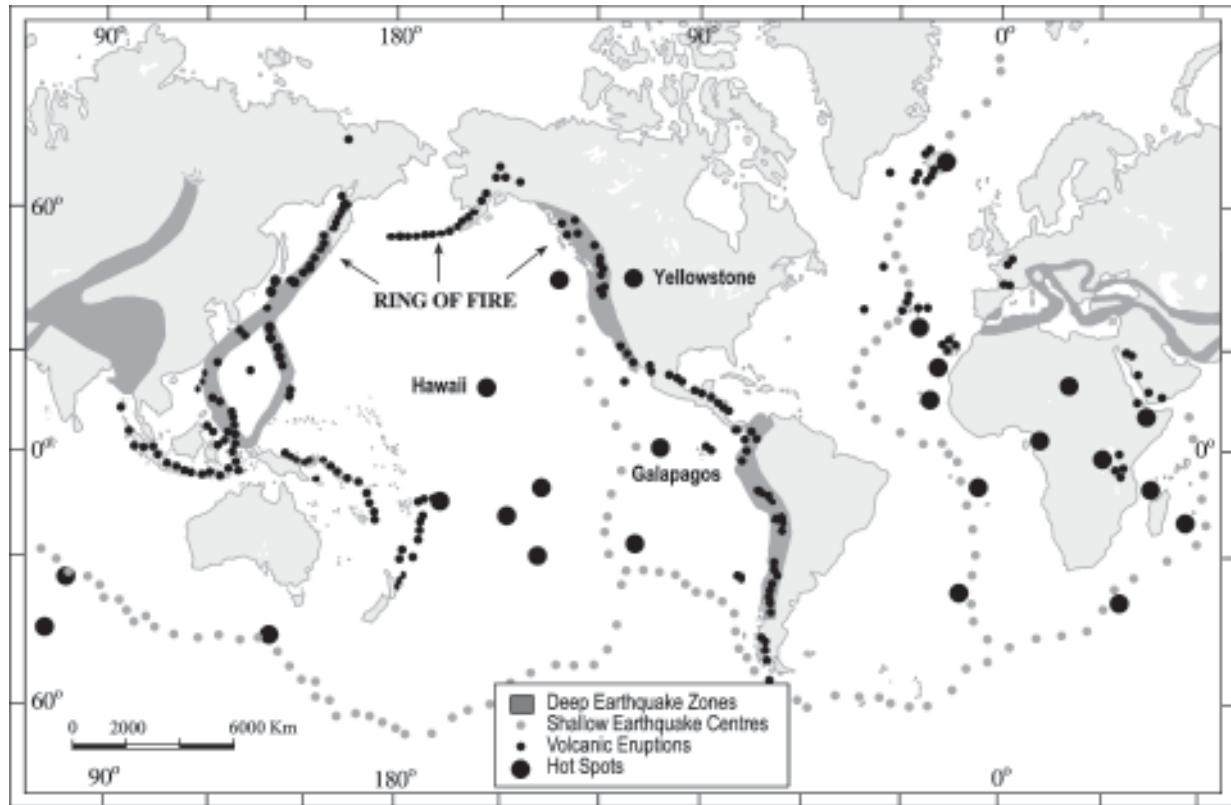


Figure 4. 2 : Distribution of earthquakes and volcanoes

available at the time Wegener put forth his concept of continental drift. Particularly, the mapping of the ocean floor and palaeomagnetic studies of rocks from oceanic regions revealed the following facts :

- (i) It was realised that all along the mid-oceanic ridges, volcanic eruptions are common and they bring huge amounts of lava to the surface in this area.
- (ii) The rocks equidistant on either sides of the crest of mid-oceanic ridges show remarkable similarities in terms of period of formation, chemical compositions and magnetic properties. Rocks closer to the mid-oceanic ridges are normal polarity and are the youngest. The age of the rocks increases as one moves away from the crest.
- (iii) The ocean crust rocks are much younger than the continental rocks. The age of rocks in the oceanic crust is nowhere more than 200 million years old. Some of the continental rock formations are as old as 3,200 million years.

- (iv) The sediments on the ocean floor are unexpectedly very thin. Scientists were expecting, if the ocean floors were as old as the continent, to have a complete sequence of sediments for a period of much longer duration. However, nowhere was the sediment column found to be older than 200 million years.
- (v) The deep trenches have deep-seated earthquake occurrences while in the mid-oceanic ridge areas, the quake foci have shallow depths.

These facts and a detailed analysis of magnetic properties of the rocks on either sides of the mid-oceanic ridge led Hess (1961) to propose his hypothesis, known as the "sea floor spreading". Hess argued that constant eruptions at the crest of oceanic ridges cause the rupture of the oceanic crust and the new lava wedges into it, pushing the oceanic crust on either side. The ocean floor, thus spreads. The younger age of the oceanic crust as well as the fact that the spreading of one ocean does not cause the shrinking of the other, made Hess

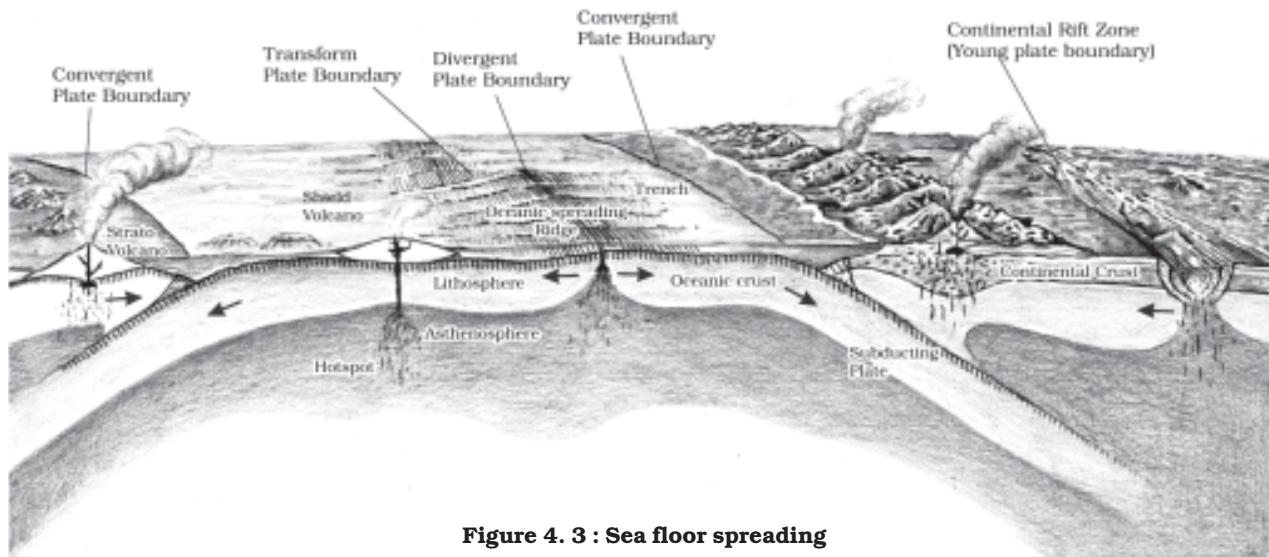


Figure 4. 3 : Sea floor spreading

think about the consumption of the oceanic crust. He further maintained that the ocean floor that gets pushed due to volcanic eruptions at the crest, sinks down at the oceanic trenches and gets consumed.

The basic concept of sea floor spreading has been depicted in Figure 4.3.

PLATE TECTONICS

Since the advent of the concept of sea floor spreading, the interest in the problem of distribution of oceans and continents was revived. It was in 1967, McKenzie and Parker and also Morgan, independently collected the available ideas and came out with another

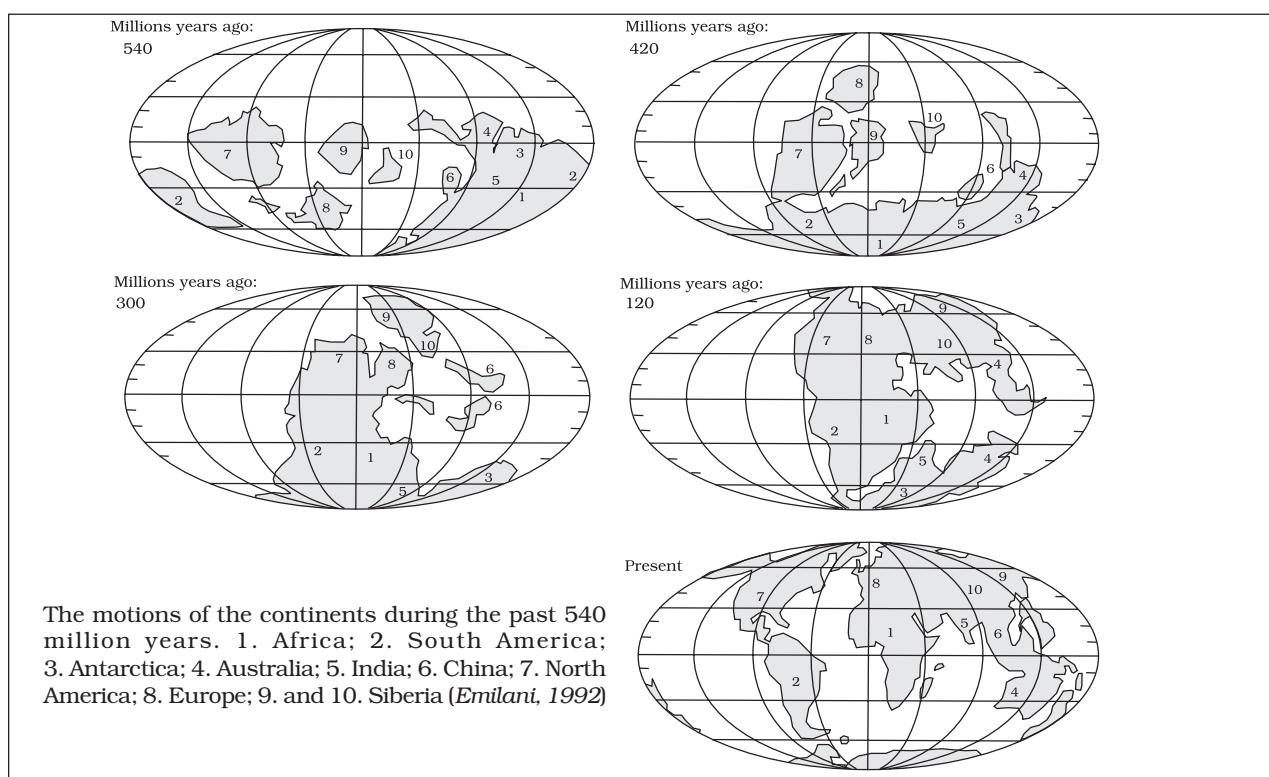


Figure 4.4 : Position of continents through geological past

concept termed *Plate Tectonics*. A tectonic plate (also called lithospheric plate) is a massive, irregularly-shaped slab of solid rock, generally composed of both continental and oceanic lithosphere. Plates move horizontally over the asthenosphere as rigid units. The lithosphere includes the crust and top mantle with its thickness range varying between 5-100 km in oceanic parts and about 200 km in the continental areas. A plate may be referred to as the continental plate or oceanic plate depending on which of the two occupy a larger portion of the plate. Pacific plate is largely an oceanic plate whereas the Eurasian plate may be called a continental plate. The theory of plate tectonics proposes that the earth's lithosphere is divided into seven major and some minor plates. Young Fold Mountain ridges, trenches, and/or faults surround these major plates (Figure 4.5). The major plates are as follows :

- (i) Antarctica and the surrounding oceanic plate

- (ii) North American (with western Atlantic floor separated from the South American plate along the Caribbean islands) plate
- (iii) South American (with western Atlantic floor separated from the North American plate along the Caribbean islands) plate
- (iv) Pacific plate
- (v) India-Australia-New Zealand plate
- (vi) Africa with the eastern Atlantic floor plate
- (vii) Eurasia and the adjacent oceanic plate.

Some important minor plates are listed below:

- (i) *Cocos plate* : Between Central America and Pacific plate
- (ii) *Nazca plate* : Between South America and Pacific plate
- (iii) *Arabian plate* : Mostly the Saudi Arabian landmass
- (iv) *Philippine plate* : Between the Asiatic and Pacific plate

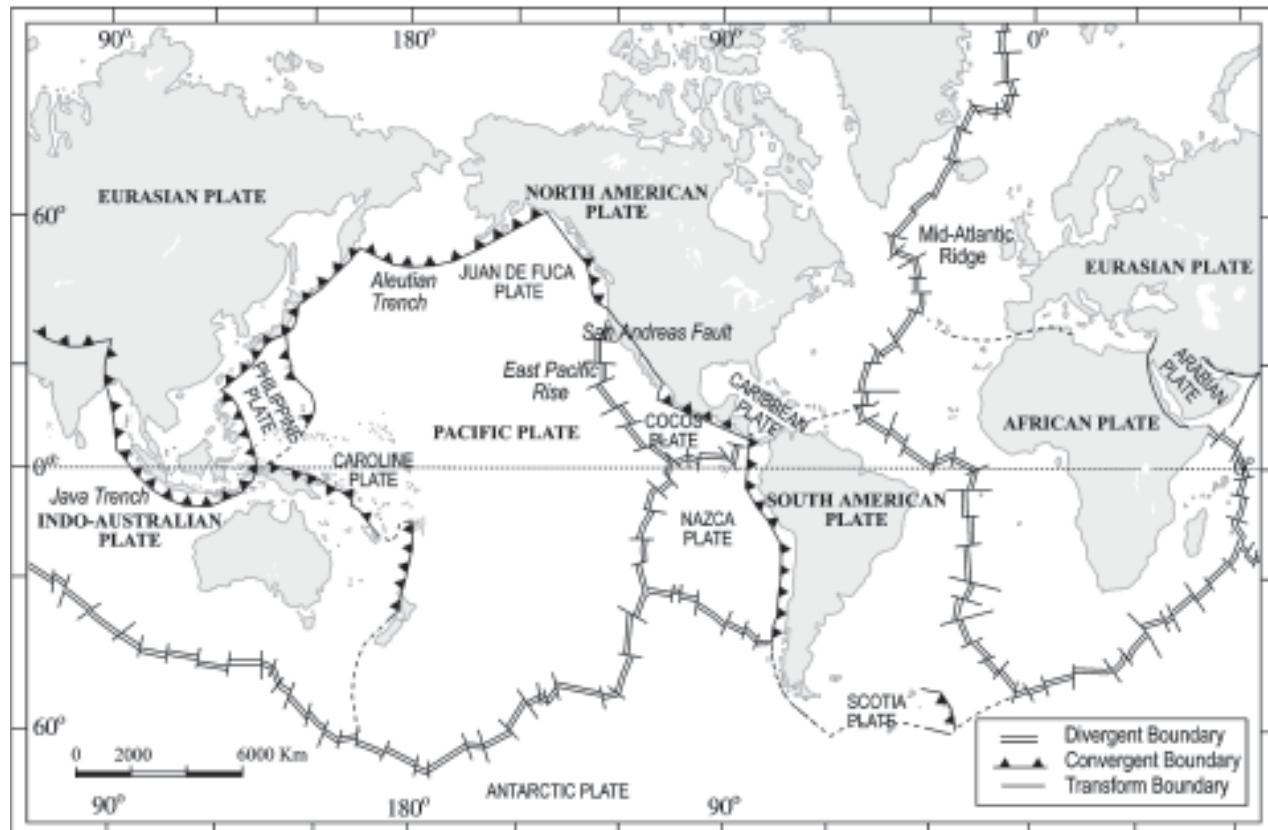


Figure 4.5 : Major and minor plates of the world

- (v) *Caroline plate* : Between the Philippine and Indian plate (North of New Guinea)
- (vi) *Fiji plate* : North-east of Australia.

These plates have been constantly moving over the globe throughout the history of the earth. It is not the continent that moves as believed by Wegener. Continents are part of a plate and what moves is the plate. Moreover, it may be noted that all the plates, without exception, have moved in the geological past, and shall continue to move in the future period as well. Wegener had thought of all the continents to have initially existed as a super continent in the form of Pangaea. However, later discoveries reveal that the continental masses, resting on the plates, have been wandering all through the geological period, and Pangaea was a result of converging of different continental masses that were parts of one or the other plates. Scientists using the palaeomagnetic data have determined the positions held by each of the present continental landmass in different geological periods. Position of the Indian sub-continent (mostly Peninsular India) is traced with the help of the rocks analysed from the Nagpur area.

There are three types of plate boundaries:

Divergent Boundaries

Where new crust is generated as the plates pull away from each other. The sites where the plates move away from each other are called *spreading sites*. The best-known example of divergent boundaries is the Mid-Atlantic Ridge. At this, the American Plate(s) is/are separated from the Eurasian and African Plates.

Convergent Boundaries

Where the crust is destroyed as one plate dives under another. The location where sinking of a plate occurs is called a *subduction zone*. There are three ways in which convergence can occur. These are: (i) between an oceanic and continental plate; (ii) between two oceanic plates; and (iii) between two continental plates.

Transform Boundaries

Where the crust is neither produced nor destroyed as the plates slide horizontally past each other. Transform faults are the planes of separation generally perpendicular to the mid-oceanic ridges. As the eruptions do not take all along the entire crest at the same time, there is a differential movement of a portion of the plate away from the axis of the earth. Also, the rotation of the earth has its effect on the separated blocks of the plate portions.

How do you think the rate of plate movement is determined?

Rates of Plate Movement

The strips of normal and reverse magnetic field that parallel the mid-oceanic ridges help scientists determine the rates of plate movement. These rates vary considerably. The Arctic Ridge has the slowest rate (less than 2.5 cm/yr), and the East Pacific Rise near Easter Island, in the South Pacific about 3,400 km west of Chile, has the fastest rate (more than 15 cm/yr).

Force for the Plate Movement

At the time that Wegener proposed his theory of continental drift, most scientists believed that the earth was a solid, motionless body. However, concepts of sea floor spreading and the unified theory of plate tectonics have emphasised that both the surface of the earth and the interior are not static and motionless but are dynamic. The fact that the plates move is now a well-accepted fact. The mobile rock beneath the rigid plates is believed to be moving in a circular manner. The heated material rises to the surface, spreads and begins to cool, and then sinks back into deeper depths. This cycle is repeated over and over to generate what scientists call a convection cell or convective flow. Heat within the earth comes from two main sources: radioactive decay and residual heat. Arthur Holmes first considered

this idea in the 1930s, which later influenced Harry Hess' thinking about seafloor spreading. The slow movement of hot, softened mantle that lies below the rigid plates is the driving force behind the plate movement.

MOVEMENT OF THE INDIAN PLATE

The Indian plate includes Peninsular India and the Australian continental portions. The subduction zone along the Himalayas forms the northern plate boundary in the form of continent—*continent convergence*. In the east, it extends through Rakinyoma Mountains of Myanmar towards the island arc along the Java Trench. The eastern margin is a *spreading site* lying to the east of Australia in the form of an oceanic ridge in SW Pacific. The Western margin follows Kirthar Mountain of Pakistan. It further extends along the Makrana coast and joins the *spreading site* from the Red Sea rift southeastward along the Chagos Archipelago. The boundary between India and the Antarctic plate is also marked by oceanic ridge (*divergent boundary*) running in roughly W-E direction and merging into the *spreading site*, a little south of New Zealand.

India was a large island situated off the Australian coast, in a vast ocean. The Tethys Sea separated it from the Asian continent till about 225 million years ago. India is supposed to have started her northward journey about 200 million years ago at the time when Pangaea broke. India collided with Asia about 40-50 million years ago causing rapid uplift of the Himalayas. The positions of India since about 71 million years till the present are shown in the Figure 4.6. It also shows the position of the Indian subcontinent and the Eurasian plate. About 140 million years before the present, the subcontinent was located as south as 50°S. latitude. The two major plates were separated by the Tethys Sea and the Tibetan block was closer to the Asiatic landmass. During the movement of the Indian

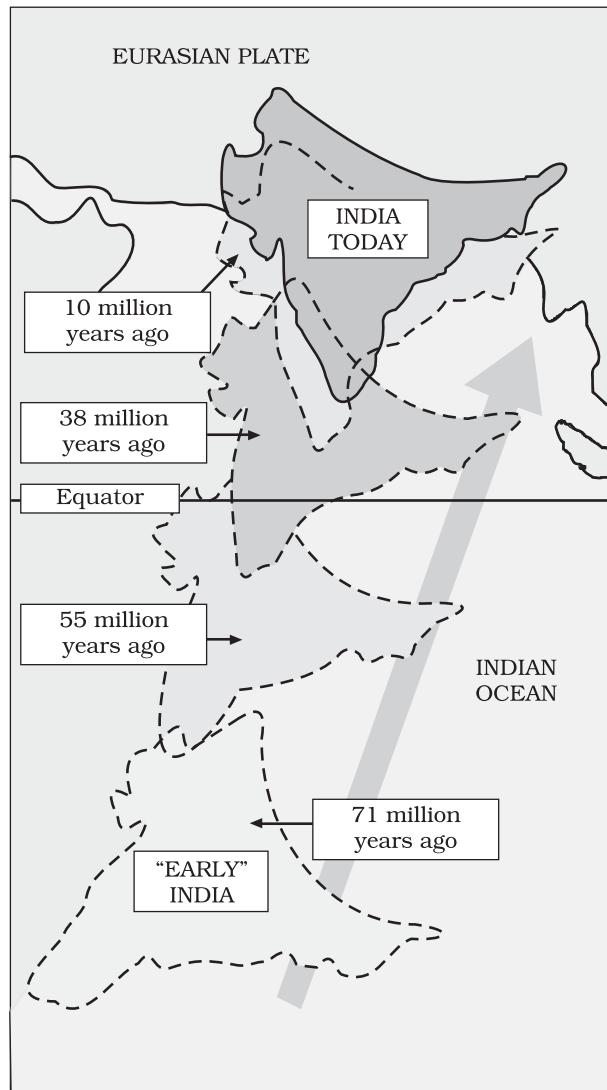


Figure 4.6 : Movement of the Indian plate

plate towards the Asiatic plate, a major event that occurred was the outpouring of lava and formation of the Deccan Traps. This started somewhere around 60 million years ago and continued for a long period of time. Note that the subcontinent was still close to the equator. From 40 million years ago and thereafter, the event of formation of the Himalayas took place. Scientists believe that the process is still continuing and the height of the Himalayas is rising even to this date.

EXERCISES

1. Multiple choice questions.

- (i) Who amongst the following was the first to consider the possibility of Europe, Africa and America having been located side by side.
 - (a) Alfred Wegener
 - (c) Abraham Ortelius
 - (b) Antonio Pellegrini
 - (d) Edmond Hess
- (ii) Polar fleeing force relates to:
 - (a) Revolution of the Earth
 - (c) Rotation of the earth
 - (b) Gravitation
 - (d) Tides
- (iii) Which one of the following is not a minor plate?
 - (a) Nazca
 - (c) Philippines
 - (b) Arabia
 - (d) Antarctica
- (iv) Which one of the following facts was not considered by those while discussing the concept of sea floor spreading?
 - (a) Volcanic activity along the mid-oceanic ridges.
 - (b) Stripes of normal and reverse magnetic field observed in rocks of ocean floor.
 - (c) Distribution of fossils in different continents.
 - (d) Age of rocks from the ocean floor.
- (v) Which one of the following is the type of plate boundary of the Indian plate along the Himalayan mountains?
 - (a) Ocean-continent convergence
 - (b) Divergent boundary
 - (c) Transform boundary
 - (d) Continent-continent convergence

2. Answer the following questions in about 30 words.

- (i) What were the forces suggested by Wegener for the movement of the continents?
- (ii) How are the convectional currents in the mantle initiated and maintained?
- (iii) What is the major difference between the transform boundary and the convergent or divergent boundaries of plates?
- (iv) What was the location of the Indian landmass during the formation of the Deccan Traps?

3. Answer the following questions in about 150 words.

- (i) What are the evidences in support of the continental drift theory?
- (ii) Bring about the basic difference between the drift theory and Plate tectonics.
- (iii) What were the major post-drift discoveries that rejuvenated the interest of scientists in the study of distribution of oceans and continents?

Project Work

Prepare a collage related to damages caused by an earthquake.

UNIT III

LANDFORMS

This unit deals with

- *Rocks and minerals — major types of rocks and their characteristics*
- *Landforms and their evolution*
- *Geomorphic processes — weathering, mass wasting, erosion and deposition; soils — formation*

C H A P T E R

5

The earth is composed of various kinds of elements. These elements are in solid form in the outer layer of the earth and in hot and molten form in the interior.

About 98 per cent of the total crust of the earth is composed of eight elements like oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium (Table 5.1), and the rest is constituted by titanium, hydrogen, phosphorous, manganese, sulphur, carbon, nickel and other elements.

Table 5.1 : The Major Elements of the Earth's Crust

Sl. No.	Elements	By Weight(%)
1.	Oxygen	46.60
2.	Silicon	27.72
3.	Aluminium	8.13
4.	Iron	5.00
5.	Calcium	3.63
6.	Sodium	2.83
7.	Potassium	2.59
8.	Magnesium	2.09
9.	Others	1.41

The elements in the earth's crust are rarely found exclusively but are usually combined with other elements to make various substances. These substances are recognised as minerals.

Thus, a mineral is a naturally occurring inorganic substance, having an orderly atomic structure and a definite chemical composition and physical properties. A mineral is composed of two or more elements. But, sometimes single element minerals like sulphur, copper, silver, gold, graphite etc. are found.

MINERALS AND ROCKS

Though the number of elements making up the lithosphere are limited they are combined in many different ways to make up many varieties of minerals. There are at least 2,000 minerals that have been named and identified in the earth crust; but almost all the commonly occurring ones are related to six major mineral groups that are known as major rock forming minerals.

The basic source of all minerals is the hot magma in the interior of the earth. When magma cools, crystals of minerals appear and a systematic series of minerals are formed in sequence to solidify so as to form rocks. Minerals such as coal, petroleum and natural gas are organic substances found in solid, liquid and gaseous forms respectively.

A brief information about some important minerals in terms of their nature and physical characteristics is given below :

PHYSICAL CHARACTERISTICS

- (i) External crystal form — determined by internal arrangement of the molecules — cubes, octahedrons, hexagonal prisms, etc.
- (ii) Cleavage — tendency to break in given directions producing relatively plane surfaces — result of internal arrangement of the molecules — may cleave in one or more directions and at any angle to each other.

- (iii) Fracture — internal molecular arrangement so complex there are no planes of molecules; the crystal will break in an irregular manner, not along planes of cleavage.
- (iv) Lustre — appearance of a material without regard to colour; each mineral has a distinctive lustre like metallic, silky, glossy etc.
- (v) Colour — some minerals have characteristic colour determined by their molecular structure — malachite, azurite, chalcopyrite etc., and some minerals are coloured by impurities. For example, because of impurities quartz may be white, green, red, yellow etc.
- (vi) Streak — colour of the ground powder of any mineral. It may be of the same colour as the mineral or may differ — malachite is green and gives green streak, fluorite is purple or green but gives a white streak.
- (vii) Transparency — transparent: light rays pass through so that objects can be seen plainly; translucent — light rays pass through but will get diffused so that objects cannot be seen; opaque — light will not pass at all.
- (viii) Structure — particular arrangement of the individual crystals; fine, medium or coarse grained; fibrous — separable, divergent, radiating.
- (ix) Hardness — relative resistance being scratched; ten minerals are selected to measure the degree of hardness from 1-10. They are: 1. talc; 2. gypsum; 3. calcite; 4. fluorite; 5. apatite; 6. feldspar; 7. quartz; 8. topaz; 9. corundum; 10. diamond. Compared to this for example, a fingernail is 2.5 and glass or knife blade is 5.5.
- (x) Specific gravity — the ratio between the weight of a given object and the weight of an equal volume of water; object weighed in air and then weighed in water and divide weight in air by the difference of the two weights.

SOME MAJOR MINERALS AND THEIR CHARACTERISTICS

Feldspar

Silicon and oxygen are common elements in all types of feldspar and sodium, potassium, calcium, aluminium etc. are found in specific feldspar variety. Half of the earth's crust is composed of feldspar. It has light cream to salmon pink colour. It is used in ceramics and glass making.

Quartz

It is one of the most important components of sand and granite. It consists of silica. It is a hard mineral virtually insoluble in water. It is white or colourless and used in radio and radar. It is one of the most important components of granite.

Pyroxene

Pyroxene consists of calcium, aluminum, magnesium, iron and silica. Pyroxene forms 10 per cent of the earth's crust. It is commonly found in meteorites. It is in green or black colour.

Amphibole

Aluminium, calcium, silica, iron, magnesium are the major elements of amphiboles. They form 7 per cent of the earth's crust. It is in green or black colour and is used in asbestos industry. Hornblende is another form of amphiboles.

Mica

It comprises of potassium, aluminium, magnesium, iron, silica etc. It forms 4 per cent of the earth's crust. It is commonly found in igneous and metamorphic rocks. It is used in electrical instruments.

Olivine

Magnesium, iron and silica are major elements of olivine. It is used in jewellery. It is usually a greenish crystal, often found in basaltic rocks.

Besides these main minerals, other minerals like chlorite, calcite, magnetite, haematite, bauxite and barite are also present in some quantities in the rocks.

Metallic Minerals

These minerals contain metal content and can be sub-divided into three types:

- (i) *Precious metals*: gold, silver, platinum etc.
- (ii) *Ferrous metals*: iron and other metals often mixed with iron to form various kinds of steel.
- (iii) *Non-ferrous metals* : include metals like copper, lead, zinc, tin, aluminium etc.

Non-Metallic Minerals

These minerals do not contain metal content. Sulphur, phosphates and nitrates are examples of non-metallic minerals. Cement is a mixture of non-metallic minerals.

Rocks

The earth's crust is composed of rocks. A rock is an aggregate of one or more minerals. Rock may be hard or soft and in varied colours. For example, granite is hard, soapstone is soft. Gabbro is black and quartzite can be milky white. Rocks do not have definite composition of mineral constituents. Feldspar and quartz are the most common minerals found in rocks.

Petrology is science of rocks. A petrologist studies rocks in all their aspects viz., mineral composition, texture, structure, origin, occurrence, alteration and relationship with other rocks.

As there is a close relation between rocks and landforms, rocks and soils, a geographer requires basic knowledge of rocks. There are many different kinds of rocks which are grouped under three families on the basis of their mode of formation. They are: (i) Igneous Rocks — solidified from magma and lava; (ii) Sedimentary Rocks — the result of deposition of fragments of rocks by exogenous processes; (iii) Metamorphic Rocks — formed out of existing rocks undergoing recrystallisation.

Igneous Rocks

As igneous rocks form out of magma and lava from the interior of the earth, they are known as primary rocks. The igneous rocks (*Ignis* – in Latin means 'Fire') are formed when magma cools and solidifies. You already know what magma is. When magma in its upward movement cools and turns into solid form it is called igneous rock. The process of cooling and solidification can happen in the earth's crust or on the surface of the earth.

Igneous rocks are classified based on texture. Texture depends upon size and arrangement of grains or other physical conditions of the materials. If molten material is cooled slowly at great depths, mineral grains may be very large. Sudden cooling (at the surface) results in small and smooth grains. Intermediate conditions of cooling would result in intermediate sizes of grains making up igneous rocks. Granite, gabbro, pegmatite, basalt, volcanic breccia and tuff are some of the examples of igneous rocks.

Sedimentary Rocks

The word 'sedimentary' is derived from the Latin word *sedimentum*, which means settling. Rocks (igneous, sedimentary and metamorphic) of the earth's surface are exposed to denudational agents, and are broken up into various sizes of fragments. Such fragments are transported by different exogenous agencies and deposited. These deposits through compaction turn into rocks. This process is called *lithification*. In many sedimentary rocks, the layers of deposits retain their characteristics even after lithification. Hence, we see a number of layers of varying thickness in sedimentary rocks like sandstone, shale etc.

Depending upon the mode of formation, sedimentary rocks are classified into three major groups: (i) mechanically formed — sandstone, conglomerate, limestone, shale, loess etc. are examples; (ii) organically formed — geyserite, chalk, limestone, coal etc. are some examples; (iii) chemically formed — chert, limestone, halite, potash etc. are some examples.

Metamorphic Rocks

The word metamorphic means 'change of form'. These rocks form under the action of pressure, volume and temperature (PVT) changes. Metamorphism occurs when rocks are forced down to lower levels by tectonic processes or when molten magma rising through the crust comes in contact with the crustal rocks or the underlying rocks are subjected to great amounts of pressure by overlying rocks. Metamorphism is a process by which already consolidated rocks undergo recrystallisation and reorganisation of materials within original rocks.

Mechanical disruption and reorganisation of the original minerals within rocks due to breaking and crushing without any appreciable chemical changes is called dynamic metamorphism. The materials of rocks chemically alter and recrystallise due to thermal metamorphism. There are two types of thermal metamorphism — contact metamorphism and regional metamorphism. In contact metamorphism the rocks come in contact with hot intruding magma and lava and the rock materials recrystallise under high temperatures. Quite often new materials form out of magma or lava are added to the rocks. In regional metamorphism, rocks undergo recrystallisation due to deformation caused by tectonic shearing together with high temperature or pressure or both. In the process of metamorphism in some rocks grains or minerals get arranged in layers or lines. Such an arrangement of minerals or grains in metamorphic rocks is called *foliation* or *lineation*. Sometimes minerals or materials of different groups are arranged into alternating thin to thick layers appearing in light and dark shades. Such a structure in metamorphic rocks is called *banding* and rocks displaying banding are called *banded rocks*. Types of metamorphic rocks depend upon original rocks that were subjected to metamorphism. Metamorphic rocks are classified into two

major groups — foliated rocks and non-foliated rocks. Gneissoid, granite, syenite, slate, schist, marble, quartzite etc. are some examples of metamorphic rocks.

ROCK CYCLE

Rocks do not remain in their original form for long but may undergo transformation. Rock cycle is a continuous process through which old rocks are transformed into new ones.

Igneous rocks are primary rocks and other rocks (sedimentary and metamorphic) form from these primary rocks. Igneous rocks can be changed into metamorphic rocks. The fragments derived out of igneous and metamorphic rocks form into sedimentary

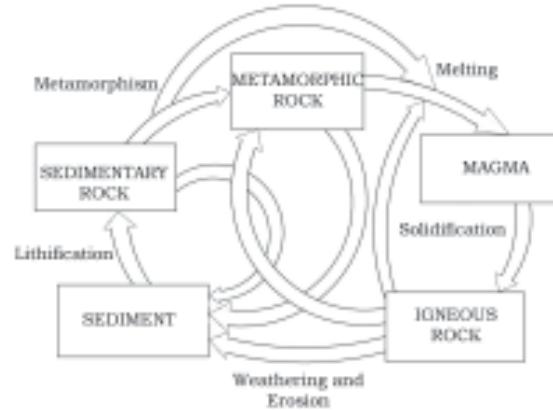


Fig 5.1 : Rock Cycle

rocks. Sedimentary rocks themselves can turn into fragments and the fragments can be a source for formation of sedimentary rocks. The crustal rocks (igneous, metamorphic and sedimentary) once formed may be carried down into the mantle (interior of the earth) through subduction process (parts or whole of crustal plates going down under another plate in zones of plate convergence) and the same melt down due to increase in temperature in the interior and turn into molten magma, the original source for igneous rocks (Figure 5.1).

EXERCISES

1. Multiple choice questions.

- (i) Which one of the following are the two main constituents of granite?
 - (a) Iron and nickel (c) Silica and aluminium
 - (b) Iron and silver (d) Iron Oxide and potassium
- (ii) Which one of the following is the salient feature of metamorphic rocks?
 - (a) Changeable (c) Crystalline
 - (b) Quite (d) Foliation
- (iii) Which one of the following is not a single element mineral?
 - (a) Gold (c) Mica
 - (b) Silver (d) Graphite
- (iv) Which one of the following is the hardest mineral?
 - (a) Topaz (c) Quartz
 - (b) Diamond (d) Feldspar
- (v) Which one of the following is not a sedimentary rock?
 - (a) Tillite (c) Breccia
 - (b) Borax (d) Marble

2. Answer the following questions in about 30 words.

- (i) What do you mean by rocks? Name the three major classes of rocks.
- (ii) What is an igneous rock? Describe the method of formation and characteristics of igneous rock.
- (iii) What is meant by sedimentary rock? Describe the mode of formation of sedimentary rock.
- (iv) What relationship explained by rock cycle between the major type of rock?

3. Answer the following questions in about 150 words.

- (i) Define the term 'mineral' and name the major classes of minerals with their physical characteristics.
- (ii) Describe the nature and mode of origin of the chief types of rock at the earth's crust. How will you distinguish them?
- (iii) What are metamorphic rocks? Describe the types of metamorphic rock and how are they formed?

Project Work

Collect different rock samples and try to recognise them from their physical characteristics and identify their family.

GEOMORPHIC PROCESSES

After learning about how the earth was born, how it evolved its crust and other inner layers, how its crustal plates moved and are moving, and other information on earthquakes, the forms of volcanism and about the rocks and minerals the crust is composed of, it is time to know in detail about the surface of the earth on which we live. Let us start with this question.

Why is the surface of the earth uneven?

First of all, the earth's crust is dynamic. You are well aware that it has moved and moves vertically and horizontally. Of course, it moved a bit faster in the past than the rate at which it is moving now. The differences in the internal forces operating from within the earth which built up the crust have been responsible for the variations in the outer surface of the crust. The earth's surface is being continuously subjected to external forces induced basically by energy (sunlight). Of course, the internal forces are still active though with different intensities. That means, the earth's surface is being continuously subjected to by external forces originating within the earth's atmosphere and by internal forces from within the earth. The external forces are known as *exogenic forces* and the internal forces are known as *endogenic forces*. The actions of exogenic forces result in wearing down (degradation) of relief/elevations and filling up (aggradation) of basins/depressions, on the earth's surface. The phenomenon of wearing down of relief variations of the surface of the earth through erosion is known as *gradation*. The endogenic

forces continuously elevate or build up parts of the earth's surface and hence the exogenic processes fail to even out the relief variations of the surface of the earth. So, variations remain as long as the opposing actions of exogenic and endogenic forces continue. In general terms, the endogenic forces are mainly land building forces and the exogenic processes are mainly land wearing forces. The surface of the earth is sensitive. Humans depend on it for their sustenance and have been using it extensively and intensively. So, it is essential to understand its nature in order to use it effectively without disturbing its balance and diminishing its potential for the future. Almost all organisms contribute to sustain the earth's environment. However, humans have caused over use of resources. Use we must, but must also leave it potential enough to sustain life through the future. Most of the surface of the earth had and has been shaped over very long periods of time (hundreds and thousands of years) and because of its use and misuse by humans its potential is being diminished at a fast rate. If the processes which shaped and are shaping the surface of the earth into varieties of forms (shapes) and the nature of materials of which it is composed of, are understood, precautions can be taken to minimise the detrimental effects of human use and to preserve it for posterity.

GEOMORPHIC PROCESSES

You would like to know the meaning of geomorphic processes. The endogenic and exogenic forces causing physical stresses and chemical actions on earth materials and

bringing about changes in the configuration of the surface of the earth are known as *geomorphic processes*. Diastrophism and volcanism are endogenic geomorphic processes. These have already been discussed in brief in the preceding unit. Weathering, mass wasting, erosion and deposition are exogenic geomorphic processes. These exogenic processes are dealt with in detail in this chapter.

Any exogenic element of nature (like water, ice, wind, etc..) capable of acquiring and transporting earth materials can be called a geomorphic agent. When these elements of nature become mobile due to gradients, they remove the materials and transport them over slopes and deposit them at lower level. Geomorphic processes and geomorphic agents especially exogenic, unless stated separately, are one and the same.

A process is a force applied on earth materials affecting the same. An agent is a mobile medium (like running water, moving ice masses, wind, waves and currents etc.) which removes, transports and deposits earth materials. Running water, groundwater, glaciers, wind, waves and currents, etc., can be called *geomorphic agents*.

Do you think it is essential to distinguish geomorphic agents and geomorphic processes?

Gravity besides being a directional force activating all downslope movements of matter also causes stresses on the earth's materials. Indirect gravitational stresses activate wave and tide induced currents and winds. Without gravity and gradients there would be no mobility and hence no erosion, transportation and deposition are possible. So, gravitational stresses are as important as the other geomorphic processes. Gravity is the force that is keeping us in contact with the surface and it is the force that switches on the movement of all surface material on earth. All the movements either within the earth or on the surface of the earth occur due to gradients — from higher levels to lower levels, from high pressure to low pressure areas etc.

ENDOGENIC PROCESSES

The energy emanating from within the earth is the main force behind endogenic geomorphic processes. This energy is mostly generated by radioactivity, rotational and tidal friction and primordial heat from the origin of the earth. This energy due to geothermal gradients and heat flow from within induces diastrophism and volcanism in the lithosphere. Due to variations in geothermal gradients and heat flow from within, crustal thickness and strength, the action of endogenic forces are not uniform and hence the tectonically controlled original crustal surface is uneven.

Diastrophism

All processes that move, elevate or build up portions of the earth's crust come under *diastrophism*. They include: (i) *orogenic* processes involving mountain building through severe folding and affecting long and narrow belts of the earth's crust; (ii) *epeirogenic* processes involving uplift or warping of large parts of the earth's crust; (iii) earthquakes involving local relatively minor movements; (iv) plate tectonics involving horizontal movements of crustal plates.

In the process of orogeny, the crust is severely deformed into folds. Due to epeirogeny, there may be simple deformation. Orogeny is a mountain building process whereas epeirogeny is continental building process. Through the processes of orogeny, epeirogeny, earthquakes and plate tectonics, there can be faulting and fracturing of the crust. All these processes cause pressure, volume and temperature (PVT) changes which in turn induce metamorphism of rocks.

Epeirogeny and orogeny, cite the differences.

Volcanism

Volcanism includes the movement of molten rock (magma) onto or toward the earth's surface and also formation of many intrusive and extrusive volcanic forms. Many aspects of volcanism have already been dealt in detail

under volcanoes in the Unit II and under igneous rocks in the preceding chapter in this unit.

What do the words **volcanism** and **volcanoes** indicate?

EXOGENIC PROCESSES

The exogenic processes derive their energy from atmosphere determined by the ultimate energy from the sun and also the gradients created by tectonic factors.

Why do you think that the slopes or gradients are created by tectonic factors?

Gravitational force acts upon all earth materials having a sloping surface and tend to produce movement of matter in down slope direction. Force applied per unit area is called **stress**. Stress is produced in a solid by pushing or pulling. This induces deformation. Forces acting along the faces of earth materials are shear stresses (separating forces). It is this stress that breaks rocks and other earth materials. The shear stresses result in angular displacement or slippage. Besides the gravitational stress earth materials become subjected to molecular stresses that may be caused by a number of factors amongst which temperature changes, crystallisation and melting are the most common. Chemical processes normally lead to loosening of bonds between grains, dissolving of soluble minerals or cementing materials. Thus, the basic reason that leads to weathering, mass movements, erosion and deposition is development of stresses in the body of the earth materials.

As there are different climatic regions on the earth's surface the exogenic geomorphic processes vary from region to region. Temperature and precipitation are the two important climatic elements that control various processes.

All the exogenic geomorphic processes are covered under a general term, *denudation*. The word 'denude' means to strip off or to uncover. Weathering, mass wasting/movements, erosion and transportation are included in denudation. The flow chart (Figure 6.1) gives the denudation

processes and their respective driving forces. It should become clear from this chart that for each process there exists a distinct driving force or energy.

As there are different climatic regions on the earth's surface owing to thermal gradients created by latitudinal, seasonal and land and water spread variations, the exogenic geomorphic processes vary from region to region. The density, type and distribution of vegetation which largely depend upon

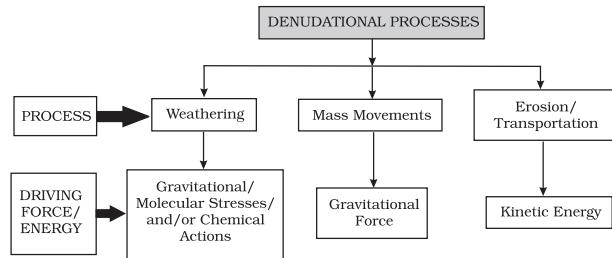


Figure 6.1 : Denudational processes and their driving forces

precipitation and temperature exert influence indirectly on exogenic geomorphic processes. Within different climatic regions there may be local variations of the effects of different climatic elements due to altitudinal differences, aspect variations and the variation in the amount of insolation received by north and south facing slopes as compared to east and west facing slopes. Further, due to differences in wind velocities and directions, amount and kind of precipitation, its intensity, the relation between precipitation and evaporation, daily range of temperature, freezing and thawing frequency, depth of frost penetration, the geomorphic processes vary within any climatic region.

What is the sole driving force behind all the exogenic processes?

Climatic factors being equal, the intensity of action of exogenic geomorphic processes depends upon type and structure of rocks. The term structure includes such aspects of rocks as folds, faults, orientation and inclination of beds, presence or absence of joints, bedding planes, hardness or softness of constituent minerals, chemical susceptibility of mineral constituents; the permeability or impermeability

etc. Different types of rocks with differences in their structure offer varying resistances to various geomorphic processes. A particular rock may be resistant to one process and non-resistant to another. And, under varying climatic conditions, particular rocks may exhibit different degrees of resistance to geomorphic processes and hence they operate at differential rates and give rise to differences in topography. The effects of most of the exogenic geomorphic processes are small and slow and may be imperceptible in a short time span, but will in the long run affect the rocks severely due to continued fatigue.

Finally, it boils down to one fact that the differences on the surface of the earth though originally related to the crustal evolution continue to exist in some form or the other due to differences in the type and structure of earth materials, differences in geomorphic processes and in their rates of operation.

Some of the exogenic geomorphic processes have been dealt in detail here.

WEATHERING

Weathering is action of elements of weather and climate over earth materials. There are a number of processes within weathering which act either individually or together to affect the earth materials in order to reduce them to fragmental state.

Weathering is defined as mechanical disintegration and chemical decomposition of rocks through the actions of various elements of weather and climate.

As very little or no motion of materials takes place in weathering, it is an *in-situ* or on-site process.

Is this little motion which can occur sometimes due to weathering synonymous with transportation? If not, why?

Weathering processes are conditioned by many complex geological, climatic, topographic and vegetative factors. Climate is of particular importance. Not only weathering processes differ from climate to climate, but also the depth of the weathering mantle (Figure 6.2).

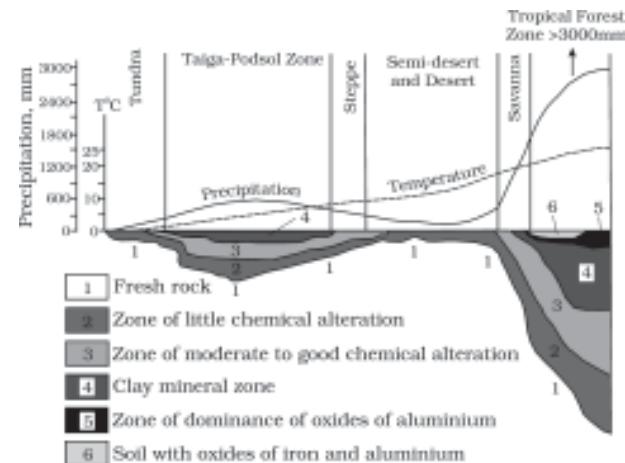


Figure 6.2 : Climatic regimes and depth of weathering mantles (adapted and modified from Strakhov, 1967)

Activity

Mark the latitude values of different climatic regimes in Figure 6.2 and compare the details.

There are three major groups of weathering processes : (i) chemical; (ii) physical or mechanical; (iii) biological weathering processes. Very rarely does any one of these processes ever operate completely by itself, but quite often a dominance of one process can be seen.

Chemical Weathering Processes

A group of weathering processes viz; solution, carbonation, hydration, oxidation and reduction act on the rocks to decompose, dissolve or reduce them to a fine clastic state through chemical reactions by oxygen, surface and/or soil water and other acids. Water and air (oxygen and carbon dioxide) along with heat must be present to speed up all chemical reactions. Over and above the carbon dioxide present in the air, decomposition of plants and animals increases the quantity of carbon dioxide underground. These chemical reactions on various minerals are very much similar to the chemical reactions in a laboratory.

Solution

When something is dissolved in water or acids, the water or acid with dissolved contents is

called *solution*. This process involves removal of solids in solution and depends upon solubility of a mineral in water or weak acids. On coming in contact with water many solids disintegrate and mix up as suspension in water. Soluble rock forming minerals like nitrates, sulphates, and potassium etc. are affected by this process. So, these minerals are easily leached out without leaving any residue in rainy climates and accumulate in dry regions. Minerals like calcium carbonate and calcium magnesium bicarbonate present in limestones are soluble in water containing carbonic acid (formed with the addition of carbon dioxide in water), and are carried away in water as solution. Carbon dioxide produced by decaying organic matter along with soil water greatly aids in this reaction. Common salt (sodium chloride) is also a rock forming mineral and is susceptible to this process of solution.

Carbonation

Carbonation is the reaction of carbonate and bicarbonate with minerals and is a common process helping the breaking down of feldspars and carbonate minerals. Carbon dioxide from the atmosphere and soil air is absorbed by water, to form carbonic acid that acts as a weak acid. Calcium carbonates and magnesium carbonates are dissolved in carbonic acid and are removed in a solution without leaving any residue resulting in cave formation.

Why are clay minerals easily erodible?

Hydration

Hydration is the chemical addition of water. Minerals take up water and expand; this expansion causes an increase in the volume of the material itself or rock. Calcium sulphate takes in water and turns to gypsum, which is more unstable than calcium sulphate. This process is reversible and long, continued repetition of this process causes fatigue in the rocks and may lead to their disintegration.

Many clay minerals swell and contract during wetting and drying and a repetition of this process results in cracking of overlying materials. Salts in pore spaces undergo rapid and repeated hydration and help in rock fracturing. The volume changes in minerals due to hydration will also help in physical weathering through exfoliation and granular disintegration.

Oxidation and Reduction

In weathering, oxidation means a combination of a mineral with oxygen to form oxides or hydroxides. Oxidation occurs where there is ready access to the atmosphere and oxygenated waters. The minerals most commonly involved in this process are iron, manganese, sulphur etc. In the process of oxidation rock breakdown occurs due to the disturbance caused by addition of oxygen. Red colour of iron upon oxidation turns to brown or yellow. When oxidised minerals are placed in an environment where oxygen is absent, reduction takes place. Such conditions exist usually below the water table, in areas of stagnant water and waterlogged ground. Red colour of iron upon reduction turns to greenish or bluish grey.

These weathering processes are inter-related. Hydration, carbonation and oxidation go hand in hand and hasten the weathering process.

Can we give iron rusting as an example of oxidation? How essential is water in chemical weathering processes? Can chemical weathering processes dominate in water scarce hot deserts?

Physical Weathering Processes

Physical or mechanical weathering processes depend on some applied forces. The applied forces could be: (i) gravitational forces such as overburden pressure, load and shearing stress; (ii) expansion forces due to temperature changes, crystal growth or animal activity; (iii) water pressures controlled by wetting and

drying cycles. Many of these forces are applied both at the surface and within different earth materials leading to rock fracture. Most of the physical weathering processes are caused by thermal expansion and pressure release. These processes are small and slow but can cause great damage to the rocks because of continued fatigue the rocks suffer due to repetition of contraction and expansion.

Unloading and Expansion

Removal of overlying rock load because of continued erosion causes vertical pressure release with the result that the upper layers of the rock expand producing disintegration of rock masses. Fractures will develop roughly parallel to the ground surface. In areas of curved ground surface, arched fractures tend to produce massive sheets or exfoliation slabs of rock. Exfoliation sheets resulting from expansion due to unloading and pressure release may measure hundreds or even thousands of metres in horizontal extent. Large, smooth rounded domes called *exfoliation domes* (Figure 6.3) result due to this process.

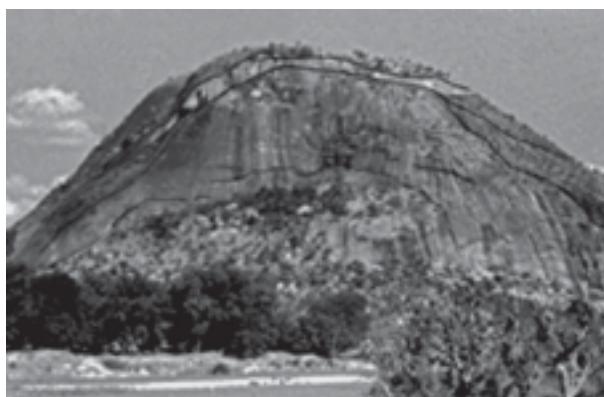


Figure 6.3 : A large exfoliation dome in granite rock near bhongir (Bhuvanagiri) town in Andhra Pradesh

Temperature Changes and Expansion

Various minerals in rocks possess their own limits of expansion and contraction. With rise in temperature, every mineral expands and pushes against its neighbour and as temperature falls, a corresponding contraction takes place. Because of diurnal changes in the

temperatures, this internal movement among the mineral grains of the superficial layers of rocks takes place regularly. This process is most effective in dry climates and high elevations where diurnal temperature changes are drastic. As has been mentioned earlier though these movements are very small they make the rocks weak due to continued fatigue. The surface layers of the rocks tend to expand more than the rock at depth and this leads to the formation of stress within the rock resulting in heaving and fracturing parallel to the surface. Due to differential heating and resulting expansion and contraction of surface layers and their subsequent exfoliation from the surface results in smooth rounded surfaces in rocks. In rocks like granites, smooth surfaced and rounded small to big boulders called *tors* form due to such exfoliation.

What is the difference between exfoliation domes and exfoliated tors?

Freezing, Thawing and Frost Wedging

Frost weathering occurs due to growth of ice within pores and cracks of rocks during repeated cycles of freezing and melting. This process is most effective at high elevations in mid-latitudes where freezing and melting is often repeated. Glacial areas are subject to frost wedging daily. In this process, the rate of freezing is important. Rapid freezing of water causes its sudden expansion and high pressure. The resulting expansion affects joints, cracks and small inter granular fractures to become wider and wider till the rock breaks apart.

Salt Weathering

Salts in rocks expand due to thermal action, hydration and crystallisation. Many salts like calcium, sodium, magnesium, potassium and barium have a tendency to expand. Expansion of these salts depends on temperature and their thermal properties. High temperature ranges between 30 and 50°C of surface temperatures in deserts favour such salt expansion. Salt crystals in near-surface pores

cause splitting of individual grains within rocks, which eventually fall off. This process of falling off of individual grains may result in granular disintegration or granular foliation.

Salt crystallisation is most effective of all salt-weathering processes. In areas with alternating wetting and drying conditions salt crystal growth is favoured and the neighbouring grains are pushed aside. Sodium chloride and gypsum crystals in desert areas heave up overlying layers of materials and with the result polygonal cracks develop all over the heaved surface. With salt crystal growth, chalk breaks down most readily, followed by limestone, sandstone, shale, gneiss and granite etc.

BIOLOGICAL ACTIVITY AND WEATHERING

Biological weathering is contribution to or removal of minerals and ions from the weathering environment and physical changes due to growth or movement of organisms. Burrowing and wedging by organisms like earthworms, termites, rodents etc., help in exposing the new surfaces to chemical attack and assists in the penetration of moisture and air. Human beings by disturbing vegetation, ploughing and cultivating soils, also help in mixing and creating new contacts between air, water and minerals in the earth materials. Decaying plant and animal matter help in the production of humic, carbonic and other acids which enhance decay and solubility of some elements. Algae utilise mineral nutrients for growth and help in concentration of iron and manganese oxides. Plant roots exert a tremendous pressure on the earth materials mechanically breaking them apart.

SOME SPECIAL EFFECTS OF WEATHERING

This has already been explained under physical weathering processes of unloading, thermal contraction and expansion and salt weathering. Exfoliation is a result but not a process. Flaking off of more or less curved sheets of shells from over rocks or bedrock results in smooth and rounded surfaces (Figure 6.4). Exfoliation can occur due to expansion and contraction induced by



Fig.6.4 : Exfoliation (Flacking) and granular disintegration

temperature changes. Exfoliation domes and tors result due to unloading and thermal expansion respectively.

SIGNIFICANCE OF WEATHERING

Weathering processes are responsible for breaking down the rocks into smaller fragments and preparing the way for formation of not only regolith and soils, but also erosion and mass movements. Biomes and biodiversity is basically a result of forests (vegetation) and forests depend upon the depth of weathering mantles. Erosion cannot be significant if the rocks are not weathered. That means, weathering aids mass wasting, erosion and reduction of relief and changes in landforms are a consequence of erosion. Weathering of rocks and deposits helps in the enrichment and concentrations of certain valuable ores of iron, manganese, aluminium, copper etc., which are of great importance for the national economy. Weathering is an important process in the formation of soils.

When rocks undergo weathering, some materials are removed through chemical or physical leaching by groundwater and thereby the concentration of remaining (valuable) materials increases. Without such a weathering taking place, the concentration of the same valuable material may not be sufficient and economically viable to exploit, process and refine. This is what is called enrichment.

MASS MOVEMENTS

These movements transfer the mass of rock debris down the slopes under the direct influence of gravity. That means, air, water or ice do not carry debris with them from place to place but on the other hand the debris may carry with it air, water or ice. The movements of mass may range from slow to rapid, affecting shallow to deep columns of materials and include creep, flow, slide and fall. Gravity exerts its force on all matter, both bedrock and the products of weathering. So, weathering is not a pre-requisite for mass movement though it aids mass movements. Mass movements are very active over weathered slopes rather than over unweathered materials.

Mass movements are aided by gravity and no geomorphic agent like running water, glaciers, wind, waves and currents participate in the process of mass movements. That means mass movements do not come under erosion though there is a shift (aided by gravity) of materials from one place to another. Materials over the slopes have their own resistance to disturbing forces and will yield only when force is greater than the shearing resistance of the materials. Weak unconsolidated materials, thinly bedded rocks, faults, steeply dipping beds, vertical cliffs or steep slopes, abundant precipitation and torrential rains and scarcity of vegetation etc., favour mass movements.

Several activating causes precede mass movements. They are : (i) removal of support from below to materials above through natural or artificial means; (ii) increase in gradient and height of slopes; (iii) overloading through addition of materials naturally or by artificial filling; (iv) overloading due to heavy rainfall, saturation and lubrication of slope materials; (v) removal of material or load from over the original slope surfaces; (vi) occurrence of earthquakes, explosions or machinery; (vii) excessive natural seepage; (viii) heavy drawdown of water from lakes, reservoirs and rivers leading to slow outflow of water from under the slopes or river banks; (ix) indiscriminate removal of natural vegetation.

Heave (heaving up of soils due to frost growth and other causes), *flow* and *slide* are

the three forms of movements. Figure 6.5 shows the relationships among different types of mass movements, their relative rates of movement and moisture limits.

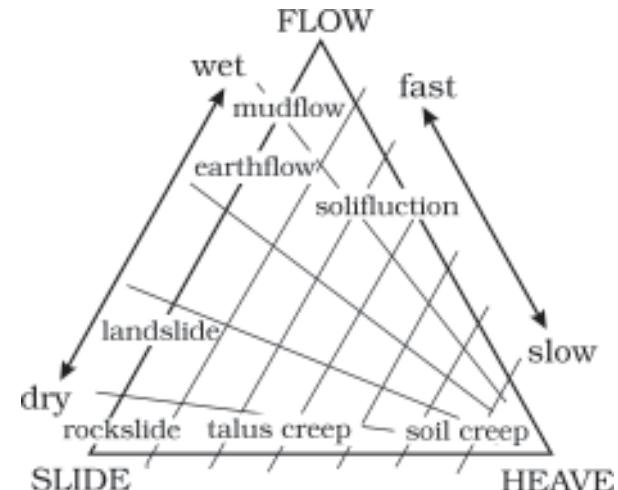


Figure 6.5 : Relationships among different types of mass movements, their relative rates of movement and moisture limits (after Whitehead, 2001)

Mass movements can be grouped under three major classes: (i) slow movements; (ii) rapid movements; (iii) landslides.

Slow Movements

Creep is one type under this category which can occur on moderately steep, soil covered slopes. Movement of materials is extremely slow and imperceptible except through extended observation. Materials involved can be soil or rock debris. Have you ever seen fence posts, telephone poles lean downslope from their vertical position and in their linear alignment? If you have, that is due to the creep effect. Depending upon the type of material involved, several types of creep viz., soil creep, talus creep, rock creep, rock-glacier creep etc., can be identified. Also included in this group is *solifluction* which involves slow downslope flowing soil mass or fine grained rock debris saturated or lubricated with water. This process is quite common in moist temperate areas where surface melting of deeply frozen ground and long continued rain respectively, occur frequently. When the upper portions get saturated and when the lower parts are impervious to water percolation, flowing occurs in the upper parts.

Rapid Movements

These movements are mostly prevalent in humid climatic regions and occur over gentle to steep slopes. Movement of water-saturated clayey or silty earth materials down low-angle terraces or hillsides is known as *earthflow*. Quite often, the materials slump making step-like terraces and leaving arcuate scarps at their heads and an accumulation bulge at the toe. When slopes are steeper, even the bedrock especially of soft sedimentary rocks like shale or deeply weathered igneous rock may slide downslope.

Another type in this category is *mudflow*. In the absence of vegetation cover and with heavy rainfall, thick layers of weathered materials get saturated with water and either slowly or rapidly flow down along definite channels. It looks like a stream of mud within a valley. When the mudflows emerge out of channels onto the piedmont or plains, they can be very destructive engulfing roads, bridges and houses. Mudflows occur frequently on the slopes of erupting or recently erupted volcanoes. Volcanic ash, dust and other fragments turn into mud due to heavy rains and flow down as tongues or streams of mud causing great destruction to human habitations.

A third type is the debris *avalanche*, which is more characteristic of humid regions with or without vegetation cover and occurs in narrow tracks on steep slopes. This debris avalanche can be much faster than the mudflow. Debris avalanche is similar to snow avalanche.

In Andes mountains of South America and the Rockies mountains of North America, there are a few volcanoes which erupted during the last decade and very devastating mudflows occurred down their slopes during eruption as well as after eruption.

Landslides

These are known as relatively rapid and perceptible movements. The materials involved are relatively dry. The size and shape of the detached mass depends on the nature of

discontinuities in the rock, the degree of weathering and the steepness of the slope. Depending upon the type of movement of materials several types are identified in this category.

Slump is slipping of one or several units of rock debris with a backward rotation with respect to the slope over which the movement takes place (Figure 6.6). Rapid rolling or sliding

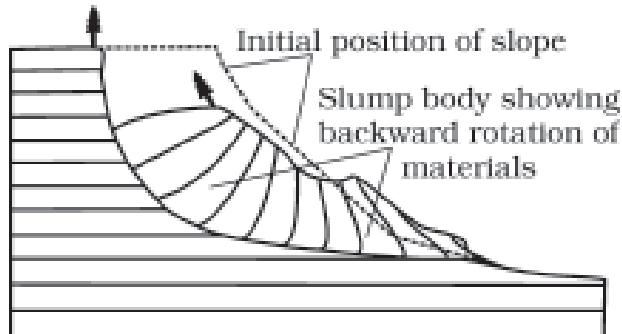


Figure 6.6 : Slumping of debris with backward rotation

of earth debris without backward rotation of mass is known as *debris slide*. Debris fall is nearly a free fall of earth debris from a vertical or overhanging face. Sliding of individual rock masses down bedding, joint or fault surfaces is *rockslide*. Over steep slopes, rock sliding is very fast and destructive. Figure 6.7 shows landslide scars over steep slopes. Slides occur as planar failures along discontinuities like bedding planes that dip steeply. Rock fall is free falling of rock blocks over any steep slope keeping itself away from the slope. Rock falls occur from the superficial layers of the rock



Figure 6.7 : Landslide scars in Shiwalik Himalayan ranges near river Sarada at India-Nepal border, Uttar Pradesh

face, an occurrence that distinguishes it from rockslide which affects materials up to a substantial depth.

Between mass wasting and mass movements, which term do you feel is most appropriate? Why? Can solifluction be included under rapid flow movements? Why it can be and can't be?

In our country, debris avalanche and landslides occur very frequently in the Himalayas. There are many reasons for this. One, the Himalayas are tectonically active. They are mostly made up of sedimentary rocks and unconsolidated and semi-consolidated deposits. The slopes are very steep. Compared to the Himalayas, the Nilgiris bordering Tamilnadu, Karnataka, Kerala and the Western Ghats along the west coast are relatively tectonically stable and are mostly made up of very hard rocks; but, still, debris avalanches and landslides occur though not as frequently as in the Himalayas, in these hills. Why? Many slopes are steeper with almost vertical cliffs and escarpments in the Western Ghats and Nilgiris. Mechanical weathering due to temperature changes and ranges is pronounced. They receive heavy amounts of rainfall over short periods. So, there is almost direct rock fall quite frequently in these places along with landslides and debris avalanches.

EROSION AND DEPOSITION

Erosion involves acquisition and transportation of rock debris. When massive rocks break into smaller fragments through weathering and any other process, erosional geomorphic agents like running water, groundwater, glaciers, wind and waves remove and transport it to other places depending upon the dynamics of each of these agents. Abrasion by rock debris carried by these geomorphic agents also aids greatly in erosion. By erosion, relief degrades, i.e., the landscape is worn down. That means, though weathering aids

erosion it is not a pre-condition for erosion to take place. Weathering, mass-wasting and erosion are degradational processes. It is erosion that is largely responsible for continuous changes that the earth's surface is undergoing. As indicated in Figure 6.1, denudational processes like erosion and transportation are controlled by kinetic energy. The erosion and transportation of earth materials is brought about by wind, running water, glaciers, waves and ground water. Of these the first three agents are controlled by climatic conditions.

Can you compare the three climatically controlled agents?

They represent three states of matter — gaseous (wind), liquid (running water) and solid (glacier) respectively. The erosion can be defined as "application of the kinetic energy associated with the agent to the surface of the land along which it moves". Kinetic energy is computed as $KE = \frac{1}{2}mv^2$ where 'm' is the mass and 'v' is the velocity. Hence the energy available to perform work will depend on the mass of the material and the velocity with which it is moving. Obviously then you will find that though the glaciers move at very low velocities due to tremendous mass are more effective as the agents of erosion and wind, being in gaseous state, are less effective.

The work of the other two agents of erosion—waves and ground water is not controlled by climate. In case of waves it is the location along the interface of litho and hydro sphere — coastal region — that will determine the work of waves, whereas the work of ground water is determined more by the lithological character of the region. If the rocks are permeable and soluble and water is available only then karst topography develops. In the next chapter we shall be dealing with the landforms produced by each of the agents of erosion.

Deposition is a consequence of erosion. The erosional agents loose their velocity and hence energy on gentler slopes and the materials carried by them start to settle themselves. In other words, deposition is not actually the work of any agent. The coarser materials get

deposited first and finer ones later. By deposition depressions get filled up. The same erosional agents viz., running water, glaciers, wind, waves and groundwater act as aggradational or depositional agents also.

What happens to the surface of the earth due to erosion and deposition is elaborated in the next chapter on landforms and their evolution.

There is a shift of materials in mass movements as well as in erosion from one place to the other. So, why can't both be treated as one and the same? Can there be appreciable erosion without rocks undergoing weathering?

SOIL FORMATION

Soil and Soil Contents

You see plants growing in soils. You play in the ground and come into contact with soil. You touch and feel soil and soil your clothes while playing. Can you describe it?

A pedologist who studies soils defines soil as a collection of natural bodies on the earth's surface containing living matter and supporting or capable of supporting plants.

Soil is a dynamic medium in which many chemical, physical and biological activities go on constantly. Soil is a result of decay, it is also the medium for growth. It is a changing and developing body. It has many characteristics that fluctuate with the seasons. It may be alternatively cold and warm or dry and moist. Biological activity is slowed or stopped if the soil becomes too cold or too dry. Organic matter increases when leaves fall or grasses die. The soil chemistry, the amount of organic matter, the soil flora and fauna, the temperature and the moisture, all change with the seasons as well as with more extended periods of time. That means, soil becomes adjusted to conditions of climate, landform and vegetation and will change internally when these controlling conditions change.

Process of Soil Formation

Soil formation or pedogenesis depends first on weathering. It is this weathering mantle (depth

of the weathered material) which is the basic input for soil to form. First, the weathered material or transported deposits are colonised by bacteria and other inferior plant bodies like mosses and lichens. Also, several minor organisms may take shelter within the mantle and deposits. The dead remains of organisms and plants help in humus accumulation. Minor grasses and ferns may grow; later, bushes and trees will start growing through seeds brought in by birds and wind. Plant roots penetrate down, burrowing animals bring up particles, mass of material becomes porous and sponge-like with a capacity to retain water and to permit the passage of air and finally a mature soil, a complex mixture of mineral and organic products forms.

Is weathering solely responsible for soil formation? If not, why?

Pedology is soil science. A pedologist is a soil-scientist.

Soil-forming Factors

Five basic factors control the formation of soils: (i) parent material; (ii) topography; (iii) climate; (iv) biological activity; (v) time. In fact soil forming factors act in union and affect the action of one another.

Parent Material

Parent material is a passive control factor in soil formation. Parent materials can be any *in-situ* or on-site weathered rock debris (residual soils) or transported deposits (transported soils). Soil formation depends upon the texture (sizes of debris) and structure (disposition of individual grains/particles of debris) as well as the mineral and chemical composition of the rock debris/deposits.

Nature and rate of weathering and depth of weathering mantle are important consideration under parent materials. There may be differences in soil over similar bedrock and dissimilar bedrocks may have similar soils above them. But when soils are very young and have not matured these show strong links

with the type of parent rock. Also, in case of some limestone areas, where the weathering processes are specific and peculiar, soils will show clear relation with the parent rock.

Topography

Topography like parent materials is another passive control factor. The influence of topography is felt through the amount of exposure of a surface covered by parent materials to sunlight and the amount of surface and sub-surface drainage over and through the parent materials. Soils will be thin on steep slopes and thick over flat upland areas. Over gentle slopes where erosion is slow and percolation of water is good, soil formation is very favourable. Soils over flat areas may develop a thick layer of clay with good accumulation of organic matter giving the soil dark colour. In middle latitudes, the south facing slopes exposed to sunlight have different conditions of vegetation and soils and the north facing slopes with cool, moist conditions have some other soils and vegetation.

Climate

Climate is an important active factor in soil formation. The climatic elements involved in soil development are : (i) moisture in terms of its intensity, frequency and duration of precipitation - evaporation and humidity; (ii) temperature in terms of seasonal and diurnal variations.

Precipitation gives soil its moisture content which makes the chemical and biological activities possible. Excess of water helps in the downward transportation of soil components through the soil (eluviation) and deposits the same down below (illuviation). In climates like wet equatorial rainy areas with high rainfall, not only calcium, sodium, magnesium, potassium etc. but also a major part of silica is removed from the soil. Removal of silica from the soil is known as *desilication*. In dry climates, because of high temperature, evaporation exceeds precipitation and hence ground water is brought up to the surface by capillary action and in the process the water evaporates leaving behind salts in the soil. Such salts form into a crust in the soil known as hardpans. In tropical

climates and in areas with intermediate precipitation conditions, calcium carbonate nodules (*kanker*) are formed.

Temperature acts in two ways — increasing or reducing chemical and biological activity. Chemical activity is increased in higher temperatures, reduced in cooler temperatures (with an exception of carbonation) and stops in freezing conditions. That is why, tropical soils with higher temperatures show deeper profiles and in the frozen tundra regions soils contain largely mechanically broken materials.

Biological Activity

The vegetative cover and organisms that occupy the parent materials from the beginning and also at later stages help in adding organic matter, moisture retention, nitrogen etc. Dead plants provide humus, the finely divided organic matter of the soil. Some organic acids which form during humification aid in decomposing the minerals of the soil parent materials.

Intensity of bacterial activity shows up differences between soils of cold and warm climates. Humus accumulates in cold climates as bacterial growth is slow. With undecomposed organic matter because of low bacterial activity, layers of peat develop in sub-arctic and tundra climates. In humid tropical and equatorial climates, bacterial growth and action is intense and dead vegetation is rapidly oxidised leaving very low humus content in the soil. Further, bacteria and other soil organisms take gaseous nitrogen from the air and convert it into a chemical form that can be used by plants. This process is known as nitrogen fixation. Rhizobium, a type of bacteria, lives in the root nodules of leguminous plants and fixes nitrogen beneficial to the host plant. The influence of large animals like ants, termites, earthworms, rodents etc., is mechanical, but, it is nevertheless important in soil formation as they rework the soil up and down. In case of earthworms, as they feed on soil, the texture and chemistry of the soil that comes out of their body changes.

Time

Time is the third important controlling factor in soil formation. The length of time the soil forming processes operate, determines

Is it necessary to separate the process of soil formation and the soil forming control factors?

Why are time, topography and parent material considered as passive control factors in soil formation?

maturity of soils and profile development. A soil becomes mature when all soil-forming processes act for a sufficiently long time developing a profile. Soils developing from recently deposited alluvium or glacial till are considered young and they exhibit no horizons or only poorly developed horizons. No specific length of time in absolute terms can be fixed for soils to develop and mature.

EXERCISES

1. Multiple choice questions.

(i) Which one of the following processes is a gradational process?

- | | |
|------------------|---------------|
| (a) Deposition | (c) Volcanism |
| (b) Diastrophism | (d) Erosion |

(ii) Which one of the following materials is affected by hydration process?

- | | |
|-------------|------------|
| (a) Granite | (c) Quartz |
| (b) Clay | (d) Salts |

(iii) Debris avalanche can be included in the category of:

- | | |
|------------------------------|-------------------------------|
| (a) Landslides | (c) Rapid flow mass movements |
| (b) Slow flow mass movements | (d) Subsidence |

2. Answer the following questions in about 30 words.

(i) It is weathering that is responsible for bio-diversity on the earth. How?

(ii) What are mass movements that are real rapid and perceptible? List.

(iii) What are the various mobile and mighty exogenic geomorphic agents and what is the prime job they perform?

(iv) Is weathering essential as a pre-requisite in the formation of soils? Why?

3. Answer the following questions in about 150 words.

(i) "Our earth is a playfield for two opposing groups of geomorphic processes." Discuss.

(ii) Exogenic geomorphic processes derive their ultimate energy from the sun's heat. Explain.

(iii) Are physical and chemical weathering processes independent of each other? If not, why? Explain with examples.

(iv) How do you distinguish between the process of soil formation and soil-forming factors? What is the role of climate and biological activity as two important control factors in the formation of soils?

Project Work

Depending upon the topography and materials around you, observe and record climate, possible weathering process and soil contents and characteristics.

C H A P T E R

7

LANDFORMS AND THEIR EVOLUTION

After weathering processes have had their actions on the earth materials making up the surface of the earth, the geomorphic agents like running water, ground water, wind, glaciers, waves perform erosion. It is already known to you that erosion causes changes on the surface of the earth. Deposition follows erosion and because of deposition too, changes occur on the surface of the earth.

As this chapter deals with landforms and their evolution first start with the question, what is a landform? In simple words, small to medium tracts or parcels of the earth's surface are called landforms.

If landform is a small to medium sized part of the surface of the earth, what is a landscape?

Several related landforms together make up landscapes, (large tracts of earth's surface). Each landform has its own physical shape, size, materials and is a result of the action of certain geomorphic processes and agent(s). Actions of most of the geomorphic processes and agents are slow, and hence the results take a long time to take shape. Every landform has a beginning. Landforms once formed may change in their shape, size and nature slowly or fast due to continued action of geomorphic processes and agents.

Due to changes in climatic conditions and vertical or horizontal movements of landmasses, either the intensity of processes or the processes themselves might change leading to new modifications in the landforms. Evolution here implies stages of transformation of either a part of the earth's surface from one landform into another or transformation of individual landforms after they are once formed. That

means, each and every landform has a history of development and changes through time. A landmass passes through stages of development somewhat comparable to the stages of life — youth, mature and old age.

What are the two important aspects of the evolution of landforms?

The evolutionary history of the continually changing surface of the earth is essential to be understood in order to use it effectively without disturbing its balance and diminishing its potential for the future. Geomorphology deals with the reconstruction of the history of the surface of the earth through a study of its forms, the materials of which it is made up of and the processes that shape it.

Changes on the surface of the earth owe mostly to erosion by various geomorphic agents. Of course, the process of deposition too, by covering the land surfaces and filling the basins, valleys or depressions, brings changes in the surface of the land. Deposition follows erosion and the depositional surfaces too are ultimately subjected to erosion. Running water, ground-water, glaciers, wind and waves are powerful erosional and depositional agents shaping and changing the surface of the earth aided by weathering and mass wasting processes. These geomorphic agents acting over long periods of time produce systematic changes leading to sequential development of landforms. Each geomorphic agent produces its own assemblage of landforms. Not only this, each geomorphic process and agent leave their distinct imprints on the landforms they

produce. You know that most of the geomorphic processes are imperceptible functions and can only be seen and measured through their results. What are the results? These results are nothing but landforms and their characteristics. Hence, a study of landforms, will reveal to us the process and agent which has made or has been making those landforms.

Most of the geomorphic processes are imperceptible. Cite a few processes which can be seen and a few which can't be seen.

As the geomorphic agents are capable of erosion and deposition, two sets — erosional or destructional and depositional or constructional — of landforms are produced by them. Many varieties of landforms develop by the action of each of the geomorphic agents depending upon especially the type and structure i.e. folds, faults, joints, fractures, hardness and softness, permeability and impermeability, etc. come under structure of rocks. There are some other independent controls like (i) stability of sea level; (ii) tectonic stability of landmasses; (iii) climate, which influence the evolution of landforms. Any disturbance in any of these three controlling factors can upset the systematic and sequential stages in the development and evolution of landforms.

In the following pages, under each of the geomorphic regimes i.e. running water; groundwater, glaciers, waves, and winds, first a brief discussion is presented as to how landmasses are reduced in their relief through erosion and then, development of some of the erosional and depositional landforms is dealt with.

RUNNING WATER

In humid regions, which receive heavy rainfall running water is considered the most important of the geomorphic agents in bringing about the degradation of the land surface. There are two components of running water. One is overland flow on general land surface as a sheet. Another is linear flow as

streams and rivers in valleys. Most of the erosional landforms made by running water are associated with vigorous and youthful rivers flowing along gradients. With time, stream channels over steep gradients turn gentler due to continued erosion, and as a consequence, lose their velocity, facilitating active deposition. There may be depositional forms associated with streams flowing over steep slopes. But these phenomena will be on a small scale compared to those associated with rivers flowing over medium to gentle slopes. The gentler the river channels in gradient or slope, the greater is the deposition. When the stream beds turn gentler due to continued erosion, downward cutting becomes less dominant and lateral erosion of banks increases and as a consequence the hills and valleys are reduced to plains.

Is complete reduction of relief of a high land mass possible?

Overland flow causes sheet erosion. Depending upon irregularities of the land surface, the overland flow may concentrate into narrow to wide paths. Because of the sheer friction of the column of flowing water, minor or major quantities of materials from the surface of the land are removed in the direction of flow and gradually small and narrow rills will form. These rills will gradually develop into long and wide gullies; the gullies will further deepen, widen, lengthen and unite to give rise to a network of valleys. In the early stages, down-cutting dominates during which irregularities such as waterfalls and cascades will be removed. In the middle stages, streams cut their beds slower, and lateral erosion of valley sides becomes severe. Gradually, the valley sides are reduced to lower and lower slopes. The divides between drainage basins are likewise lowered until they are almost completely flattened leaving finally, a lowland of faint relief with some low resistant remnants called *monadnocks* standing out here and there. This type of plain forming as a result of stream erosion is called a *peneplain* (an almost plain). The characteristics of each of the stages of landscapes developing in running water regimes may be summarised as follows:

Youth

Streams are few during this stage with poor integration and flow over original slopes showing shallow V-shaped valleys with no floodplains or with very narrow floodplains along trunk streams. Stream divides are broad and flat with marshes, swamp and lakes. Meanders if present develop over these broad upland surfaces. These meanders may eventually entrench themselves into the uplands. Waterfalls and rapids may exist where local hard rock bodies are exposed.

Mature

During this stage streams are plenty with good integration. The valleys are still V-shaped but deep; trunk streams are broad enough to have wider floodplains within which streams may flow in meanders confined within the valley. The flat and broad inter stream areas and swamps and marshes of youth disappear and the stream divides turn sharp. Waterfalls and rapids disappear.

Old

Smaller tributaries during old age are few with gentle gradients. Streams meander freely over vast floodplains showing natural levees, oxbow lakes, etc. Divides are broad and flat with lakes, swamps and marshes. Most of the landscape is at or slightly above sea level.

EROSIONAL LANDFORMS

Valleys

Valleys start as small and narrow rills; the rills will gradually develop into long and wide gullies; the gullies will further deepen, widen and lengthen to give rise to valleys. Depending upon dimensions and shape, many types of valleys like *V-shaped valley*, *gorge*, *canyon*, etc. can be recognised. A gorge is a deep valley with very steep to straight sides (Figure 7.1) and a canyon is characterised by steep step-like side slopes (Figure 7.2) and may be as deep as a gorge. A gorge is almost equal in width at its top as well as its bottom. In contrast, a canyon



Figure 7.1 : The Valley of Kaveri river near Hogenekal, Dharmapuri district, Tamilnadu in the form of gorge



Figure 7.2 : An entrenched meander loop of river Colorado in USA showing step-like side slopes of its valley typical of a canyon

is wider at its top than at its bottom. In fact, a canyon is a variant of gorge. Valley types depend upon the type and structure of rocks in which they form. For example, canyons commonly form in horizontal bedded sedimentary rocks and gorges form in hard rocks.

Potholes and Plunge Pools

Over the rocky beds of hill-streams more or less circular depressions called *potholes* form because of stream erosion aided by the abrasion of rock fragments. Once a small and shallow depression forms, pebbles and boulders get collected in those depressions and get rotated by flowing water and consequently the depressions grow in dimensions. A series of such depressions eventually join and the stream valley gets deepened. At the foot of waterfalls also, large potholes, quite deep and wide, form because of the sheer impact of water and rotation of boulders. Such large and deep holes at the base of waterfalls are called *plunge pools*. These pools also help in the deepening of valleys. Waterfalls are also transitory like any other landform and will recede gradually and bring the floor of the valley above waterfalls to the level below.

INCISED OR ENTRENCHED MEANDERS

In streams that flow rapidly over steep gradients, normally erosion is concentrated on the bottom of the stream channel. Also, in the case of steep gradient streams, lateral erosion on the sides of the valleys is not much when compared to the streams flowing on low and gentle slopes. Because of active lateral erosion, streams flowing over gentle slopes, develop sinuous or meandering courses. It is common to find meandering courses over floodplains and delta plains where stream gradients are very gentle. But very deep and wide meanders can also be found cut in hard rocks. Such meanders are called *incised or entrenched meanders* (Figure 7.2). Meander loops develop over original gentle surfaces in the initial stages of development of streams and the same loops get entrenched into the rocks normally due to erosion or slow, continued uplift of the land over which they start. They widen and deepen over time and can be found as deep gorges and canyons in hard rock areas. They give an indication on the status of original land surfaces over which streams have developed.

What are the differences between incised meanders and meanders over flood and delta plains?

River Terraces

River terraces are surfaces marking old valley floor or floodplain levels. They may be bedrock surfaces without any alluvial cover or alluvial terraces consisting of stream deposits. River terraces are basically products of erosion as they result due to vertical erosion by the stream into its own depositional floodplain. There can be a number of such terraces at different heights indicating former river bed levels. The river terraces may occur at the same elevation on either side of the rivers in which case they are called *paired terraces* (Figure 7.3).

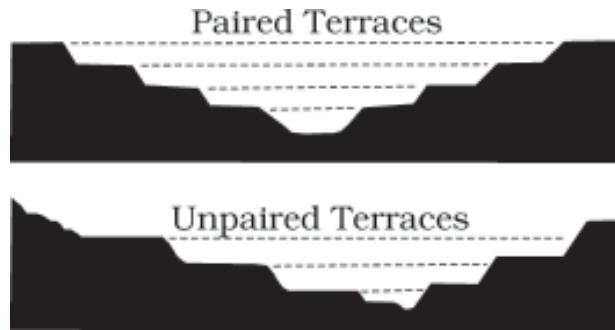


Figure 7.3 : Paired and unpaired river terraces

When a terrace is present only on one side of the stream and with none on the other side or one at quite a different elevation on the other side, the terraces are called *non-paired terraces*. Unpaired terraces are typical in areas of slow uplift of land or where the water column changes are not uniform along both the banks. The terraces may result due to (i) receding water after a peak flow; (ii) change in hydrological regime due to climatic changes; (iii) tectonic uplift of land; (iv) sea level changes in case of rivers closer to the sea.

DEPOSITIONAL LANDFORMS

Alluvial Fans

Alluvial fans (Figure 7.4) are formed when streams flowing from higher levels break into foot slope plains of low gradient. Normally very coarse load is carried by streams flowing over mountain slopes. This load becomes too heavy for the streams to be carried over gentler

gradients and gets dumped and spread as a broad low to high cone shaped deposit called *alluvial fan*. Usually, the streams which flow over fans are not confined to their original channels for long and shift their position across the fan forming many channels called *distributaries*. Alluvial fans in humid areas show normally low cones with gentle slope from



Figure 7.4 : An alluvial fan deposited by a hill stream on the way to Amarnath, Jammu and Kashmir

head to toe and they appear as high cones with steep slope in arid and semi-arid climates.

Deltas

Deltas are like alluvial fans but develop at a different location. The load carried by the rivers is dumped and spread into the sea. If this load is not carried away far into the sea or distributed along the coast, it spreads and accumulates

as a low cone. Unlike in alluvial fans, the deposits making up deltas are very well sorted with clear stratification. The coarsest materials settle out first and the finer fractions like silts and clays are carried out into the sea. As the delta grows, the river distributaries continue to increase in length (Figure 7.5) and delta continues to build up into the sea.

Floodplains, Natural Levees and Point Bars

Deposition develops a floodplain just as erosion makes valleys. Floodplain is a major landform of river deposition. Large sized materials are deposited first when stream channel breaks into a gentle slope. Thus, normally, fine sized materials like sand, silt and clay are carried by relatively slow moving waters in gentler channels usually found in the plains and deposited over the bed and when the waters spill over the banks during flooding above the bed. A river bed made of river deposits is the active floodplain. The floodplain above the bank is inactive floodplain. Inactive floodplain above the banks basically contain two types of deposits — flood deposits and channel deposits. In plains, channels shift laterally and change their courses occasionally leaving cut-off courses which get filled up gradually. Such areas over flood plains built up by abandoned or cut-off channels contain coarse deposits. The flood deposits of spilled waters carry relatively finer materials like silt and clay. The flood plains in a delta are called *delta plains*.

Natural levees and point bars (Figure 7.6) are some of the important landforms found associated with floodplains. *Natural levees* are found along the banks of large rivers. They are low, linear and parallel ridges of coarse deposits along the banks of rivers, quite often cut into individual mounds. During flooding as the water spills over the bank, the velocity of the water comes down and large sized and high specific gravity materials get dumped in the immediate vicinity of the bank as ridges. They are high nearer the banks and slope gently away from the river. The levee deposits are coarser than the deposits spread by flood waters away from the river. When rivers shift laterally, a series of natural levees can form.

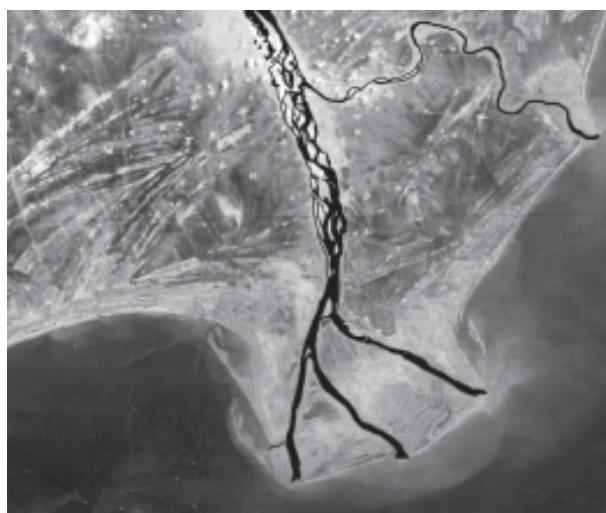


Figure 7.5 : A satellite view of part of Krishna river delta, Andhra Pradesh

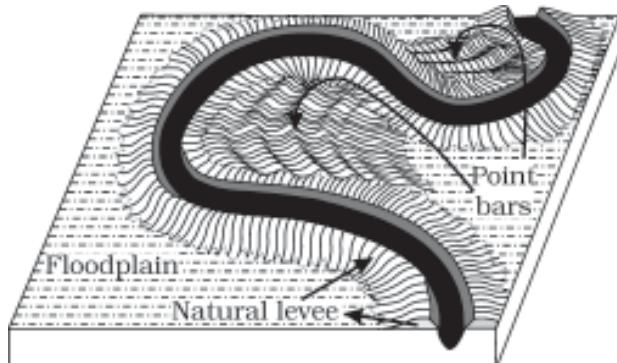


Figure 7.6 : Natural levee and point bars

Point bars are also known as *meander bars*. They are found on the convex side of meanders of large rivers and are sediments deposited in a linear fashion by flowing waters along the bank. They are almost uniform in profile and in width and contain mixed sizes of sediments. If there more than one ridge, narrow and elongated depressions are found in between the point bars. Rivers build a series of them depending upon the water flow and supply of sediment. As the rivers build the point bars on the convex side, the bank on the concave side will erode actively.

In what way do natural levees differ from point bars?

Meanders

In large flood and delta plains, rivers rarely flow in straight courses. Loop-like channel patterns called *meanders* develop over flood and delta plains (Figure 7.7).

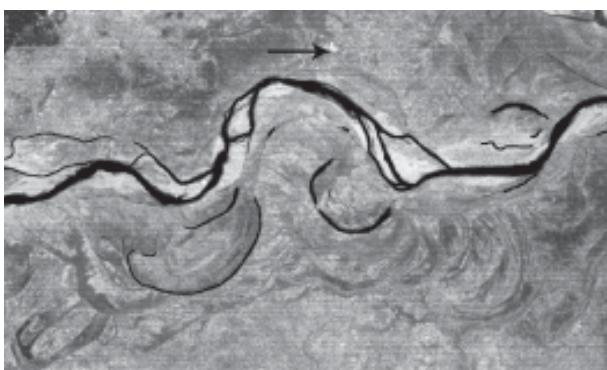


Figure 7.7 : A satellite scene showing meandering Burhi Gandak river near Muzaffarpur, Bihar, showing a number of oxbow lakes and cut-offs

Meander is not a landform but is only a type of channel pattern. This is because of (i) propensity of water flowing over very gentle gradients to work laterally on the banks; (ii) unconsolidated nature of alluvial deposits making up the banks with many irregularities which can be used by water exerting pressure laterally; (iii) coriolis force acting on the fluid water deflecting it like it deflects the wind. When the gradient of the channel becomes extremely low, water flows leisurely and starts working laterally. Slight irregularities along the banks slowly get transformed into a small curvature in the banks; the curvature deepens due to deposition on the inside of the curve and erosion along the bank on the outside. If there is no deposition and no erosion or undercutting, the tendency to meander is reduced. Normally, in meanders of large rivers, there is active deposition along the convex bank and undercutting along the concave bank.

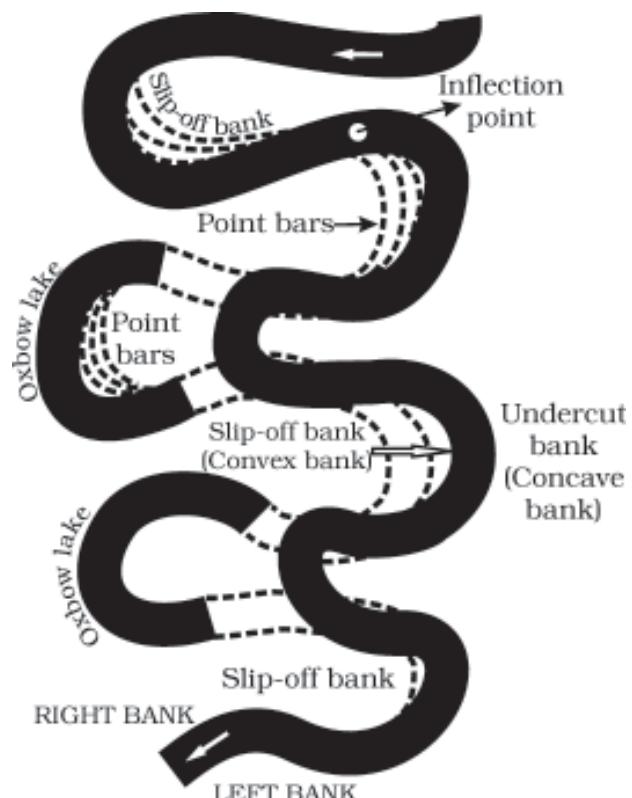


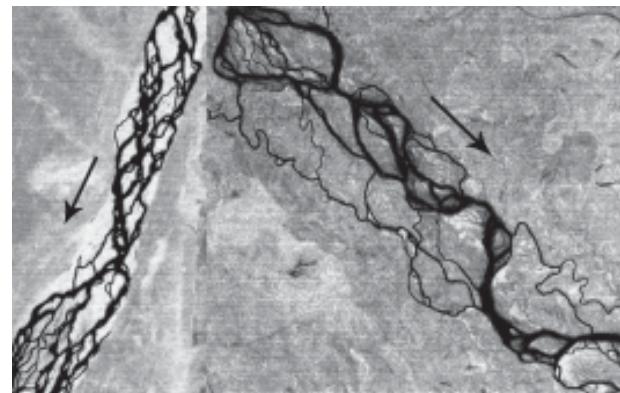
Figure 7.8 : Meander growth and cut-off loops and slip-off and undercut banks

The concave bank is known as cut-off bank which shows up as a steep scarp and the convex bank presents a long, gentle profile and is known as slip-off bank (Figure 7.8). As meanders grow into deep loops, the same may get cut-off due to erosion at the inflection points and are left as *ox-bow lakes*.

Braided Channels

When rivers carry coarse material, there can be selective deposition of coarser materials causing formation of a central bar which diverts the flow towards the banks; and this flow increases lateral erosion on the banks. As the valley widens, the water column is reduced and more and more materials get deposited as islands and lateral bars developing a number of separate channels of water flow. Deposition and lateral erosion of banks are essential for the formation of braided pattern. Or, alternatively, when discharge is less and load

is more in the valley, channel bars and islands of sand, gravel and pebbles develop on the floor of the channel and the water flow is divided into multiple threads. These thread-like streams of water rejoin and subdivide repeatedly to give a typical braided pattern (Figure 7.9).



**Figure 7.9 : Satellite scenes showing braided channel segments of Gandak (left) and Son (right) rivers
Arrows show the direction of flow**

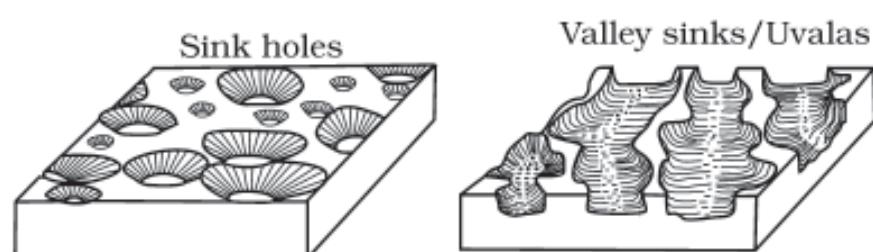
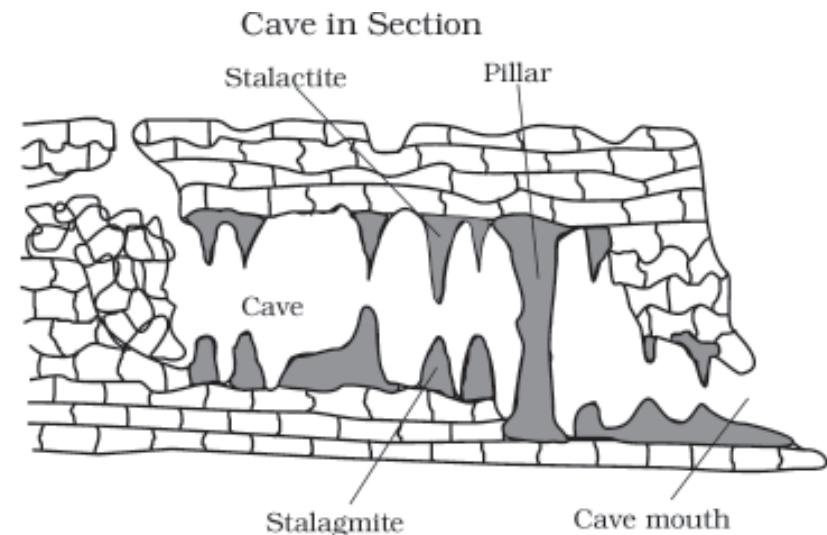
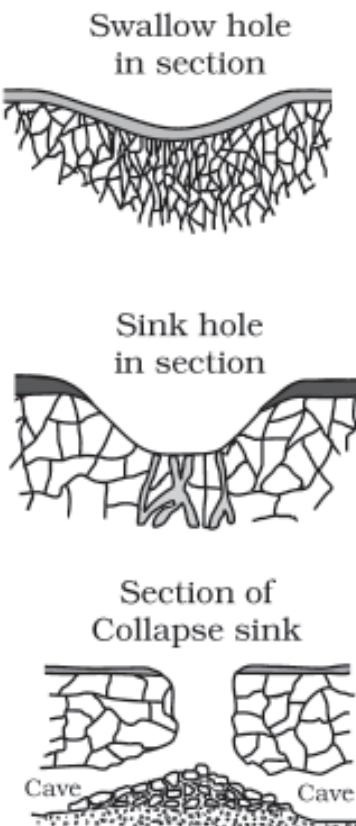


Figure 7.10 : Various karst features

GROUNDWATER

Here the interest is not on groundwater as a resource. Our focus is on the work of groundwater in the erosion of landmasses and evolution of landforms. The surface water percolates well when the rocks are permeable, thinly bedded and highly jointed and cracked. After vertically going down to some depth, the water under the ground flows horizontally through the bedding planes, joints or through the materials themselves. It is this downward and horizontal movement of water which causes the rocks to erode. Physical or mechanical removal of materials by moving groundwater is insignificant in developing landforms. That is why, the results of the work of groundwater cannot be seen in all types of rocks. But in rocks like limestones or dolomites rich in calcium carbonate, the surface water as well as groundwater through the chemical process of solution and precipitation deposition develop varieties of landforms. These two processes of solution and precipitation are active in limestones or dolomites occurring either exclusively or interbedded with other rocks. Any limestone or dolomitic region showing typical landforms produced by the action of groundwater through the processes of solution and deposition is called *Karst topography* after the typical topography developed in limestone rocks of Karst region in the Balkans adjacent to Adriatic sea.

The karst topography is also characterised by erosional and depositional landforms.

EROSIONAL LANDFORMS

Pools, Sinkholes, Lapiés and Limestone Pavements

Small to medium sized round to sub-rounded shallow depressions called *swallow holes* form on the surface of limestones through solution. Sinkholes are very common in limestone/karst areas. A *sinkhole* is an opening more or less circular at the top and funnel-shaped towards the bottom with sizes varying in area from a few sq. m to a hectare and with depth from a less than half a metre to thirty metres or more. Some of these form solely through solution action (solution sinks) and others might start

as solution forms first and if the bottom of a sinkhole forms the roof of a void or cave underground, it might collapse leaving a large hole opening into a cave or a void below (collapse sinks). Quite often, sinkholes are covered up with soil mantle and appear as shallow water pools. Anybody stepping over such pools would go down like it happens in quicksands in deserts. The term *doline* is sometimes used to refer the collapse sinks. Solution sinks are more common than collapse sinks. Quite often the surface run-off simply goes down swallow and sink holes and flow as underground streams and re-emerge at a distance downstream through a cave opening. When sink holes and dolines join together because of slumping of materials along their margins or due to roof collapse of caves, long, narrow to wide trenches called *valley sinks* or *Uvalas* form. Gradually, most of the surface of the limestone is eaten away by these pits and trenches, leaving it extremely irregular with a maze of points, grooves and *ridges* or *lapiés*. Especially, these ridges or lapiés form due to differential solution activity along parallel to sub-parallel joints. The lapie field may eventually turn into somewhat smooth *limestone pavements*.

Caves

In areas where there are alternating beds of rocks (shales, sandstones, quartzites) with limestones or dolomites in between or in areas where limestones are dense, massive and occurring as thick beds, cave formation is prominent. Water percolates down either through the materials or through cracks and joints and moves horizontally along bedding planes. It is along these bedding planes that the limestone dissolves and long and narrow to wide gaps called *caves* result. There can be a maze of caves at different elevations depending upon the limestone beds and intervening rocks. Caves normally have an opening through which cave streams are discharged. Caves having openings at both the ends are called tunnels.

Depositional Landforms

Many depositional forms develop within the limestone caves. The chief chemical in limestone

is calcium carbonate which is easily soluble in carbonated water (carbon dioxide absorbed rainwater). This calcium carbonate is deposited when the water carrying it in solution evaporates or loses its carbon dioxide as it trickles over rough rock surfaces.

Stalactites, Stalagmites and Pillars

Stalactites hang as icicles of different diameters. Normally they are broad at their bases and taper towards the free ends showing up in a variety of forms. *Stalagmites* rise up from the floor of the caves. In fact, stalagmites form due to dripping water from the surface or through the thin pipe, of the stalactite, immediately below it (Figure 7.11).

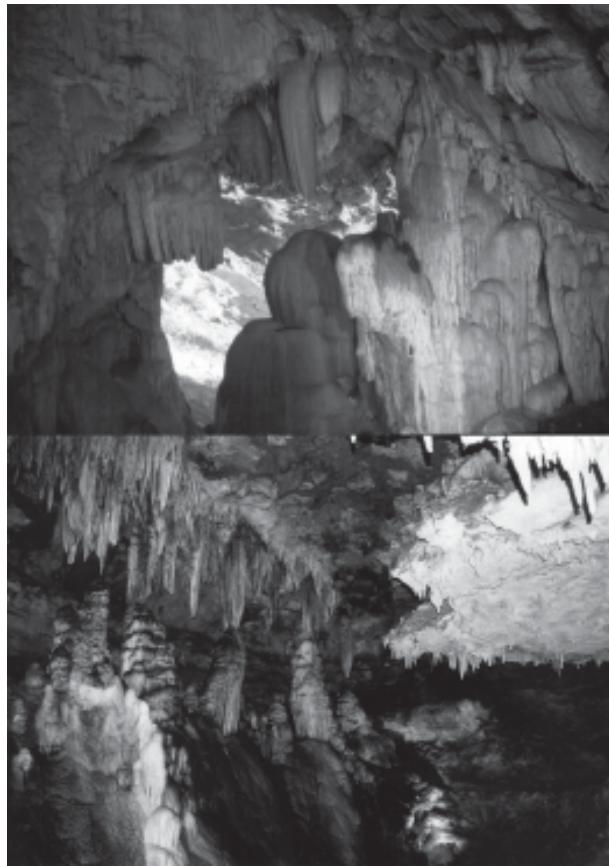


Figure 7.11 : Stalactites and stalagmites in a limestone cave

Stalagmites may take the shape of a column, a disc, with either a smooth, rounded bulging end or a miniature crater like depression. The stalagmite and stalactites eventually fuse to give rise to *columns and pillars* of different diameters.

GLACIERS

Masses of ice moving as sheets over the land (continental glacier or piedmont glacier if a vast sheet of ice is spread over the plains at the foot of mountains) or as linear flows down the slopes of mountains in broad trough-like valleys (mountain and valley glaciers) are called *glaciers* (Figure 7.12). The movement of glaciers



Figure 7.12 : A glacier in its valley

is slow unlike water flow. The movement could be a few centimetres to a few metres a day or even less or more. Glaciers move basically because of the force of gravity.

We have many glaciers in our country moving down the slopes and valleys in Himalayas. Higher reaches of Uttarakhand, Himachal Pradesh and Jammu and Kashmir, are places to see some of them. Do you know where one can see river Bhagirathi is basically fed by meltwaters from under the snout (Gaumukh) of the Gangotri glacier. In fact, Alkapuri glacier feeds waters to Alakananda river. Rivers Alkananda and Bhagirathi join to make river Ganga near Deoprayag.

Erosion by glaciers is tremendous because of friction caused by sheer weight of the ice. The material plucked from the land by glaciers (usually large-sized angular blocks and fragments) get dragged along the floors or sides of the valleys and cause great damage through abrasion and plucking. Glaciers can cause significant damage to even un-weathered rocks and can reduce high mountains into low hills and plains.

As glaciers continue to move, debris gets removed, divides get lowered and eventually the slope is reduced to such an extent that glaciers will stop moving leaving only a mass of low hills and vast outwash plains along with other depositional features. Figures 7.13 and 7.14 show various glacial erosional and depositional forms described in the text.

EROSIONAL LANDFORMS

Cirque

Cirques are the most common of landforms in glaciated mountains. The cirques quite often are found at the heads of glacial valleys. The accumulated ice cuts these cirques while moving down the mountain tops. They are deep, long and wide troughs or basins with very steep concave to vertically dropping high walls at its head as well as sides. A lake of water can be seen quite often within the cirques after

the glacier disappears. Such lakes are called *cirque or tarn lakes*. There can be two or more cirques one leading into another down below in a stepped sequence.

Horns and Serrated Ridges

Horns form through head ward erosion of the cirque walls. If three or more radiating glaciers cut headward until their cirques meet, high, sharp pointed and steep sided peaks called *horns* form. The divides between cirque side walls or head walls get narrow because of progressive erosion and turn into serrated or saw-toothed ridges sometimes referred to as *arêtes* with very sharp crest and a zig-zag outline.

The highest peak in the Alps, Matterhorn and the highest peak in the Himalayas, Everest are in fact horns formed through headward erosion of radiating cirques.

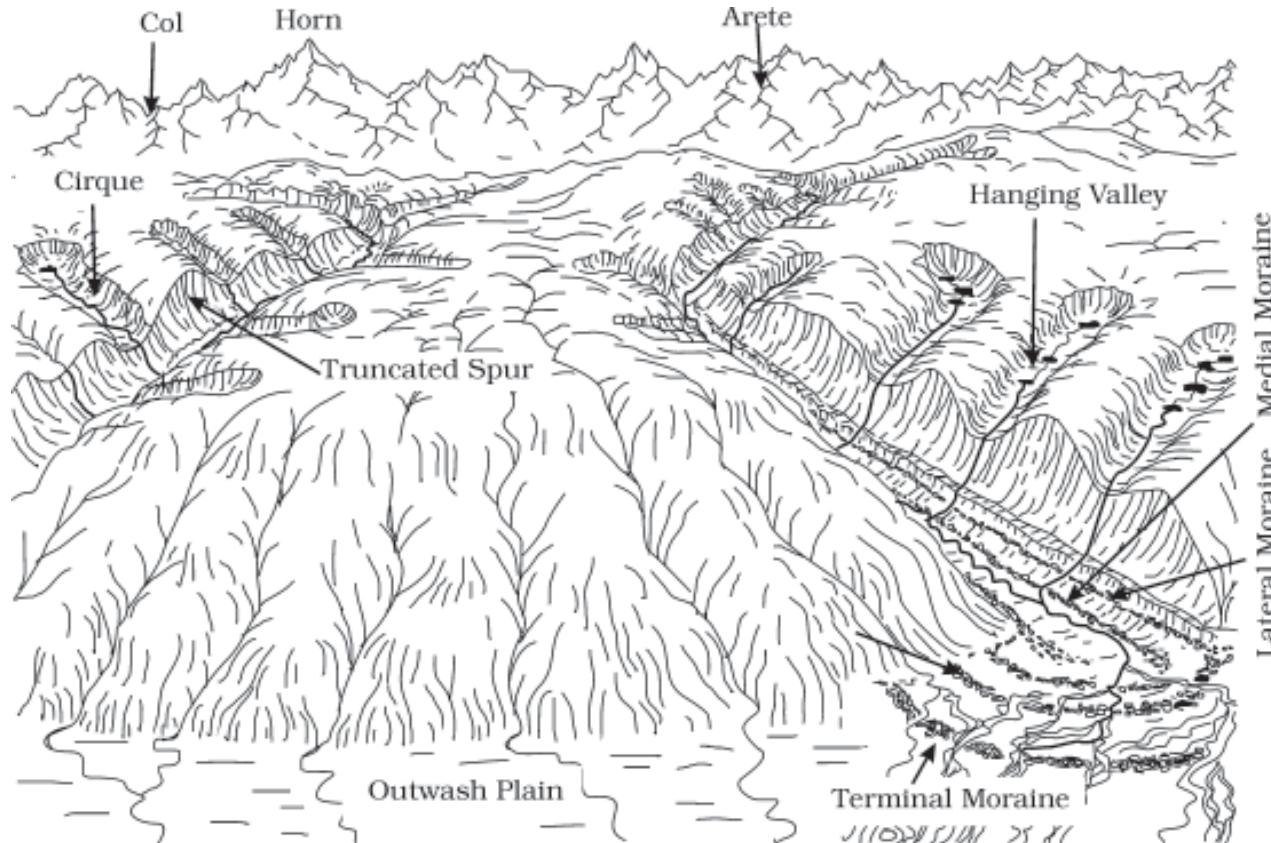


Figure 7.13 : Some glacial erosional and depositional forms (adapted and modified from Spencer, 1962)

Glacial Valleys/Troughs

Glaciated valleys are trough-like and *U-shaped* with broad floors and relatively smooth, and steep sides. The valleys may contain littered debris or debris shaped as *moraines* with swampy appearance. There may be lakes gouged out of rocky floor or formed by debris within the valleys. There can be hanging valleys at an elevation on one or both sides of the main glacial valley. The faces of divides or spurs of such hanging valleys opening into main glacial valleys are quite often truncated to give them an appearance like triangular facets. Very deep glacial troughs filled with sea water and making up shorelines (in high latitudes) are called *fjords/fiords*.

What are the basic differences between glacial valleys and river valleys?

Depositional Landforms

The unassorted coarse and fine debris dropped by the melting glaciers is called *glacial till*. Most of the rock fragments in till are angular to sub-angular in form. Streams form by melting ice at the bottom, sides or lower ends of glaciers.

Some amount of rock debris small enough to be carried by such melt-water streams is washed down and deposited. Such glacio-fluvial deposits are called *outwash deposits*. Unlike till deposits, the outwash deposits are roughly stratified and assorted. The rock fragments in outwash deposits are somewhat rounded at their edges. Figure 7.14 shows a few depositional landforms commonly found in glaciated areas.

Moraines

They are long ridges of deposits of glacial till. Terminal moraines are long ridges of debris deposited at the end (toe) of the glaciers. Lateral moraines form along the sides parallel to the glacial valleys. The lateral moraines may join a terminal moraine forming a horse-shoe shaped ridge. There can be many lateral moraines on either side in a glacial valley. These moraines partly or fully owe their origin to glacio-fluvial waters pushing up materials to the sides of glaciers. Many valley glaciers retreating rapidly leave an irregular sheet of till over their valley floors. Such deposits varying greatly in thickness and in surface topography are called *ground moraines*. The moraine in the centre of the

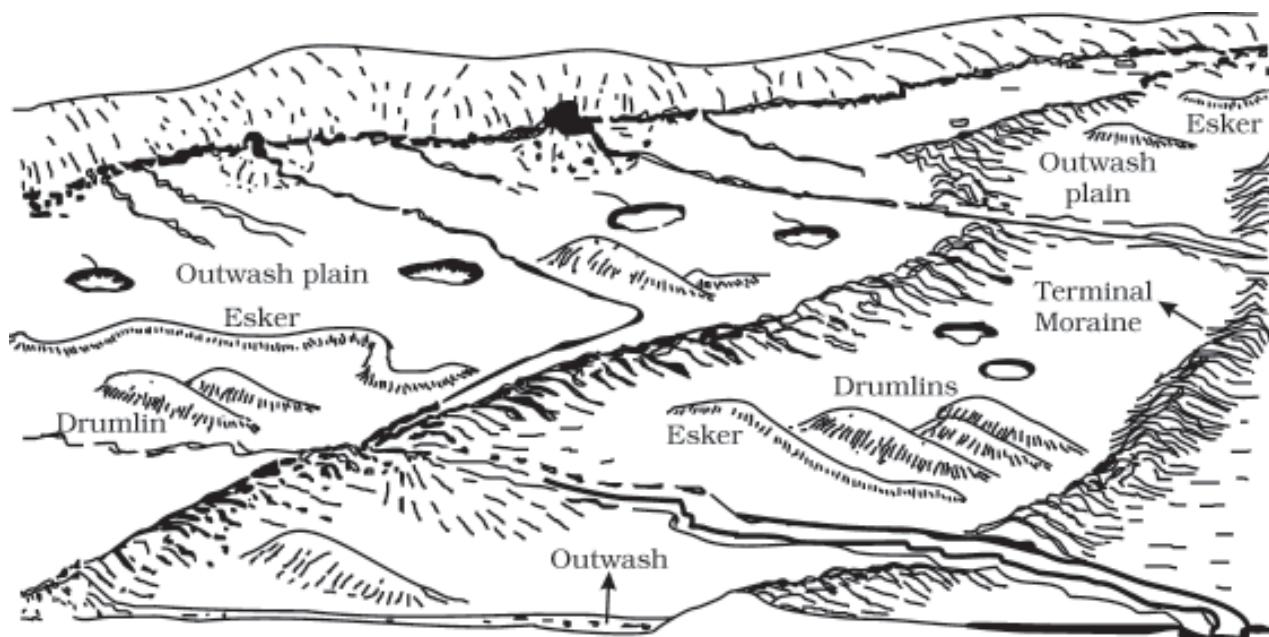


Figure 7.14 : A panoramic diagram of glacial landscape with various depositional landforms (adapted and modified from Spencer, 1962)

glacial valley flanked by lateral moraines is called *medial moraine*. They are imperfectly formed as compared to lateral moraines. Sometimes medial moraines are indistinguishable from ground moraines.

Eskers

When glaciers melt in summer, the water flows on the surface of the ice or seeps down along the margins or even moves through holes in the ice. These waters accumulate beneath the glacier and flow like streams in a channel beneath the ice. Such streams flow over the ground (not in a valley cut in the ground) with ice forming its banks. Very coarse materials like boulders and blocks along with some minor fractions of rock debris carried into this stream settle in the valley of ice beneath the glacier and after the ice melts can be found as a sinuous ridge called *esker*.

Outwash Plains

The plains at the foot of the glacial mountains or beyond the limits of continental ice sheets are covered with glacio-fluvial deposits in the form of broad flat alluvial fans which may join to form outwash plains of gravel, silt, sand and clay.

Distinguish between river alluvial plains and glacial outwash plains.

Drumlins

Drumlins are smooth oval shaped ridge-like features composed mainly of glacial till with some masses of gravel and sand. The long axes of drumlins are parallel to the direction of ice movement. They may measure up to 1 km in length and 30 m or so in height. One end of the drumlins facing the glacier called the *stoss* end is blunter and steeper than the other end called *tail*. The drumlins form due to dumping of rock debris beneath heavily loaded ice through fissures in the glacier. The stoss end gets blunted due to pushing by moving ice. Drumlins give an indication of direction of glacier movement.

What is the difference between till and alluvium?

WAVES AND CURRENTS

Coastal processes are the most dynamic and hence most destructive. So, don't you think it is important to know about the coastal processes and forms?

Some of the changes along the coasts take place very fast. At one place, there can be erosion in one season and deposition in another. Most of the changes along the coasts are accomplished by waves. When waves break, the water is thrown with great force onto the shore, and simultaneously, there is a great churning of sediments on the sea bottom. Constant impact of breaking waves drastically affects the coasts. Storm waves and tsunami waves can cause far-reaching changes in a short period of time than normal breaking waves. As wave environment changes, the intensity of the force of breaking waves changes.

Do you know about the generating forces behind waves and currents? If not, refer to the chapter on movements in ocean waters.

Other than the action of waves, the coastal landforms depend upon (i) the configuration of land and sea floor; (ii) whether the coast is advancing (emerging) seaward or retreating (submerging) landward. Assuming sea level to be constant, two types of coasts are considered to explain the concept of evolution of coastal landforms: (i) high, rocky coasts (submerged coasts); (ii) low, smooth and gently sloping sedimentary coasts (emerged coasts).

HIGH ROCKY COASTS

Along the high rocky coasts, the rivers appear to have been drowned with highly irregular coastline. The coastline appears highly indented with extension of water into the land where glacial valleys (*fjords*) are present. The hill sides drop off sharply into the water. Shores do not show any depositional landforms initially. Erosion features dominate.

Along high rocky coasts, waves break with great force against the land shaping the hill sides into cliffs. With constant pounding by waves, the cliffs recede leaving a *wave-cut platform* in front of the sea cliff. Waves gradually minimise the irregularities along the shore.

The materials which fall off, and removed from the sea cliffs, gradually break into smaller fragments and roll to roundness, will get deposited in the offshore. After a considerable period of cliff development and retreat when coastline turns somewhat smooth, with the addition of some more material to this deposit in the offshore, a wave-built terrace would develop in front of wave-cut terrace. As the erosion along the coast takes place a good supply material becomes available to longshore currents and waves to deposit them as beaches along the shore and as bars (long ridges of sand and/or shingle parallel to the coast) in the nearshore zone. Bars are submerged features and when bars show up above water, they are called *barrier bars*. Barrier bar which get keyed up to the headland of a bay is called a *spit*. When barrier bars and spits form at the mouth of a bay and block it, a *lagoon* forms. The lagoons would gradually get filled up by sediments from the land giving rise to a coastal plain.

LOW SEDIMENTARY COASTS

Along low sedimentary coasts the rivers appear to extend their length by building coastal plains and deltas. The coastline appears smooth with occasional incursions of water in the form of *lagoons and tidal creeks*. The land slopes gently into the water. Marshes and swamps may abound along the coasts. Depositional features dominate.

When waves break over a gently sloping sedimentary coast, the bottom sediments get churned and move readily building *bars, barrier bars, spits and lagoons*. Lagoons would eventually turn into a swamp which would subsequently turn into a coastal plain. The maintenance of these depositional features depends upon the steady supply of materials.

Storm and tsunami waves cause drastic changes irrespective of supply of sediments. Large rivers which bring lots of sediments build deltas along low sedimentary coasts.

The west coast of our country is a high rocky retreating coast. Erosional forms dominate in the west coast. The east coast of India is a low sedimentary coast. Depositional forms dominate in the east coast.

What are the various differences between a high rocky coast and a low sedimentary coast in terms of processes and landforms?

EROSIONAL LANDFORMS

Cliffs, Terraces, Caves and Stacks

Wave-cut cliffs and terraces are two forms usually found where erosion is the dominant shore process. Almost all sea cliffs are steep and may range from a few m to 30 m or even more. At the foot of such cliffs there may be a flat or gently sloping platform covered by rock debris derived from the sea cliff behind. Such platforms occurring at elevations above the average height of waves is called a *wave-cut terrace*. The lashing of waves against the base of the cliff and the rock debris that gets smashed against the cliff along with lashing waves create hollows and these hollows get widened and deepened to form *sea caves*. The roofs of caves collapse and the sea cliffs recede further inland. Retreat of the cliff may leave some remnants of rock standing isolated as small islands just off the shore. Such resistant masses of rock, originally parts of a cliff or hill are called *sea stacks*. Like all other features, sea stacks are also temporary and eventually coastal hills and cliffs will disappear because of wave erosion giving rise to narrow coastal plains, and with onrush of deposits from over the land behind may get covered up by alluvium or may get covered up by shingle or sand to form a wide beach.

DEPOSITIONAL LANDFORMS

Beaches and Dunes

Beaches are characteristic of shorelines that are dominated by deposition, but may occur as patches along even the rugged shores. Most of the sediment making up the beaches comes from land carried by the streams and rivers or from wave erosion. Beaches are temporary features. The sandy beach which appears so permanent may be reduced to a very narrow strip of coarse pebbles in some other season. Most of the beaches are made up of sand sized materials. Beaches called shingle beaches contain excessively small pebbles and even cobbles.

Just behind the beach, the sands lifted and winnowed from over the beach surfaces will be deposited as sand dunes. Sand dunes forming long ridges parallel to the coastline are very common along low sedimentary coasts.

Bars, Barriers and Spits

A ridge of sand and shingle formed in the sea in the off-shore zone (from the position of low tide waterline to seaward) lying approximately parallel to the coast is called an *off-shore bar*. An off-shore bar which is exposed due to further addition of sand is termed a *barrier bar*. The off-shore bars and barriers commonly form across the mouth of a river or at the entrance of a bay. Sometimes such barrier bars get keyed up to one end of the bay when they are called spits (Figure 7.15). Spits may also



Figure 7.15 : A satellite picture of a part of Godavari river delta showing a spit

develop attached to headlands/hills. The barriers, bars and spits at the mouth of the bay gradually extend leaving only a small opening of the bay into the sea and the bay will eventually develop into a lagoon. The lagoons get filled up gradually by sediment coming from the land or from the beach itself (aided by wind) and a broad and wide coastal plain may develop replacing a lagoon.

Do you know, the coastal off-shore bars offer the first buffer or defence against storm or tsunami by absorbing most of their destructive force. Then come the barriers, beaches, beach dunes and mangroves, if any, to absorb the destructive force of storm and tsunami waves. So, if we do anything which disturbs the 'sediment budget' and the mangroves along the coast, these coastal forms will get eroded away leaving human habitations to bear first strike of storm and tsunami waves.

WINDS

Wind is one of the two dominant agents in hot deserts. The desert floors get heated up too much and too quickly because of being dry and barren. The heated floors heat up the air directly above them and result in upward movements in the hot lighter air with turbulence, and any obstructions in its path sets up eddies, whirlwinds, updrafts and downdrafts. Winds also move along the desert floors with great speed and the obstructions in their path create turbulence. Of course, there are storm winds which are very destructive. Winds cause deflation, abrasion and impact. Deflation includes lifting and removal of dust and smaller particles from the surface of rocks. In the transportation process sand and silt act as effective tools to abrade the land surface. The impact is simply sheer force of momentum which occurs when sand is blown into or against a rock surface. It is similar to sand-blasting operation. The wind action creates a number of interesting erosional and depositional features in the deserts.

In fact, many features of deserts owe their

formation to mass wasting and running water as sheet floods. Though rain is scarce in deserts, it comes down torrentially in a short period of time. The desert rocks devoid of vegetation, exposed to mechanical and chemical weathering processes due to drastic diurnal temperature changes, decay faster and the torrential rains help in removing the weathered materials easily. That means, the weathered debris in deserts is moved by not only wind but also by rain/sheet wash. The wind moves fine materials and general mass erosion is accomplished mainly through sheet floods or sheet wash. Stream channels in desert areas are broad, smooth and indefinite and flow for a brief time after rains.

EROSIONAL LANDFORMS

Pediments and Pediplains

Landscape evolution in deserts is primarily concerned with the formation and extension of pediments. Gently inclined rocky floors close to the mountains at their foot with or without a thin cover of debris, are called *pediments*. Such rocky floors form through the erosion of mountain front through a combination of lateral erosion by streams and sheet flooding.

Erosion starts along the steep margins of the landmass or the steep sides of the tectonically controlled steep incision features over the landmass. Once, pediments are formed with a steep wash slope followed by cliff or free face above it, the steep wash slope and free face retreat backwards. This method of erosion is termed as parallel retreat of slopes through backwasting. So, through parallel retreat of slopes, the pediments extend backwards at the expense of mountain front, and gradually, the mountain gets reduced leaving an *inselberg* which is a remnant of the mountain. That's how the high relief in desert areas is reduced to low featureless plains called *pediplains*.

Playas

Plains are by far the most prominent landforms in the deserts. In basins with mountains and hills around and along, the drainage is towards the centre of the basin and due to gradual

deposition of sediment from basin margins, a nearly level plain forms at the centre of the basin. In times of sufficient water, this plain is covered up by a shallow water body. Such types of shallow lakes are called as *playas* where water is retained only for short duration due to evaporation and quite often the playas contain good deposition of salts. The playa plain covered up by salts is called *alkali flats*.

Deflation Hollows and Caves

Weathered mantle from over the rocks or bare soil, gets blown out by persistent movement of wind currents in one direction. This process may create shallow depressions called *deflation hollows*. Deflation also creates numerous small pits or cavities over rock surfaces. The rock faces suffer impact and abrasion of wind-borne sand and first shallow depressions called blow outs are created, and some of the *blow outs* become deeper and wider fit to be called *caves*.

Mushroom, Table and Pedestal Rocks

Many rock-outcrops in the deserts easily susceptible to wind deflation and abrasion are worn out quickly leaving some remnants of resistant rocks polished beautifully in the shape of mushroom with a slender stalk and a broad and rounded pear shaped cap above. Sometimes, the top surface is broad like a table top and quite often, the remnants stand out like pedestals.

List the erosional features carved out by wind action and action of sheet floods.

Depositional Landforms

Wind is a good sorting agent. Depending upon the velocity of wind, different sizes of grains are moved along the floors by rolling or saltation and carried in suspension and in this process of transportation itself, the materials get sorted. When the wind slows or begins to die down, depending upon sizes of grains and their critical velocities, the grains will begin to settle. So, in depositional landforms made by wind, good sorting of grains can be found. Since

wind is there everywhere and wherever there is good source of sand and with constant wind directions, depositional features in arid regions can develop anywhere.

Sand Dunes

Dry hot deserts are good places for sand dune formation. Obstacles to initiate dune formation

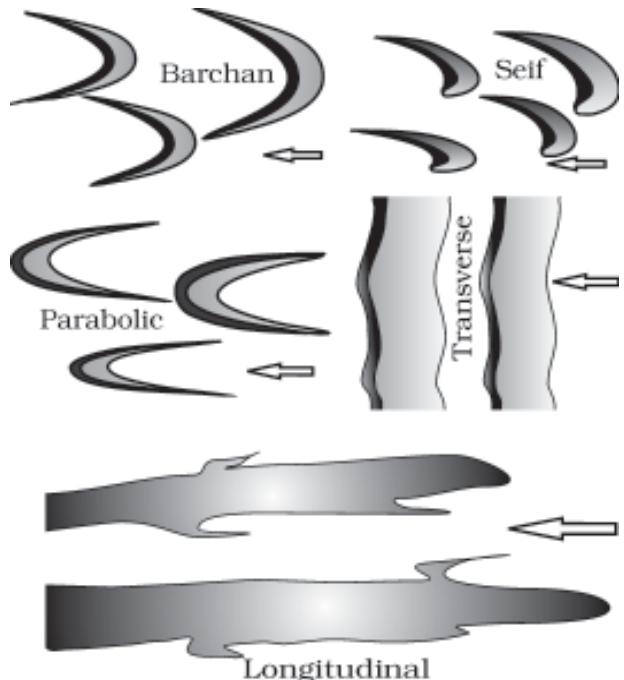


Figure 7.16 : Various types of sand dunes
Arrows indicate wind direction

are equally important. There can be a great variety of dune forms (Figure 7.16).

Barchans

Crescent shaped dunes called *barchans* with the points or wings directed away from wind direction i.e., downwind, form where the wind direction is constant and moderate and where the original surface over which sand is moving is almost uniform. *Parabolic dunes* form when sandy surfaces are partially covered with vegetation. That means parabolic dunes are reversed barchans with wind direction being the same. *Seif* is similar to barchan with a small difference. Seif has only one wing or point. This happens when there is shift in wind conditions. The lone wings of seifs can grow very long and high. *Longitudinal dunes* form when supply of sand is poor and wind direction is constant. They appear as long ridges of considerable length but low in height. *Transverse dunes* are aligned perpendicular to wind direction. These dunes form when the wind direction is constant and the source of sand is an elongated feature at right angles to the wind direction. They may be very long and low in height. When sand is plenty, quite often, the regular shaped dunes coalesce and lose their individual characteristics. Most of the dunes in the deserts shift and a few of them will get stabilised especially near human habitations.

EXERCISES

1. Multiple choice questions.

- In which of the following stages of landform development, downward cutting is dominated?
 - Youth stage
 - Late mature stage
 - Early mature stage
 - Old stage
- A deep valley characterised by steep step-like side slopes is known as
 - U-shaped valley
 - Gorge
 - Blind valley
 - Canyon
- In which one of the following regions the chemical weathering process is more dominant than the mechanical process?
 - Humid region
 - Limestone region
 - Arid region
 - Glacier region

- (iv) Which one of the following sentences best defines the term 'Lapies'?
- (a) A small to medium sized shallow depression
 - (b) A landform whose opening is more or less circular at the top and funnel shaped towards bottom
 - (c) A landform forms due to dripping water from surface
 - (d) An irregular surface with sharp pinnacles, grooves and ridges
- (v) A deep, long and wide trough or basin with very steep concave high walls at its head as well as in sides is known as:
- (a) Cirque
 - (b) Glacial valley
 - (c) Lateral Moraine
 - (d) Esker
2. Answer the following questions in about 30 words.
- (i) What do incised meanders in rocks and meanders in plains of alluvium indicate?
 - (ii) Explain the evolution of valley sinks or uvalas.
 - (iii) Underground flow of water is more common than surface run-off in limestone areas. Why?
 - (iv) Glacial valleys show up many linear depositional forms. Give their locations and names.
 - (v) How does wind perform its task in desert areas? Is it the only agent responsible for the erosional features in the deserts?
3. Answer the following questions in about 150 words.
- (i) Running water is by far the most dominating geomorphic agent in shaping the earth's surface in humid as well as in arid climates. Explain.
 - (ii) Limestones behave differently in humid and arid climates. Why? What is the dominant and almost exclusive geomorphic process in limestone areas and what are its results?
 - (iii) How do glaciers accomplish the work of reducing high mountains into low hills and plains?

Project Work

Identify the landforms, materials and processes around your area.

UNIT V

WATER (OCEANS)

This unit deals with

- *Hydrological Cycle*
- *Oceans — submarine relief; distribution of temperature and salinity; movements of ocean water-waves, tides and currents*

Can we think of life without water? It is said that the water is life. Water is an essential component of all life forms that exist over the surface of the earth. The creatures on the earth are lucky that it is a water planet, otherwise we all would have no existence. Water is a rare commodity in our solar system. There is no water on the sun or anywhere else in the solar system. The earth, fortunately has an abundant supply of water on its surface. Hence, our planet is called the '*Blue Planet*'.

HYDROLOGICAL CYCLE

Water is a cyclic resource. It can be used and re-used. Water also undergoes a cycle from

the ocean to land and land to ocean. The hydrological cycle describes the movement of water on, in, and above the earth. The water cycle has been working for billions of years and all the life on earth depends on it. Next to air, water is the most important element required for the existence of life on earth. The distribution of water on earth is quite uneven. Many locations have plenty of water while others have very limited quantity. The *hydrological cycle*, is the circulation of water within the earth's hydrosphere in different forms i.e. the liquid, solid and the gaseous phases. It also refers to the continuous exchange of water between the oceans,

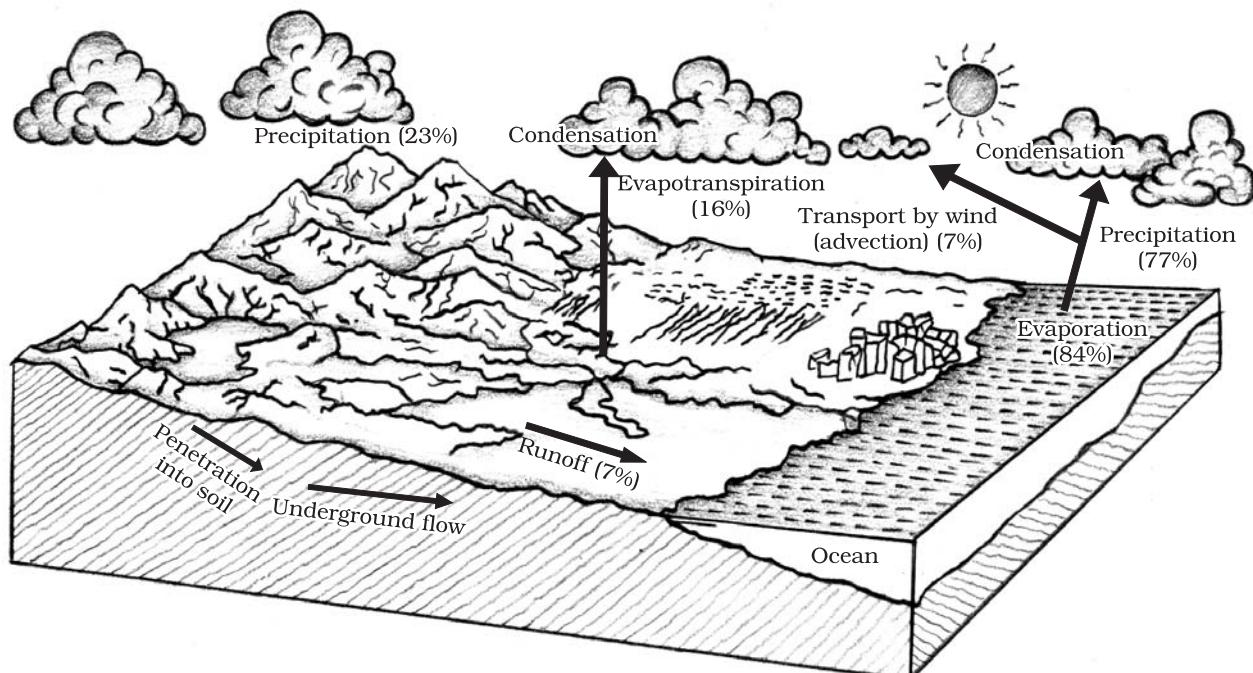


Figure 13.1 : Hydrological Cycle

Table 13.1 : Water on the Earth's surface

Reservoir	Volume (Million Cubic km)	Percentage of the Total
Oceans	1,370	97.25
Ice Caps	29	2.05
and Glaciers		
Groundwater	9.5	0.68
Lakes	0.125	0.01
Soil Moisture	0.065	0.005
Atmosphere	0.013	0.001
Streams and Rivers	0.0017	0.0001
Biosphere	0.0006	0.00004

Table 13.2 : Components and Processes of the Water Cycle

Components	Processes
Water storage in oceans	Evaporation Evapotranspiration Sublimation
Water in the atmosphere	Condensation Precipitation
Water storage in ice and snow	Snowmelt runoff to streams
Surface runoff	Stream flow freshwater storage infiltration
Groundwater storage	Groundwater discharge springs

atmosphere, landsurface and subsurface and the organisms.

Table 13.1 shows distribution of water on the surface of the earth. About 71 per cent of the planetary water is found in the oceans. The remaining is held as freshwater in glaciers and icecaps, groundwater sources, lakes, soil moisture, atmosphere, streams and within life. Nearly 59 per cent of the water that falls on land returns to the atmosphere through evaporation from over the oceans as well as from other places. The remainder runs-off on the surface, infiltrates into the ground or a part of it becomes glacier (Figure 13.1).

It is to be noted that the renewable water on the earth is constant while the demand is increasing tremendously. This leads to water

crisis in different parts of the world — spatially and temporally. The pollution of river waters has further aggravated the crisis. How can you intervene in improving the water quality and augmenting the available quantity of water?

RELIEF OF THE OCEAN FLOOR

The oceans are confined to the great depressions of the earth's outer layer. In this section, we shall see the nature of the ocean basins of the earth and their topography. The oceans, unlike the continents, merge so naturally into one another that it is hard to demarcate them. The geographers have divided the oceanic part of the earth into four oceans, namely the Pacific, the Atlantic, the Indian and the Arctic. The various seas, bays, gulfs and other inlets are parts of these four large oceans.

A major portion of the ocean floor is found between 3-6 km below the sea level. The 'land' under the waters of the oceans, that is, the ocean floor exhibits complex and varied features as those observed over the land (Figure 13.2). The floors of the oceans are rugged with the world's largest mountain ranges, deepest trenches and the largest plains. These features are formed, like those of the continents, by the factors of tectonic, volcanic and depositional processes.

Divisions of the Ocean Floors

The ocean floors can be divided into four major divisions: (i) the Continental Shelf; (ii) the Continental Slope; (iii) the Deep Sea Plain; (iv) the Oceanic Deeps. Besides, these divisions there are also major and minor relief features in the ocean floors like ridges, hills, sea mounts, guyots, trenches, canyons, etc.

Continental Shelf

The continental shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs. It is the shallowest part of the ocean showing an average gradient of 1° or even less. The shelf typically ends at a very steep slope, called the shelf break.

The width of the continental shelves vary from one ocean to another. The average width

of continental shelves is about 80 km. The shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc. On the contrary, the Siberian shelf in the Arctic Ocean, the largest in the world, stretches to 1,500 km in width. The depth of the shelves also varies. It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.

The continental shelves are covered with variable thicknesses of sediments brought down by rivers, glaciers, wind, from the land and distributed by waves and currents. Massive sedimentary deposits received over a long time by the continental shelves, become the source of fossil fuels.

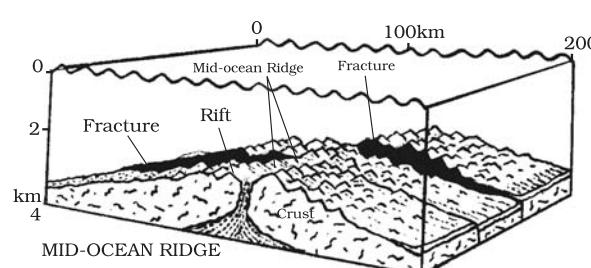
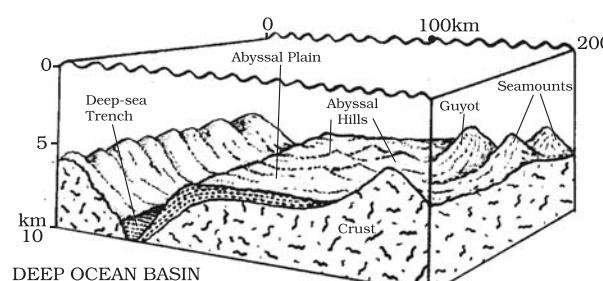
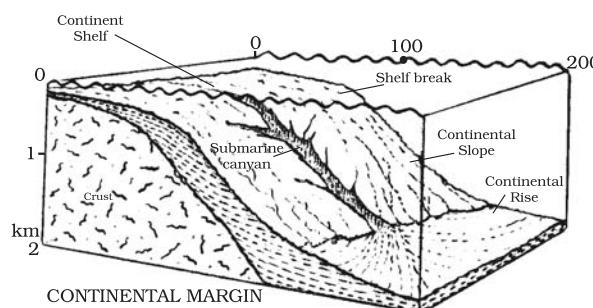


Figure 13.2 : Relief features of ocean floors

Continental Slope

The continental slope connects the continental shelf and the ocean basins. It begins where the bottom of the continental shelf sharply drops off into a steep slope. The gradient of the slope region varies between 2-5°. The depth of the slope region varies between 200 and 3,000 m. The slope boundary indicates the end of the continents. Canyons and trenches are observed in this region.

Deep Sea Plain

Deep sea plains are gently sloping areas of the ocean basins. These are the flattest and smoothest regions of the world. The depths vary between 3,000 and 6,000m. These plains are covered with fine-grained sediments like clay and silt.

Oceanic Deeps or Trenches

These areas are the deepest parts of the oceans. The trenches are relatively steep sided, narrow basins. They are some 3-5 km deeper than the surrounding ocean floor. They occur at the bases of continental slopes and along island arcs and are associated with active volcanoes and strong earthquakes. That is why they are very significant in the study of plate movements. As many as 57 deeps have been explored so far; of which 32 are in the Pacific Ocean; 19 in the Atlantic Ocean and 6 in the Indian Ocean.

Minor Relief Features

Apart from the above mentioned major relief features of the ocean floor, some minor but significant features predominate in different parts of the oceans.

Mid-Oceanic Ridges

A mid-oceanic ridge is composed of two chains of mountains separated by a large depression. The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface. Iceland, a part of the mid-Atlantic Ridge, is an example.

Seamount

It is a mountain with pointed summits, rising from the seafloor that does not reach the surface of the ocean. Seamounts are volcanic in origin. These can be 3,000-4,500 m tall. The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean, is a good example.

Submarine Canyons

These are deep valleys, some comparable to the Grand Canyon of the Colorado river. They are sometimes found cutting across the continental shelves and slopes, often extending from the mouths of large rivers. The Hudson Canyon is the best known canyon in the world.

Guyots

It is a flat topped seamount. They show evidences of gradual subsidence through stages to become flat topped submerged mountains. It is estimated that more than 10,000 seamounts and guyots exist in the Pacific Ocean alone.

Atoll

These are low islands found in the tropical oceans consisting of coral reefs surrounding a central depression. It may be a part of the sea (lagoon), or sometimes form enclosing a body of fresh, brackish, or highly saline water.

TEMPERATURE OF OCEAN WATERS

This section deals with the spatial and vertical variations of temperature in various oceans. Ocean waters get heated up by the solar energy just as land. The process of heating and cooling of the oceanic water is slower than land.

Factors Affecting Temperature Distribution

The factors which affect the distribution of temperature of ocean water are :

- (i) *Latitude* : the temperature of surface water decreases from the equator towards the poles because the amount of insolation decreases poleward.
- (ii) *Unequal distribution of land and water* : the oceans in the northern hemisphere

receive more heat due to their contact with larger extent of land than the oceans in the southern hemisphere.

- (iii) *Prevailing wind* : the winds blowing from the land towards the oceans drive warm surface water away from the coast resulting in the upwelling of cold water from below. It results into the longitudinal variation in the temperature. Contrary to this, the onshore winds pile up warm water near the coast and this raises the temperature.
- (iv) *Ocean currents* : warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas. Gulf stream (warm current) raises the temperature near the eastern coast of North America and the West Coast of Europe while the Labrador current (cold current) lowers the temperature near the north-east coast of North America.

All these factors influence the temperature of the ocean currents locally. The enclosed seas in the low latitudes record relatively higher temperature than the open seas; whereas the enclosed seas in the high latitudes have lower temperature than the open seas.

Horizontal and Vertical Distribution of Temperature

The temperature-depth profile for the ocean water shows how the temperature decreases with the increasing depth. The profile shows a boundary region between the surface waters of the ocean and the deeper layers. The boundary usually begins around 100 - 400 m below the sea surface and extends several hundred of m downward (Figure 13.3). This boundary region, from where there is a rapid decrease of temperature, is called the *thermocline*. About 90 per cent of the total volume of water is found below the thermocline in the deep ocean. In this zone, temperatures approach 0° C.

The temperature structure of oceans over middle and low latitudes can be described as a three-layer system from surface to the bottom.

The *first layer* represents the top layer of

warm oceanic water and it is about 500m thick with temperatures ranging between 20° and 25° C. This layer, within the tropical region, is present throughout the year but in mid latitudes it develops only during summer.

The *second layer* called the thermocline layer lies below the first layer and is characterised by rapid decrease in temperature with increasing depth. The thermocline is 500 - 1,000 m thick.

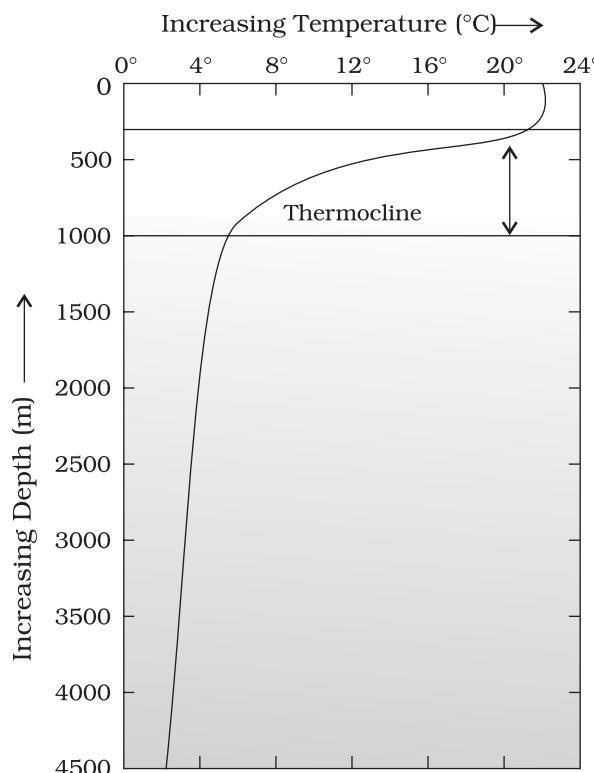


Figure 13.3 : Thermocline

The *third layer* is very cold and extends upto the deep ocean floor. In the Arctic and Antarctic circles, the surface water temperatures are close to 0° C and so the temperature change with the depth is very slight. Here, only one layer of cold water exists, which extends from surface to deep ocean floor.

The average temperature of surface water of the oceans is about 27°C and it gradually decreases from the equator towards the poles. The rate of decrease of temperature with increasing latitude is generally 0.5°C per latitude. The average temperature is around 22°C at 20° latitudes, 14° C at 40° latitudes and 0° C near poles. The oceans in the northern

hemisphere record relatively higher temperature than in the southern hemisphere. The highest temperature is not recorded at the equator but slightly towards north of it. The average annual temperatures for the northern and southern hemisphere are around 19° C and 16° C respectively. This variation is due to the unequal distribution of land and water in the northern and southern hemispheres. Figure 13.4 shows the spatial pattern of surface temperature of the oceans.

It is a well known fact that the maximum temperature of the oceans is always at their surfaces because they directly receive the heat from the sun and the heat is transmitted to the lower sections of the oceans through the process of conduction. It results into decrease of temperature with the increasing depth, but the rate of decrease is not uniform throughout. The temperature falls very rapidly up to the depth of 200 m and thereafter, the rate of decrease of temperature is slowed down.

SALINITY OF OCEAN WATERS

All waters in nature, whether rain water or ocean water, contain dissolved mineral salts. Salinity is the term used to define the total content of dissolved salts in sea water (Table 13.4). It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater. It is usually expressed as parts per thousand (°/₀₀₀) or ppt. Salinity is an important property of sea water. Salinity of 24.7°/₀₀₀ has been considered as the upper limit to demarcate 'brackish water'.

Factors affecting ocean salinity are mentioned below:

- (i) The salinity of water in the surface layer of oceans depend mainly on evaporation and precipitation.
- (ii) Surface salinity is greatly influenced in coastal regions by the fresh water flow from rivers, and in polar regions by the processes of freezing and thawing of ice.
- (iii) Wind, also influences salinity of an area by transferring water to other areas.
- (iv) The ocean currents contribute to the salinity variations. Salinity, temperature and density of water are interrelated. Hence, any change in the temperature or density influences the salinity of an area.

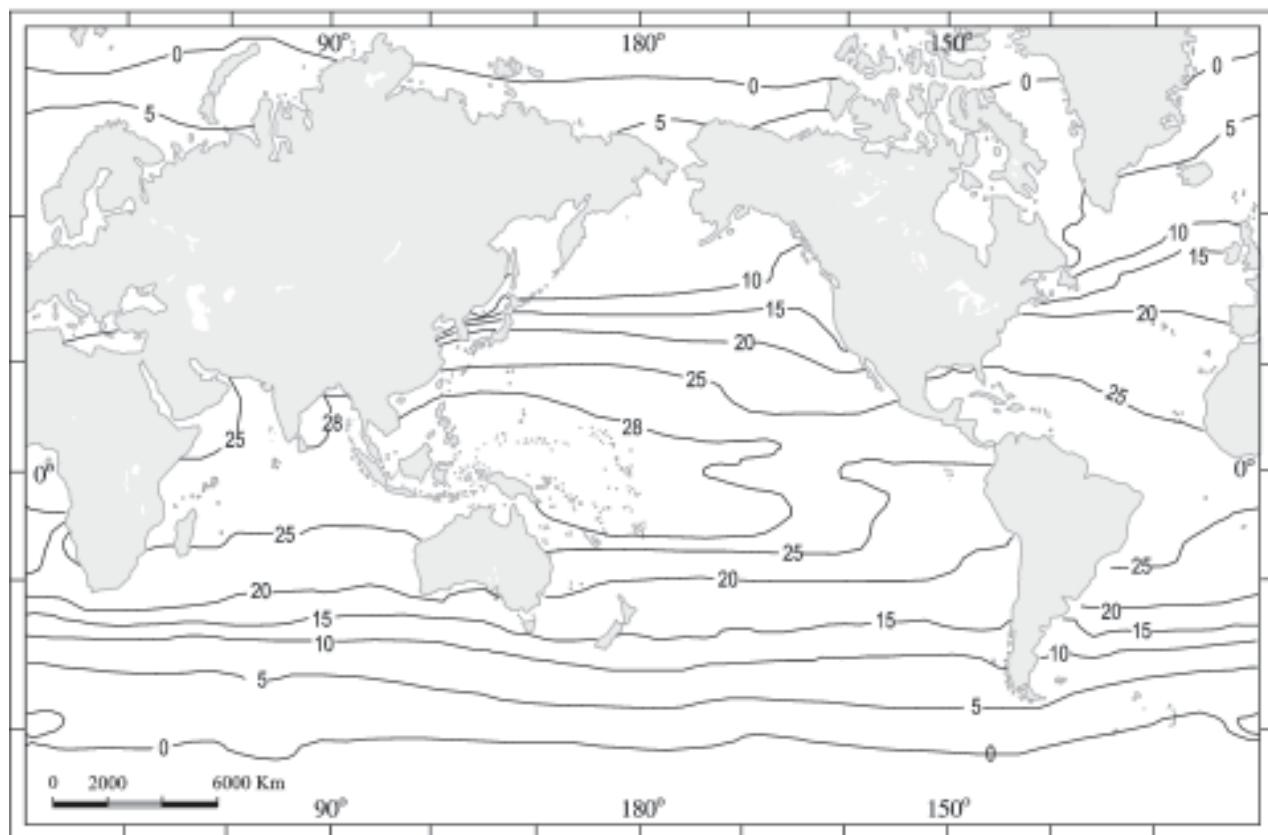


Figure 13.4 : Spatial pattern of surface temperature (°C) of the oceans

Highest salinity in water bodies
Lake Van in Turkey (330‰),
Dead Sea (238‰),
Great Salt Lake (220‰)

Red Sea, it is as high as 41‰ , while in the estuaries and the Arctic, the salinity fluctuates from $0 - 35\text{‰}$, seasonally. In hot and dry regions, where evaporation is high, the salinity sometimes reaches to 70‰ .

The salinity variation in the Pacific Ocean is mainly due to its shape and larger areal extent. Salinity decreases from $35\text{‰} - 31\text{‰}$ on the western parts of the northern hemisphere because of the influx of melted water from the Arctic region. In the same way, after $15^\circ - 20^\circ$ south, it decreases to 33‰ .

The average salinity of the Atlantic Ocean is around 36‰ . The highest salinity is recorded between 15° and 20° latitudes. Maximum salinity (37‰) is observed between 20°N and 30°N and $20^\circ\text{W} - 60^\circ\text{W}$. It gradually decreases towards the north. The North Sea, in spite of its location in higher latitudes, records higher salinity due to more saline water brought by the North Atlantic Drift. Baltic Sea records low salinity due to influx of river waters in large quantity. The Mediterranean Sea

**Table 13.4 : Dissolved Salts in Sea Water
(gm of Salt per kg of Water)**

Chlorine	18.97
Sodium	10.47
Sulphate	2.65
Magnesium	1.28
Calcium	0.41
Potassium	0.38
Bicarbonate	0.14
Bromine	0.06
Borate	0.02
Strontium	0.01

HORIZONTAL DISTRIBUTION OF SALINITY

The salinity for normal open ocean ranges between 33‰ and 37‰ . In the land locked

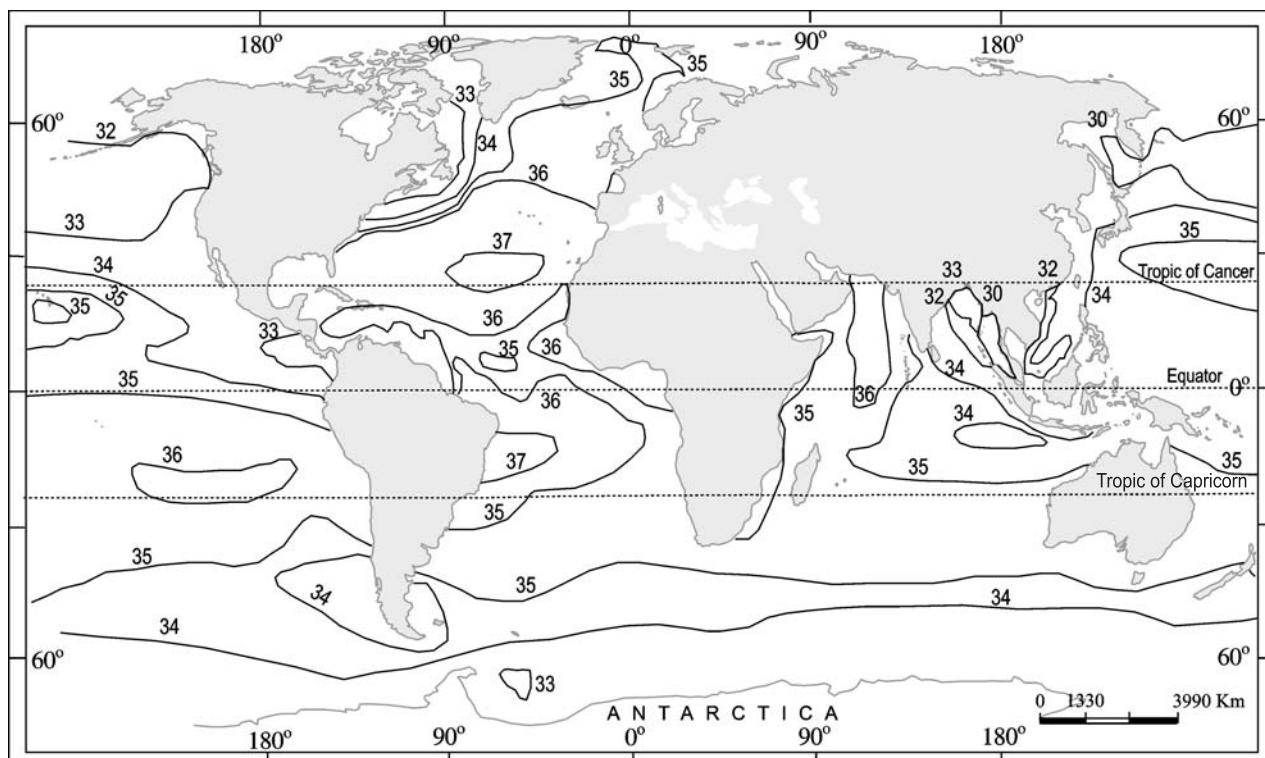


Figure 13.5 : Surface salinity of the World's Oceans

records higher salinity due to high evaporation. Salinity is, however, very low in Black Sea due to enormous fresh water influx by rivers. See the atlas to find out the rivers joining Black Sea.

The average salinity of the Indian Ocean is $35 \text{ } \text{o}_{\text{o}}$. The low salinity trend is observed in the Bay of Bengal due to influx of river water by the river Ganga. On the contrary, the Arabian Sea shows higher salinity due to high evaporation and low influx of fresh water. Figure 13.5 shows the salinity of the World's oceans.

Vertical Distribution of Salinity

Salinity changes with depth, but the way it changes depends upon the location of the sea. Salinity at the surface increases by the loss of

water to ice or evaporation, or decreased by the input of fresh waters, such as from the rivers. Salinity at depth is very much fixed, because there is no way that water is 'lost', or the salt is 'added.' There is a marked difference in the salinity between the surface zones and the deep zones of the oceans. The lower salinity water rests above the higher salinity dense water. Salinity, generally, increases with depth and there is a distinct zone called the *halocline*, where salinity increases sharply. Other factors being constant, increasing salinity of seawater causes its density to increase. High salinity seawater, generally, sinks below the lower salinity water. This leads to stratification by salinity.

EXERCISES

1. Multiple choice questions.
 - (i) Identify the element which is not a part of the hydrological cycle

(a) Evaporation	(c) Precipitation
(b) Hydration	(d) Condensation

- (ii) The average depth of continental slope varies between
(a) 2-20m (c) 20-200m
(b) 200-2,000m (d) 2,000-20,000m
- (iii) Which one of the following is not a minor relief feature in the oceans:
(a) Seamount (c) Oceanic Deep
(b) Atoll (d) Guyot
- (iv) Salinity is expressed as the amount of salt in grams dissolved in sea water per
(a) 10 gm (c) 100 gm
(b) 1,000 gm (d) 10,000 gm
- (v) Which one of the following is the smallest ocean:
(a) Indian Ocean (c) Atlantic Ocean
(b) Arctic Ocean (d) Pacific Ocean
2. Answer the following questions in about 30 words.
- (i) Why do we call the earth a Blue Planet?
 - (ii) What is a continental margin?
 - (iii) List out the deepest trenches of various oceans.
 - (iv) What is a thermocline?
 - (v) When you move into the ocean what thermal layers would you encounter?
Why the temperature varies with depth?
 - (vi) What is salinity of sea water?
3. Answer the following questions in about 150 words.
- (i) How are various elements of the hydrological cycle interrelated?
 - (ii) Examine the factors that influence the temperature distribution of the oceans.

Project Work

- (i) Consult the atlas and show ocean floor relief on the outline of the world map.
- (ii) Identify the areas of mid oceanic ridges from the Indian Ocean.

The ocean water is dynamic. Its physical characteristics like temperature, salinity, density and the external forces like of the sun, moon and the winds influence the movement of ocean water. The horizontal and vertical motions are common in ocean water bodies. The horizontal motion refers to the ocean currents and waves. The vertical motion refers to tides. Ocean currents are the continuous flow of huge amount of water in a definite direction while the waves are the horizontal motion of water. Water moves ahead from one place to another through ocean currents while the water in the waves does not move, but the wave trains move ahead. The vertical motion refers to the rise and fall of water in the oceans and seas. Due to attraction of the sun and the moon, the ocean water is raised up and falls down twice a day. The upwelling of cold water from subsurface and the sinking of surface water are also forms of vertical motion of ocean water.

WAVES

Waves are actually the energy, not the water as such, which moves across the ocean surface. Water particles only travel in a small circle as a wave passes. Wind provides energy to the waves. Wind causes waves to travel in the ocean and the energy is released on shorelines. The motion of the surface water seldom affects the stagnant deep bottom water of the oceans. As a wave approaches the beach, it slows down. This is due to the friction occurring between the dynamic water and the sea floor. And, when the depth of water is less than half the

wavelength of the wave, the wave breaks. The largest waves are found in the open oceans. Waves continue to grow larger as they move and absorb energy from the wind.

Most of the waves are caused by the wind driving against water. When a breeze of two knots or less blows over calm water, small ripples form and grow as the wind speed increases until white caps appear in the breaking waves. Waves may travel thousands of km before rolling ashore, breaking and dissolving as surf.

A wave's size and shape reveal its origin. Steep waves are fairly young ones and are probably formed by local wind. Slow and steady waves originate from far away places, possibly from another hemisphere. The maximum wave height is determined by the strength of the wind, i.e. how long it blows and the area over which it blows in a single direction.

Waves travel because wind pushes the water body in its course while gravity pulls the crests of the waves downward. The falling water pushes the former troughs upward, and the

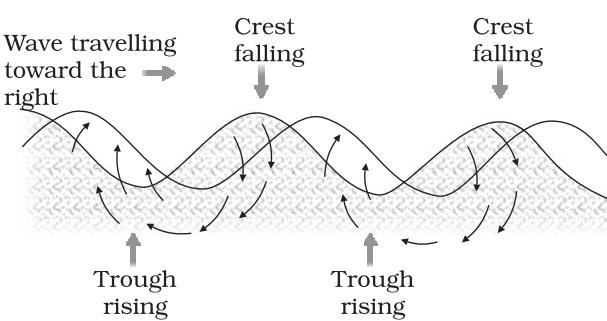


Figure 14.1 : Motion of waves and water molecules

wave moves to a new position (Figure 14.1). The actual motion of the water beneath the waves is circular. It indicates that things are carried up and forward as the wave approaches, and down and back as it passes.

Characteristics of Waves

Wave crest and trough : The highest and lowest points of a wave are called the crest and trough respectively.

Wave height : It is the vertical distance from the bottom of a trough to the top of a crest of a wave.

Wave amplitude : It is one-half of the wave height.

Wave period : It is merely the time interval between two successive wave crests or troughs as they pass a fixed point.

Wavelength : It is the horizontal distance between two successive crests.

Wave speed : It is the rate at which the wave moves through the water, and is measured in knots.

Wave frequency : It is the number of waves passing a given point during a one-second time interval.

attraction of the moon is less as it is farther away, the centrifugal force causes tidal bulge on the other side (Figure 14.2).

The 'tide-generating' force is the difference between these two forces; i.e. the gravitational attraction of the moon and the centrifugal force. On the surface of the earth, nearest the moon, pull or the attractive force of the moon is greater than the centrifugal force, and so there is a net force causing a bulge towards the moon. On the opposite side of the earth, the attractive force is less, as it is farther away from the moon, the centrifugal force is dominant. Hence, there is a net force away from the moon. It creates the second bulge away from the moon. On the surface of the earth, the horizontal tide generating forces are more important than the vertical forces in generating the tidal bulges.

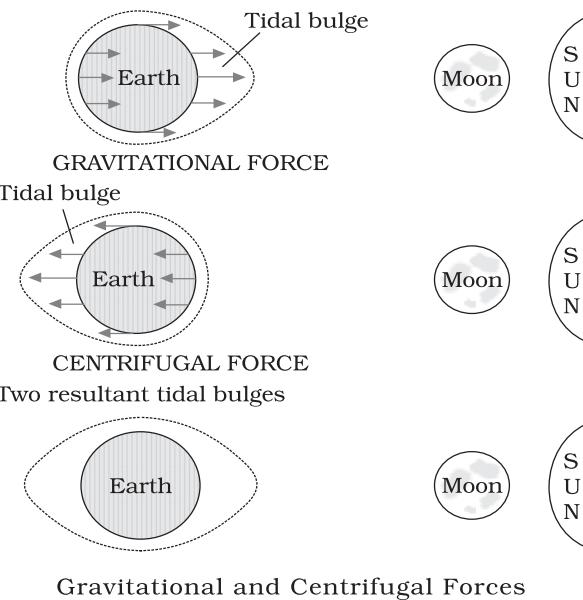


Figure 14.2 : Relation between gravitational forces and tides

The tidal bulges on wide continental shelves, have greater height. When tidal bulges hit the mid-oceanic islands they become low. The shape of bays and estuaries along a coastline can also magnify the intensity of tides. Funnel-shaped bays greatly change tidal magnitudes. When the tide is channelled between islands or into bays and estuaries they are called *tidal currents*.

TIDES

The periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a *tide*. Movement of water caused by meteorological effects (winds and atmospheric pressure changes) are called *surges*. Surges are not regular like tides. The study of tides is very complex, spatially and temporally, as it has great variations in frequency, magnitude and height.

The moon's gravitational pull to a great extent and to a lesser extent the sun's gravitational pull, are the major causes for the occurrence of tides. Another factor is centrifugal force, which is the force that acts to counter the balance the gravity. Together, the gravitational pull and the centrifugal force are responsible for creating the two major tidal bulges on the earth. On the side of the earth facing the moon, a tidal bulge occurs while on the opposite side though the gravitational

Tides of Bay of Fundy, Canada

The highest tides in the world occur in the Bay of Fundy in Nova Scotia, Canada. The tidal bulge is 15 - 16 m. Because there are two high tides and two low tides every day (roughly a 24 hour period); then a tide must come in within about a six hour period. As a rough estimate, the tide rises about 240 cm an hour (1,440 cm divided by 6 hours). If you have walked down a beach with a steep cliff alongside (which is common there), make sure you watch the tides. If you walk for about an hour and then notice that the tide is coming in, the water will be over your head before you get back to where you started!

Types of Tides

Tides vary in their frequency, direction and movement from place to place and also from time to time. Tides may be grouped into various types based on their frequency of occurrence in one day or 24 hours or based on their height.

Tides based on Frequency

Semi-diurnal tide : The most common tidal pattern, featuring two high tides and two low tides each day. The successive high or low tides are approximately of the same height.

Diurnal tide : There is only one high tide and one low tide during each day. The successive high and low tides are approximately of the same height.

Mixed tide : Tides having variations in height are known as mixed tides. These tides generally occur along the west coast of North America and on many islands of the Pacific Ocean.

Tides based on the Sun, Moon and the Earth Positions

The height of rising water (high tide) varies appreciably depending upon the position of sun and moon with respect to the earth. Spring tides and neap tides come under this category.

Spring tides : The position of both the sun and the moon in relation to the earth has direct bearing on tide height. When the sun, the moon and the earth are in a straight line, the height of the tide will be higher. These are called spring tides and they occur twice a month, one on full moon period and another during new moon period.

Neap tides : Normally, there is a seven day interval between the spring tides and neap tides. At this time the sun and moon are at right angles to each other and the forces of the sun and moon tend to counteract one another. The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull.

Once in a month, when the moon's orbit is closest to the earth (*perigee*), unusually high and low tides occur. During this time the tidal range is greater than normal. Two weeks later, when the moon is farthest from earth (*apogee*), the moon's gravitational force is limited and the tidal ranges are less than their average heights.

When the earth is closest to the sun (*perihelion*), around 3rd January each year, tidal ranges are also much greater, with unusually high and unusually low tides. When the earth is farthest from the sun (*aphelion*), around 4th July each year, tidal ranges are much less than average.

The time between the high tide and low tide, when the water level is falling, is called the *ebb*. The time between the low tide and high tide, when the tide is rising, is called the *flow* or *flood*.

Importance of Tides

Since tides are caused by the earth-moon-sun positions which are known accurately, the tides can be predicted well in advance. This helps the navigators and fishermen plan their activities. Tidal flows are of great importance in navigation. Tidal heights are very important, especially harbours near rivers and within estuaries having shallow 'bars' at the entrance, which prevent ships and boats from entering into the harbour. Tides are also helpful in

desilting the sediments and in removing polluted water from river estuaries. Tides are used to generate electrical power (in Canada, France, Russia, and China). A 3 MW tidal power project at Durgaduani in Sunderbans of West Bengal is under way.

OCEAN CURRENTS

Ocean currents are like river flow in oceans. They represent a regular volume of water in a definite path and direction. Ocean currents are influenced by two types of forces namely : (i) primary forces that initiate the movement of water; (ii) secondary forces that influence the currents to flow.

The primary forces that influence the currents are: (i) heating by solar energy; (ii) wind; (iii) gravity; (iv) coriolis force. Heating by solar energy causes the water to expand. That is why, near the equator the ocean water is about 8 cm higher in level than in the middle latitudes. This causes a very slight gradient and water tends to flow down the slope. Wind blowing on the surface of the ocean pushes the water to move. Friction between the wind and the water surface affects the movement of the water body in its course. Gravity tends to pull the water down to pile and create gradient variation. The Coriolis force intervenes and causes the water to move to the right in the northern hemisphere and to the left in the southern hemisphere. These large accumulations of water and the flow around them are called *Gyres*. These produce large circular currents in all the ocean basins.

Characteristics of Ocean Currents

Currents are referred to by their "drift". Usually, the currents are strongest near the surface and may attain speeds over five knots. At depths, currents are generally slow with speeds less than 0.5 knots. We refer to the speed of a current as its "drift." Drift is measured in terms of knots. The strength of a current refers to the speed of the current. A fast current is considered strong. A current is usually strongest at the surface and decreases in strength (speed) with depth. Most currents have speeds less than or equal to 5 knots.

Differences in water density affect vertical mobility of ocean currents. Water with high salinity is denser than water with low salinity and in the same way cold water is denser than warm water. Denser water tends to sink, while relatively lighter water tends to rise. Cold-water ocean currents occur when the cold water at the poles sinks and slowly moves towards the equator. Warm-water currents travel out from the equator along the surface, flowing towards the poles to replace the sinking cold water.

Types of Ocean Currents

The ocean currents may be classified based on their depth as surface currents and deep water currents : (i) *surface currents* constitute about 10 per cent of all the water in the ocean, these waters are the upper 400 m of the ocean; (ii) *deep water currents* make up the other 90 per cent of the ocean water. These waters move around the ocean basins due to variations in the density and gravity. Deep waters sink into the deep ocean basins at high latitudes, where the temperatures are cold enough to cause the density to increase.

Ocean currents can also be classified based on temperature : as cold currents and warm currents: (i) *cold currents* bring cold water into warm water areas. These currents are usually found on the west coast of the continents in the low and middle latitudes (true in both hemispheres) and on the east coast in the higher latitudes in the Northern Hemisphere; (ii) *warm currents* bring warm water into cold water areas and are usually observed on the east coast of continents in the low and middle latitudes (true in both hemispheres). In the northern hemisphere they are found on the west coasts of continents in high latitudes.

Major Ocean Currents

Major ocean currents are greatly influenced by the stresses exerted by the prevailing winds and coriolis force. The oceanic circulation pattern roughly corresponds to the earth's atmospheric circulation pattern. The air circulation over the oceans in the middle latitudes is mainly anticyclonic (more pronounced in the southern hemisphere than in the northern hemisphere). The oceanic circulation pattern also corresponds with the same. At higher latitudes,

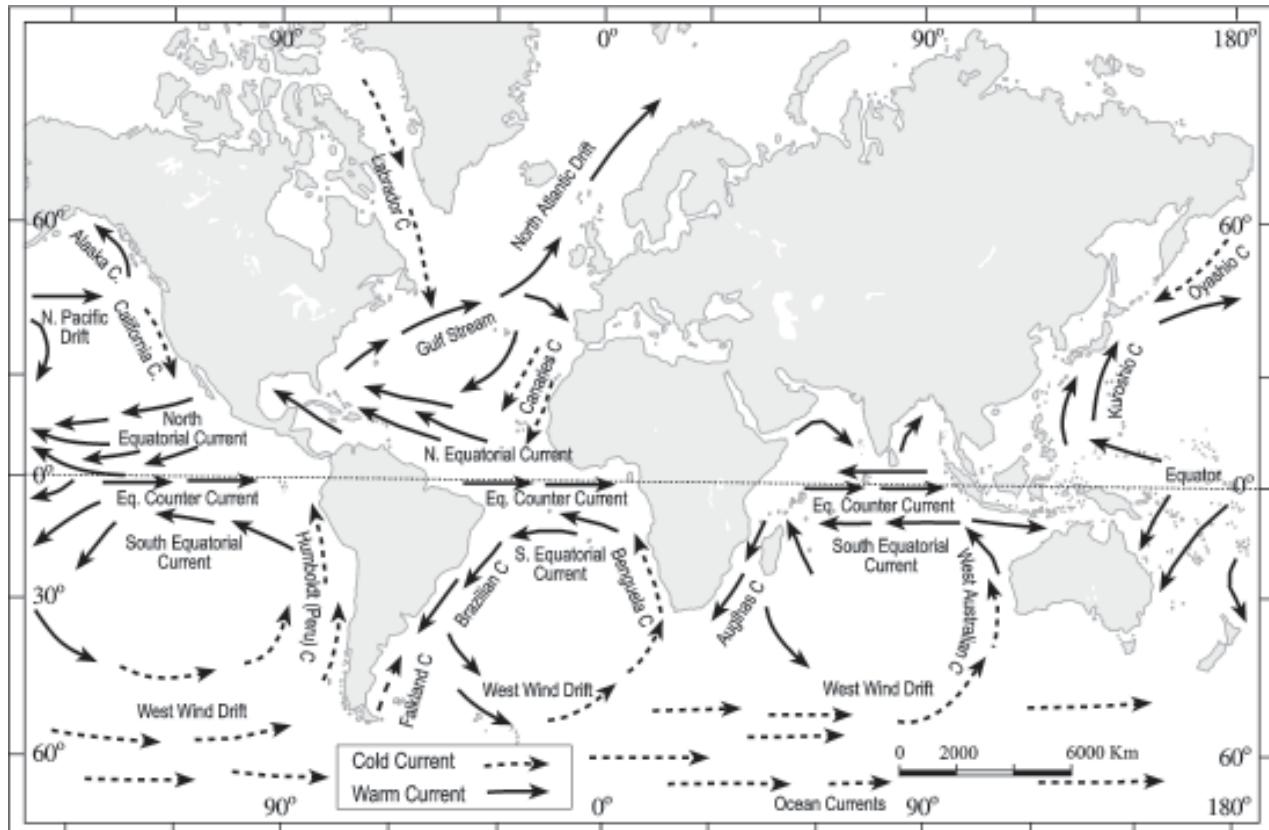


Fig. 14.3 : Major currents in the Pacific, Atlantic and Indian oceans

where the wind flow is mostly cyclonic, the oceanic circulation follows this pattern. In regions of pronounced monsoonal flow, the monsoon winds influence the current movements. Due to the coriolis force, the warm currents from low latitudes tend to move to the right in the northern hemisphere and to their left in the southern hemisphere.

The oceanic circulation transports heat from one latitude belt to another in a manner similar to the heat transported by the general circulation of the atmosphere. The cold waters of the Arctic and Antarctic circles move towards warmer water in tropical and equatorial regions, while the warm waters of the lower latitudes move polewards. The major currents in the different oceans are shown in Figure 14.3.

Prepare a list of currents which are found in Pacific, Atlantic and Indian Oceans.

How is the movement of currents influenced by prevailing winds? Give some examples from Figure 14.3.

Effects of Ocean Currents

Ocean currents have a number of direct and indirect influences on human activities. West coasts of the continents in tropical and subtropical latitudes (except close to the equator) are bordered by cool waters. Their average temperatures are relatively low with a narrow diurnal and annual ranges. There is fog, but generally the areas are arid. West coasts of the continents in the middle and higher latitudes are bordered by warm waters which cause a distinct marine climate. They are characterised by cool summers and relatively mild winters with a narrow annual range of temperatures. Warm currents flow parallel to the east coasts of the continents in tropical and subtropical latitudes. This results in warm and rainy climates. These areas lie in the western margins of the subtropical anti-cyclones. The mixing of warm and cold currents help to replenish the oxygen and favour the growth of plankton, the primary food for fish population. The best fishing grounds of the world exist mainly in these mixing zones.

EXERCISES

1. Multiple choice questions.

- (i) Upward and downward movement of ocean water is known as the :
 - (a) tide (c) wave
 - (b) current (d) none of the above
- (ii) Spring tides are caused :
 - (a) As result of the moon and the sun pulling the earth gravitationally in the same direction.
 - (b) As result of the moon and the sun pulling the earth gravitationally in the opposite direction.
 - (c) Indention in the coast line.
 - (d) None of the above.
- (iii) The distance between the earth and the moon is minimum when the moon is in :
 - (a) Aphelion (c) Perihelion
 - (b) Perigee (d) Apogee
- (iv) The earth reaches its perihelion in:
 - (a) October (c) July
 - (b) September (d) January

2. Answer the following questions in about 30 words.

- (i) What are waves?
- (ii) Where do waves in the ocean get their energy from?
- (iii) What are tides?
- (iv) How are tides caused?
- (v) How are tides related to navigation?

3. Answer the following questions in about 150 words.

- (i) How do currents affect the temperature? How does it affect the temperature of coastal areas in the N. W. Europe?
- (ii) What are the causes of currents?

Project Work

- (i) Visit a lake or a pond and observe the movement of waves. Throw a stone and notice how waves are generated. Draw the diagram of a wave and measure its length, distance and amplitude and record them in your note.
- (ii) Take a globe and a map showing the currents of the oceans. Discuss why certain currents are warm or cold and why they deflect in certain places and examine the reasons.

UNIT IV

NATURAL HAZARDS AND DISASTERS: CAUSES, CONSEQUENCES AND MANAGEMENT

This unit deals with

- *Floods and droughts*
- *Earthquakes and tsunami*
- *Cyclones*
- *Landslides*

NATURAL HAZARDS AND DISASTERS

You might have read about tsunami or seen the images of horror on television set immediately after it happened. You may also be aware of the severe earthquake in Kashmir on both sides of the Line of Control (LOC). The damage caused to human life and properties during these episodes has moved us all. What are these as phenomena and how they are caused? How can we save ourselves? These are some questions which come to our minds. This chapter will attempt to analyse some of these questions.

Change is the law of nature. It is a continuous process that goes on uninterruptedly involving phenomena, big and small, material and non-material that make our physical and socio-cultural environment. It is a process present everywhere with variations in terms of magnitude, intensity and scale. Change can be a gradual or slow process like the evolution of landforms and organisms and it can be as sudden and swift as volcanic eruptions, tsunamis, earthquakes and lightening, etc. Similarly, it may remain confined to a smaller area occurring within a few seconds like hailstorms, tornadoes and dust storms, and it can also have global dimensions such as global warming and depletion of the ozone layer.

Besides these, changes have different meanings for different people. It depends upon the perspective one takes while trying to understand them. From the perspective of nature, changes are value-neutral (these are neither good nor bad). But from the human perspective, these are value-loaded. There are some changes that are desirable and good like

the change of seasons, ripening of fruits, while there are others like earthquakes, floods and wars that are considered bad and undesirable.

Observe the environment you live in and prepare a list of changes, which take place over a long period of time and those, which take place within a short period of time. Do you know why some changes are considered good and others bad? Prepare a list of changes, which you notice in your daily life and give reasons why some of these are considered good and others bad.

In this chapter, we will read about some of these changes, which are considered bad and have haunted humankind for a long time.

Disasters in general and natural disasters in particular, are some such changes that are always disliked and feared by humankind.

What is a Disaster?

“Disaster is an undesirable occurrence resulting from forces that are largely outside human control, strikes quickly with little or no warning, which causes or threatens serious disruption of life and property including death and injury to a large number of people, and requires therefore, mobilisation of efforts in excess of that which are normally provided by statutory emergency services”.

For a long time, geographical literature viewed disasters as a consequence of natural forces; and human beings were treated as innocent and helpless victims in front of the mighty forces of nature. But natural forces are

not the only causes of disasters. Disasters are also caused by some human activities. There are some activities carried by human beings that are directly responsible for disasters. Bhopal Gas tragedy, Chernobyl nuclear disaster, wars, release of CFCs (Chlorofluorocarbons) and increase of green house gases, environmental pollutions like noise, air, water and soil are some of the disasters which are caused directly by human actions. There are some other activities of human beings that accelerate or intensify disasters indirectly. Landslides and floods due to deforestation, unscientific land use and construction activities in fragile areas are some of the disasters that are the results of indirect human actions. Can you identify some other human activities going on in and around your neighbourhood and schools that can lead to disasters in the near future? Can you suggest some measures to prevent it? It is a common experience that human-made disasters have increased both in their numbers and magnitudes over the years and concerted efforts are on at various levels to prevent and minimise their occurrences. Though the success has been only nominal so far, it is possible to prevent some of these disasters created by human actions. As opposed to this, very little is possible to prevent natural disasters; therefore, the best way out is to emphasise on natural disaster mitigation and management. Establishment of National Institute of Disaster Management, India, Earth Summit at Rio de Janeiro, Brazil, 1992 and the World Conference on Disaster Management in May 1994 at Yokohama, Japan, etc. are some of the concrete steps towards this direction initiated at different levels.

Most often it is observed that scholars use disasters and natural hazards as interchangeable. Both are related phenomena, yet quite distinct from each other. Hence, it is necessary to distinguish between the two.

Natural Hazards are elements of circumstances in the Natural environment that have the potential to cause harm to people or property or both. These may be swift or permanent aspects of the respective environmental settings like currents in the oceans, steep slope and unstable structural

features in the Himalayas or extreme climatic conditions in deserts or glaciated areas.

As compared to natural hazards, *natural disasters are relatively sudden and cause large scale, widespread death, loss of property and disturbance to social systems and life over which people have a little or no control.* Thus, any event can be classed as disaster when the magnitude of destruction and damage caused by it is very high.

Generally, disasters are generalised experiences of people the world over, and no two disasters are similar and comparable to each other. Every disaster is unique in terms of the local socio-environmental factors that control it, the social response it generates, and the way each social group negotiates with it. However, the opinion mentioned above is indicative of three important things. Firstly, the magnitude, intensity, frequency and damages caused by natural disasters have increased over the years. Secondly, there is a growing concern among people the world over to deal with the menace created by these so that the loss of human life and property can be minimised. And finally, significant changes have taken place in the pattern of natural disasters over the years.

There has also been a change in the perception of natural disasters and hazards. Previously, hazards and disasters were seen as two closely associated and interrelated phenomena, i.e. areas prone to natural hazards, were more vulnerable to disasters. Hence, people avoided tampering with the delicate balance that existed in a given ecosystem. People avoided intensification of their activities in such areas and that is how disasters were less damaging. Technological power has given large capacity to human intervention in nature. Consequently, now, human beings tend to intensify their activities into disaster prone areas increasing their vulnerability to disasters. Colonisation of flood plains of most of the rivers and development of large cities and port-towns like – Mumbai and Chennai along the coast, and touching the shore due to high land values, make them vulnerable to the occurrence of cyclones, hurricanes and tsunamis.

These observations can also be corroborated by the data given in Table 7.1 showing the magnitude of deaths caused by twelve serious natural disasters in the past sixty years in different countries of the world.

It is evident from the table that natural disasters have caused widespread loss of life and property. Conceted efforts are on at various levels to take appropriate measures to deal with the situation. It is also being felt that the damages caused by natural disasters have global repercussions that are beyond the means and capabilities of individual nation-states to cope up with. Hence, this issue was raised at the U.N. General Assembly in 1989 and it was finally formalised at the *World Conference on Disaster Management* in May 1994 at Yokohama, Japan. This was subsequently called the *Yokohama Strategy and Plan of Action for a Safer World*.

CLASSIFICATION OF NATURAL DISASTERS

Human beings the world over have experienced disasters and have faced and lived with them. Now people are becoming aware and various steps have been initiated at different levels for mitigating the effects of disasters. Identification and classification of disasters is being considered as an effective and scientific step to deal promptly and efficiently with the disasters. Broadly, natural disasters can be classified under four categories (See Table 7.2).

India is one of those countries which has experienced most of the natural disasters mentioned in Table 7.2. Every year it loses thousands of lives and property worth millions of rupees due to these natural calamities. In the following section, some of

Table 7.1 : Top Twelve Natural Disasters Since 1948

Year	Location	Type	Deaths
1948	The Soviet Union (now Russia)	Earthquakes	110,000
1949	China	Floods	57,000
1954	China	Floods	30,000
1965	East Pakistan (now Bangladesh)	Tropical Cyclones	36,000
1968	Iran	Earthquakes	30,000
1970	Peru	Earthquakes	66,794
1970	East Pakistan (now Bangladesh)	Tropical Cyclones	500,000
1971	India	Tropical Cyclones	30,000
1976	China	Earthquakes	700,000
1990	Iran	Earthquakes	50,000
2004	Indonesia, Sri Lanka, India, etc.	Tsunamis	500,000*
2005	Pakistan, India	Earthquakes	70,000*

Source : United Nations Environmental Programme (UNEP), 1991

*News Report from National Institute for Disaster Management, Government of India, New Delhi

Table 7.2 : Classification of Natural Disasters

Atmospheric	Terrestrial	Aquatic	Biological
Blizzards	Earthquakes	Floods	Plants and Animals as colonisers (Locusts, etc.).
Thunderstorms	Volcanic Eruptions	Tidal Waves	Insects infestation— fungal, bacterial and viral diseases such as bird flu, dengue, etc.
Lightning	Landslides	Ocean Currents	
Tornadoes	Avalanches	Storm Surge	
Tropical Cyclone	Subsidence	Tsunami	
Drought	Soil Erosion		
Hailstorm			
Frost, Heat Wave or Loo.Cold Waves, etc.			

Yokohama Strategy and International Decade for Natural Disaster Reduction (IDNDR)
Yokohama Strategy and Plan of Action for a Safer World

All the member states of the United Nations and other states met at the **World Conference on Natural Disaster Reduction** in the city of Yokohama from May 23rd-27th 1994. It acknowledged that the impact of natural disasters in terms of human and economic losses has risen in recent years, and society, in general, has become vulnerable to natural disasters. It also accepted that these disasters affected the poor and disadvantaged groups the worst, particularly in the developing countries, which are ill-equipped to cope with them. Hence, the conference adopted the Yokohama strategy as a guide to rest of the decade and beyond, to mitigate the losses due to these disasters.

The resolution of the World Conference on Natural Disasters Reduction is as mentioned below:

- (i) It will note that each country has the sovereign responsibility to protect its citizens from natural disasters;
- (ii) It will give priority attention to the developing countries, particularly the least developed, land-locked countries and small-island developing states;
- (iii) It will develop and strengthen national capacities and capabilities and, where appropriate, national legislation for natural and other disaster prevention, mitigation and preparedness, including the mobilisation of non-governmental organisations and participation of local communities;
- (iv) It will promote and strengthen sub-regional, regional and international cooperation in activities to prevent, reduce and mitigate natural and other disasters, with particular emphasis on:
 - (a) human and institutional capacity-building and strengthening;
 - (b) technology sharing: the collection, the dissemination and utilisation of information; and
 - (c) mobilisation of resources.

It also declared the decade 1990-2000 as the *International Decade for Natural Disaster Reduction (IDNDR)*.

the highly devastating natural disasters have been discussed, particularly in the context of India.

NATURAL DISASTERS AND HAZARDS IN INDIA

It was discussed in one of the previous chapters that India is vast and diverse in terms of its physical and socio-cultural attributes. It is largely due to its vast geographical area, environmental diversities and cultural pluralities that scholars often described it using two meaningful adjectives like the 'Indian-subcontinent' and the 'land of unity in diversity'. Its vastness in terms of natural attributes combined with its prolonged colonial past, continuing various forms of social discriminations and also equally large population have enhanced its vulnerability to natural disasters. These observations can also be illustrated by focussing on some of the major natural disasters in India.

Earthquakes

Earthquakes are by far the most unpredictable and highly destructive of all the natural disasters. You have already learnt the causes

of earthquakes in your book *Fundamentals of Physical Geography* (NCERT, 2006). Earthquakes that are of tectonic origin have proved to be the most devastating and their area of influence is also quite large. These earthquakes result from a series of earth movements brought about by a sudden release of energy during the tectonic activities in the earth's crust. As compared to these, the earthquakes associated with volcanic eruption, rock fall, landslides, subsidence, particularly in the mining areas, impounding of dams and reservoirs, etc. have limited area of influence and the scale of damage.

It was mentioned in Chapter 2 of the book that the Indian plate is moving at a speed of one centimetre per year towards the north and northeastern direction and this movement of plates is being constantly obstructed by the Eurasian plate from the north. As a result of this, both the plates are said to be locked with each other resulting in accumulation of energy at different points of time. Excessive accumulation of energy results in building up of stress, which ultimately leads to the breaking up of the lock and the sudden release of energy causes

earthquakes along the Himalayan arch. Some of the most vulnerable states are Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and the Darjiling and subdivision of West Bengal and all the seven states of the northeast.



Figure 7.1 : A Damaged Building Due to an Earthquake

Apart from these regions, the central-western parts of India, particularly Gujarat (in 1819, 1956 and 2001) and Maharashtra (in 1967 and 1993) have also experienced some severe earthquakes. Earth scientists have found it difficult to explain the occurrence of earthquakes in one of the oldest, most stable and mature landmass of Peninsular block for a long time. Recently, some earth scientists have come up with a theory of emergence of a fault line and energy build-up along the fault line represented by the river Bhima (Krishna) near Latur and Osmanabad (Maharashtra) and the possible breaking down of the Indian plate (Figure 7.2).

National Geophysical Laboratory, Geological Survey of India, Department of Meteorology, Government of India, along with the recently formed *National Institute of Disaster Management*, have made an intensive analysis of more than 1,200 earthquakes that have occurred in India in different years in the past, and based on these, they divided India into the following five earthquake zones:

- (i) Very high damage risk zone
- (ii) High damage risk zone
- (iii) Moderate damage risk zone
- (iv) Low damage risk zone
- (v) Very low damage risk zone.

Out of these, the first two zones had experienced some of the most devastating earthquakes in India. As shown in the Figure 7.2,

areas vulnerable to these earthquakes are the North-east states, areas to the north of Darbhanga and Araria along the Indo-Nepal border in Bihar, Uttarakhand, Western Himachal Pradesh (around Dharamshala) and Kashmir Valley in the Himalayan region and the Kuchchh (Gujarat). These are included in the Very High Damage Risk Zone. Similarly, the remaining parts of Jammu and Kashmir, Himachal Pradesh, Northern parts of Punjab, Eastern parts of Haryana, Delhi, Western Uttar Pradesh, and Northern Bihar fall under the High Damage Risk Zone. Remaining parts of the country fall under moderate to very Low Damage Risk Zone. Most of the areas that can be considered safe are from the stable landmass covered under the Deccan plateau.

Socio-Environmental Consequences of Earthquakes

The idea of an earthquake is often associated with fear and horror due to the scale, magnitude and suddenness at which it spreads disasters on the surface of the earth without discrimination. It becomes a calamity when it strikes the areas of high density of population. It not only damages and destroys the settlements, infrastructure, transport and communication network, industries and other developmental activities but also robs the population of their material and socio-cultural gains that they have preserved over generations. It renders them homeless, which puts an extra-pressure and stress, particularly on the weak economy of the developing countries.

Effects of Earthquakes

Earthquakes have all encompassing disastrous effects on the area of their occurrence. Some of the important ones are listed in Table 7.3.

Table 7.3 : Effects of Earthquakes		
<i>On Ground</i>	<i>On Manmade Structures</i>	<i>On Water</i>
Fissures Settlements	Cracking Slidings	Waves Hydro-Dynamic Pressure Tsunami
Landslides Liquefaction Earth Pressure Possible Chain-effects	Overturning Buckling Collapse	Possible Chain-effects

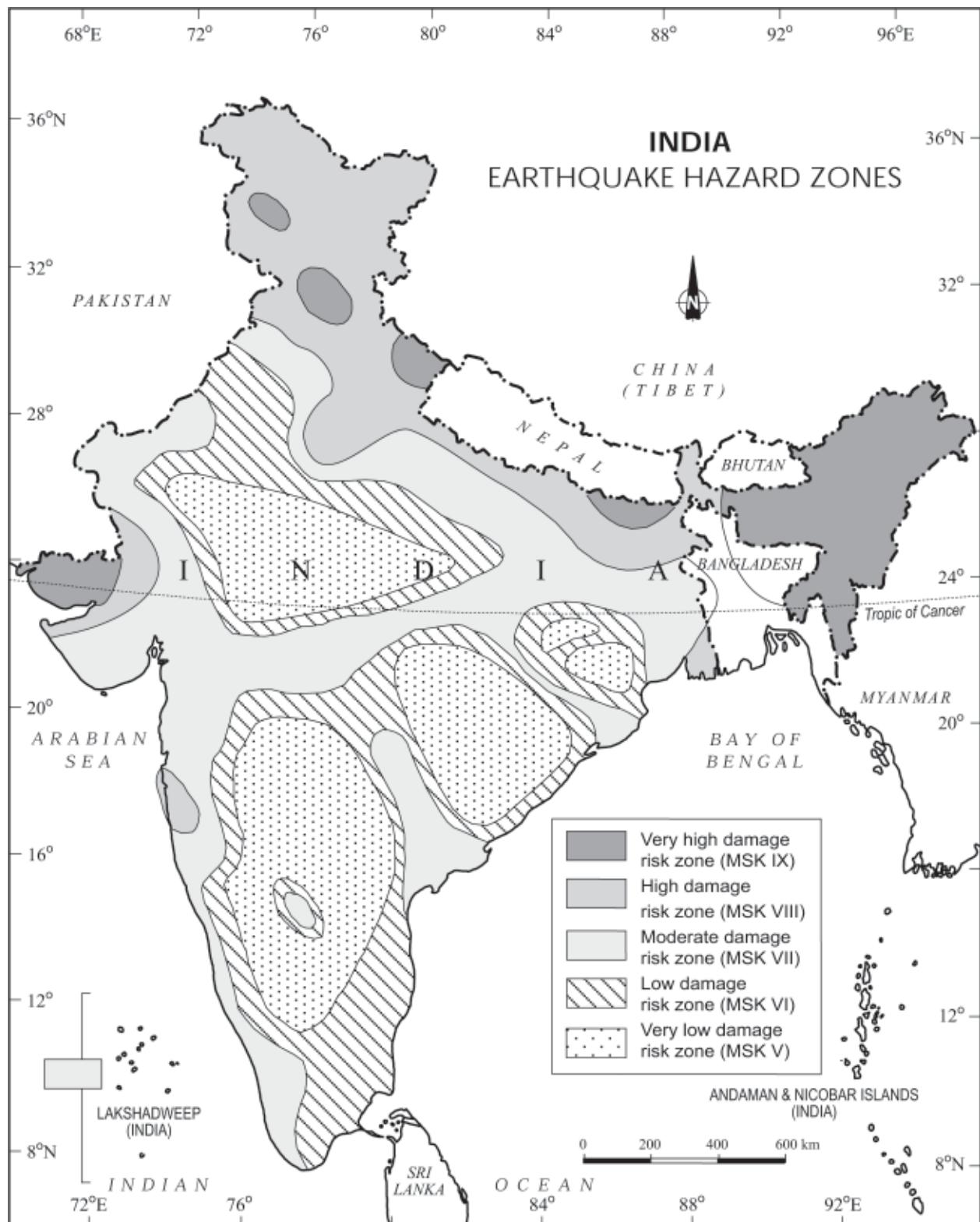


Figure 7.2 : India: Earthquake Hazard Zones

Apart from these, earthquakes also have some serious and far-reaching environmental consequences. Surface seismic waves produce fissures on the upper layers of the earth's crust through which water and other volatile materials gush out, inundating the neighbouring areas. Earthquakes are also responsible for landslides and often these cause obstructions in the flow of rivers and channels resulting in the formation of reservoirs. Sometimes, rivers also change their course causing floods and other calamities in the affected areas.

Earthquake Hazard Mitigation

Unlike other disasters, the damages caused by earthquakes are more devastating. Since it also destroys most of the transport and communication links, providing timely relief to the victims becomes difficult. It is not possible to prevent the occurrence of an earthquake; hence, the next best option is to emphasis on disaster preparedness and mitigation rather than curative measures such as:

- (i) Establishing earthquake monitoring centres (seismological centres) for regular monitoring and fast dissemination of information among the people in the vulnerable areas. Use of Geographical Positioning System (GPS) can be of great help in monitoring the movement of tectonic plates.
- (ii) Preparing a vulnerability map of the country and dissemination of vulnerability risk information among the people and educating them about the ways and means minimising the adverse impacts of disasters.
- (iii) Modifying the house types and building designs in the vulnerable areas and discouraging construction of high-rise buildings, large industrial establishments and big urban centres in such areas.
- (iv) Finally, making it mandatory to adopt earthquake-resistant designs and use light materials in major construction activities in the vulnerable areas.

Tsunami

Earthquakes and volcanic eruptions that cause the sea-floor to move abruptly resulting in sudden displacement of ocean water in the form of high vertical waves are called *tsunamis* (harbour waves) or seismic sea waves. Normally, the seismic waves cause only one instantaneous vertical wave; but, after the initial disturbance, a series of afterwaves are created in the water that oscillate between high crest and low trough in order to restore the water level.

The speed of wave in the ocean depends upon the depth of water. It is more in the shallow water than in the ocean deep. As a result of this, the impact of *tsunami* is less over the ocean and more near the coast where they cause large-scale devastations. Therefore, a ship at sea is not much affected by *tsunami* and it is difficult to detect a *tsunami* in the deeper parts of sea. It is so because over deep water the *tsunami* has very long wave-length and limited wave-height. Thus, a *tsunami* wave raises the ship only a metre or two and each rise and fall takes several minutes. As opposed to this, when a *tsunami* enters shallow water, its wave-length gets reduced and the period remains unchanged, which increases the wave-height. Sometimes, this height can be up to 15m or more, which causes large-scale destructions along the shores. Thus, these are also called *Shallow Water Waves*. *Tsunamis* are frequently observed along the Pacific ring of fire, particularly along the coast of Alaska, Japan, Philippines, and other islands of South-east Asia, Indonesia, Malaysia, Myanmar, Sri Lanka, and India etc.

After reaching the coast, the *tsunami* waves release enormous energy stored in them and water flows turbulently onto the land destroying port-cities and towns, structures, buildings and other settlements. Since the coastal areas are densely populated the world over, and these are also centres of intense human activity, the loss of life and property is likely to be much higher by a *tsunami* as compared to other natural hazards in the coastal areas. The extent of devastation caused by *tsunami* can be assessed through the

visuals on Banda Ache (Indonesia) presented in the book *Practical Work in Geography - Part I* (NCERT, 2006).

Unlike other natural hazards, the mitigation of hazards created by tsunami is difficult, mainly because of the fact that losses are on a much larger scale.



Figure 7.3 : Tsunami Affected Area

It is beyond the capacity of individual state or government to mitigate the damage. Hence, combined efforts at the international levels are the possible ways of dealing with these disasters as has been in the case of the tsunami that occurred on 26th December 2004 in which more than 300,000 people lost their lives. India has volunteered to join the *International Tsunami Warning System* after the December 2004 tsunami disaster.

Tropical Cyclone

Tropical cyclones are intense low-pressure areas confined to the area lying between 30° N and 30° S latitudes, in the atmosphere around which high velocity winds blow. Horizontally, it extends up to 500-1,000 km and vertically from surface to 12-14 km. A tropical cyclone or hurricane is like a heat engine that is energised by the release of latent heat on account of the condensation of moisture that the wind gathers after moving over the oceans and seas.

There are differences of opinion among scientists about the exact mechanism of a tropical cyclone. However, some initial conditions for the emergence of a tropical cyclone are:

- (i) Large and continuous supply of warm and moist air that can release enormous latent heat.
- (ii) Strong Coriolis force that can prevent filling of low pressure at the centre (absence of Coriolis force near the equator prohibits the formation of tropical cyclone between 0° - 5° latitude).
- (iii) Unstable condition through the troposphere that creates local disturbances around which a cyclone develops.
- (iv) Finally, absence of strong vertical wind wedge, which disturbs the vertical transport of latent heat.

Structure of Tropical Cyclone

Tropical cyclones are characterised by large pressure gradients. The centre of the cyclone is mostly a warm and low-pressure, cloudless core known as *eye of the storm*. Generally, the isobars are closely placed to each other showing high-pressure gradients. Normally, it varies between 14-17mb/100 km, but sometimes it can be as high as 60mb/100km. Expansion of the wind belt is about 10-150 km from the centre.

Spatio-temporal Distribution of Tropical Cyclone in India

Owing to its Peninsular shape surrounded by the Bay of Bengal in the east and the Arabian Sea in the west, the tropical cyclones in India also originate in these two important locations. Though most of the cyclones originate between 10° - 15° north latitudes during the monsoon season, yet in case of the Bay of Bengal, cyclones mostly develop during the months of October and November. Here, they originate between 16° - 2° N latitudes and to the west of 92° E. By July the place of origin of these storms shifts to around 18° N latitude and west of 90° E near the Sunderban Delta. Table 7.4 and Figure 7.4 show the frequency and tracks of time of cyclonic storms in India.

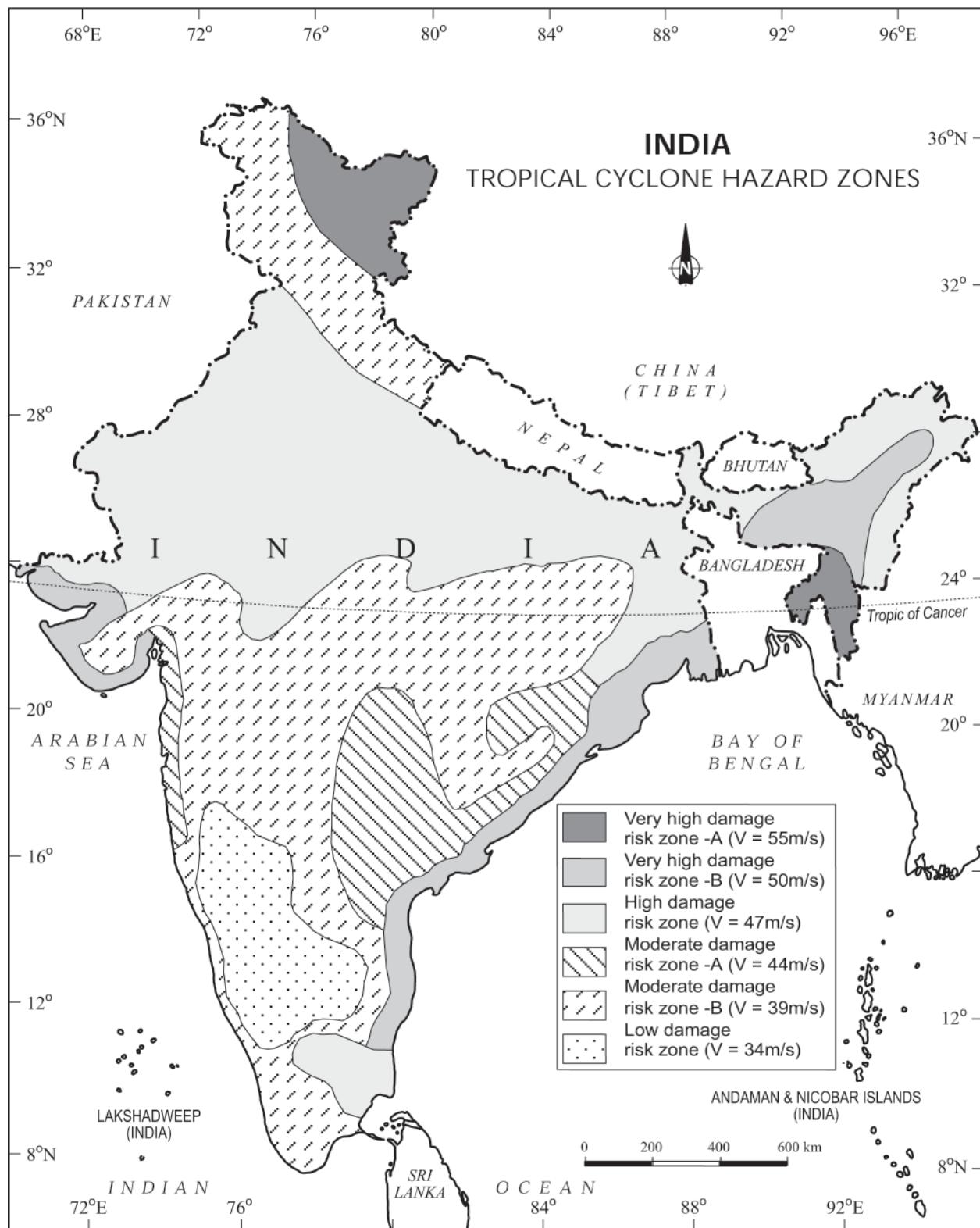


Figure 7.4 : Tropical Cyclone Hazard Zones

Months	<i>Bay of Bengal Sea</i>	<i>Arabian</i>
January	4 (1.3) *	2 (2.4)
February	1 (0.3)	0 (0.0)
March	4 (1.30)	0 (0.0)
April	18 (5.7)	5 (6.1)
May	28 (8.9)	13 (15.9)
June	34 (10.8)	13 (15.9)
July	38 (12.1)	3 (3.7)
August	25 (8.0)	1 (1.2)
September	27 (8.6)	4 (4.8)
October	53 (16.9)	17 (20.7)
November	56 (17.8)	21 (25.6)
December	26 (8.3)	3 (3.7)
Total	314 (100)	82 (100)

*Data in the brackets are in percentage to total number of storms taking place in a year

Consequences of Tropical Cyclones

It was mentioned that the energy to the tropical cyclone comes from the latent heat released by the warm moist air. Hence, with the increase in distance from the sea, the force of the cyclone decreases. In India, the force of the cyclone decreases with increase in distance from the Bay of Bengal and the Arabian Sea. So, the coastal areas are often struck by severe cyclonic storms with an average velocity of 180 km/h. Often, this results in abnormal rise in the sea level known as *Storm Surge*.

A surge is generated due to interaction of air, sea and land. The cyclone provides the driving force in the form of very high horizontal pressure-gradient and very strong surface winds. The sea water flows across the coast along with strong winds and heavy downpour.

This results in inundation of human settlements, agricultural fields, damaging crops and destruction of structures created by human beings.

Floods

You read in newspapers and watch images of floods on televisions occurring in some regions during rainy seasons. Inundation of land and human settlements by the rise of water in the channels and its spill-over presents the condition of flooding. Unlike other natural

disasters, the causes of floods are well-established. Floods are relatively slow in occurrences and often, occur in well-identified regions and within expected time in a year. Floods occur commonly when water in the form of surface run-off exceeds the carrying capacity of the river channels and streams and flows into the neighbouring low-lying flood plains. At times, this even goes beyond the capacity of lakes and other inland water bodies in which they flow. Floods can also be caused due to a storm surge (in the coastal areas), high intensity rainfall for a considerably longer time period, melting of ice and snow, reduction in the infiltration rate and presence of eroded material in the water due to higher rate of soil erosion. Though floods occur frequently over wide geographical area having disastrous ramifications in many parts of the world, floods in the South, Southeast and East Asian countries, particularly in China, India and Bangladesh, are frequent and equally disastrous.

Once again, unlike other natural disasters, human beings play an important role in the genesis as well as spread of floods. Indiscriminate deforestation, unscientific agricultural practices, disturbances along the natural drainage channels and colonisation of flood-plains and river-beds are some of the human activities that play an important role in increasing the intensity, magnitude and gravity of floods.



Figure 7.5 : Brahmaputra During Flood

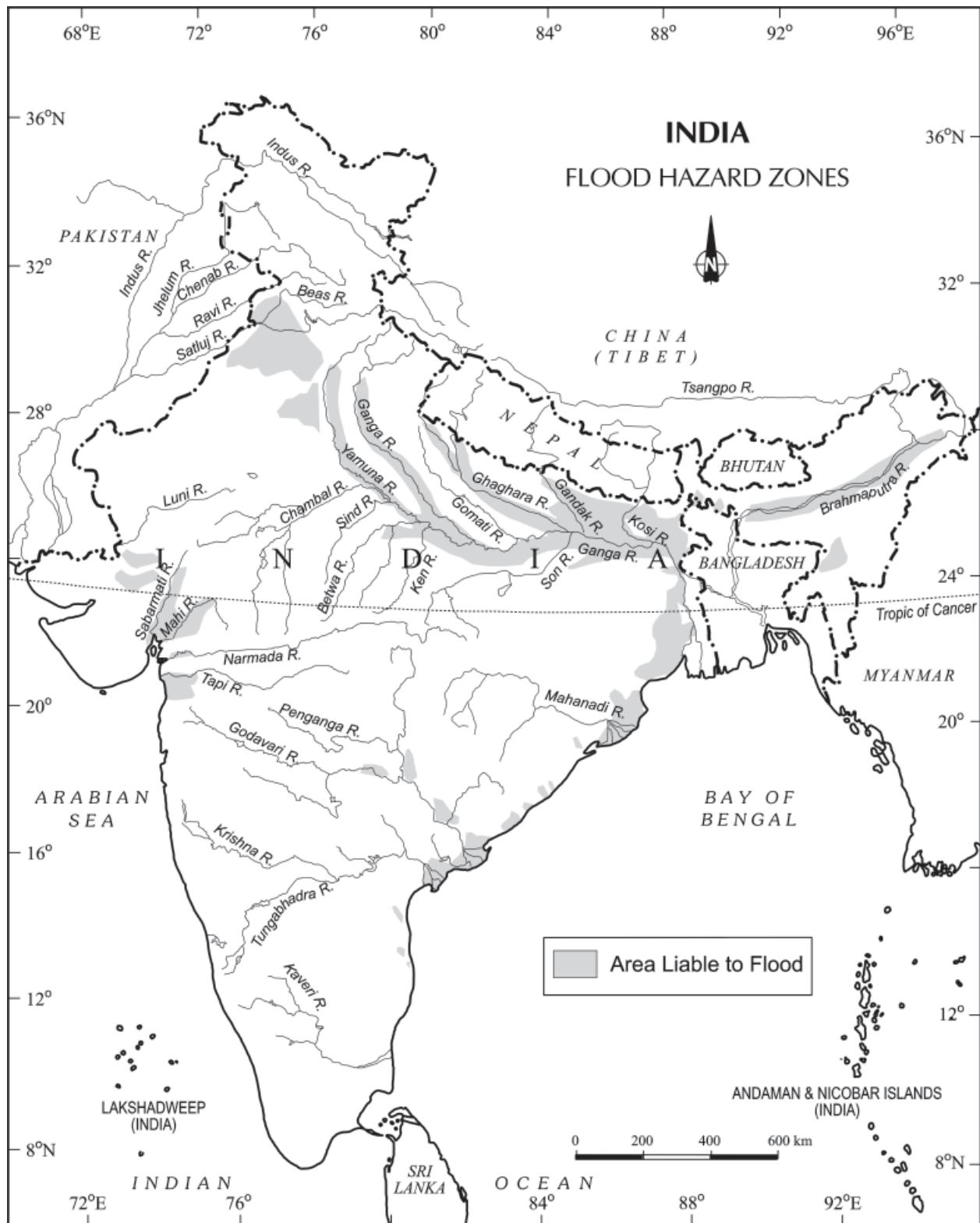


Figure 7.6 : Flood Hazard Zones

Various states of India face heavy loss of lives and property due to recurrent floods. *Rashtriya Barh Ayog* (National Flood Commission) identified 40 million hectares of land as flood-prone in India. The Figure 7.6 shows the flood-affected areas in India. Assam, West Bengal and Bihar are among the high flood-prone states of India. Apart from these, most of the rivers in the northern states like Punjab and Uttar Pradesh, are also vulnerable to occasional floods. It has been noticed that states like Rajasthan, Gujarat, Haryana and Punjab are also getting inundated in recent decades due to flash floods. This is partly because of the pattern of the monsoon and partly because of blocking of most of the streams and river channels by human activities. Sometimes, Tamil Nadu experiences flooding during November-January due to the retreating monsoon.

Consequence and Control of Floods

Frequent inundation of agricultural land and human settlement, particularly in Assam, West Bengal, Bihar and Eastern Uttar Pradesh (flooding rivers), coastal areas of Orissa, Andhra Pradesh, Tamil Nadu and Gujarat (cyclone) and Punjab, Rajasthan, Northern Gujarat and Haryana (flash floods) have serious consequences on the national economy and society. Floods do not only destroy valuable crops every year but these also damage physical infrastructure such as roads, rails, bridges and human settlements. Millions of people are rendered homeless and are also washed down along with their cattle in the floods. Spread of diseases like cholera, gastro-enteritis, hepatitis and other water-borne diseases spread in the flood-affected areas. However, floods also make a few positive contributions. Every year, floods deposit fertile silt over agricultural fields which is good for the crops. Majuli (Assam), the largest riverine island in the world, is the best example of good paddy crops after the annual floods in Brahmaputra. But these are insignificant benefits in comparison to the grave losses.

The Government of India as well as the state governments are well aware of the menace created by floods every year. How do these

governments generally respond to the floods? Construction of flood protection embankments in the flood-prone areas, construction of dams, afforestation and discouraging major construction activities in the upper reaches of most of the flood-creating rivers, etc. are some steps that need to be taken up on urgent basis. Removal of human encroachment from the river channels and depopulating the flood plains can be the other steps. This is particularly true in western and northern parts of the country which experience *flash-floods*. Cyclone centres may provide relief in coastal areas which are hit by a storm surge.

Droughts

The term 'drought' is applied to an extended period when there is a shortage of water availability due to inadequate precipitation, excessive rate of evaporation and over-utilisation of water from the reservoirs and other storages, including the ground water.

Drought is a complex phenomenon as it involves elements of meteorology like precipitation, evaporation, evapotranspiration, ground water, soil moisture, storage and surface run-off, agricultural practices, particularly the types of crops grown, socio-economic practices and ecological conditions.

Types of Droughts

Meteorological Drought : It is a situation when there is a prolonged period of inadequate rainfall marked with mal-distribution of the same over time and space.

Agricultural Drought : It is also known as soil moisture drought, characterised by low soil moisture that is necessary to support the crops, thereby resulting in crop failures. Moreover, if an area has more than 30 per cent of its gross cropped area under irrigation, the area is excluded from the drought-prone category.

Hydrological Drought : It results when the availability of water in different storages and reservoirs like aquifers, lakes, reservoirs, etc. falls below what the precipitation can replenish.

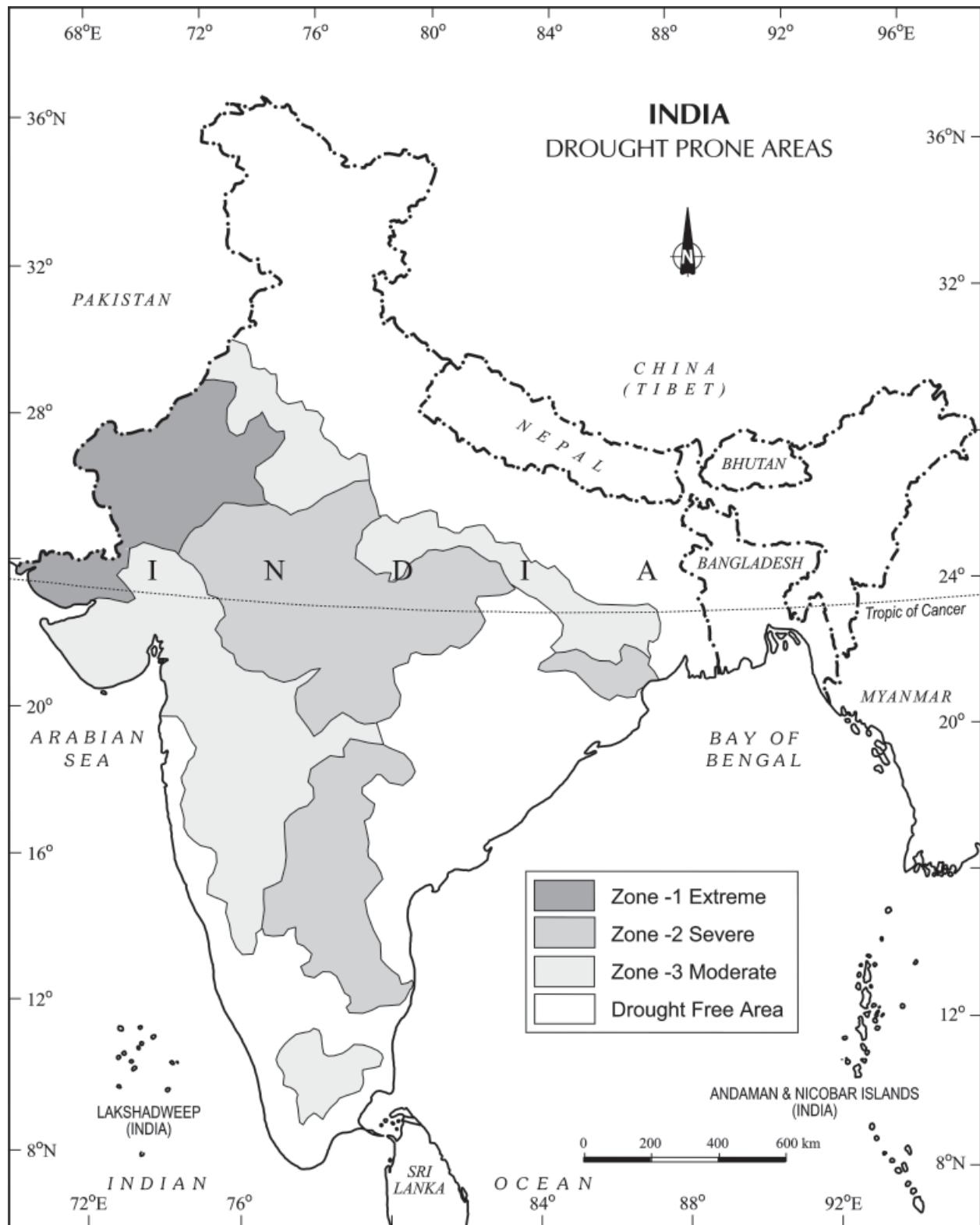
**Figure 7.8 : Drought Prone Areas**



Figure 7.7 : Drought

Ecological Drought : When the productivity of a natural ecosystem fails due to shortage of water and as a consequence of ecological distress, damages are induced in the ecosystem.

Various parts of India experience these droughts recurrently which result in some serious socio-economic and ecological problems.

Drought Prone Areas in India

Indian agriculture has been heavily dependent on the monsoon rainfall. Droughts and floods are the two accompanying features of Indian climate. According to some estimates, nearly 19 per cent of the total geographical area of the country and 12 per cent of its total population suffer due to drought every year. About 30 per cent of the country's total area is identified as drought prone affecting around 50 million people. It is a common experience that while some parts of the country reel under floods, there are regions that face severe drought during the same period. Moreover, it is also a common sight to witness that one region suffers due to floods in one season and experiences drought in the other. This is mainly because of the large-scale variations and unpredictability in the behaviour of the monsoon in India. Thus, droughts are widespread and common phenomena in most parts of the country, but these are most recurrent and severe in some and not so in others. On the basis of severity of droughts, India can be divided into the following regions:

Extreme Drought Affected Areas : It is evident from the Figure 7.8 that most parts of Rajasthan, particularly areas to the west of the Aravali hills, i.e. Marusthal and Kachchh regions of Gujarat fall in this category. Included here are also the districts like Jaisalmer and Barmer from the Indian desert that receive less than 90 mm average annual rainfall.

Severe Drought Prone Area : Parts of eastern Rajasthan, most parts of Madhya Pradesh, eastern parts of Maharashtra, interior parts of Andhra Pradesh and Karnataka Plateau, northern parts of interior Tamil Nadu and southern parts of Jharkhand and interior Orissa are included in this category.

Moderate Drought Affected Area : Northern parts of Rajasthan, Haryana, southern districts of Uttar Pradesh, the remaining parts of Gujarat, Maharashtra except Konkan, Jharkhand and Coimbatore plateau of Tamil Nadu and interior Karnataka are included in this category. The remaining parts of India can be considered either free or less prone to the drought.

Consequences of Drought

Droughts have cascading effects on various other aspects of environment and society. Crop failure leading to scarcity of food grains (*akal*), fodder (*trinkal*), inadequate rainfall, resulting in shortage of water (*jalkal*), and often shortage in all the three (*trikal*) is most devastating. Large-scale death of cattle and other animals, migration of humans and livestock are the most common sight to be seen in the drought-affected areas. Scarcity of water compels people to consume contaminated water resulting in spread of many waterborne diseases like gastro-enteritis, cholera, hepatitis, etc.

Droughts have both immediate as well as long-term disastrous consequences on the social and physical environments. Consequently, planning for drought has to take both aspects into consideration. Provision for the distribution of safe drinking water, medicines for the victims and availability of fodder and water for the cattle and shifting of the people and their livestock

to safer places, etc. are some steps that need to be taken immediately. Identification of ground water potential in the form of aquifers, transfer of river water from the surplus to the deficit areas, and particularly planning for inter-linking of rivers and construction of reservoirs and dams, etc. should be given a serious thought. Remote sensing and satellite imageries can be useful in identifying the possible river-basins that can be inter-linked and in identifying the ground water potential.

Dissemination of knowledge about drought-resistant crops and proper training to practise the same can be some of the long-term measures that will be helpful in drought-mitigation. Rainwater harvesting can also be an effective method in minimising the effects of drought.

Observe the methods adopted for roof-top rainwater harvesting in your locality and suggest measures to make it more effective.

Landslides

Have you ever read about the blocking of roads to Srinagar or disruption of rail services by stones falling on the Konkan Railway track? It happens due to landslide, which is the rapid sliding of large mass of bedrocks. Disasters due to landslides, are in general, far less dramatic than due to earthquakes, volcanic eruptions, tsunamis and cyclones but their impact on the natural environment and national economy is in no way less severe. Unlike other disasters that are sudden, unpredictable and are largely controlled by macro or regional factors, landslides are largely controlled by highly localised factors. Hence, gathering information and monitoring the possibilities of landslide is not only difficult but also immensely cost-intensive.

It is always difficult to define in a precise statement and generalise the occurrence and behaviour of a landslide. However, on the basis of past experiences, frequency and certain causal relationships with the controlling factors like geology, geomorphic agents, slope, land-use, vegetation cover and

human activities, India has been divided into a number of zones.

Landslide Vulnerability Zones

Very High Vulnerability Zone : Highly unstable, relatively young mountainous areas in the Himalayas and Andaman and Nicobar, high rainfall regions with steep slopes in the Western Ghats and Nilgiris, the north-eastern regions, along with areas that experience frequent ground-shaking due to earthquakes, etc. and areas of intense human activities, particularly those related to construction of roads, dams, etc. are included in this zone.

High Vulnerability Zone : Areas that have almost similar conditions to those included in the very high vulnerability zone are also included in this category. The only difference between these two is the combination, intensity and frequency of the controlling factors. All the Himalayan states and the states from the north-eastern regions except the plains of Assam are included in the high vulnerability zones.

Moderate to Low Vulnerability Zone : Areas that receive less precipitation such as Trans-Himalayan areas of Ladakh and Spiti (Himachal Pradesh), undulated yet stable relief and low precipitation areas in the Aravali, rain shadow areas in the Western and Eastern Ghats and Deccan plateau also experience occasional landslides. Landslides due to mining and

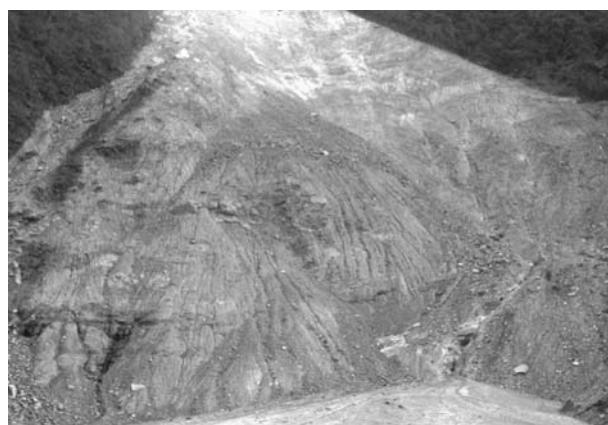


Figure 7.9 : Landslide

subsidence are most common in states like Jharkhand, Orissa, Chhattisgarh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Goa and Kerala.

Other Areas : The remaining parts of India, particularly states like Rajasthan, Haryana, Uttar Pradesh, Bihar, West Bengal (except district Darjiling), Assam (except district Karbi Anglong) and Coastal regions of the southern States are safe as far as landslides are concerned.

Consequences of Landslides

Landslides have relatively small and localised area of direct influence, but roadblock, destruction of railway lines and channel-blocking due to rock-falls have far-reaching consequences. Diversion of river courses due to landslides can also lead to flood and loss of life and property. It also makes spatial interaction difficult, risky as well as a costly affair, which, in turn, adversely affects the developmental activities in these areas.

Mitigation

It is always advisable to adopt area-specific measures to deal with landslides. Restriction on the construction and other developmental activities such as roads and dams, limiting agriculture to valleys and areas with moderate slopes, and control on the development of large settlements in the high vulnerability zones, should be enforced. This should be supplemented by some positive actions like promoting large-scale afforestation programmes and construction of bunds to reduce the flow of water. Terrace farming should be encouraged in the northeastern hill states where *Jhumming* (Slash and Burn/Shifting Cultivation) is still prevalent.

DISASTER MANAGEMENT

Disasters due to cyclones, unlike the ones caused by earthquakes, tsunamis and volcanic eruptions are more predictable in terms of the time and place of their occurrences. Moreover, with the help of development of techniques to monitor the behaviour of cyclones, their intensity, direction and magnitude, it has become possible to manage the cyclonic hazard

to some extent. Construction of cyclone-shelters, embankments, dykes, reservoirs and afforestation to reduce the speed of the winds are some of the steps that can help in minimising the damages. However, increase in the loss of life and property in countries like India, Bangladesh, Myanmar, etc. in successive storms is largely due to high vulnerability of their population residing in the coastal areas.

Disaster Management Bill, 2005

The Disaster Management Bill, 2005, defines disaster as a catastrophe, mishap, calamity or grave occurrence affecting any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, environment, and is of such nature or magnitude as to be beyond the coping capacity of the community of the affected area.

CONCLUSION

On the basis of the above discussion, it can be concluded that disasters can be natural or the results of human activities, and all hazards need not turn into disasters since it is difficult to eliminate disasters, particularly natural disasters. Then the next best option is mitigation and preparedness. There are three stages involved in disaster mitigation and management:

- (i) Pre-disaster management involves generating data and information about the disasters, preparing vulnerability zoning maps and spreading awareness among the people about these. Apart from these, disaster planning, preparedness and preventive measures are other steps that need to be taken in the vulnerable areas.
- (ii) During disasters, rescue and relief operations such as evacuation, construction of shelters and relief camps, supplying of water, food, clothing and medical aids etc. should be done on an emergency basis.
- (iii) Post-disaster operations should involve rehabilitation and recovery of victims. It

should also concentrate on capacity-building in order to cope up with future disasters, if any.

These measures have special significance to a country like India, which has about two-third of its geographical area and equal

proportion of its population, vulnerable to disasters. Introduction of the Disaster Management Bill, 2005 and establishment of National Institute of Disaster Management are some examples of the positive steps taken by the Government of India.

EXERCISES

1. Choose the right answer from the four alternatives given below.
 - (i) Which one of the following states of India experiences floods frequently?

(a) Bihar	(c) Assam
(b) West Bengal	(d) Uttar Pradesh
 - (ii) In which one of the following districts of Uttarakhand did Malpa Landslide disaster take place?

(a) Bageshwar	(c) Almora
(b) Champawat	(d) Pithoragarh
 - (iii) Which one of the following states receives floods in the winter months?

(a) Assam	(c) Kerala
(b) West Bengal	(d) Tamil Nadu
 - (iv) In which of the following rivers is the Majuli River Island situated?

(a) Ganga	(c) Godavari
(b) Brahmaputra	(d) Indus
 - (v) Under which type of natural hazards do blizzards come?

(a) Atmospheric	(c) Terrestrial
(b) Aquatic	(d) Biological
2. Answer the following questions in less than 30 words.
 - (i) When can a hazard become a disaster?
 - (ii) Why are there more earthquakes in the Himalayas and in the north-eastern region of India?
 - (iii) What are the basic requirements for the formation of a cyclone?
 - (iv) How are the floods in Eastern India different from the ones in Western India?
 - (v) Why are there more droughts in Central and Western India?
3. Answer the following questions in not more than 125 words.
 - (i) Identify the Landslide-prone regions of India and suggest some measures to mitigate the disasters caused by these.
 - (ii) What is vulnerability? Divide India into natural disaster vulnerability zones based on droughts and suggest some mitigation measures.
 - (v) When can developmental activities become the cause of disasters?

Project/Activity

Prepare a project report on any one of the topics given below.

- | | |
|-----------------------------------|--|
| (i) Malpa Landslide | (v) Tehri Dam/Sardar Sarovar |
| (ii) Tsunami | (vi) Bhuj/Latur Earthquakes |
| (iii) Orissa and Gujarat Cyclones | (vii) Life in a delta/riverine island |
| (iv) Inter-linking of rivers | (viii) Prepare a model of rooftop rainwater harvesting |

APPENDIX



STATES, THEIR CAPITALS, NUMBER OF DISTRICTS, AREA AND POPULATION

Sl. No.	State	Capital	No. of Districts	Area in sq. km	Population
1.	Andhra Pradesh	Hyderabad	23	2,75,060	7,57,27,541
2.	Arunachal Pradesh	Itanagar	14	83,743	10,91,117
3.	Assam	Dispur	23	78,438	2,66,38,407
4.	Bihar	Patna	37	94,163	8,28,78,796
5.	Chhattisgarh	Raipur	16	1,36,034	2,07,95,956
6.	Goa	Panji	02	3,702	13,43,998
7.	Gujarat	Gandhi Nagar	25	1,96,024	5,05,96,992
8.	Haryana	Chandigarh	19	44,212	2,10,82,982
9.	Himachal Pradesh	Shimla	12	55,673	60,77,248
10.	Jammu and Kashmir	Srinagar	14	2,22,236	1,00,69,917
11.	Jharkhand	Ranchi	18	79,714	2,69,09,428
12.	Karnataka	Bangalore	27	1,91,791	5,27,83,958
13.	Kerala	Tiruvananantapuram	14	38,863	3,18,38,619
14.	Madhya Pradesh	Bhopal	45	3,08,000	6,03,85,118
15.	Maharashtra	Mumbai	35	3,07,713	9,67,52,247
16.	Manipur	Imphal	9	22,327	23,88,634
17.	Meghalaya	Shillong	7	22,327	23,06,069
18.	Mizoram	Aizawl	8	21,081	8,91,058
19.	Nagaland	Kohima	8	16,579	19,88,636
20.	Orissa	Bhubaneshwar	30	1,55,707	3,67,06,920
21.	Punjab	Chandigarh	17	50,362	2,42,89,296
22.	Rajasthan	Jaipur	32	3,42,239	5,64,73,122
23.	Sikkim	Gangtok	04	7,096	5,40,493
24.	Tamil Nadu	Chennai	29	1,30,058	6,21,10,839
25.	Tripura	Agartala	04	10,49,169	31,91,168
26.	Uttaranchal	Dehra Dun	13	53,484	84,79,562
27.	Uttar Pradesh	Lucknow	70	2,38,566	16,60,52,859
28.	West Bengal	Kolkata	18	88,752	8,02,21,171

APPENDIX**UNION TERRITORIES, THEIR CAPITALS, AREA AND POPULATION**

Sl. No.	Union Territories	Capital	Area	Population
1.	Andaman and Nicobar Islands	Port Blair	8,249	3,56,152
2.	Chandigarh	Chandigarh	114	9,00,914
3.	Dadra and Nagar Haveli	Silvassa	491	2,20,490
4.	Daman and Diu	Daman	112	1,58,204
5.	NCT Delhi	* Delhi	1483	1,38,00000
6.	Lakshadweep	Kavaratti	32	60,595
7.	Pondicherry	**Pondicherry	492	9,73,829

Note : * Delhi has the status of National Capital Territory with a Legislative Assembly

** Pondicherry also has a Legislative Assembly

Source : *India-2005, A Reference Annual*, Publications Division, Ministry of Information and Broadcasting

APPENDIX



IMPORTANT RIVER BASINS

Rivers	Length (in km)	Catchment Area (sq. km) Potential Discharge in the River (km ³)	Average Annual Flow Excluding the Groundwater (km ³)	Estimated Utilisable
Indus (in India)	1,114	321,289	73.31	46.0
Ganga (in India)	2,525	861,452	525.02	250.0
Brahmaputra (in India)	916	194,413		
Barak and others		41,723		
Flowing to Meghna				
Sabarmati	371	21,674	3.81	1.99
Mahi	585	34,842	11.02	3.10
Narmada	1,312	98,796	45.64	34.30
Tapti	724	65,145	14.88	14.50
Brahmani and Baitarni	799+365	39,033+12,789	28.48	18.30
Mahanadi	851	141,589	66.88	49.99
Godavari	1,465	312,812	110.54	76.30
Krishna	1,401	258,948	78.12	58.00
Penner	597	55,213	6.32	6.86
Kaveri	800	81,155	21.36	19.00
Suvarnarekha	395	19,296	12.37	6.81
Total		2,528,084	1,869.35	690.31
{ Medium river basins flowing towards the east and west directions		248,505	255.02	59.03
Total		2,776,589	2,124.37	749.34

APPENDIX
IV
STATE/UNION TERRITORY WISE FOREST COVER

State/UT	Geographic Area	Forest Cover			
		Dense	Open	Total	Percent
Andhra Pradesh	275,069	25,827	18,810	44,637	16.23
Arunachal Pradesh	83,743	53,932	14,113	68,045	81.25
Assam	78,438	15,830	11,884	27,714	35.33
Bihar	94,163	3,372	2,348	5,720	6.07
Chhattisgarh	135,191	37,880	18,568	56,448	41.75
Delhi	1,483	38	73	111	7.51
Goa	3,702	1,785	310	2,095	56.59
Gujarat	196,022	8,673	6,479	15,152	7.73
Haryana	44,212	1,139	615	1,754	3.97
Himachal Pradesh	55,673	10,429	3,931	14,360	25.79
Jammu & Kashmir	222,236	11,848	9,389	21,237	9.56
Jharkhand	79,714	11,787	10,850	22,637	28.40
Karnataka	191,791	26,156	10,835	36,991	19.29
Kerala	38,863	11,772	3,788	15,560	40.04
Madhya Pradesh	308,245	44,384	32,881	77,265	25.07
Maharashtra	307,713	30,894	16,588	47,482	15.43
Manipur	22,327	5,710	11,216	16,926	75.81
Meghalaya	22,429	5,681	9,903	15,584	69.48
Mizoram	21,081	8,936	8,558	17,494	82.98
Nagaland	16,579	5,393	7,952	13,345	80.49
Orissa	155,707	27,972	20,866	48,838	31.36
Punjab	50,362	1,549	883	2,432	4.83
Rajasthan	342,239	6,322	10,045	16,367	4.78
Sikkim	7,096	2,391	802	3,193	45.00
Tamilnadu	130,058	12,499	8,983	21,482	16.52
Tripura	10,486	3,463	3,602	7,065	67.38
Uttar Pradesh	240,928	8,965	4,781	13,746	5.71
Uttaranchal	53,483	19,023	4,915	23,938	44.76
West Bengal	88,752	6,346	4,347	10,693	12.05
Andaman & Nicobar	8,249	6,593	337	6,930	84.01
Chandigarh	114	5	4	9	7.51
Dadra & Nagar Haveli	491	151	68	219	44.60
Daman & Diu	112	2	4	6	5.53
Lakshadweep	32	27	0	27	85.91
Pondicherry	480	35	1	36	7.45
Total	3,287,263	416,809	258,729	675,538	20.55

Source : State Forest Report, 2001

APPENDIX



NATIONAL PARKS OF INDIA

<i>State/UT</i>	<i>Area of State</i>	<i>National Parks (km²)</i>	<i>Area Covered (km²)</i>	<i>% of State Area</i>
Andhra Pradesh	275,068	4	373.23	0.14
Arunachal Pradesh	83,743	2	2290.82	2.74
Assam	78,438	5	1968.60	2.51
Bihar	94,163	1	335.65	0.36
Chhattisgarh	135,194	3	2929.50	2.17
Goa	3,702	1	107.00	2.89
Gujarat	196,024	4	480.11	0.24
Haryana	442,122	2	117.13	0.26
Himachal Pradesh	55,673	2	1429.40	2.57
Jammu and Kashmir	222,235	4	4680.25	2.11
Jharkhand	79,714	1	231.67	0.29
Karnataka	191,791	5	2435.14	1.27
Kerala	38,863	4	549.34	1.41
Madhya Pradesh	308,252	9	3656.36	1.19
Maharashtra	307,690	5	955.93	0.31
Manipur	22,327	1	40.00	0.18
Meghalaya	22,429	2	267.48	1.19
Mizoram	21,081	2	250.00	1.19
Nagaland	16,579	1	202.02	1.22
Orissa	155,707	2	990.70	0.64
Punjab	50,362	0	0.00	0.00
Rajasthan	342,239	5	4122.33	1.20
Sikkim	7,096	1	1784.00	25.14
Tamil Nadu	130,058	5	307.84	0.24
Tripura	10,486	0	0.00	0.00
Uttar Pradesh	240,926	1	490.00	0.20
Uttaranchal	53,485	6	4725.00	7.62
West Bengal	88,752	5	1693.25	1.91
Union Territories				
Andaman and Nicobar	8,249	9	1156.91	14.02
Chandigarh	114	0	0.00	0.00
Dadra and Nagar Haveli	491	0	0.00	0.00
Daman & Diu	112	0	0.00	0.00
Delhi	1,483	0	0.00	0.00
Lakshadweep	32	0	0.00	0.00
Pondicherry	493	0	0.00	0.00
India	3,287,263	92	38,569.66	1.17

Source: State Forest Report, 2001

GLOSSARY

Alluvial Plain : A level tract of land made up of alluvium or fine rock material brought down by a river.

Archipelago : A group of islands that lie in fairly close proximity.

Arid : Denoting any climate or region in which the rainfall is insufficient or barely sufficient to support vegetation.

Backwater : A stretch of water that has become bypassed by the main flow of a stream, although still joined to it. It has a very low rate of flow.

Bedrock : The solid rock lying beneath soil and weathered material.

Biosphere Reserve : These are multi-purpose protected areas, where every plant and animal size is to be protected in its natural habitat. Its major objectives are : (i) to conserve and maintain diversity and integrity of the natural heritage in its full form, i.e. physical environment, the flora and the fauna; (ii) to promote research on ecological conservation and other aspects of environment at preservation; (iii) to provide facilities for education, awareness and explaining.

Bunding : The practice of constructing embankments of earth or stone for conserving water and soil to increase crop production.

Calcareous : Composed of or containing a high proportion of calcium carbonate.

Catchment Area : The area drained by a major river and its tributaries.

Climate : The average weather conditions of a sizeable area of the earth's surface over a period of time (usually spread over a span of at least 30 years).

Coast : The boundary between land and sea. It includes the strip of land that borders the sea shore.

Coastal Plain : It is a flat low lying land between the coast and higher ground inland.

Conservation : The protection of natural environment and natural resources for the future. It includes the management of minerals, landscape, soil and forests to prevent their destruction and over exploitation.

Coral : It is a small calcium secreting marine polyp that occurs in colonies, mainly in warm shallow sea water. It forms the coral reefs.

Depression : In meteorology; it denotes an area of relatively low atmospheric pressure, which is found mainly in temperate regions. It is also used as synonym for temperate cyclones.

Estuary : The tidal mouth of a river where fresh and saline water get mixed.

Fauna : The animal life of a given area or time.

Fold : A bend in rock strata resulting from compression of an area of the earth's crust.

Glacier : A mass of snow and ice that moves slowly away from its place of accumulation carving gradually a broad and steepsided valley on its way.

Gneiss : A coarse grained metamorphic rock with a banded structure. It is formed by the large scale application of heat and pressure associated with mountain building and volcanic activity.

Gorge : A deep valley with steep and rocky side walls.

Gully Erosion : It is the erosion of the soil and rock by the concentration of runoff into gullies.

Humus : The dead organic content of the soil.

Island : A mass of land that is surrounded by water and is smaller than a continent.

Jet Stream : A very strong and steady westerly wind blowing just below the tropopause.

Lake : A body of water that lives in a hollow in the earth's surface and is entirely surrounded by land.

Landslide : A form of mass movement in which rock and debris moves rapidly downslope under the influence of gravity as a result of failure along a shear plane.

Meander : A pronounced curve or loop in the course of a river channel.

Monsoon : A complete reversal of winds over a large area leading to a change of seasons.

National Park : A National park is an area which is strictly reserved for the protection of the wildlife and where activities such as forestry, grazing or cultivation are not allowed.

Pass : A route through a mountain range which follows the line of a col or a gap.

Peninsula : A piece of land jutting out into the sea.

Plain : An extensive area of flat or gently undulating land.

Plateau : An extensive elevated area of relatively flat land.

Playa : The low flat central area of a basin of inland drainage. Playas occur in areas of low rainfall.

Protected Forest : An area notified under the provisions of Indian Forest Act or the State Forest Acts having limited degree of protection. In Protected Forests, all activities are permitted unless prohibited.

Rapids : A stretch of swift flowing water where a river bed suddenly becomes steeper due to the presence of hard rocks.

Reserved Forest : An area notified under the provisions of Indian Forest Act or the State Forest Acts having full degree of protection. In Reserved Forests, all activities are prohibited unless permitted.

Sanctuary : A sanctuary is an area, which is reserved for the conservation of animals only and operations such as harvesting of timber, collection of minor forest products are allowed so long as they do not affect the animals adversely.

Soil Profile : It is the vertical section of soil from the ground surface to the parent rock.

Subcontinent : A big geographical unit which stands out distinctly from the rest of the continent.

Terai : A belt of marshy ground and vegetation on the lower parts of the alluvial fans.

Tectonic : Forces originating within the earth and responsible for bringing widespread changes in the landform features.

Unclassed Forest : An area recorded as forest but not included in reserved or protected forest category. Ownership status of such forests varies from state to state.

8

Winds, Storms and Cyclones

Orissa was hit by a cyclone with wind speed of 200 km/h on 18 October 1999. The cyclone smashed 45,000 houses making 7,00,000 people homeless. On 29 October the same year, a second cyclone with wind speed of 260 km/h hit Orissa again. It was accompanied by water waves about 9 m high. Thousands of people lost their lives. Property worth crores of rupees was destroyed. The cyclone affected agriculture, transport, communication, and electricity supply.

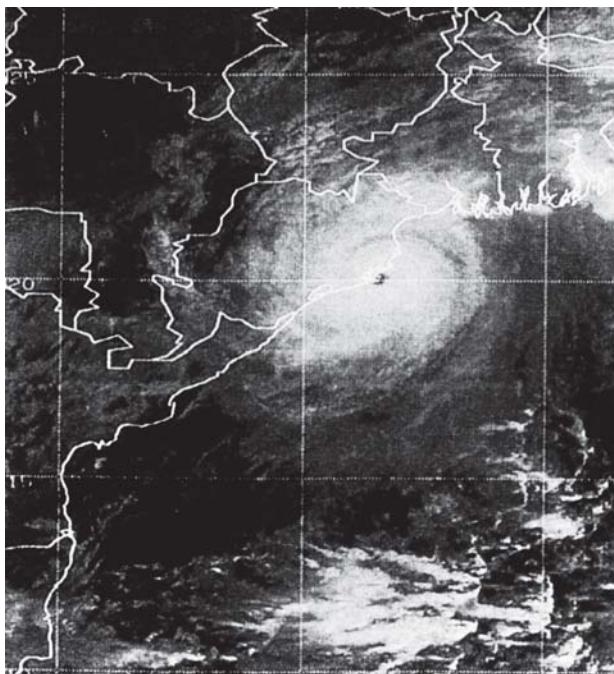


Fig. 8.1 Image taken by a satellite of a cyclone approaching the coast of Orissa

Courtesy: India Meteorological Department,
New Delhi

But, what are cyclones? How are they formed? Why are they so destructive? In this chapter we shall seek answers to some of these questions.

We begin with some activities involving air. These activities will clarify some basic features concerning a cyclone. Before we begin, remember that the moving air is called the **wind**.

8.1 AIR EXERTS PRESSURE

Activity 8.1

Whenever an activity involves heating, be very careful. It is advised that such activities are performed in the presence of an elderly person from your family. Or, carry out these activities in the presence of your teacher.

You need to boil water in the following activity.

Take a tin can with a lid. Fill it approximately half with water. Heat the can on a candle flame till the water boils. Let the water boil for a few minutes. Blow out the candle. Immediately put the lid tightly on the can. Be careful in handling the hot can. Put the can carefully in a shallow metallic vessel or a washbasin. Pour fresh water over the can. What happens to the shape of the can?

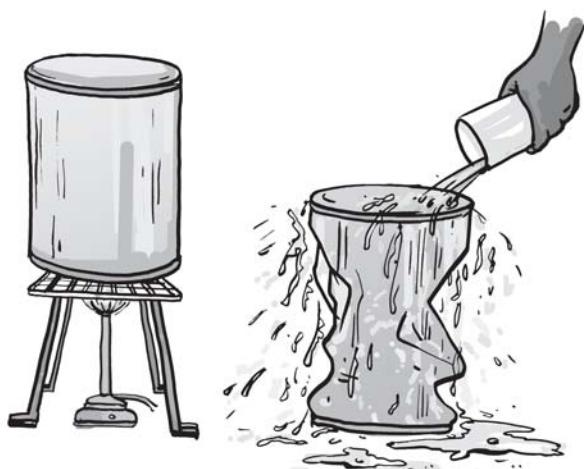


Fig. 8.2 Can with hot water being cooled

Can you guess why the shape of the can gets distorted?

If you cannot get a tin can, take a soft plastic bottle. Fill it with hot water. Empty the bottle and immediately cap it tightly. Place the bottle under running water.

Recall now some of your experiences.

When you fly a kite, does the wind coming from your back help?

If you are in a boat, is it easier to row it if there is wind coming from behind you?

Do you find it difficult to ride a bicycle against the direction of the wind?

You know that we have to fill air into the bicycle tube to keep it tight. Also, you know that a bicycle tube overfilled with air may burst. What is the air doing inside the tube?

Discuss with your friends how the air in the bicycle tube keeps it in shape.

All these experiences show that the air exerts pressure. It is due to this pressure that the leaves of trees, banners, or flags flutter when the wind

is blowing. You can list some more experiences which show that the air has pressure.

Let us now try to explain why the can (or the bottle) gets distorted. As water is poured over the can, some steam in the can condenses into water, reducing the amount of air inside. The pressure of air inside the can decreases than the pressure exerted by the air from outside the can. As a result the can gets compressed.

This activity again confirms that air exerts pressure.

8.2 HIGH SPEED WINDS ARE ACCOMPANIED BY REDUCED AIR PRESSURE

Activity 8.2



Fig. 8.3 Blowing into the bottle

Crumple a small piece of paper into a ball of size smaller than the mouth of an empty bottle. Hold the empty bottle on its side and place the paper ball just inside its mouth. Now try to blow on the ball to force it into the bottle. Try the activity with bottles of different sizes. Challenge your friends if they can force

the paper ball in by blowing into the bottle.

Paheli and Boojho are thinking about the following question:

Why is it difficult to force the paper ball into the bottle?

Activity 8.3

Blow the balloons

Take two balloons of approximately equal size. Put a little water into the



Fig. 8.4 Blowing between the balloons

balloons. Blow up both the balloons and tie each one to a string. Hang the balloons 8–10 cm apart on a cycle spoke or a stick. Blow in the space between the balloons.

What did you expect? What happens?

Try different ways of blowing on the balloons to see what happens.

Activity 8.4

Can you blow and lift?

Hold a strip of paper, 20 cm long and 3 cm wide, between your thumb and forefinger as shown in the Fig. 8.5. Now blow over the paper.

Paheli thinks that the strip will be lifted up. Boojho thinks that the strip will bend down.

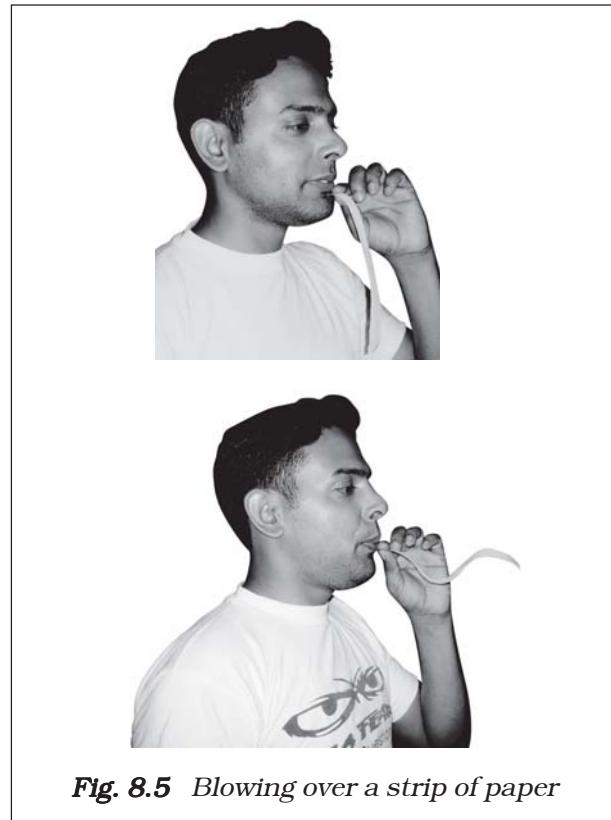


Fig. 8.5 Blowing over a strip of paper

What do you think will happen to the paper?

Let us try to understand the observations in Activities 8.2, 8.3 and 8.4.

Were the observations along the lines you thought? Do you get the feeling that the increased wind speed is accompanied by a reduced air pressure?

When we blow into the mouth of the bottle, the air near the mouth has higher speed. This decreases the pressure there. The air pressure inside the bottle is higher than near the mouth. The air inside the bottle pushes the ball out.

In Activity 8.3 you saw that when you blew between the balloons, they moved

towards each other. How could this happen? This could happen if the pressure of air between the balloons were somehow reduced. The pressure outside the balloons would then push them towards each other.

In Activity 8.4 you saw that when you blew over the paper strip, it went upwards. Again, this could happen if blowing over the paper reduced the air pressure above the strip.

We see that the **increased wind speed is, indeed, accompanied by a reduced air pressure**.

Can you imagine what would happen if high-speed winds blew over the roofs of buildings? If the roofs were weak, they could be lifted and blown away. If you have any such experience, share it with your friends.

Let us try to understand how winds are produced, how they bring rain and how they can be destructive sometimes.

You already know that when air moves, it is called wind. **Air moves from**

the region where the air pressure is high to the region where the pressure is low. The greater the difference in pressure, the faster the air moves. But how are the pressure differences created in nature? Is the difference in temperature involved? The following activities will help you to understand this.

8.3 AIR EXPANDS ON HEATING

Activity 8.5

Take a boiling tube. Stretch a balloon tightly over the neck of the tube. You can use a tape to make it tight. Pour some hot water in a beaker. Insert the boiling tube with the balloon in the hot water. Observe for 2–3 minutes for any change in shape of the balloon. Take the tube out, let it cool down to the room temperature. Take some ice-cold water in another beaker and place the tube with the balloon in cold water for 2–3 minutes. Observe the change in the shape of the balloon.

Think and try to answer:

What makes the balloon inflated when the boiling tube is placed in hot water?

Why is the same balloon deflated when the tube is kept in cold water?

Can we infer from the first observation that air expands on heating? Can you now state what happens to the air in the boiling tube when it cools down?



Balloon tied over the neck of the boiling tube

Boiling tube immersed in hot water

Boiling tube immersed in ice-cold water

Fig. 8.6 The shape of the balloon in hot and cold water

The next activity is very interesting. This will make you understand more about hot air.

Activity 8.6

Take two paper bags or empty paper cups of the same size. Hang the two bags in

CAUTION

Handle the burning candle carefully.

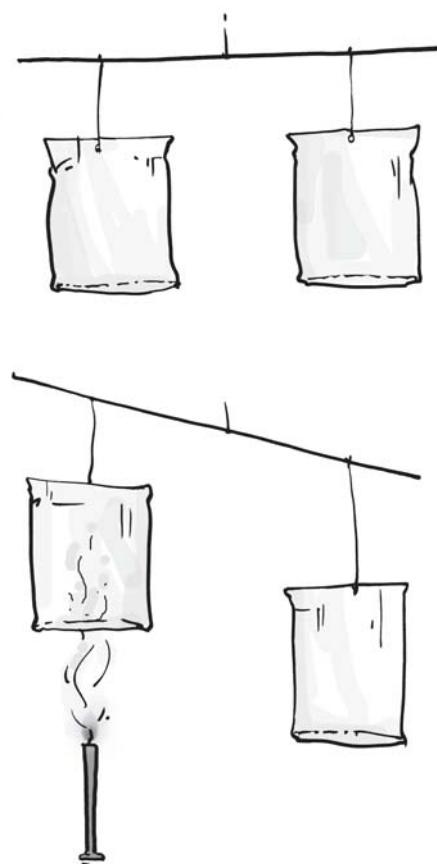


Fig. 8.7 Hot air rising up

the inverted position on the two ends of a metal or wooden stick.

Tie a piece of thread in the middle of the stick. Hold the stick by the thread (Fig. 8.7) as in a balance. Put a burning

candle below one of the bags as shown in the figure. Observe what happens.

Why is the balance of the bags disturbed?

Does this activity indicate that warm air rises up? As the warm air rises up, it pushes the bag above the candle. Does the disturbance of the balance suggest that the warm air is lighter than the cold air?

Can you now explain why smoke always rises up?

Also, it is important to remember that on heating the air expands and occupies more space. When the same thing occupies more space, it becomes lighter. **The warm air is, therefore, lighter than the cold air.** That is the reason that the smoke goes up.

In nature there are several situations, where warm air rises at a place. The air pressure at that place is lowered. The cold air from the surrounding areas rushes in to fill its place. This sets up convection in air, as you learnt in Chapter 4.

8.4 WIND CURRENTS ARE GENERATED DUE TO UNEVEN HEATING ON THE EARTH

These situations are:

(a) Uneven heating between the equator and the poles

You might have learnt in Geography that regions close to the equator get maximum heat from the Sun. The air in these regions gets warm. The warm air rises, and the cooler air from the

regions in the 0–30 degrees latitude belt on either side of the equator moves in. These winds blow from the north and the south towards the equator. At the poles, the air is colder than that at latitudes about 60 degrees. The warm air at these latitudes rises up and the cold wind from the polar regions rushes in, to take its place. In this way, wind circulation is set up from the poles to the warmer latitudes, as shown in Fig. 8.8.



Fig. 8.8 The wind flow pattern because of uneven heating on the earth



I wonder why the winds shown in the figure are not in the exact north-south direction.

The winds would have flown in the north-south direction from north to south, or from south to north. A change in direction is however, caused by the rotation of the earth.

(b) Uneven heating of land and water

You have read about the sea breeze and the land breeze in Chapter 4.

In summer, near the equator the land warms up faster and most of the time the temperature of the land is higher than that of water in the oceans. The air over the land gets heated and rises. This causes the winds to flow from the oceans towards the land. These are monsoon winds (Fig. 8.9).

The word monsoon is derived from the Arabic word 'mausam', which means 'season'.

In winter, the direction of the wind flow gets reversed; it flows from the land to the ocean (Fig. 8.10).



The winds from the oceans carry water and bring rain. It is a part of the water cycle.

The monsoon winds carry water and it rains.

Clouds bring rain and give us happiness. Farmers in our country depend mainly on rains for their harvests. There are many folk songs associated with clouds and rain. Sing and enjoy with your friends, if you know such a song. Here is one for you.

Roaring clouds across the sky
 Tell us that monsoon's here
 Dark and floating clouds then pour
 Raindrops every where.
 Clouds make lightning flash overhead
 And irrigate fields with rain
 Clouds make earth, its fragrance spread
 When wet with drops of rain.
 Rising from the ocean vast
 Clouds fill up with rain
 Rain to ocean, back at last
 To mingle with ocean again!

JULY — $\frac{0.5 \text{ Km.}}{1,600 \text{ Ft.}}$ a.s.l.

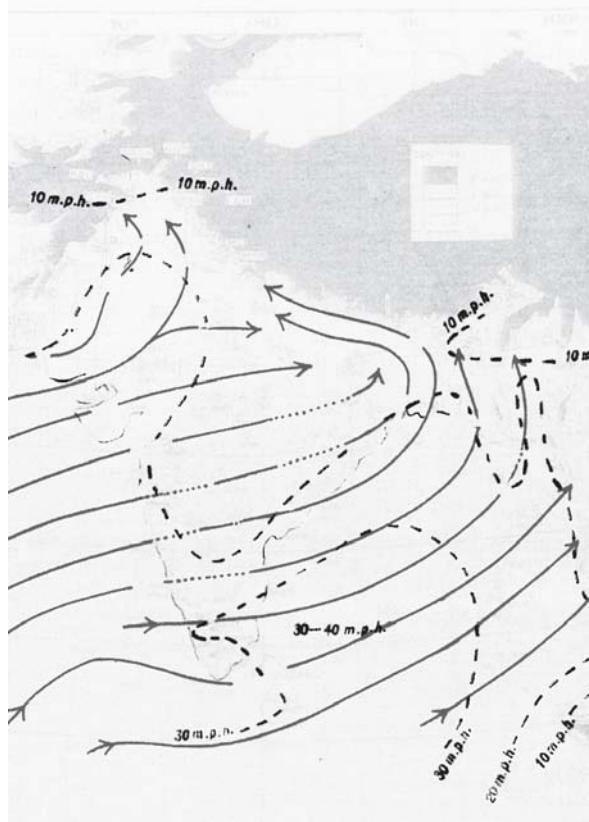


Fig. 8.9 Uneven heating of land especially the Rajasthan desert generates monsoon winds from **southwest** direction in **summer**. These winds carry lots of water from the Indian Ocean.

However, it is not always a happy ending. Rains often create problems.

Can you list some of the problems?

You can discuss the causes and solutions of the problems with your teacher and parents.

In nature itself there are certain situations that can sometimes create disasters and pose threat to humans, animals and plant life.

Let's study two such situations — **thunderstorms** and **cyclones**.

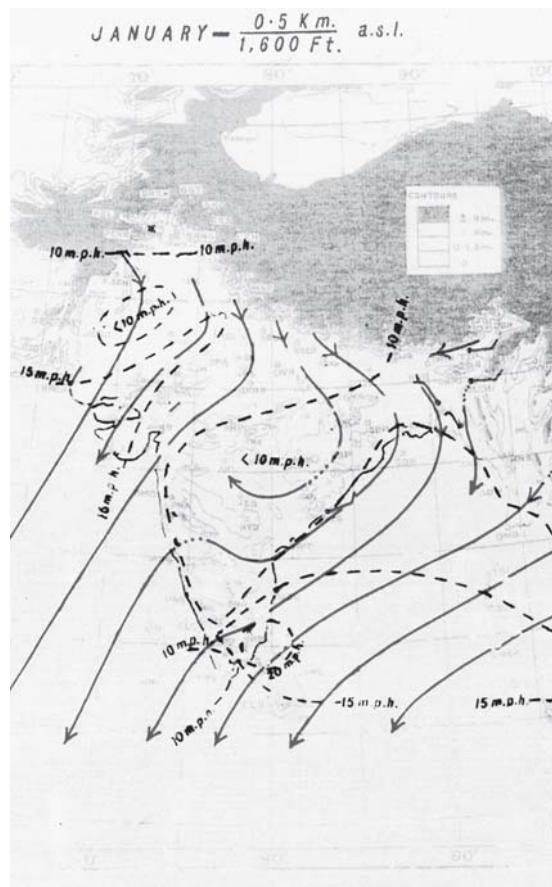


Fig. 8.10 Uneven heating of land and water in **winter** generate winds from the **northwest** colder land. These colder winds carry little water, hence bring small amount of rain in winter.

Courtesy: India Meteorological Department, New Delhi

8.5 THUNDERSTORMS AND CYCLONES

Thunderstorms develop in hot, humid tropical areas like India very frequently. The rising temperatures produce strong upward rising winds. These winds carry water droplets upwards, where they freeze, and fall down again. The swift movement of the falling water droplets along with the rising air create lightning and sound. It is this event that we call a **thunderstorm**. You will read about lightning in higher classes.

If a storm is accompanied by lightning, we must take the following precautions:

- Do not take shelter under an isolated tree. If you are in a forest take shelter under a small tree. Do not lie on the ground.
- Do not take shelter under an umbrella with a metallic end.
- Do not sit near a window. Open garages, storage sheds, metal sheds are not safe places to take shelter.
- A car or a bus is a safe place to take shelter.
- If you are in water, get out and go inside a building.

How a thunderstorm becomes a cyclone

You know that water requires heat when it changes from liquid to vapour state. Does the water give back heat when vapour condenses into liquid? Can you recall any experience to support this?

Structure of a cyclone

The centre of a cyclone is a calm area. It is called the **eye** of the storm. A large cyclone is a violently rotating mass of air in the atmosphere, 10 to 15 km high. The diameter of the eye varies from 10 to 30 km (Fig. 8.11). It is a region free of clouds and has light winds. Around this calm and clear eye (Fig. 8.12), there is a cloud region of about 150 km in size. In this region there are high-speed winds (150–250 km/h) and thick clouds with heavy rain. Away from this region the wind speed gradually decreases. The formation of a cyclone is a very complex process. A model is shown in Fig. 8.11.

Before cloud formation, water takes up heat from the atmosphere to change into vapour. When water vapour changes back to liquid form as raindrops, this heat is released to the atmosphere. The heat released to the atmosphere warms the air around. The air tends to rise and causes a drop in pressure. More air rushes to the centre of the storm. This cycle is repeated. The chain of events ends with the formation of a very low-pressure system with very high-speed winds revolving around it. It is this weather condition that we call a **cyclone**. Factors like wind speed, wind direction, temperature and humidity contribute to the development of cyclones.

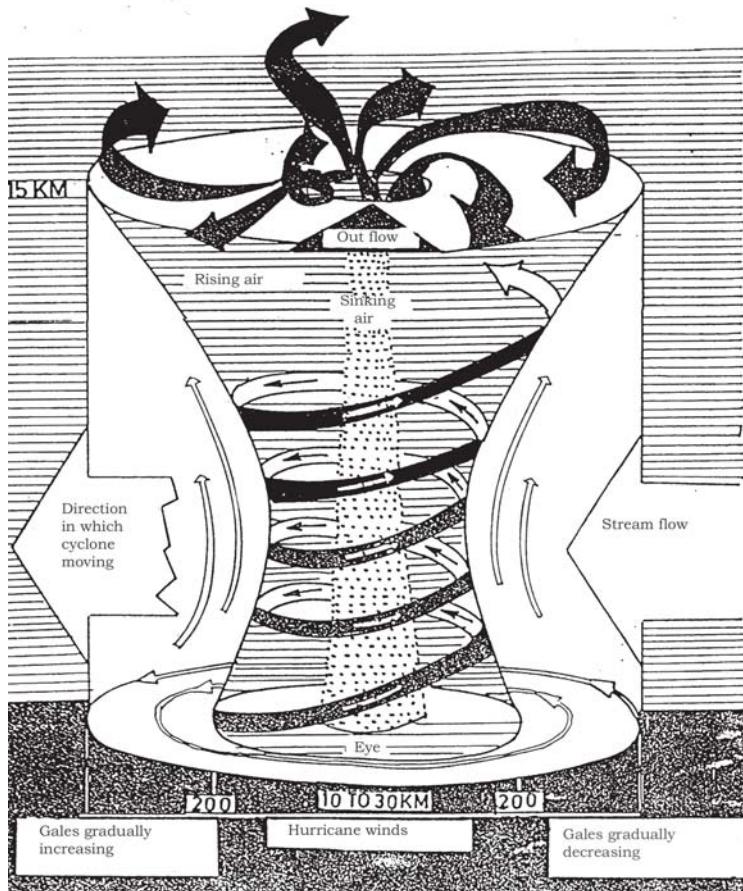


Fig. 8.11 Formation of a cyclone

Courtesy: India Meteorological Department, New Delhi

8.6 DESTRUCTION CAUSED BY CYCLONES

Cyclones can be very destructive. Strong winds push water towards the shore even if the storm is hundreds of kilometres away. These are the first indications of an approaching cyclone. The water waves produced by the wind are so powerful that a person cannot overcome them.

The low pressure in the eye lifts water surface in the centre. The rising water may be as high as 3–12 metres

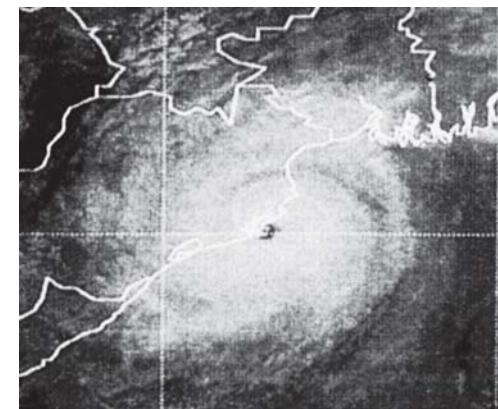


Fig. 8.12 The image of the 'eye' of a cyclone



Fig. 8.13 Rising water caused by a cyclone.

(Fig. 8.13). It appears like a water-wall moving towards the shore. As a result, the seawater enters the low-lying coastal areas, causing severe loss of life and property. It also reduces the fertility of the soil.

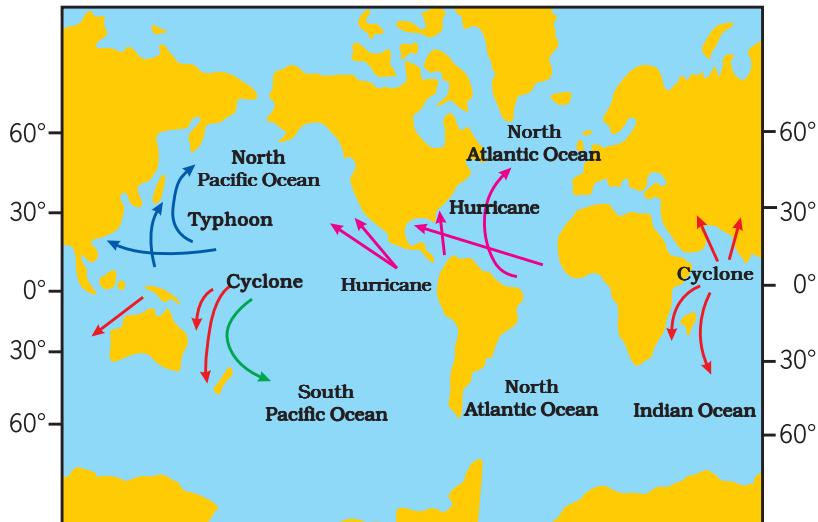
Continuous heavy rainfall may further worsen the flood situation.

High-speed winds accompanying a cyclone can damage houses, telephones and other communication systems, trees, etc., causing tremendous loss of life and property.

A cyclone is known by different names in different parts of the world. It is called a '**hurricane**' in the American continent. In Philippines and Japan it is called a '**typhoon**' (Fig. 8.14).

Fig. 8.14 Regions near the equator where cyclones form.

Cyclones are worldwide phenomena.



The diameter of a tornado can be as small as a metre and as large as a km, or even wider. The funnel of a tornado sucks dust, debris and everything near it at the base (due to low pressure) and throws them out near the top. Here are a few accounts of the survivors of tornados—(from Discovery channel's "Young Discovery Series").

"I saw the cloud coming and tried to take shelter inside. But as soon as I reached for the doorknob, the house took off into the sky. I was not hurt at all."

"After the storm we had to clean the debris from the wheat fields. We picked up splintered boards and tree branches as well as dead chickens with their feathers blown off and rabbits looked like they had been skinned."

A tornado shelter is a room situated deep inside or underground having no windows. Or otherwise it is better to shut windows and take shelter under a table, workbench, where debris cannot reach. One has to bow down on knees protecting head and neck using arms (Fig. 8.15).



Fig. 8.15 Protecting from a tornado

Tornadoes: In our country they are not very frequent. A tornado is a dark funnel shaped cloud that reaches from the sky to the ground (Fig. 8.16). Most of the tornadoes are weak. A violent tornado can travel at speeds of about 300 km/h. Tornadoes may form within cyclones.

The whole coastline of India is vulnerable to cyclones, particularly the east coast. The west coast of India is less vulnerable to cyclonic storms both in terms of intensity and frequency of the cyclones.

8.7 EFFECTIVE SAFETY MEASURES

- A cyclone forecast and warning service.
- Rapid communication of warnings to the



Fig. 8.16 Image of a tornado

[National Severe Storm Laboratory (NSSL)]
Courtesy: India Meteorological Department,
New Delhi

We have learnt that all storms are low-pressure systems. Wind speed plays an important role in the formation of storms. It is, therefore, important to measure the wind speed. The instrument that measures the wind speed is called an anemometer.

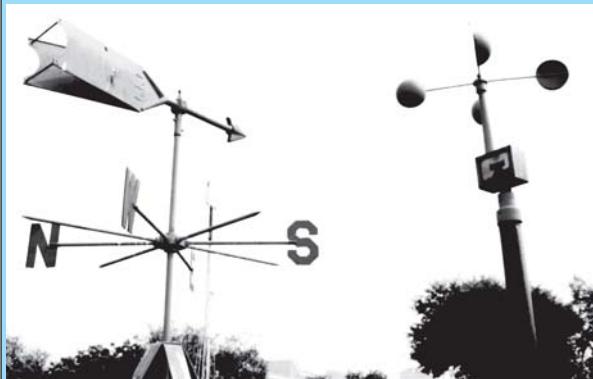


Fig. 8.17 An anemometer for measuring the speed of wind

Courtesy: India Meteorological Department,
New Delhi

Government agencies, the ports, fishermen, ships and to the general public.

- Construction of cyclone shelters in the cyclone prone areas, and Administrative arrangements for moving people fast to safer places.

Action on the part of the people

- We should not ignore the warnings issued by the meteorological department through TV, radio, or newspapers.
- We should —
 - make necessary arrangements to shift the essential household goods, domestic animals and vehicles, etc. to safer places;
 - avoid driving on roads through standing water, as floods may have damaged the roads; and
 - keep ready the phone numbers of all emergency services like police, fire brigade, and medical centres.

Some other precautions, if you are staying in a cyclone hit area —

- Do not drink water that could be contaminated. Always store drinking water for emergencies.
- Do not touch wet switches and fallen power lines.
- Do not go out just for the sake of fun.
- Do not pressurise the rescue force by making undue demands.
- Cooperate and help your neighbours and friends.

8.8 ADVANCED TECHNOLOGY HAS HELPED

These days we are better protected. In the early part of the last century, coastal

residents may have had less than a day to prepare or evacuate their homes from an oncoming cyclone. The world today is very different. Thanks to satellites and radars, a **Cyclone alert** or **Cyclone watch** is issued 48 hours in advance of any

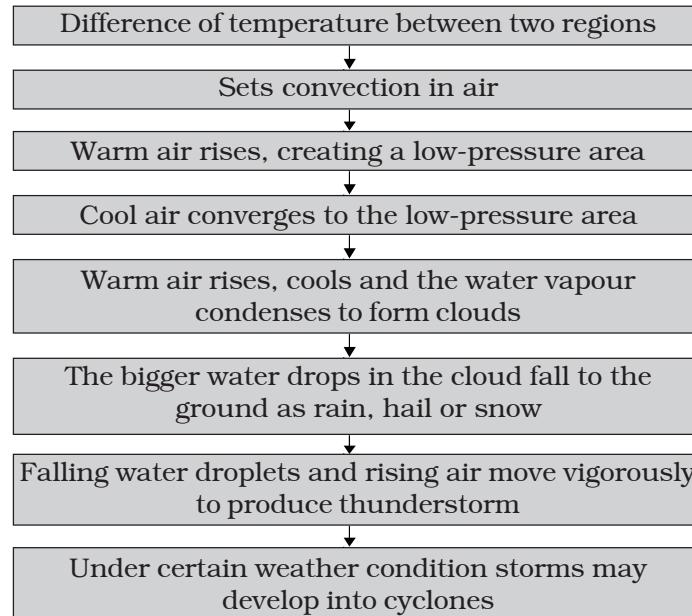
expected storm and a **Cyclone warning** is issued 24 hrs in advance. The message is broadcast every hour or half hour when a cyclone is nearer the coast. Several national and international organisations cooperate to monitor the cyclone-related disasters.

Keywords

Anemometer	Low pressure	Tornado
Cyclone	Monsoon winds	Typhoon
Hurricane	Pressure	Wind flow pattern
Lightning	Thunderstorms	

What you have learnt

- Air around us exerts pressure.
- Air expands on heating and contracts on cooling.
- Warm air rises up, whereas comparatively cooler air tends to sink towards the earth's surface.
- As warm air rises, air pressure at that place is reduced and the cooler air moves to that place.
- The moving air is called wind.
- Uneven heating on the earth is the main cause of wind movements.
- Winds carrying water vapour bring rain.
- High-speed winds and air pressure difference can cause cyclones.
- It has become easier to monitor cyclones with the help of advance technology like satellites and radars.
- Self-help is the best help. Therefore it is better to plan in advance and be ready with defence against any approaching cyclone.
- The following flow chart will help you to understand the phenomena that lead to the formation of clouds and falling of rain and creation of storms and cyclones:



Exercises

1. Fill the missing word in the blank spaces in the following statements:
 - (a) Wind is _____ air.
 - (b) Winds are generated due to _____ heating on the earth.
 - (c) Near the earth's surface _____ air rises up whereas _____ air comes down.
 - (d) Air moves from a region of _____ pressure to a region of _____ pressure.
2. Suggest two methods to find out wind direction at a given place.
3. State two experiences that made you think that air exerts pressure (other than those given in the text).
4. You want to buy a house. Would you like to buy a house having windows but no ventilators? Explain your answer.
5. Explain why holes are made in hanging banners and hoardings.
6. How will you help your neighbours in case cyclone approaches your village/town?
7. What planning is required in advance to deal with the situation created by a cyclone?
8. Which one of the following place is unlikely to be affected by a cyclone.

(i) Chennai	(ii) Mangaluru (Mangalore)
-------------	----------------------------

(iii) Amritsar

(iv) Puri

9. Which of the statements given below is correct?

- (i) In winter the winds flow from the land to the ocean.
- (ii) In summer the winds flow from the land towards the ocean.
- (iii) A cyclone is formed by a very high-pressure system with very high-speed winds revolving around it.
- (iv) The coastline of India is not vulnerable to cyclones.

Extended Learning — Activities and Projects

1. You can perform the Activity 8.5 in the chapter slightly differently at home. Use two plastic bottles of the same size. Stretch one balloon on the neck of each bottle. Keep one bottle in the sun and the other in the shade. Record your observations. Compare these observations and the result with those of Activity 8.5.
2. You can make your own anemometer.

Collect the following items:

4 small paper cups (used ice cream cups), 2 strips of cardboard (20cm long and 2cm wide), gum, stapler, a sketch pen and a sharpened pencil with eraser at one end.

Take a scale; draw crosses on the cardboard strips as shown in the Fig. 8.18. This will give you the centres of the strips.

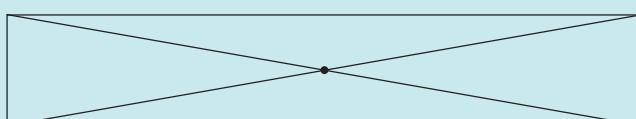


Fig. 8.18 Finding centre of the strips

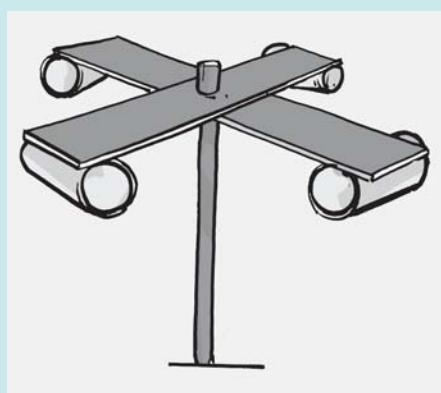


Fig. 8.19 A model of an anemometer

Fix the strips at the centre, putting one over the other so that they make a plus (+) sign. Now fix the cups at the ends of the strips. Colour the outer surface of one cup with a marker or a sketch pen. All the 4 cups should face in the same direction.

Push a pin through the centre of the strips and attach the strips and the cups to the eraser of the pencil. Check that the strips rotate freely when you blow on the cups. Your anemometer is ready. Counting the number of rotations per minute will give you an estimate of the speed of the wind. To observe the changes in the wind speed, use it at different places and different times of the day.

If you do not have a pencil with attached eraser you can use the tip of a ball pen. The only condition is that the strips should rotate freely.

Remember that this anemometer will indicate only speed changes. It will not give you the actual wind speed.

3. Collect articles and photographs from newspapers and magazines about storms and cyclones. Make a story on the basis of what you learnt in this chapter and the matter collected by you.
4. Suppose you are a member of a committee, which is responsible for creating **development plan** of a coastal state. Prepare a short speech indicating the measures to be taken to reduce the suffering of the people caused by cyclones.
5. Interview eyewitness to collect the actual experience of people affected by a cyclone.
6. Take an aluminium tube about 15 cm long and 1 to 1.5 cm in diameter. Cut slice of a medium-sized potato about 2 cm thick. Insert the tube in the slice, press it, and rotate it 2–3 times. Remove the tube. You will find a piece of potato fixed in the tube like a piston head. Repeat the same process with the other end of the tube. Now you have the tube with both ends closed by potato pieces with an air column in between. Take a pencil with one end unsharpened. Place this end at one of the pieces of potato. Press it suddenly to push the potato piece in the tube. Observe what happens. The activity shows rather dramatically how increased air pressure can push things.

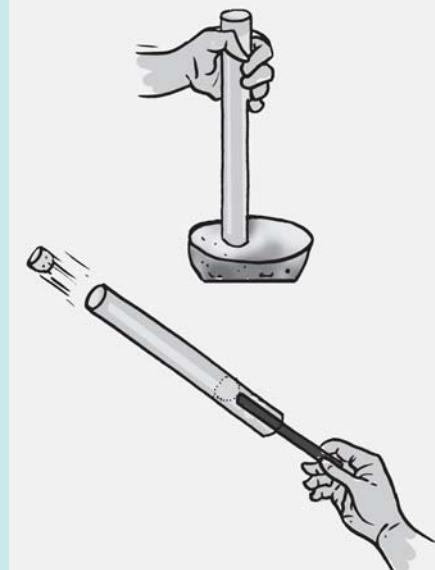


Fig. 8.20

CAUTION: When you perform this activity, make sure that nobody is standing in front of the tube.

You can read more on the related topics on the following websites:

<http://www.imd.gov.in/>

<http://library.thinkquest.org/10136/>

www.bom.gov.au/lam/students_teachers/cycmod.shtml

www.chunder.com/ski/lightanim.html

Did you know?

A bolt of lightning travels at a speed of more than 400,000 km/h. It can heat the air around it to a temperature which is more than 4 times the temperature of the surface of the sun. That is what makes lightning so dangerous.

CHAPTER 15

SOME NATURAL PHENOMENA

In Class VII you read about winds, storms and cyclones. You learnt that cyclones can cause a lot of damage to human life and property. You also learnt that we can protect ourselves from these destructive phenomena to some extent. In this chapter we shall discuss two other destructive natural phenomena. These are lightning and earthquakes. We shall also discuss what steps we can take to minimise destruction caused by these phenomena.

15.1 Lightning

You might have seen sparks on a electric pole when wires become loose. This phenomenon is quite common when a wind is blowing and shacking the wires. You might also have seen sparks when a plug is loose in its socket. Lightning is also an electric spark, but on a huge scale.

In ancient times people did not understand the cause of these sparks. They were, therefore, afraid of lightning and thought that the wrath of gods was visiting them. Now, of course, we understand that lightning is caused by the accumulation of charges in the clouds. We need not be afraid of lightning, but we have to take

precautions to protect ourselves from the deadly sparks.

The Sparks that the Greeks Knew About

The ancient Greeks knew as early as 600 B.C. that when amber (amber is a kind of resin) was rubbed with fur, it attracted light objects such as hair. You might have seen that when you take off woollen or polyester clothes, your hair stands on ends. If you take off these clothes in the dark, you see even a spark and hear crackling sound. In 1752 Benjamin Franklin, an American scientist, showed that lightning and the spark from your clothes are essentially the same phenomena. However, this realisation took 2000 years.

I wonder why they took so many years to realise the similarity.



Scientific discoveries are a result of hardwork by many people. It can sometime takes a long time.

We shall now study some properties of electric charges. We shall also see how they are related to the lightning in the sky.

Let us perform some activities to understand the nature of electric charges. But recall first what you might have played as a game. When you rub a plastic scale on your dry hair, the scale can attract very small pieces of paper.

15.2 Charging by rubbing

Activity 15.1

Take a used ballpen refill and rub it vigorously with a piece of polythene. Bring it close to small pieces of paper. Take care not to touch the rubbed end of the refill with your hand or with a metallic object. Repeat the activity with small pieces of dry leaf, husk and mustard seeds. Record your observations.

When a plastic refill is rubbed with polythene, it acquires a small electric charge. Similarly, when a plastic comb is rubbed with dry hair, it acquires a small charge. These objects are called **charged objects**. In the process of charging the refill and the plastic comb, polythene and hair also get charged.

Let's try to charge some other objects that are familiar to you.

Activity 15.2

Collect the objects and the materials listed in Table 15.1. Try to charge each by rubbing with the materials mentioned in the Table. Record your findings. You can add more items to the Table.

Table 15.1

Objects rubbed	Materials used for rubbing	Attracts/does not attract pieces of paper	Charged/not charged
Refill	Polythene, woollen cloth		
Balloon	Polythene, woollen cloth, dry hair		
Eraser	Wool		
Steel spoon	Polythene, woollen cloth		

15.3 Types of Charges and their Interaction

We will select some objects from Table 15.1 for the next activity.

Activity 15.3

- a) Inflate two balloons. Hang them in such a way that they do not touch each other (Fig. 15.1). Rub both the balloons with a woollen cloth and release them. What do you observe?

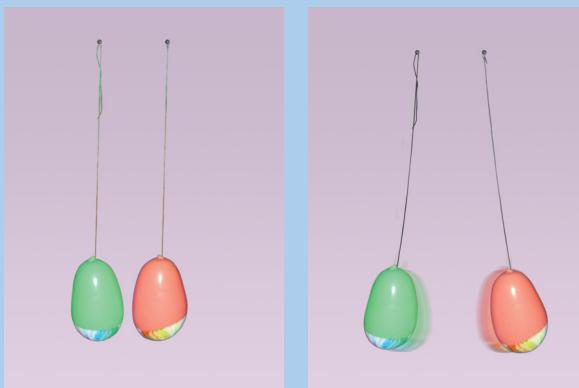


Fig. 15.1 : Like charges repel each other

Now let us repeat this activity with the used pen refills. Rub one refill with polythene. Place it carefully in a glass tumbler using the tumbler as a stand (Fig. 15.2). Rub the other



Fig. 15.2 : Interaction between like charges

refill also with polythene. Bring it close to the charged refill. Be careful not to touch the charged end with your hand. Is there any effect on the refill in the tumbler? Do the two attract each other, or repel each other?

In this activity we have brought close together the charged objects that were made of the same material. What happens if two charged objects made of different materials are brought close to each other? Let's find out.

- b) Rub a refill and place it gently in a glass tumbler as before (Fig. 15.3). Bring an inflated charged balloon near the refill and observe.



Fig. 15.3 : Unlike charges attract each other

Let's summarise the observations:

A charged balloon repelled a charged balloon.

A charged refill repelled a charged refill.

But a charged balloon attracted a charged refill.

Does it indicate that the charge on the balloon is of a different kind from the charge on the refill? Can we say then, that there are two kinds of

charges? Can we also say that the charges of the same kind repel each other, while charges of different kind attract each other?

It is a convention to call the charge acquired by a glass rod when it is rubbed with silk as positive. The other kind of charge is said to be negative.

It is observed that when a charged glass rod is brought near a charged plastic straw rubbed with polythene there is attraction between the two.

What do you think would be the kind of charge on the plastic straw? Your guess, that the plastic straw would carry a negative charge is correct.

The electrical charges generated by rubbing are static. They do not move by themselves. When charges move, they constitute an electric current. You have been reading about electric current since Class VI. The current in a circuit which makes a bulb glow, or the current that makes a wire hot, is nothing but a motion of charges.

15.4 Transfer of Charge

Activity 15.4

Take an empty jam bottle. Take a piece of cardboard slightly bigger in size than the mouth of the bottle. Pierce a hole in it so that a metal paper clip could be inserted. Open out paper clip as shown in Fig. 15.4. Cut two strips of aluminium foil about $4\text{ cm} \times 1\text{ cm}$ each. Hang them on the paper clip as shown. Insert the paper clip in the cardboard lid so that it is perpendicular to it (Fig. 15.4). Charge a refill and touch it

with the end of the paper clip. Observe what happens. Is there any effect on the foil strips? Do they repel each other or attract each other? Touch now, other charged bodies with the end of the paper clip. Do foil strips behave in the same way in all cases? Can this apparatus be used to detect whether a body is charged or not? Can you explain why the foil strips repel each other?



Fig 15.4 : A simple electroscope

The aluminium foil strips receive the same charge from the charged refill through the paper clip (remember that metals are good conductors of electricity). The strips carrying similar charges repel each other and they become wide open. Such a device can be used to test whether an object is carrying charge or not. This device is known as **electroscope**.

Thus, we find that electrical charge can be transferred from a charged object to another through a metal conductor.

Touch the end of the paper clip gently with hand and you will find a change in

the foil strips. They come back to their original state. Repeat charging of foil strips and touching the paper clip. Every time you will find that the foil strips collapse as soon as you touch the paperclip with hand. Why does it happen? The reason is that the foil strips lose charge to the earth through your body. We say that the foil strips are **discharged**. The process of transferring of charge from a charged object to the earth is called **earthing**.

Earthing is provided in buildings to protect us from electrical shocks due to any leakage of electrical current.

15.5 The Story of Lightning

It is now possible to explain lightning in terms of the charges produced by rubbing.

You learnt in Class VII that during the development of a thunderstorm, the air currents move upward while the water droplets move downward. These vigorous movements cause separation of charges. By a process, not yet completely understood, the positive charges collect near the upper edges of the clouds and the negative charges accumulate near the lower edges. There is accumulation of positive charges near the ground also. When the magnitude of the accumulated charges becomes very large, the air which is normally a poor conductor of electricity, is no longer able to resist their flow. Negative and positive charges meet, producing streaks of bright light and sound. We see streaks as lightning (Fig. 15.5). The process is called an electric discharge.

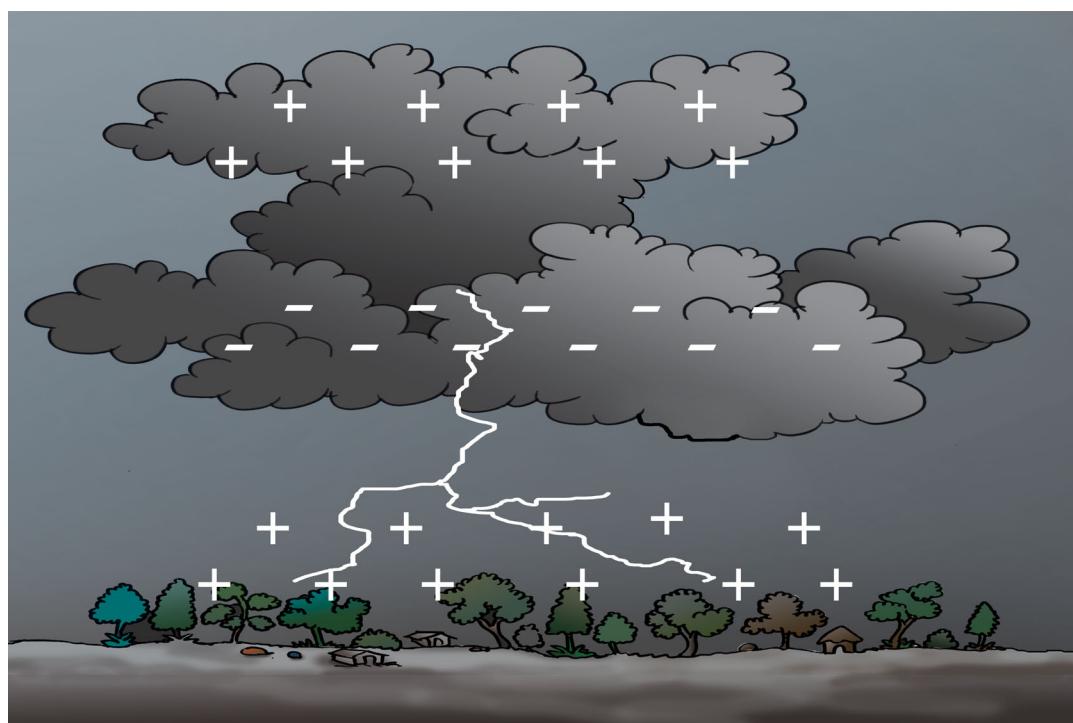


Fig 15.5 : Accumulation of charges leading to lightning.

The process of electric discharge can occur between two or more clouds, or between clouds and the earth. Today we need not get frightened by lightning like the ancient people did. Now we understand the basic phenomenon. Scientists are trying hard to improve our understanding. However, lightning strike could destroy life and property. It is, therefore, necessary to take measures to protect ourselves.

15.6 Lightning Safety

During lightning and thunderstorm no open place is safe.

- ⦿ Hearing thunder is an alert to rush to a safer place.
- ⦿ After hearing the last thunder, wait for some time before coming out of the safe place.

Finding a safe place

A house or a building is a safe place.

If you are travelling by car or by bus, you are safe inside with windows and doors of the vehicle shut.

Do's and Don'ts during a Thunder-storm

Outside

Open vehicles, like motorbikes, tractors, construction machinery, open cars are not safe. Open fields, tall trees, shelters in parks, elevated places do not protect us from lightning strokes.

Carrying umbrella is not a good idea at all during thunderstorms.

If in a forest, take shelter under shorter trees.

If no shelter is available and you are in an open field, stay far away from all trees. Stay away from poles or other

metal objects. Do not lie on the ground. Instead, squat low on the ground. Place your hands on your knees with your head between the hands (Fig. 15.6). This position will make you the smallest target to be struck.



Fig. 15.6 : Safe position during lightning

Inside the house

Lightning can strike telephone cords, electrical wires and metal pipes (Do you remember, lightning is an electrical discharge?). During a thunderstorm contact with these should be avoided. It is safer to use mobile phones and cordless phones. However, it is not wise to call up a person who is receiving your phone through a wired phone.

Bathing should be avoided during thunderstorms to avoid contact with running water.

Electrical appliances like computers, TVs, etc., should be unplugged. Electrical lights can remain on. They do not cause any harm.

Lightning Conductors

Lightning Conductor is a device used to protect buildings from the effect of lightning. A metallic rod, taller than the building, is installed in the walls of the building during its construction. One end of the rod is kept out in the air and the other is buried deep in the ground (Fig. 15.7). The rod provides easy route for the transfer of electric charge to the ground.

The metal columns used during construction, electrical wires and water pipes in the buildings also protect us to an extent. But do not touch them during a thunderstorm.

15.7 Earthquakes

You just learnt about thunderstorm and lightning. In Class VII you learnt about cyclones. These natural phenomena can cause large scale destruction of human life and property. Fortunately, these phenomena can be predicted to some extent. The weather department can warn about a thunderstorm developing in some area.

If a thunderstorm occurs there is always a possibility of lightning and cyclones accompanying it. So, we get time to take measures to protect ourselves from the damage caused by these phenomena.

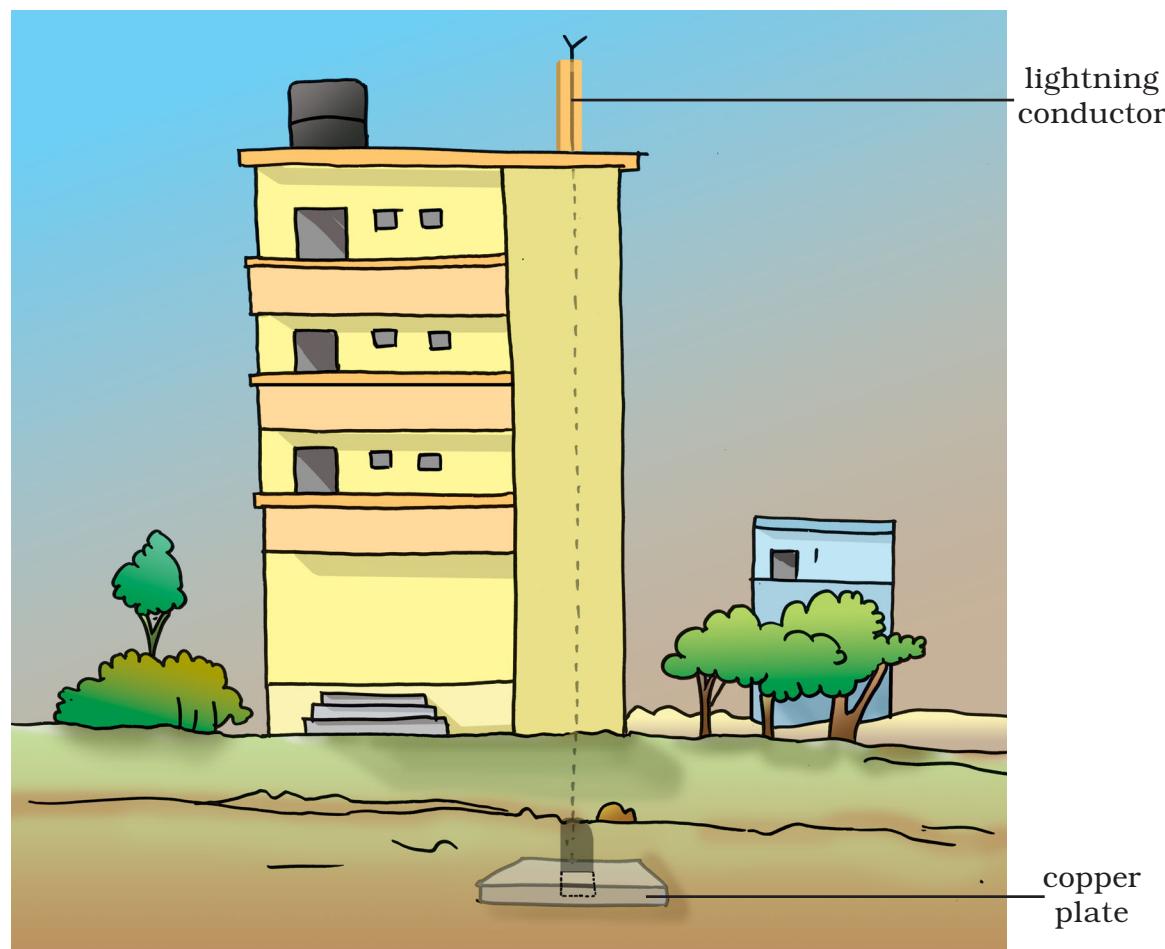


Fig. 15.7 : Lightning conductor

There is, however, one natural phenomenon which we are not yet able to predict. It is an earthquake. It can cause damage to human life and property on a huge scale.

A major earthquake occurred in India on 8th October 2005 in Uri and Tangdhar towns of North Kashmir (Fig. 15.8). Before that a major earthquake occurred on 26th January 2001 in Bhuj District of Gujarat.

Activity 15.5

Ask your parents about the huge damages to life and property caused by these earthquakes. Collect a few pictures showing the damage

caused by these earthquakes from newspapers and magazines of those days. Prepare a short report on the suffering of the people during the earthquakes.

What is an earthquake? What happens when it occurs? What can we do to minimise its effects? These are some of the questions which we shall discuss below.

What is an Earthquake?

An earthquake is a sudden shaking or trembling of the earth lasting for a very short time. It is caused by a disturbance deep inside the earth's crust.



Fig. 15.8 : Kashmir earthquake

Earthquakes occur all the time, all over the earth. They are not even noticed. Major earthquakes are much less frequent. They can cause immense damage to buildings, bridges, dams and people. There can be a great loss to life and property. The earthquakes can cause floods, landslides and tsunamis. A major tsunami occurred in the Indian Ocean on 26th December 2004. All the coastal areas around the ocean suffered huge losses.

Activity 15.6

Take an outline map of the world. Locate the eastern coast and Andaman and Nicobar Islands in India. Mark other countries around the Indian Ocean which could have suffered damage. Collect accounts of the devastation caused by the tsunami in India from your parents, or other elders in the family or in the neighbourhood.

What Causes an Earthquake?



My grandmother told me that the earth is balanced on the horn of a bull and when the bull shifts it to the other horn, an earthquake takes place. How could it be true?

In ancient times, people did not know the true cause of earthquakes. Their ideas were, therefore, expressed in mythical stories such as the one told by Boojho's grandmother. Similar myths were prevalent in other parts of the world.

What could cause a disturbance inside the earth?



Now we know that the tremors are caused by the disturbance deep down inside the uppermost layer of the earth called the crust (Fig. 15.9).

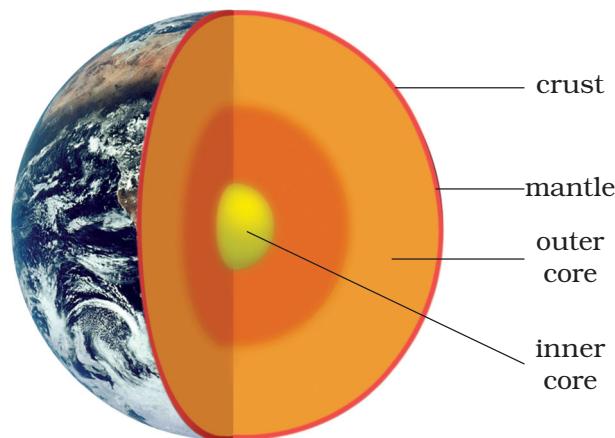


Fig. 15.9 : Structure of the earth

The outermost layer of the earth is not in one piece. It is fragmented. Each fragment is called a plate (Fig. 15.10). These plates are in continual motion. When they brush past one another, or

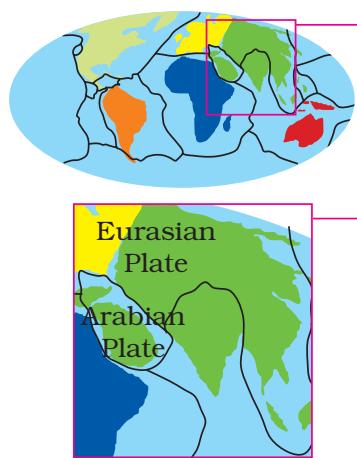


Fig. 15.10 : Earth plates

a plate goes under another due to collision (Fig. 15.11), they cause disturbance in the earth's crust. It is this disturbance that shows up as an earthquake on the surface of the earth.

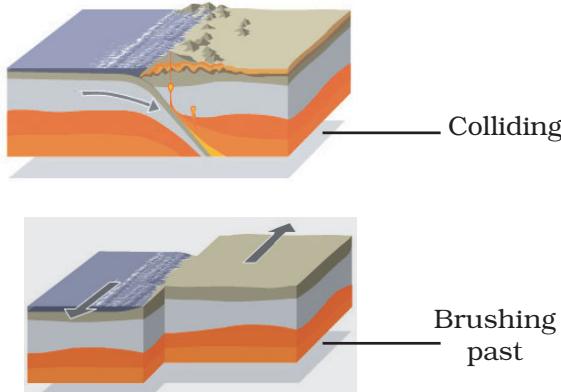


Fig. 15.11 : Movements of earth's plates



If scientists know so much about earthquakes, can they also predict when and where the next one will strike?

Although, we know for sure what causes an earthquake, it is not yet possible to predict when and where the next earthquake might occur.



I read somewhere that underground explosions could also cause tremors.

Tremors on the earth can also be caused when a volcano erupts, or a meteor hits the earth, or an underground nuclear explosion is

carried out. However, most earthquakes are caused by the movement of earth's plates.

Since earthquakes are caused by the movement of plates, the boundaries of the plates are the weak zones where earthquakes are more likely to occur. The weak zones are also known as **seismic** or **fault zones**. In India, the areas most threatened are Kashmir, Western and Central Himalayas, the whole of North-East, Rann of Kutch, Rajasthan and the Indo - Gangetic Plane. Some areas of South India also fall in the danger zone (Fig. 15.12).

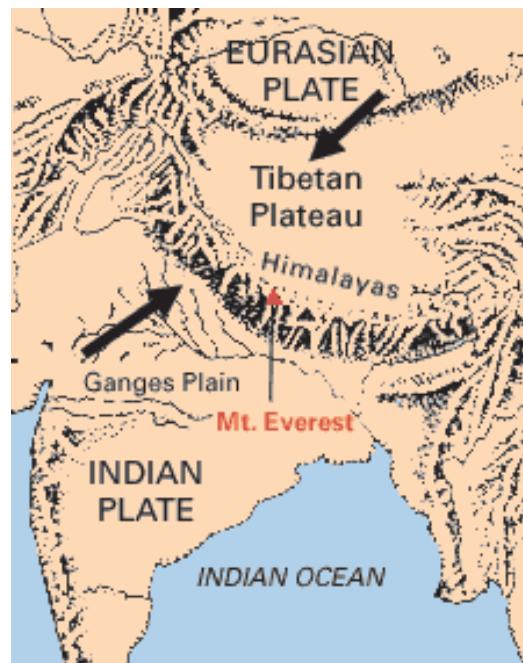


Fig. 15.12 : Movements of Indian earth's plate

The power of an earthquake is expressed in terms of a magnitude on a scale called **Richter scale**. Really destructive earthquakes have magnitudes higher than 7 on the Richter scale. Both Bhuj and Kashmir earthquakes had magnitudes greater than 7.5.

The tremors produce waves on the surface of the earth. These are called seismic waves. The waves are recorded by an instrument called the **seismograph** (Fig. 15.13). The instrument is simply a vibrating rod, or a pendulum, which starts vibrating when tremors occur. A pen is attached to the vibrating system. The pen records the seismic waves on a paper which moves under it. By studying these waves, scientists can construct a complete map of the earthquake, as shown in Fig. 15.14. They can also estimate its power to cause destruction.

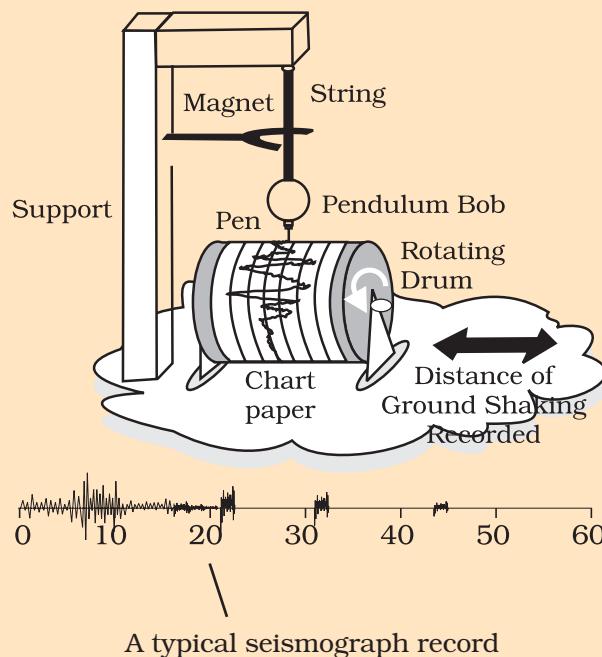


Fig. 15.13 : A seismograph

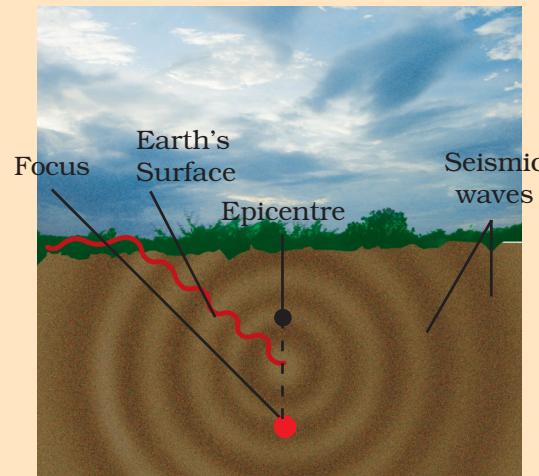


Fig. 15.14 : Map of the earthquake

Like many other scales in science (decibel is another example), Richter scale is not linear. This means that an earthquake of magnitude 6 does not have one and half times the destructive energy of an earthquake of magnitude 4. In fact, an increase of 2 in magnitude means 1000 times more destructive energy. For example, an earthquake of magnitude 6 has thousand times more destructive energy than an earthquake of magnitude 4.

Protection against Earthquakes

We know from the earlier pages that earthquakes cannot be predicted. We have also seen that they can be highly destructive. It is, therefore, important that we take necessary precautions to protect ourselves all the time. People living in seismic zones, where the earthquakes are more likely to occur,

have to be specially prepared. First of all, the buildings in these zones should be designed so that they can withstand major tremors. Modern building technology can make it possible.

It is advisable to make the structure simple so that it is 'Quake Safe'.

- Consult qualified architects and structural engineers.

- In highly seismic areas, the use of mud or timber is better than the heavy construction material. Keep roofs as light as possible. In case the structure falls, the damage will not be heavy.
- It is better if the cupboards and shelves are fixed to the walls, so that they do not fall easily.
- Be careful where you hang wall clocks, photo-frames, water heaters etc., so that in the event of an earthquake, they do not fall on people.
- Since some buildings may catch fire due to an earthquake, it is necessary that all buildings, especially tall buildings, have fire fighting equipment in working order.

The Central Building Research Institute, Roorkee, has developed knowhow to make quake proof houses.

In the event that an earthquake does strike, take the following steps to protect yourself:

1. If you are at home:

- Take shelter under a table and stay there till shaking stops.
- Stay away from tall and heavy objects that may fall on you.
- If you are in bed, do not get up. Protect your head with a pillow.

2. If you are outdoors:

- Find a clear spot, away from buildings, trees and overhead power lines. Drop to the ground.
- If you are in a car or a bus, do not come out. Ask the driver to drive slowly to a clear spot. Do not come out till the tremors stop.

KEYWORDS**CRUST****DISCHARGE****EARTH'S PLATES****EARTHQUAKE****ELECTROSCOPE****LIGHTNING****LIGHTNING****CONDUCTOR****NEGATIVE CHARGE****POSITIVE CHARGE****RICHTER SCALE****SEISMOGRAPH****THUNDER****THUNDERSTORM****TRANSFER OF
CHARGE****TSUNAMI****TREMOR****WHAT YOU HAVE LEARNT**

- ⌚ Some objects can be charged by rubbing with other objects.
- ⌚ There are two kinds of charges — positive charge and negative charge
- ⌚ Like charges repel and unlike charges attract each other.
- ⌚ The electrical charges produced by rubbing are called static charges.
- ⌚ When charges move, they constitute an electric current.
- ⌚ An electroscope may be used to detect whether a body is charged or not.
- ⌚ The process of transfer of charge from a charged object to the earth is called earthing.
- ⌚ The process of electric discharge between clouds and the earth or between different clouds causes lightning.
- ⌚ Lightning strike could destroy life and property.
- ⌚ Lightning conductors can protect buildings from the effects of lightning.
- ⌚ An earthquake is a sudden shaking or trembling of the earth.
- ⌚ Earthquake is caused by a disturbance deep inside the earth's crust.
- ⌚ It is not possible to predict the occurrence of an earthquake.
- ⌚ Earthquakes tend to occur at the boundaries of earth's plates. These boundaries are known as fault zones.
- ⌚ Destructive energy of an earthquake is measured on the Richter scale. The earthquake measuring 7 or more on Richter scale can cause severe damage to life and property.
- ⌚ We should take necessary precautions to protect ourselves from earthquakes.

Exercises

Select the correct option in Questions 1 and 2.

1. Which of the following cannot be charged easily by friction?
 - (a) A plastic scale
 - (b) A copper rod
 - (c) An inflated balloon
 - (d) A woollen cloth.
2. When a glass rod is rubbed with a piece of silk cloth the rod
 - (a) and the cloth both acquire positive charge.
 - (b) becomes positively charged while the cloth has a negative charge.
 - (c) and the cloth both acquire negative charge.
 - (d) becomes negatively charged while the cloth has a positive charge.
3. Write T against true and F against false in the following statements:
 - (a) Like charges attract each other (T/F)
 - (b) A charged glass rod attract a charged plastic straw (T/F)
 - (c) Lightning conductor cannot protect a building from lightning (T/F)
 - (d) Earthquakes can be predicted in advance (T/F)
4. Sometime, a crackling sound is heard while taking off sweater during winters. Explain.
5. Explain why a charged body loses its charge if we touch it with our hand.
6. Name the scale on which the destructive energy of an earthquake is measured. An earthquake measures 3 on this scale. Would it be recorded by a seismograph? Is it likely to cause much damage?
7. Suggest three measures to protect ourselves from lightning.
8. Explain why a charged balloon is repelled by another charged balloon whereas an uncharged balloon is attracted by another charged balloon?
9. Describe with the help of a diagram an instrument which can be used to detect a charged body.
10. List three states in India where earthquakes are more likely to strike.
11. Suppose you are outside your home and an earthquake strikes. What precaution would you take to protect yourself?
12. The weather department has predicted that a thunderstorm is likely to occur on a certain day. Suppose you have to go out on that day. Would you carry an umbrella? Explain.

Extended Learning — Activities and Projects

1. Open a water tap. Adjust the flow so that it forms a thin stream. Charge a refill. Bring it near the water stream. Observe what happens. Write a short report on the activity.
2. Make your own charge detector. Take a paper strip roughly $10\text{ cm} \times 3\text{ cm}$. Give it a shape as shown in Fig. 15.15. Balance it on a needle. Bring a charged body near it. Observe what happens. Write a brief report, explaining its working.

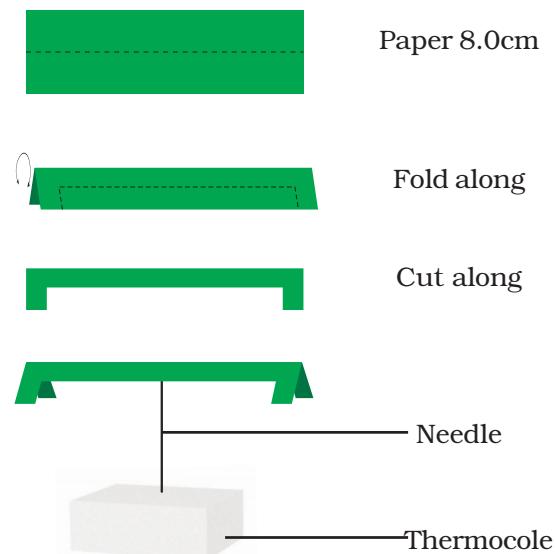


Fig. 15.15

3. This activity should be performed at night. Go to a room where there is a fluorescent tube light. Charge a balloon. Switch off the tube light so that the room is completely dark. Bring the charged balloon near the tubelight. You should see a faint glow. Move the balloon along the length of the tube and observe how glow changes.
Caution : Do not touch the metal parts of the tube or the wires connecting the tube with the mains.
4. Find out if there is an organisation in your area which provides relief to those suffering from natural disaster. Enquire about the type of help they render to the victims of earthquakes. Prepare a brief report on the problems of the earthquake victims.

For more information on these topics, visit:

- science.howstuffworks.com/lightning.htm
- science.howstuffworks.com/earthquake.htm
- www.enchantedlearning.com/subjects/astronomy/planets/earth/continents.shtml

UNIT IV

CLIMATE

This unit deals with

- *Atmosphere — compositions and structure; elements of weather and climate*
- *Insolation — angle of incidence and distribution; heat budget of the earth — heating and cooling of atmosphere (conduction, convection, terrestrial radiation, advection); temperature — factors controlling temperature; distribution of temperature — horizontal and vertical; inversion of temperature*
- *Pressure — pressure belts; winds-planetary seasonal and local, air masses and fronts; tropical and extra tropical cyclones*
- *Precipitation — evaporation; condensation — dew, frost, fog, mist and cloud; rainfall — types and world distribution*
- *World climates — classification (Koeppen), greenhouse effect, global warming and climatic changes*

CHAPTER

8

COMPOSITION AND STRUCTURE OF ATMOSPHERE

Can a person live without air? We eat food two - three times a day and drink water more frequently but breathe every few seconds. Air is essential to the survival of all organisms. Some organisms like humans may survive for some time without food and water but can't survive even a few minutes without breathing air. That shows the reason why we should understand the atmosphere in greater detail. Atmosphere is a mixture of different gases and it envelopes the earth all round. It contains life-giving gases like oxygen for humans and animals and carbon dioxide for plants. The air is an integral part of the earth's mass and 99 per cent of the total mass of the atmosphere is confined to the height of 32 km from the earth's surface. The air is colourless and odourless and can be felt only when it blows as wind.

Can you imagine what will happen to us in the absence of ozone in the atmosphere?

COMPOSITION OF THE ATMOSPHERE

The atmosphere is composed of gases, water vapour and dust particles. Table 8.1 shows details of various gases in the air, particularly in the lower atmosphere. The proportion of gases changes in the higher layers of the atmosphere in such a way that oxygen will be almost in negligible quantity at the height of 120 km. Similarly, carbon dioxide and water vapour are found only up to 90 km from the surface of the earth.

Table 8.1 : Permanent Gases of the Atmosphere

Constituent	Formula	Percentage by Volume
Nitrogen	N ₂	78.08
Oxygen	O ₂	20.95
Argon	Ar	0.93
Carbon dioxide	CO ₂	0.036
Neon	Ne	0.002
Helium	He	0.0005
Krypto	Kr	0.001
Xenon	Xe	0.00009
Hydrogen	H ₂	0.00005

Gases

Carbon dioxide is meteorologically a very important gas as it is transparent to the incoming solar radiation but opaque to the outgoing terrestrial radiation. It absorbs a part of terrestrial radiation and reflects back some part of it towards the earth's surface. It is largely responsible for the *green house effect*. The volume of other gases is constant but the volume of carbon dioxide has been rising in the past few decades mainly because of the burning of fossil fuels. This has also increased the temperature of the air. Ozone is another important component of the atmosphere found between 10 and 50 km above the earth's surface and acts as a filter and absorbs the *ultra-violet rays* radiating from the sun and prevents them from reaching the surface of the earth.

Water Vapour

Water vapour is also a variable gas in the atmosphere, which decreases with altitude. 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 desert and polar regions, it may be less than one per cent of the air. Water vapour also decreases from the equator towards the poles. It also absorbs parts of the insolation from the sun and preserves the earth's radiated heat. It thus, acts like a blanket allowing the earth neither to become too cold nor too hot. Water vapour also contributes to the stability and instability in the air.

Dust Particles

Atmosphere has a sufficient capacity to keep small solid particles, which may originate from different sources and include sea salts, fine soil, smoke-soot, ash, pollen, dust and disintegrated particles of meteors. Dust particles are generally concentrated in the lower layers of the atmosphere; yet, convectional air currents may transport them to great heights. The higher concentration of dust particles is found in subtropical and temperate regions due to dry winds in comparison to equatorial and polar regions. Dust and salt particles act as hygroscopic nuclei around which water vapour condenses to produce clouds.

STRUCTURE OF THE ATMOSPHERE

The atmosphere consists of different layers with varying density and temperature. Density is highest near the surface of the earth and decreases with increasing altitude. The column of atmosphere is divided into five different layers depending upon the temperature condition. They are: troposphere, stratosphere, mesosphere, ionosphere and exosphere.

The troposphere is the lowermost layer of the atmosphere. Its average height is 13 km and extends roughly to a height of 8 km near the poles and about 18 km at the equator. Thickness of the troposphere is greatest at the equator because heat is transported to great heights by strong convectional currents. This layer contains dust particles and water vapour. All changes in climate and weather take place in this layer. The temperature in this layer decreases at the rate of 1°C for every 165m of height. This is the most important layer for all biological activity.

The zone separating the troposphere from stratosphere is known as the *tropopause*. The air temperature at the tropopause is about minus 80°C over the equator and about minus 45°C over the poles. The temperature here is nearly constant, and hence, it is called the tropopause. *The stratosphere* is found above the tropopause and extends up to a height of 50 km. One important feature of the stratosphere is that it contains the *ozone layer*. This layer absorbs ultra-violet radiation and shields life on the earth from intense, harmful form of energy.

The mesosphere lies above the stratosphere, which extends up to a height of 80 km. In this layer, once again, temperature starts decreasing with the increase in altitude and reaches up to minus 100°C at the height of 80 km. The upper limit of mesosphere is known as the *mesopause*. *The ionosphere* is located between 80 and 400 km above the mesopause. It contains electrically charged particles known as ions, and hence, it is known as ionosphere. Radio waves transmitted from the earth are reflected back to the earth by this layer. Temperature here starts increasing with height. The uppermost layer of the atmosphere above

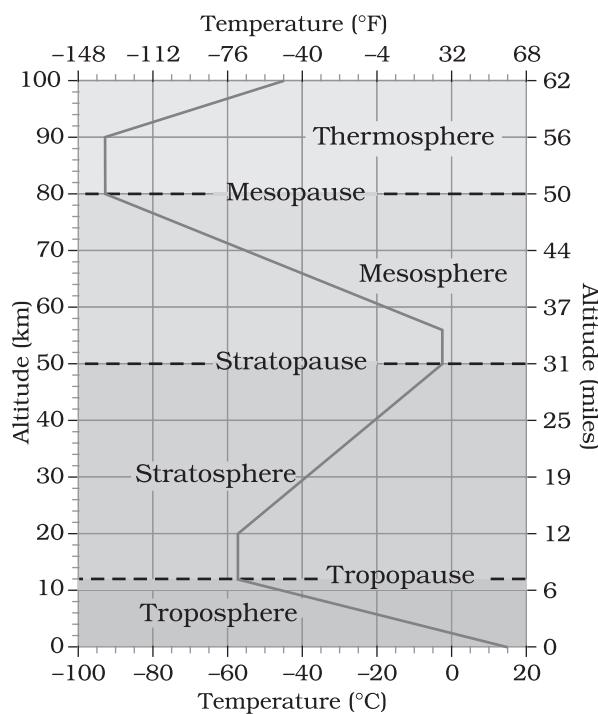


Figure 8.1 : STRUCTURE OF ATMOSPHERE

the ionosphere is known as the *exosphere*. This is the highest layer but very little is known about it. Whatever contents are there, these are extremely rarefied in this layer, and it gradually merges with the outer space. Although all layers of the atmosphere must be exercising influence on us, geographers are concerned with the first two layers of the atmosphere.

Elements of Weather and Climate

The main elements of atmosphere which are subject to change and which influence human life on earth are temperature, pressure, winds, humidity, clouds and precipitation. These elements have been dealt in detail in Chapters 9, 10 and 11.

EXERCISES

1. Multiple choice questions.
 - (i) Which one of the following gases constitutes the major portion of the atmosphere?

(a) Oxygen	(c) Argon
(b) Nitrogen	(d) Carbon dioxide
 - (ii) Atmospheric layer important for human beings is:

(a) Stratosphere	(c) Troposphere
(b) Mesosphere	(d) Ionosphere
 - (iii) Sea salt, pollen, ash, smoke soot, fine soil — these are associated with:

(a) Gases	(c) Water vapour
(b) Dust particles	(d) Meteors
 - (iv) Oxygen gas is in negligible quantity at the height of atmosphere:

(a) 90 km	(c) 100 km
(b) 120 km	(d) 150 km
 - (v) Which one of the following gases is transparent to incoming solar radiation and opaque to outgoing terrestrial radiation?

(a) Oxygen	(c) Helium
(b) Nitrogen	(d) Carbon dioxide
2. Answer the following questions in about 30 words.
 - (i) What do you understand by atmosphere?
 - (ii) What are the elements of weather and climate?
 - (iii) Describe the composition of atmosphere.
 - (iv) Why is troposphere the most important of all the layers of the atmosphere?
3. Answer the following questions in about 150 words.
 - (i) Describe the composition of the atmosphere.
 - (ii) Draw a suitable diagram for the structure of the atmosphere and label it and describe it.

SOLAR RADIATION, HEAT BALANCE AND TEMPERATURE

Do you feel air around you? Do you know that we live at the bottom of a huge pile of air? We inhale and exhale but we feel the air when it is in motion. It means air in motion is wind. You have already learnt about the fact that earth is surrounded by air all around. This envelop of air is atmosphere which is composed of numerous gases. These gases support life over the earth's surface.

The earth receives almost all of its energy from the sun. The earth in turn radiates back to space the energy received from the sun. As a result, the earth neither warms up nor does it get cooled over a period of time. Thus, the amount of heat received by different parts of the earth is not the same. This variation causes pressure differences in the atmosphere. This leads to transfer of heat from one region to the other by winds. This chapter explains the process of heating and cooling of the atmosphere and the resultant temperature distribution over the earth's surface.

SOLAR RADIATION

The earth's surface receives most of its energy in short wavelengths. The energy received by the earth is known as incoming solar radiation which in short is termed as *insolation*.

As the earth is a geoid resembling a sphere, the sun's rays fall obliquely at the top of the atmosphere and the earth intercepts a very small portion of the sun's energy. On an average the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere.

The solar output received at the top of the atmosphere varies slightly in a year due to the variations in the distance between the earth and the sun. During its revolution around the sun, the earth is farthest from the sun (152 million km on 4th July). This position of the earth is called *aphelion*. On 3rd January, the earth is the nearest to the sun (147 million km). This position is called *perihelion*. Therefore, the annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July. However, the effect of this variation in the solar output is masked by other factors like the distribution of land and sea and the atmospheric circulation. Hence, this variation in the solar output does not have great effect on daily weather changes on the surface of the earth.

Variability of Insolation at the Surface of the Earth

The amount and the intensity of insolation vary during a day, in a season and in a year. The factors that cause these variations in insolation are : (i) the rotation of earth on its axis; (ii) the angle of inclination of the sun's rays; (iii) the length of the day; (iv) the transparency of the atmosphere; (v) the configuration of land in terms of its aspect. The last two however, have less influence.

The fact that the earth's axis makes an angle of 66½ with the plane of its orbit round the sun has a greater influence on the amount of insolation received at different latitudes. Note the variations in the duration of the day at different latitudes on solstices given in Table 9.1.

The second factor that determines the amount of insolation received is the angle of

colour of the sky are the result of scattering of light within the atmosphere.

Table 9.1 : Length of the Day in Hours and Minutes on Winter and Summer Solstices in the Northern Hemisphere

Latitude	0°	20°	40°	60°	90°
December 22	12h 00m	10h 48m	9h 8m	5h 33m	0
June 21	12 h	13h 12m	14h 52m	18h 27m	6 months

inclination of the rays. This depends on the latitude of a place. The higher the latitude the less is the angle they make with the surface of the earth resulting in slant sun rays. The area covered by vertical rays is always less than the slant rays. If more area is covered, the energy gets distributed and the net energy received per unit area decreases. Moreover, the slant rays are required to pass through greater depth of the atmosphere resulting in more absorption, scattering and diffusion.

Spatial Distribution of Insolation at the Earth's Surface

The insolation received at the surface varies from about 320 Watt/m² in the tropics to about 70 Watt/m² in the poles. Maximum insolation is received over the subtropical deserts, where the cloudiness is the least. Equator receives comparatively less insolation than the tropics. Generally, at the same latitude the insolation is more over the continent than over the oceans. In winter, the middle and higher latitudes receive less radiation than in summer.

HEATING AND COOLING OF ATMOSPHERE

There are different ways of heating and cooling of the atmosphere.

The earth after being heated by insolation transmits the heat to the atmospheric layers near to the earth in long wave form. The air in contact with the land gets heated slowly and the upper layers in contact with the lower layers also get heated. This process is called *conduction*. Conduction takes place when two bodies of unequal temperature are in contact with one another, there is a flow of energy from the warmer to cooler body. The transfer of heat continues until both the bodies attain the same temperature or the contact is broken. Conduction is important in heating the lower layers of the atmosphere.

The air in contact with the earth rises vertically on heating in the form of currents and further transmits the heat of the atmosphere. This process of vertical heating of the atmosphere is known as *convection*. The convective transfer of energy is confined only to the troposphere.

The transfer of heat through horizontal movement of air is called *advection*. Horizontal movement of the air is relatively more important

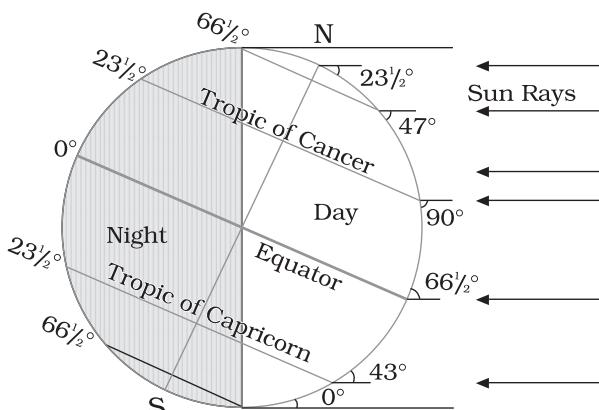


Figure 9.1 : Summer Solstice

The Passage of Solar Radiation through the Atmosphere

The atmosphere is largely transparent to short wave solar radiation. The incoming solar radiation passes through the atmosphere before striking the earth's surface. Within the troposphere water vapour, ozone and other gases absorb much of the near infrared radiation.

Very small-suspended particles in the troposphere scatter visible spectrum both to the space and towards the earth surface. This process adds colour to the sky. The red colour of the rising and the setting sun and the blue

than the vertical movement. In middle latitudes, most of diurnal (day and night) variation in daily weather are caused by advection alone. In tropical regions particularly in northern India during summer season local winds called 'loo' is the outcome of advection process.

Terrestrial Radiation

The insolation received by the earth is in short waves form and heats up its surface. The earth after being heated itself becomes a radiating body and it radiates energy to the atmosphere in long wave form. This energy heats up the atmosphere from below. This process is known as terrestrial radiation.

The long wave radiation is absorbed by the atmospheric gases particularly by carbon dioxide and the other green house gases. Thus, the atmosphere is indirectly heated by the earth's radiation.

The atmosphere in turn radiates and transmits heat to the space. Finally the amount of heat received from the sun is returned to space, thereby maintaining constant temperature at the earth's surface and in the atmosphere.

Heat Budget of the Planet Earth

Figure 9.2 depicts the heat budget of the planet earth. The earth as a whole does not

accumulate or loose heat. It maintains its temperature. This can happen only if the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation.

Consider that the insolation received at the top of the atmosphere is 100 per cent. While passing through the atmosphere some amount of energy is reflected, scattered and absorbed. Only the remaining part reaches the earth surface. 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). 48 units absorbed by the atmosphere (14 units from insolation +34 units from

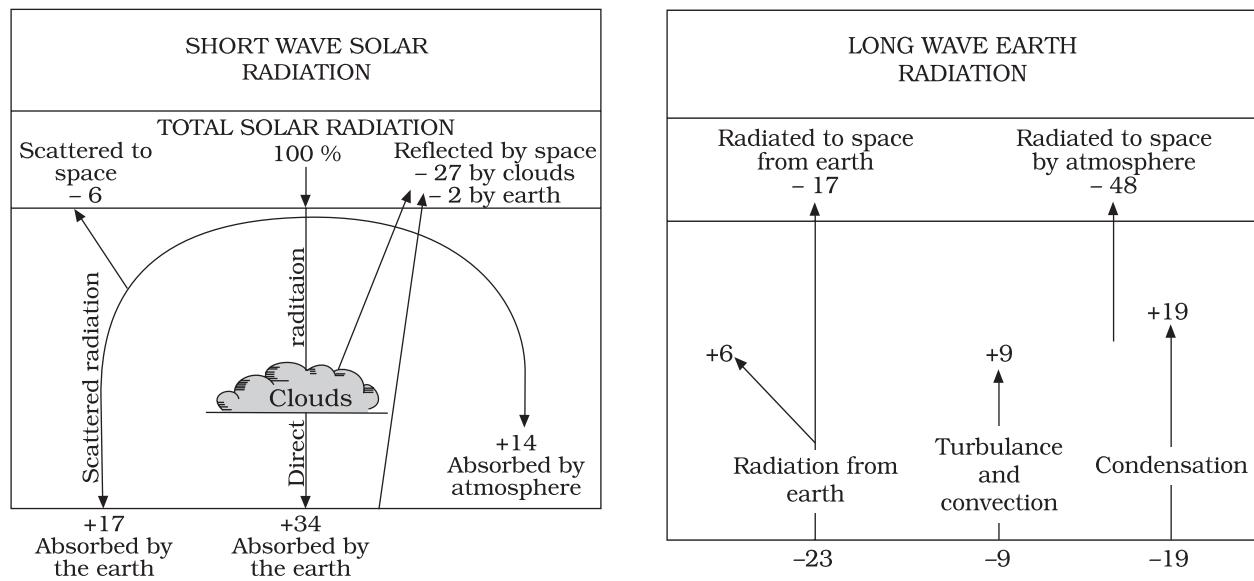


Figure 9.2 : Heat budget of the earth

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.

This explains, why the earth neither warms up nor cools down despite the huge transfer of heat that takes place.

Variation in the Net Heat Budget at the Earth's Surface

As explained earlier, there are variations in the amount of radiation received at the earth's surface. Some part of the earth has surplus radiation balance while the other part has deficit.

Figure 9.3 depicts the latitudinal variation in the net radiation balance of the earth — the atmosphere system. The figure shows that there is a surplus of net radiation balance between 40 degrees north and south and the regions near the poles have a deficit. The surplus heat energy from the tropics is redistributed polewards and as a result the tropics do not get progressively heated up due to the accumulation of excess heat or the high latitudes get permanently frozen due to excess deficit.

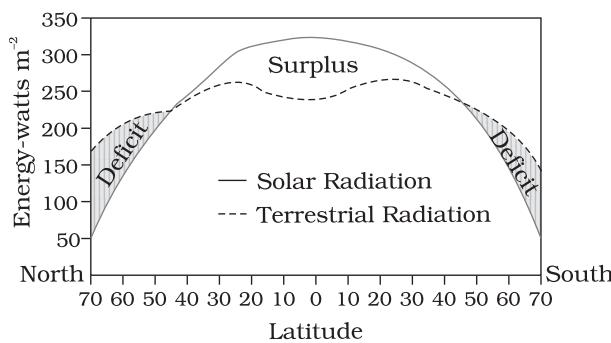


Figure 9.3 : Latitudinal variation in net radiation balance

Temperature

The interaction of insolation with the atmosphere and the earth's surface creates

heat which is measured in terms of temperature. While heat represents the molecular movement of particles comprising a substance, the temperature is the measurement in degrees of how hot (or cold) a thing (or a place) is.

Factors Controlling Temperature Distribution

The temperature of air at any place is influenced by (i) the latitude of the place; (ii) the altitude of the place; (iii) distance from the sea, the air-mass circulation; (iv) the presence of warm and cold ocean currents; (v) local aspects.

The latitude : The temperature of a place depends on the insolation received. It has been explained earlier that the insolation varies according to the latitude hence the temperature also varies accordingly.

The altitude : The atmosphere is indirectly heated by terrestrial radiation from below. Therefore, the places near the sea-level record higher temperature than the places situated at higher elevations. In other words, the temperature generally decreases with increasing height. The rate of decrease of temperature with height is termed as the normal lapse rate. It is 6.5°C per 1,000 m.

Distance from the sea : Another factor that influences the temperature is the location of a place with respect to the sea. Compared to land, the sea gets heated slowly and loses heat slowly. Land heats up and cools down quickly. Therefore, the variation in temperature over the sea is less compared to land. The places situated near the sea come under the moderating influence of the sea and land breezes which moderate the temperature.

Air-mass and Ocean currents : Like the land and sea breezes, the passage of air masses also affects the temperature. The places, which come under the influence of warm air-masses experience higher temperature and the places that come under the influence of cold air-masses experience low temperature. Similarly,

the places located on the coast where the warm ocean currents flow record higher temperature than the places located on the coast where the cold currents flow.

Distribution of Temperature

The global distribution of temperature can well be understood by studying the temperature distribution in January and July. The temperature distribution is generally shown on the map with the help of isotherms. The *Isotherms* are lines joining places having equal temperature. Figure 9.4 (a) and (b) show the distribution of surface air temperature in the month of January and July.

In general the effect of the latitude on temperature is well pronounced on the map, as the isotherms are generally parallel to the latitude. The deviation from this general trend is more pronounced in January than in July, especially in the northern hemisphere. In the

northern hemisphere the land surface area is much larger than in the southern hemisphere. Hence, the effects of land mass and the ocean currents are well pronounced. In January the isotherms deviate to the north over the ocean and to the south over the continent. This can be seen on the North Atlantic Ocean. The presence of warm ocean currents, Gulf Stream and North Atlantic drift, make the Northern Atlantic warmer and the isotherms bend towards the north. Over the land the temperature decreases sharply and the isotherms bend towards south in Europe.

It is much pronounced in the Siberian plain. The mean January temperature along 60° E longitude is minus 20° C both at 80° N and 50° N latitudes. The mean monthly temperature for January is over 27° C, in equatorial oceans over 24° C in the tropics and 2° C - 0° C in the middle latitudes and -18° C to -48° C in the Eurasian continental interior.

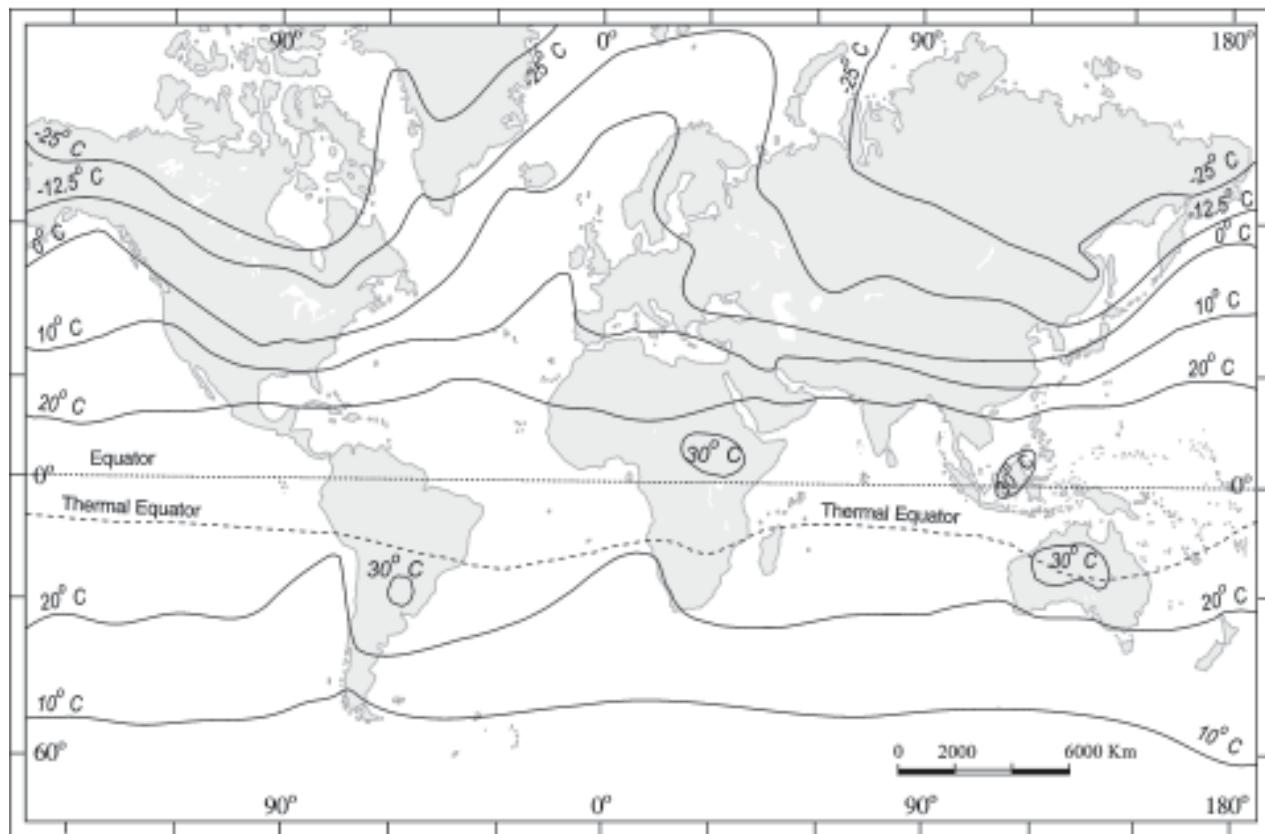


Figure 9.4 (a) : The distribution of surface air temperature in the month of January

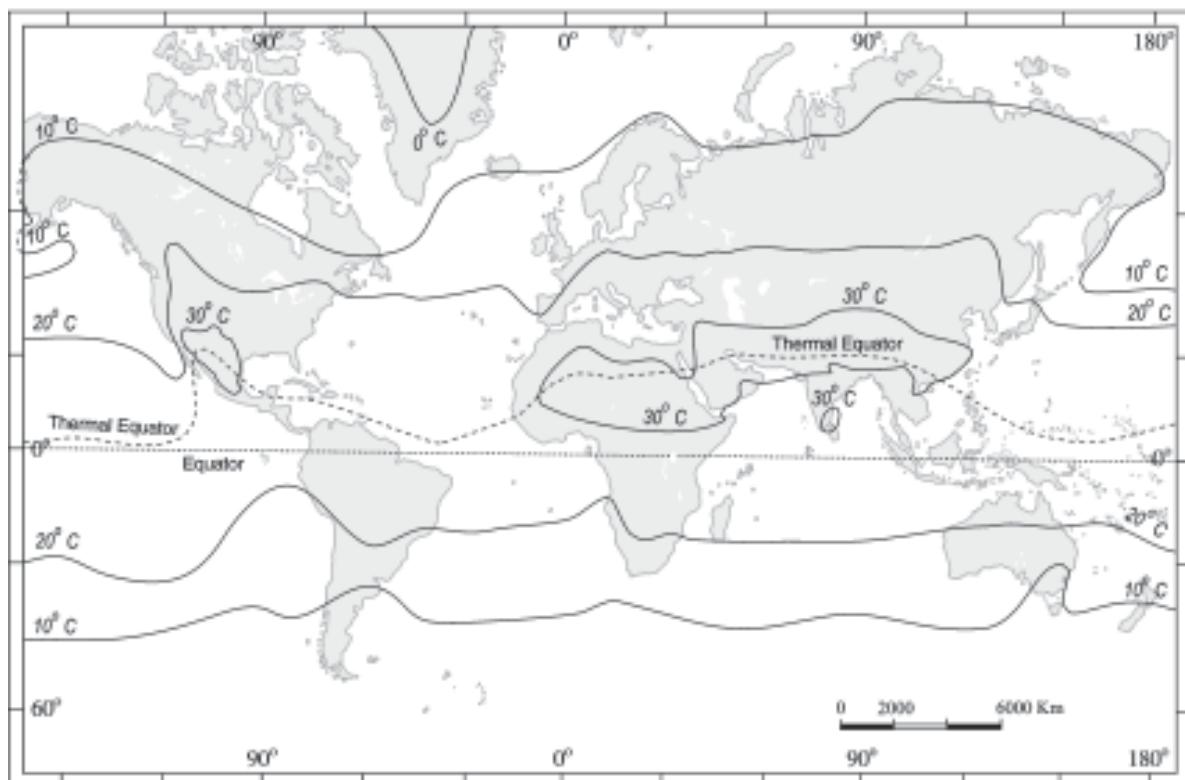


Figure 9.4 (b) : The distribution of surface air temperature in the month of July

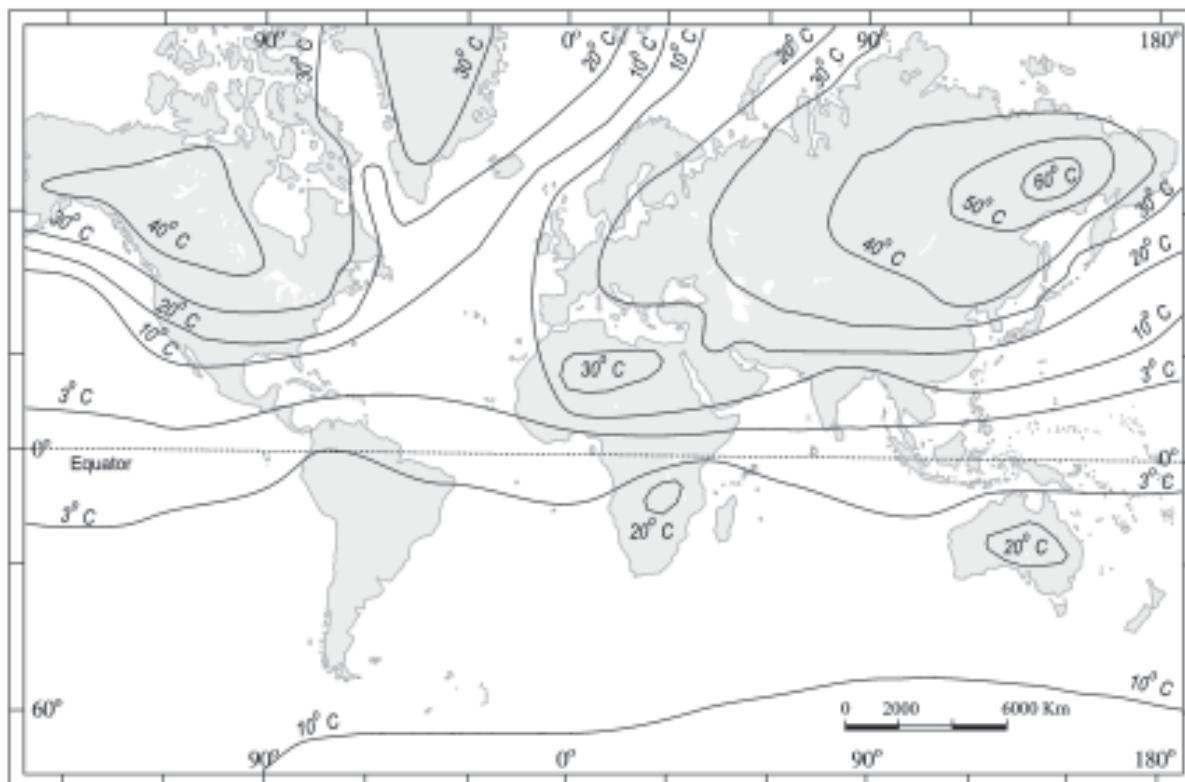


Figure 9.5 : The range of temperature between January and July

The effect of the ocean is well pronounced in the southern hemisphere. Here the isotherms are more or less parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere. The isotherm of 20°C , 10°C , and 0°C runs parallel to 35°S , 45°S and 60°S latitudes respectively.

In July the isotherms generally run parallel to the latitude. The equatorial oceans record warmer temperature, more than 27°C . Over the land more than 30°C is noticed in

the subtropical continental region of Asia, along the 30°N latitude. Along the 40°N runs the isotherm of 10°C and along the 40°S the temperature is 10°C .

Figure 9.5 shows the range of temperature between January and July. The highest range of temperature is more than 60°C over the north-eastern part of Eurasian continent. This is due to continentality. The least range of temperature, 3°C , is found between 20°S and 15°N .

EXERCISES

1. Multiple choice questions.

- (i) The sun is directly overhead at noon on 21st June at:
 - (a) The equator
 - (c) 23.5°N
 - (b) 23.5°S
 - (d) 66.5°N
- (ii) In which one of the following cities, are the days the longest?
 - (a) Tiruvananthapuram
 - (c) Hyderabad
 - (b) Chandigarh
 - (d) Nagpur
- (iii) The atmosphere is mainly heated by the:
 - (a) Short wave solar radiation
 - (c) Long wave terrestrial radiation
 - (b) Reflected solar radiation
 - (d) Scattered solar radiation
- (iv) Make correct pairs from the following two columns.

(i) Insolation	(a) The difference between the mean temperature of the warmest and the coldest months
(ii) Albedo	(b) The lines joining the places of equal temperature
(iii) Isotherm	(c) The incoming solar radiation
(iv) Annual range	(d) The percentage of visible light reflected by an object
- (v) The main reason that the earth experiences highest temperatures in the subtropics in the northern hemisphere rather than at the equator is :
 - (a) Subtropical areas tend to have less cloud cover than equatorial areas.
 - (b) Subtropical areas have longer day hours in the summer than the equatorial.
 - (c) Subtropical areas have an enhanced “green house effect” compared to equatorial areas.
 - (d) Subtropical areas are nearer to the oceanic areas than the equatorial locations.

2. Answer the following questions in about 30 words.
- How does the unequal distribution of heat over the planet earth in space and time cause variations in weather and climate?
 - What are the factors that control temperature distribution on the surface of the earth?
 - In India, why is the day temperature maximum in May and why not after the summer solstice?
 - Why is the annual range of temperature high in the Siberian plains?
3. Answer the following questions in about 150 words.
- How do the latitude and the tilt in the axis of rotation of the earth affect the amount of radiation received at the earth's surface?
 - Discuss the processes through which the earth-atmosphere system maintains heat balance.
 - Compare the global distribution of temperature in January over the northern and the southern hemisphere of the earth.

Project Work

Select a meteorological observatory located in your city or near your town. Tabulate the temperature data as given in the climatological table of observatories :

- Note the altitude, latitude of the observatory and the period for which the mean is calculated.
- Define the terms related to temperature as given in the table.
- Calculate the daily mean monthly temperature.
- Draw a graph to show the daily mean maximum, the daily mean minimum and the mean temperature.
- Calculate the annual range of temperature.
- Find out in which months the daily range of temperature is the highest and the lowest.
- List out the factors that determine the temperature of the place and explain the possible causes for temperature variation in the months of January, May, July and October.

Example

Observatory	:	New Delhi (Safdarjung)
Latitude	:	28°35' N
Based on observations	:	1951 - 1980
Altitude above mean sea level	:	216 m

Month	Mean of Daily Max.(°C)	Mean of Daily Min.(°C)	Highest Recorded (°C)	Lowest Recorded (°C)
January	21.1	7.3	29.3	0.6
May	39.6	25.9	47.2	17.5

Daily mean monthly temperature

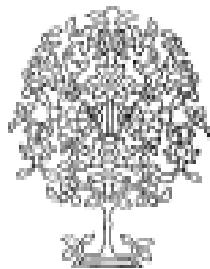
$$\text{January } \frac{21.1+7.3}{2} = 14.2^{\circ}\text{C}$$

$$\text{May } \frac{39.6+25.9}{2} = 32.75^{\circ}\text{C}$$

Annual range of temperature

Mean Max. Temperature in May - Mean Temperature in January

Annual range of temperature = $32.75^{\circ}\text{C} - 14.2^{\circ}\text{C} = 18.55^{\circ}\text{C}$



C H A P T E R

10

ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS

Earlier Chapter 9 described the uneven distribution of temperature over the surface of the earth. Air expands when heated and gets compressed when cooled. This results in variations in the atmospheric pressure. The result is that it causes the movement of air from high pressure to low pressure, setting the air in motion. You already know that air in horizontal motion is wind. Atmospheric pressure also determines when the air will rise or sink. The wind redistributes the heat and moisture across the planet, thereby, maintaining a constant temperature for the planet as a whole. The vertical rising of moist air cools it down to form the clouds and bring precipitation. This chapter has been devoted to explain the causes of pressure differences, the forces that control the atmospheric circulation, the turbulent pattern of wind, the formation of air masses, the disturbed weather when air masses interact with each other and the phenomenon of violent tropical storms.

ATMOSPHERIC PRESSURE

Do you realise that our body is subjected to a lot of air pressure. As one moves up the air gets varified and one feels breathless.

The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the *atmospheric pressure*. The atmospheric pressure is expressed in units of mb and Pascals. The widely used unit is kilo Pascal written as hPa. At sea level the average atmospheric pressure is 1,013.2 mb or 1,013.2 hPa. Due to gravity

the air at the surface is denser and hence has higher pressure. Air pressure is measured with the help of a mercury barometer or the aneroid barometer. Consult your book, *Practical Work in Geography — Part I* (NCERT, 2006) and learn about these instruments. The pressure decreases with height. At any elevation it varies from place to place and its variation is the primary cause of air motion, i.e. wind which moves from high pressure areas to low pressure areas.

Vertical Variation of Pressure

In the lower atmosphere the pressure decreases rapidly with height. The decrease amounts to about 1 mb for each 10 m increase in elevation. It does not always decrease at the same rate. Table 10.1 gives the average pressure and temperature at selected levels of elevation for a standard atmosphere.

Table 10.1 : Standard Pressure and Temperature at Selected Levels

Level	Pressure in mb	Temperature °C
Sea Level	1,013.25	15.2
1 km	898.76	8.7
5 km	540.48	-17. 3
10 km	265.00	- 49.7

The vertical pressure gradient force is much larger than that of the horizontal pressure gradient. But, it is generally balanced by a nearly equal but opposite gravitational force. Hence, we do not experience strong upward winds.

Horizontal Distribution of Pressure

Small differences in pressure are highly significant in terms of the wind direction and

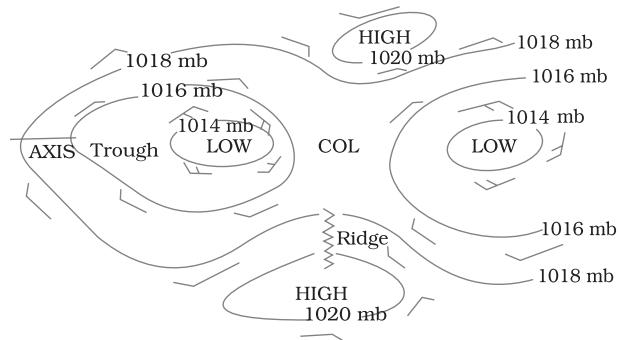


Figure 10.1 : Isobars, pressure and wind systems in Northern Hemisphere

velocity. Horizontal distribution of pressure is studied by drawing isobars at constant levels. Isobars are lines connecting places having equal pressure. In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level for

purposes of comparison. The sea level pressure distribution is shown on weather maps.

Figure 10.1 shows the patterns of isobars corresponding to pressure systems. Low-pressure system is enclosed by one or more isobars with the lowest pressure in the centre. High-pressure system is also enclosed by one or more isobars with the highest pressure in the centre.

World Distribution of Sea Level Pressure

The world distribution of sea level pressure in January and July has been shown in Figures 10.2 and 10.3. Near the equator the sea level pressure is low and the area is known as *equatorial low*. Along 30° N and 30° S are found the high-pressure areas known as the *subtropical highs*. Further polewards along 60° N and 60° S, the low-pressure belts are termed as the *sub polar lows*. Near the poles the pressure is high and it is known as the *polar high*. These pressure belts are not permanent

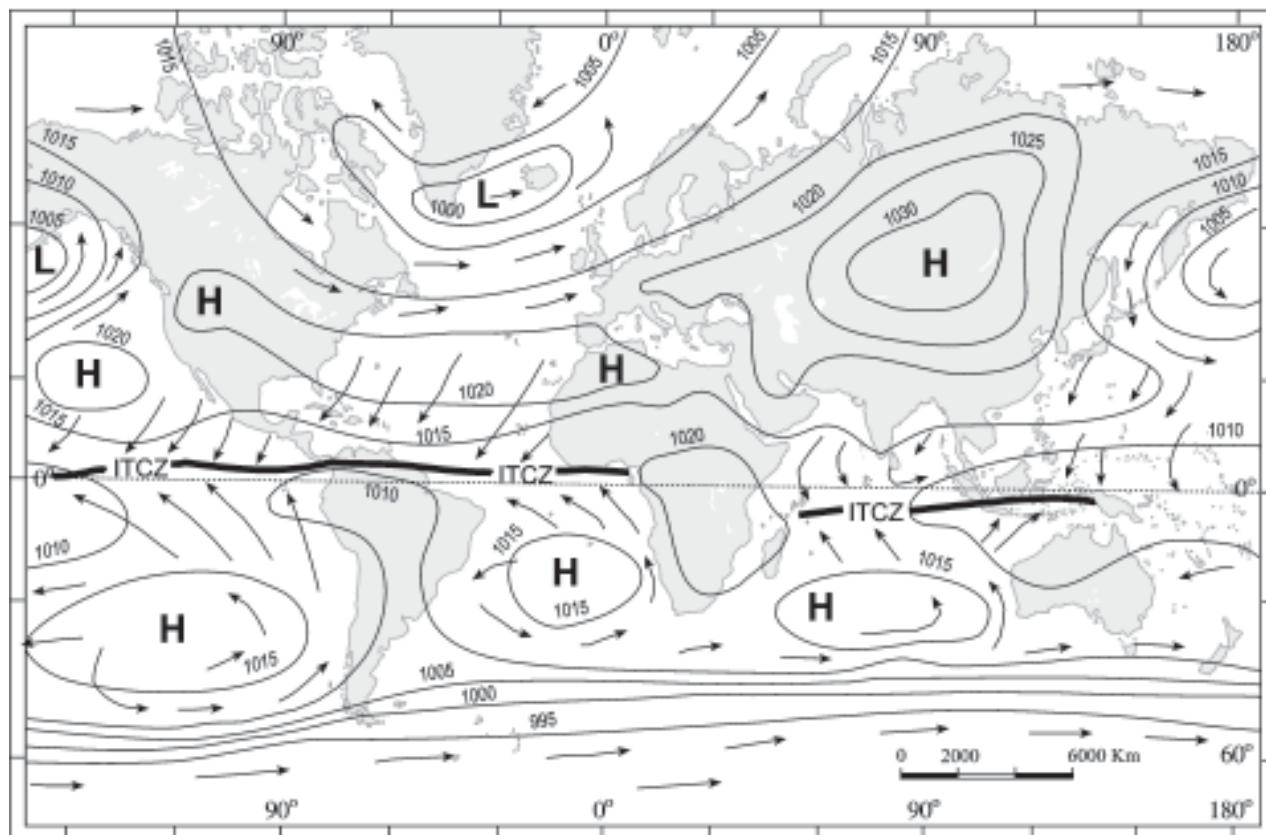


Figure 10.2 : Distribution of pressure (in millibars) — January

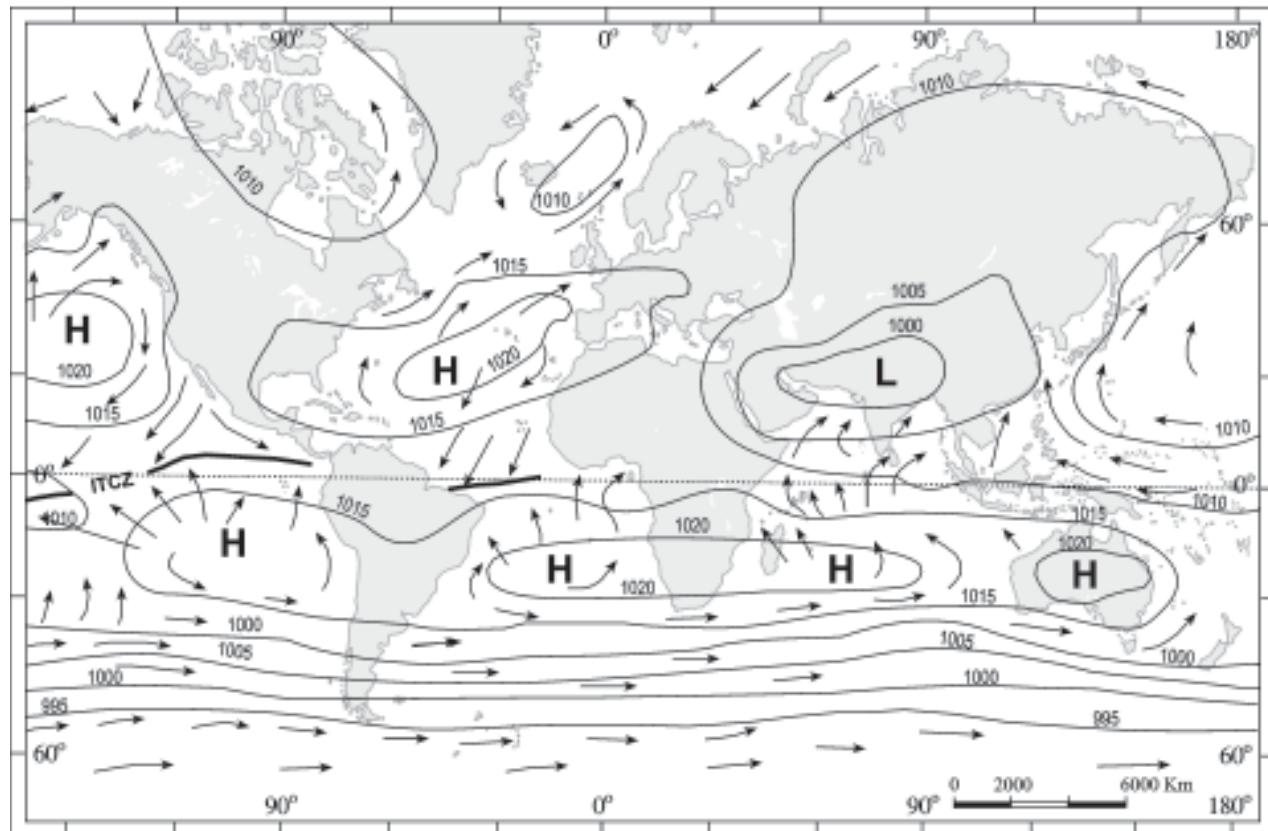


Figure 10.3 : Distribution of pressure (in millibars) — July

in nature. They oscillate with the apparent movement of the sun. In the northern hemisphere in winter they move southwards and in the summer northwards.

Forces Affecting the Velocity and Direction of Wind

You already know that the air is set in motion due to the differences in atmospheric pressure. The air in motion is called wind. The wind blows from high pressure to low pressure. The wind at the surface experiences friction. In addition, rotation of the earth also affects the wind movement. The force exerted by the rotation of the earth is known as the Coriolis force. Thus, the horizontal winds near the earth surface respond to the combined effect of three forces – the pressure gradient force, the frictional force and the Coriolis force. In addition, the gravitational force acts downward.

Pressure Gradient Force

The differences in atmospheric pressure produces a force. The rate of change of pressure with respect to distance is the pressure gradient. The pressure gradient is strong where the isobars are close to each other and is weak where the isobars are apart.

Frictional Force

It affects the speed of the wind. It is greatest at the surface and its influence generally extends upto an elevation of 1 - 3 km. Over the sea surface the friction is minimal.

Coriolis Force

The rotation of the earth about its axis affects the direction of the wind. This force is called the Coriolis force after the French physicist who described it in 1844. It deflects the wind to the right direction in the northern hemisphere and

to the left in the southern hemisphere. The deflection is more when the wind velocity is high. The Coriolis force is directly proportional to the angle of latitude. It is maximum at the poles and is absent at the equator.

The Coriolis force acts perpendicular to the pressure gradient force. The pressure gradient force is perpendicular to an isobar. The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind. As a result of these two forces operating perpendicular to each other, in the low-pressure areas the wind blows around it. At the equator, the Coriolis force is zero and the wind blows perpendicular to the isobars. The low pressure gets filled instead of getting intensified. That is the reason why tropical cyclones are not formed near the equator.

Pressure and Wind

The velocity and direction of the wind are the net result of the wind generating forces. The winds in the upper atmosphere, 2 - 3 km above the surface, are free from frictional effect of the surface and are controlled by the pressure gradient and the Coriolis force. When isobars are straight and when there is no friction, the pressure gradient force is balanced by the Coriolis force and the resultant wind blows parallel to the isobar. This wind is known as the geostrophic wind (Figure 10.4).

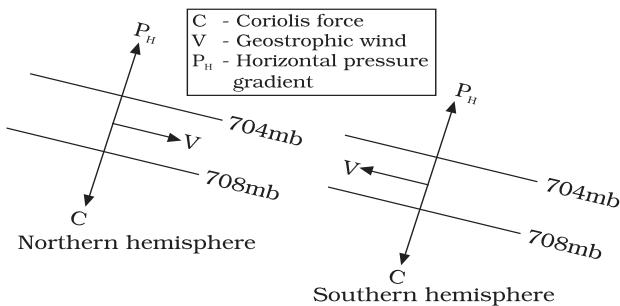


Figure 10.4 : Geostropic Wind

The wind circulation around a low is called *cyclonic circulation*. Around a high it is called *anti cyclonic circulation*. The direction of winds around such systems changes according to their location in different hemispheres (Table 10.2).

The wind circulation at the earth's surface around low and high on many occasions is closely related to the wind circulation at higher level. Generally, over low pressure area the air will converge and rise. Over high pressure area the air will subside from above and diverge at the surface (Figure 10.5). Apart from convergence, some eddies, convection currents, orographic uplift and uplift along fronts cause the rising of air, which is essential for the formation of clouds and precipitation.

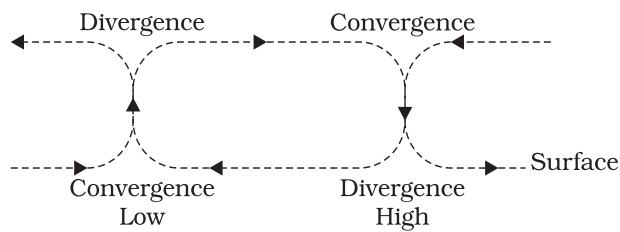


Figure 10.5 : Convergence and divergence of winds

General circulation of the atmosphere

The pattern of planetary winds largely depends on : (i) latitudinal variation of atmospheric heating; (ii) emergence of pressure belts; (iii) the migration of belts following apparent path of the sun; (iv) the distribution of continents and oceans; (v) the rotation of earth. The pattern of the movement of the planetary winds is called the general circulation of the atmosphere. The general circulation of the atmosphere also sets in motion the ocean water circulation which influences the earth's

Table 10.2 : Pattern of Wind Direction in Cyclones and Anticyclones

Pressure System	Pressure Condition at the Centre	Pattern of Wind Direction	
		Northern Hemisphere	Southern Hemisphere
Cyclone	Low	Anticlockwise	Clockwise
Anticyclone	High	Clockwise	Anticlockwise

climate. A schematic description of the general circulation is shown in Figure 10.6.

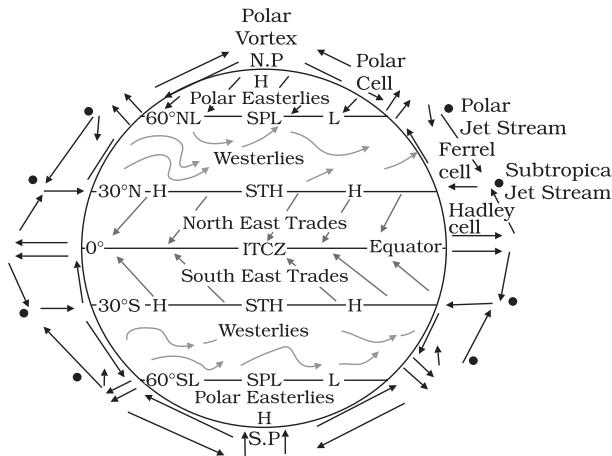


Figure 10.6 : Simplified general circulation of the atmosphere

The air at the Inter Tropical Convergence Zone (ITCZ) rises because of convection caused by high insolation and a low pressure is created. The winds from the tropics converge at this low pressure zone. The converged air rises along with the convective cell. It reaches the top of the troposphere up to an altitude of 14 km. and moves towards the poles. This causes accumulation of air at about 30° N and S. Part of the accumulated air sinks to the ground and forms a subtropical high. Another reason for sinking is the cooling of air when it reaches 30° N and S latitudes. Down below near the land surface the air flows towards the equator as the easterlies. The easterlies from either side of the equator converge in the Inter Tropical Convergence Zone (ITCZ). Such circulations from the surface upwards and vice-versa are called cells. Such a cell in the tropics is called *Hadley Cell*. In the middle latitudes the circulation is that of sinking cold air that comes from the poles and the rising warm air that blows from the subtropical high. At the surface these winds are called westerlies and the cell is known as the *Ferrel cell*. At polar latitudes the cold dense air subsides near the poles and blows towards middle latitudes as the polar easterlies. This cell is called the polar cell. These three cells set the pattern for the general circulation of the atmosphere. The transfer of heat energy from lower latitudes to higher latitudes maintains the general circulation.

The general circulation of the atmosphere also affects the oceans. The large-scale winds of the atmosphere initiate large and slow moving currents of the ocean. Oceans in turn provide input of energy and water vapour into the air. These interactions take place rather slowly over a large part of the ocean.

General Atmospheric Circulation and its Effects on Oceans

Warming and cooling of the Pacific Ocean is most important in terms of general atmospheric circulation. The warm water of the central Pacific Ocean slowly drifts towards South American coast and replaces the cool Peruvian current. Such appearance of warm water off the coast of Peru is known as the El Niño. The El Niño event is closely associated with the pressure changes in the Central Pacific and Australia. This change in pressure condition over Pacific is known as the southern oscillation. The combined phenomenon of southern oscillation and El Niño is known as ENSO. In the years when the ENSO is strong, large-scale variations in weather occur over the world. The arid west coast of South America receives heavy rainfall, drought occurs in Australia and sometimes in India and floods in China. This phenomenon is closely monitored and is used for long range forecasting in major parts of the world.

Seasonal Wind

The pattern of wind circulation is modified in different seasons due to the shifting of regions of maximum heating, pressure and wind belts. The most pronounced effect of such a shift is noticed in the monsoons, especially over southeast Asia. You would be studying the details of monsoon in the book *India : Physical Environment* (NCERT, 2006). The other local deviations from the general circulation system are as follows.

Local Winds

Differences in the heating and cooling of earth surfaces and the cycles those develop daily or annually can create several common, local or regional winds.

Land and Sea Breezes

As explained earlier, the land and sea absorb and transfer heat differently. During the day the land heats up faster and becomes warmer than the sea. Therefore, over the land the air rises giving rise to a low pressure area, whereas the sea is relatively cool and the pressure over sea is relatively high. Thus, pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze. In the night the reversal of condition takes place. The land loses heat faster and is cooler than the sea. The pressure gradient is from the land to the sea and hence land breeze results (Figure 10.7).

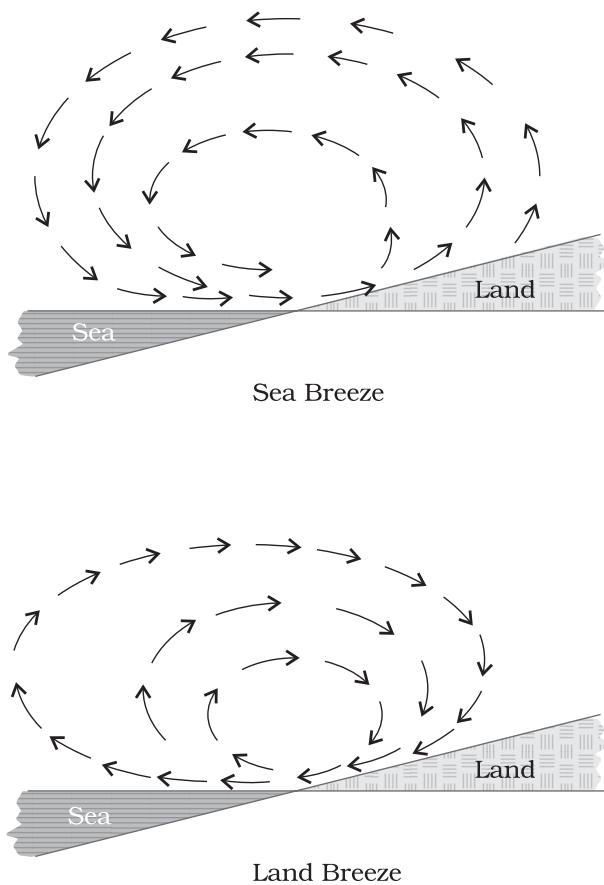


Figure 10.7 : Land and sea breezes

Mountain and Valley Winds

In mountainous regions, during the day the slopes get heated up and air moves upslope and to fill the resulting gap the air from the valley blows up the valley. This wind is known

as the valley breeze. During the night the slopes get cooled and the dense air descends into the valley as the mountain wind. The cool air, of the high plateaus and ice fields draining into the valley is called katabatic wind. Another type of warm wind occurs on the leeward side of the mountain ranges. The moisture in these winds, while crossing the mountain ranges condense and precipitate. When it descends down the leeward side of the slope the dry air gets warmed up by adiabatic process. This dry air may melt the snow in a short time.

Air Masses

When the air remains over a homogenous area for a sufficiently longer time, it acquires the characteristics of the area. The homogenous regions can be the vast ocean surface or vast plains. The air with distinctive characteristics in terms of temperature and humidity is called an airmass. It is defined as a large body of air having little horizontal variation in temperature and moisture. The homogenous surfaces, over which air masses form, are called the source regions.

The air masses are classified according to the source regions. There are five major source regions. These are: (i) Warm tropical and subtropical oceans; (ii) The subtropical hot deserts; (iii) The relatively cold high latitude oceans; (iv) The very cold snow covered continents in high latitudes; (v) Permanently ice covered continents in the Arctic and Antarctica. Accordingly, following types of air-masses are recognised: (i) Maritime tropical (mT); (ii) Continental tropical (cT); (iii) Maritime polar (mP); (iv) Continental polar (cP); (v) Continental arctic (cA). Tropical air masses are warm and polar air masses are cold.

Fronts

When two different air masses meet, the boundary zone between them is called a *front*. The process of formation of the fronts is known as *frontogenesis*. There are four types of fronts: (a) Cold; (b) Warm; (c) Stationary; (d) Occluded [(Figure 10.8 (a), (b), (c)]. When the front remains stationary, it is called a *stationary front*. When the cold air moves

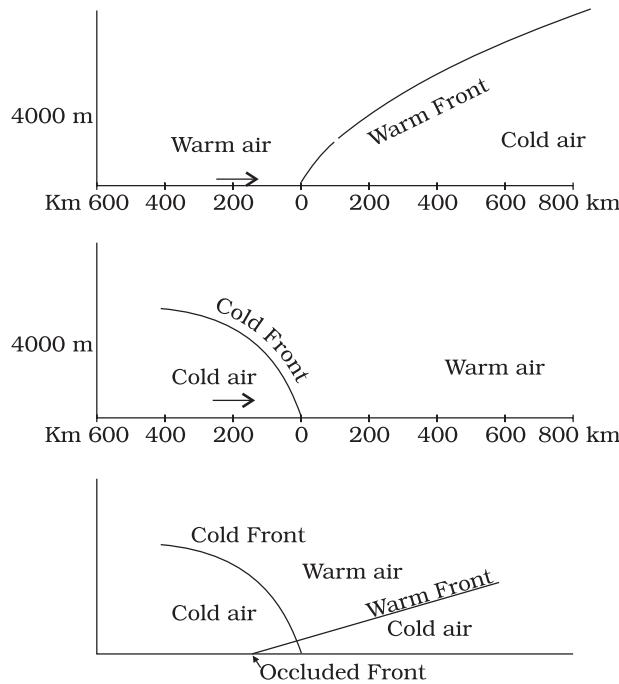


Figure 10.8 : Vertical Sections of : (a) Warm Front; (b) Cold Front; (c) Occluded Front

towards the warm air mass, its contact zone is called the *cold front*, whereas if the warm air mass moves towards the cold air mass, the contact zone is a warm front. If an air mass is fully lifted above the land surface, it is called the *occluded front*. The fronts occur in middle latitudes and are characterised by steep gradient in temperature and pressure. They bring abrupt changes in temperature and cause the air to rise to form clouds and cause precipitation.

Extra Tropical Cyclones

The systems developing in the mid and high latitude, beyond the tropics are called the *middle latitude or extra tropical cyclones*. The passage of front causes abrupt changes in the weather conditions over the area in the middle and high latitudes.

Extra tropical cyclones form along the polar front. Initially, the front is stationary. In the northern hemisphere, warm air blows from the south and cold air from the north of the front. When the pressure drops along the front, the warm air moves northwards and the cold air move towards, south setting in motion an

anticlockwise cyclonic circulation. The cyclonic circulation leads to a well developed extra tropical cyclone, with a warm front and a cold front. The plan and cross section of a well developed cyclone is given in Figure 10.9. There are pockets of warm air or warm sector wedged between the forward and the rear cold air or cold sector. The warm air glides over the cold air and a sequence of clouds appear over the sky ahead of the warm front and cause precipitation. The cold front approaches the warm air from behind and pushes the warm air up. As a result, cumulus clouds develop along the cold front. The cold front moves faster than the warm front ultimately overtaking the warm front. The warm air is completely lifted up and the front is occluded and the cyclone dissipates.

The processes of wind circulation both at the surface and aloft are closely interlinked. The extra tropical cyclone differs from the tropical cyclone in number of ways. The extra tropical cyclones have a clear frontal system

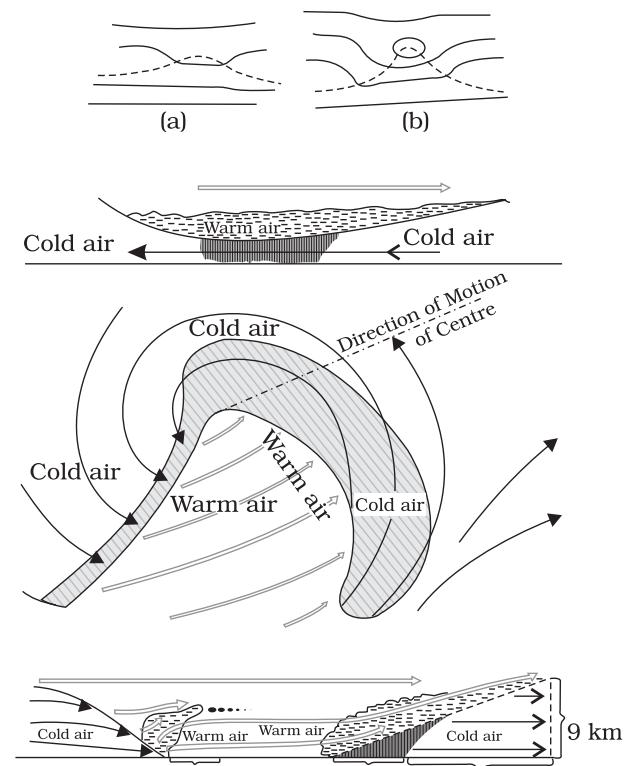


Figure 10.9 : Extra tropical cyclones

which is not present in the tropical cyclones. They cover a larger area and can originate over the land and sea. Whereas the tropical cyclones originate only over the seas and on reaching the land they dissipate. The extra tropical cyclone affects a much larger area as compared to the tropical cyclone. The wind velocity in a tropical cyclone is much higher and it is more destructive. The extra tropical cyclones move from west to east but tropical cyclones, move from east to west.

Tropical Cyclones

Tropical cyclones are violent storms that originate over oceans in tropical areas and move over to the coastal areas bringing about large scale destruction caused by violent winds, very heavy rainfall and storm surges. This is one of the most devastating natural calamities. They are known as *Cyclones* in the Indian Ocean, *Hurricanes* in the Atlantic, *Typhoons* in the Western Pacific and South China Sea, and *Willy-willies* in the Western Australia.

Tropical cyclones originate and intensify over warm tropical oceans. The conditions favourable for the formation and intensification of tropical storms are: (i) Large sea surface with temperature higher than 27°C ; (ii) Presence of the Coriolis force; (iii) Small variations in the vertical wind speed; (iv) A pre-existing weak-low-pressure area or low-level-cyclonic circulation; (v) Upper divergence above the sea level system.

The energy that intensifies the storm, comes from the condensation process in the towering cumulonimbus clouds, surrounding the centre of the storm. With continuous supply of moisture from the sea, the storm is further strengthened. On reaching the land the moisture supply is cut off and the storm dissipates. The place where a tropical cyclone crosses the coast is called the landfall of the cyclone. The cyclones, which cross 20°N latitude generally, recurve and they are more destructive.

A schematic representation of the vertical structure of a mature tropical cyclonic storm is shown in Figure 10.10.

A mature tropical cyclone is characterised by the strong spirally circulating wind around the centre, called the eye. The diameter of the circulating system can vary between 150 and 250 km.

The eye is a region of calm with subsiding air. Around the eye is the eye wall, where there is a strong spiralling ascent of air to greater height reaching the tropopause. The wind reaches maximum velocity in this region, reaching as high as 250 km per hour. Torrential rain occurs here. From the eye wall rain bands may radiate and trains of cumulus and cumulonimbus clouds may drift into the outer region. The diameter of the storm over the Bay of Bengal, Arabian sea and Indian ocean is between 600 - 1200 km. The system moves slowly about 300 - 500 km per day. The cyclone creates storm surges and they inundate the coastal low lands. The storm peters out on the land.

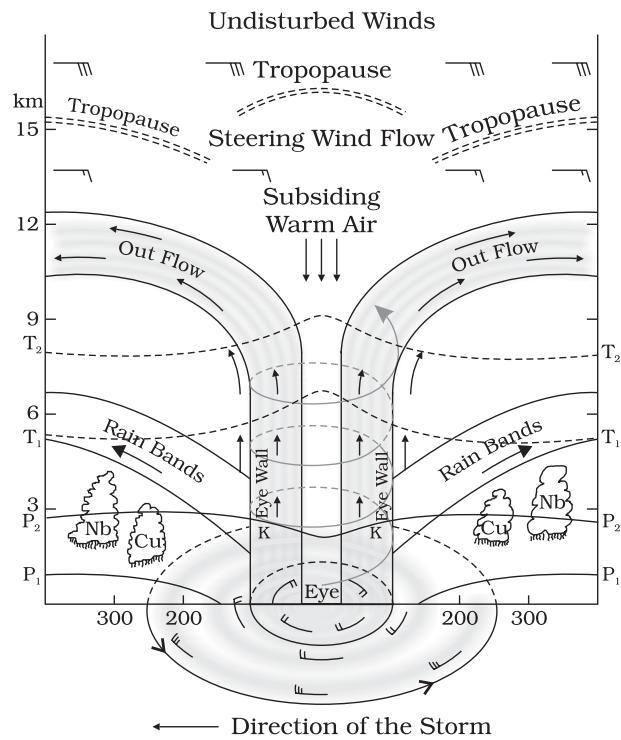


Figure 10.10 : Vertical section of the tropical cyclone (after Rama Sastry)

Thunderstorms and Tornadoes

Other severe local storms are thunderstorms and tornadoes. They are of short duration, occurring over a small area but are violent. *Thunderstorms* are caused by intense convection on moist hot days. A thunderstorm is a well-grown cumulonimbus cloud producing thunder and lightening. When the clouds extend to heights where sub-zero temperature prevails, hails are formed and they come down as hailstorm. If there is insufficient moisture, a thunderstorm can generate dust-storms. A thunderstorm is characterised by intense updraft of rising warm air, which causes the clouds to grow bigger and rise to

greater height. This causes precipitation. Later, downdraft brings down to earth the cool air and the rain. From severe thunderstorms sometimes spiralling wind descends like a trunk of an elephant with great force, with very low pressure at the centre, causing massive destruction on its way. Such a phenomenon is called a *tornado*. Tornadoes generally occur in middle latitudes. The tornado over the sea is called *water sprouts*.

These violent storms are the manifestation of the atmosphere's adjustments to varying energy distribution. The potential and heat energies are converted into kinetic energy in these storms and the restless atmosphere again returns to its stable state.

EXERCISES

1. Multiple choice questions.

- (i) If the surface air pressure is 1,000 mb, the air pressure at 1 km above the surface will be:
 - (a) 700 mb
 - (c) 900 mb
 - (b) 1,100 mb
 - (d) 1,300 mb
- (ii) The Inter Tropical Convergence Zone normally occurs:
 - (a) near the Equator
 - (b) near the Tropic of Cancer
 - (c) near the Tropic of Capricorn
 - (d) near the Arctic Circle
- (iii) The direction of wind around a low pressure in northern hemisphere is:
 - (a) clockwise
 - (c) anti-clock wise
 - (b) perpendicular to isobars
 - (d) parallel to isobars
- (iv) Which one of the following is the source region for the formation of air masses?
 - (a) the Equatorial forest
 - (c) the Siberian Plain
 - (b) the Himalayas
 - (d) the Deccan Plateau

2. Answer the following questions in about 30 words.

- (i) What is the unit used in measuring pressure? Why is the pressure measured at station level reduced to the sea level in preparation of weather maps?
- (ii) While the pressure gradient force is from north to south, i.e. from the subtropical high pressure to the equator in the northern hemisphere, why are the winds north easterlies in the tropics?
- (iii) What are the geotrophic winds?
- (iv) Explain the land and sea breezes.

3. Answer the following questions in about 150 words.
- (i) Discuss the factors affecting the speed and direction of wind.
 - (ii) Draw a simplified diagram to show the general circulation of the atmosphere over the globe. What are the possible reasons for the formation of subtropical high pressure over 30° N and S latitudes?
 - (iii) Why does tropical cyclone originate over the seas? In which part of the tropical cyclone do torrential rains and high velocity winds blow and why?

Project Work

- (i) Collect weather information over media such as newspaper, TV and radio for understanding the weather systems.
- (ii) Read the section on weather in any newspaper, preferably, one having a map showing a satellite picture. Mark the area of cloudiness. Attempt to infer the atmospheric circulation from the distribution of clouds. Compare the forecast given in the newspaper with the TV coverage, if you have access to TV. Estimate, how many days in a week was the forecast were accurate.



C H A P T E R

11

WATER IN THE ATMOSPHERE

You have already learnt that the air contains water vapour. It varies from zero to four per cent by volume of the atmosphere and plays an important role in the weather phenomena. Water is present in the atmosphere in three forms namely – gaseous, liquid and solid. The moisture in the atmosphere is derived from water bodies through evaporation and from plants through transpiration. Thus, there is a continuous exchange of water between the atmosphere, the oceans and the continents through the processes of evaporation, transpiration, condensation and precipitation.

Water vapour present in the air is known as humidity. It is expressed quantitatively in different ways. The actual amount of the water vapour present in the atmosphere is known as the *absolute humidity*. It is the weight of water vapour per unit volume of air and is expressed in terms of grams per cubic metre. The ability of the air to hold water vapour depends entirely on its temperature. The absolute humidity differs from place to place on the surface of the earth. The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the *relative humidity*. With the change of air temperature, the capacity to retain moisture increases or decreases and the relative humidity is also affected. It is greater over the oceans and least over the continents.

The 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 temperature at which saturation occurs in a given sample of air is known as *dew point*.

EVAPORATION AND CONDENSATION

The amount of water vapour in the atmosphere is added or withdrawn due to evaporation and condensation respectively. Evaporation is a process by which water is transformed from liquid to gaseous state. Heat is the main cause for evaporation. The temperature at which the water starts evaporating is referred to as the *latent heat of vapourisation*.

Increase in temperature increases water absorption and retention capacity of the given parcel of air. Similarly, if the moisture content is low, air has a potentiality of absorbing and retaining moisture. Movement of air replaces the saturated layer with the unsaturated layer. Hence, the greater the movement of air, the greater is the evaporation.

The transformation of water vapour into water is called *condensation*. Condensation is caused by the loss of heat. When moist air is cooled, it may reach a level when its capacity to hold water vapour ceases. Then, the excess water vapour condenses into liquid form. If it directly condenses into solid form, it is known as *sublimation*. In free air, condensation results from cooling around very small particles termed as hygroscopic condensation nuclei. Particles of dust, smoke and salt from the ocean are particularly good nuclei because they absorb water. Condensation also takes place when the moist air comes in contact with some colder object and it may also take place when the temperature is close to the dew point. Condensation, therefore, depends upon the amount of cooling and the relative humidity of the air. Condensation is influenced by the volume of air, temperature, pressure and humidity. Condensation takes place: (i) when

the temperature of the air is reduced to dew point with its volume remaining constant; (ii) when both the volume and the temperature are reduced; (iv) when moisture is added to the air through evaporation. However, the most favourable condition for condensation is the decrease in air temperature.

After condensation the water vapour or the moisture in the atmosphere takes one of the following forms — dew, frost, fog and clouds. Forms of condensation can be classified on the basis of temperature and location. Condensation takes place when the dew point is lower than the freezing point as well as higher than the freezing point.

Dew

When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects (rather than nuclei in air above the surface) such as stones, grass blades and plant leaves, it is known as *dew*. The ideal conditions for its formation are clear sky, calm air, high relative humidity, and cold and long nights. For the formation of dew, it is necessary that the dew point is above the freezing point.

Frost

Frost forms on cold surfaces when condensation takes place below freezing point (0°C), i.e. the dew point is at or below the freezing point. The excess moisture is deposited in the form of minute ice crystals instead of water droplets. 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 the freezing point.

Fog and Mist

When the temperature of an air mass containing a large quantity of water vapour falls all of a sudden, condensation takes place within itself on fine dust particles. So, the *fog* is a cloud with its base at or very near to the ground. Because of the fog and mist, the visibility becomes poor to zero. In urban and industrial centres smoke provides plenty of nuclei which help the formation of fog and mist. Such a

condition when fog is mixed with smoke, is described as *smog*. The only difference between the mist and fog is that mist contains more moisture than the fog. In mist each nuclei contains a thicker layer of moisture. Mists are frequent over mountains as the rising warm air up the slopes meets a cold surface. Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents. Fogs are mini clouds in which condensation takes place around nuclei provided by the dust, smoke, and the salt particles.

Clouds

Cloud is a mass of minute water droplets or tiny crystals of ice formed by the condensation of the water vapour in free air at considerable elevations. As the clouds are formed at some height over the surface of the earth, they take various shapes. According to their height, expanse, density and transparency or opaqueness clouds are grouped under four types : (i) cirrus; (ii) cumulus; (iii) stratus; (iv) nimbus.

Cirrus

Cirrus clouds are formed at high altitudes (8,000 - 12,000m). They are thin and detached clouds having a feathery appearance. They are always white in colour.

Cumulus

Cumulus clouds look like cotton wool. They are generally formed at a height of 4,000 - 7,000 m. They exist in patches and can be seen scattered here and there. They have a flat base.

Stratus

As their name implies, these are layered clouds covering large portions of the sky. These clouds are generally formed either due to loss of heat or the mixing of air masses with different temperatures.

Nimbus

Nimbus clouds are black or dark gray. They form at middle levels or very near to the surface

of the earth. These are extremely dense and opaque to the rays of the sun. Sometimes, the clouds are so low that they seem to touch the ground. Nimbus clouds are shapeless masses of thick vapour.



Figure 11.1



Figure 11.2

Identify these cloud types which are shown in Figure 11.1 and 11.2.

A combination of these four basic types can give rise to the following types of clouds: *high clouds* – cirrus, cirrostratus, cirrocumulus; *middle clouds* – altostratus and altocumulus; *low clouds* – stratocumulus and nimbostratus and *clouds with extensive vertical development* – cumulus and cumulonimbus.

Precipitation

The process of 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 to the earth's surface. So after the condensation of water vapour, the release of moisture is known as *precipitation*. This may take place in liquid or solid form. The precipitation in the form of water is called *rainfall*, when the temperature is lower than the 0°C, precipitation takes place in the form of fine flakes of snow and is called *snowfall*. Moisture is released in the form of hexagonal crystals. These crystals form flakes of snow. Besides rain and snow, other forms of precipitation are *sleet* and *hail*, though the latter are limited in occurrence and are sporadic in both time and space.

Sleet is frozen raindrops and refrozen melted snow-water. When a layer of air with the temperature above freezing point overlies a subfreezing layer near the ground, precipitation takes place in the form of sleet. 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.

Sometimes, drops of rain after being released by the clouds become solidified into small rounded solid pieces of ice and which reach the surface of the earth are called *hailstones*. These are formed by the rainwater passing through the colder layers. Hailstones have several concentric layers of ice one over the other.

Types of Rainfall

On the basis of origin, rainfall may be classified into three main types – the convectional, orographic or relief and the cyclonic or frontal.

Conventional Rain

The, air on being heated, becomes light and rises up in convection currents. As it rises, it expands and loses heat and consequently, condensation takes place and cumulous clouds are formed. With thunder and lightning, heavy rainfall takes place but this does not last

long. Such rain is common in the summer or in the hotter part of the day. It is very common in the equatorial regions and interior parts of the continents, particularly in the northern hemisphere.

Orographic Rain

When the saturated air mass comes across a mountain, it is forced to ascend and as it rises, it expands; the temperature falls, and the moisture is condensed. The chief characteristic of this sort of rain is that the windward slopes receive greater rainfall. After giving rain on the windward side, when these winds reach the other slope, they descend, and their temperature rises. Then their capacity to take in moisture increases and hence, these leeward slopes remain rainless and dry. The area situated on the leeward side, which gets less rainfall is known as the *rain-shadow area*. It is also known as the *relief rain*.

Cyclonic Rain

You have already read about extra tropical cyclones and cyclonic rain in Chapter 10. Please consult Chapter 10 to understand cyclonic rainfall.

World Distribution of Rainfall

Different places on the earth's surface receive different amounts of rainfall in a year and that too in different seasons.

In general, as we proceed from the equator towards the poles, rainfall goes on decreasing steadily. The coastal areas of the world receive greater amounts of rainfall than the interior of

the continents. The rainfall is more over the oceans than on the landmasses of the world because of being great sources of water. Between the latitudes 35° and 40° N and S of the equator, the rain is heavier on the eastern coasts and goes on decreasing towards the west. But, between 45° and 65° N and S of equator, due to the westerlies, the rainfall is first received on the western margins of the continents and it goes on decreasing towards the east. Wherever mountains run parallel to the coast, the rain is greater on the coastal plain, on the windward side and it decreases towards the leeward side.

On the basis of the total amount of annual precipitation, major precipitation regimes of the world are identified as follows.

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 land receive heavy rainfall of over 200 cm per annum. Interior continental areas receive moderate rainfall varying from 100 - 200 cm per annum. The coastal areas of the continents receive moderate amount of rainfall. The central parts of the tropical land and the eastern and interior parts of the temperate lands receive rainfall varying between 50 - 100 cm per annum. Areas lying in the rain shadow zone of the interior of the continents and high latitudes receive very low rainfall-less than 50 cm per annum. Seasonal distribution of rainfall provides an important aspect to judge its effectiveness. In some regions rainfall is distributed evenly throughout the year such as in the equatorial belt and in the western parts of cool temperate regions.

EXERCISES

1. Multiple choice questions.
 - (i) Which one of the following is the most important constituent of the atmosphere for human beings?
 - (a) Water vapour
 - (b) Nitrogen
 - (c) Dust particle
 - (d) Oxygen

- (ii) Which one of the following process is responsible for transforming liquid into vapour?
(a) Condensation (c) Evaporation
(b) Transpiration (d) Precipitation
- (iii) The air that contains moisture to its full capacity :
(a) Relative humidity (c) Absolute humidity
(b) Specific humidity (d) Saturated air
- (iv) Which one of the following is the highest cloud in the sky?
(a) Cirrus (c) Nimbus
(b) Stratus (d) Cumulus
2. Answer the following questions in about 30 words.
- (i) Name the three types of precipitation.
(ii) Explain relative humidity.
(iii) Why does the amount of water vapour decreases rapidly with altitude?
(iv) How are clouds formed? Classify them.
3. Answer the following questions in about 150 words.
- (i) Discuss the salient features of the world distribution of precipitation.
(ii) What are forms of condensation? Describe the process of dew and frost formation.

Project Work

Browse through the newspaper from 1st June to 31st December and note the news about extreme rainfall in different parts of the country.

WORLD CLIMATE AND CLIMATE CHANGE

The world climate can be studied by organising information and data on climate and synthesising them in smaller units for easy understanding, description and analysis. Three broad approaches have been adopted for classifying climate. They are empirical, genetic and applied. Empirical classification is based on observed data, particularly on temperature and precipitation. Genetic classification attempts to organise climates according to their causes. Applied classification is for specific purpose.

KOEPPEN'S SCHEME OF CLASSIFICATION OF CLIMATE

The most widely used classification of climate is the empirical climate classification scheme developed by V. Koeppen. Koeppen identified a close relationship between the distribution of vegetation and climate. He selected certain values of temperature and precipitation and

related them to the distribution of vegetation and used these values for classifying the climates. It is an empirical classification based on mean annual and mean monthly temperature and precipitation data. He introduced the use of capital and small letters to designate climatic groups and types. Although developed in 1918 and modified over a period of time, Koeppen's scheme is still popular and in use.

Koeppen recognised five major climatic groups, four of them are based on temperature and one on precipitation. Table 12.1 lists the climatic groups and their characteristics according to Koeppen. The capital letters : A,C, D and E delineate humid climates and B dry climates.

The climatic groups are subdivided into types, designated by small letters, based on seasonality of precipitation and temperature characteristics. The seasons of dryness are indicated by the small letters : f, m, w and s, where f corresponds to no dry season,

Table 12.1 : Climatic Groups According to Koeppen

Group	Characteristics
A - Tropical	Average temperature of the coldest month is 18° C or higher
B - Dry Climates	Potential evaporation exceeds precipitation
C - Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3°C but below 18°C
D - Cold Snow Forest Climates	The average temperature of the coldest month is minus 3° C or below
E - Cold Climates	Average temperature for all months is below 10° C
H - High Land	Cold due to elevation

m - monsoon climate, w- winter dry season and s - summer dry season. The small letters a, b, c and d refer to the degree of severity of temperature. The B- Dry Climates are subdivided using the capital letters S for steppe or semi-arid and W for deserts. The climatic types are listed in Table 12.2. The distribution of climatic groups and types is shown in Table 12.1.

islands of East Indies. Significant amount of rainfall occurs in every month of the year as thunder showers in the afternoon. The temperature is uniformly high and the annual range of temperature is negligible. The maximum temperature on any day is around 30°C while the minimum temperature is around 20°C. Tropical evergreen forests with dense canopy cover and large biodiversity are found in this climate.

Table 12.2 : Climatic Types According to Koeppen

Group	Type	Letter Code	Characteristics
A-Tropical Humid Climate	Tropical wet	Af	No dry season
	Tropical monsoon	Am	Monsoonal, short dry season
	Tropical wet and dry	Aw	Winter dry season
B-Dry Climate	Subtropical steppe	BSh	Low-latitude semi arid or dry
	Subtropical desert	BWh	Low-latitude arid or dry
	Mid-latitude steppe	BSk	Mid-latitude semi arid or dry
	Mid-latitude desert	BWk	Mid-latitude arid or dry
C-Warm temperate (Mid-latitude) Climates	Humid subtropical	Cfa	No dry season, warm summer
	Mediterranean	Cs	Dry hot summer
	Marine west coast	Cfb	No dry season, warm and cool summer
D-Cold Snow-forest Climates	Humid continental	Df	No dry season, severe winter
	Subarctic	Dw	Winter dry and very severe
E-Cold Climates	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H-Highland	Highland	H	Highland with snow cover

Group A : Tropical Humid Climates

Tropical humid climates exist between Tropic of Cancer and Tropic of Capricorn. The sun being overhead throughout the year and the presence of Inter Tropical Convergence Zone (INTCZ) make the climate hot and humid. Annual range of temperature is very low and annual rainfall is high. The tropical group is divided into three types, namely (i) Af- Tropical wet climate; (ii) Am - Tropical monsoon climate; (iii) Aw- Tropical wet and dry climate.

Tropical Wet Climate (Af)

Tropical wet climate is found near the equator. The major areas are the Amazon Basin in South America, western equatorial Africa and the

Tropical Monsoon Climate (Am)

Tropical monsoon climate (Am) is found over the Indian sub-continent, North Eastern part of South America and Northern Australia. Heavy rainfall occurs mostly in summer. Winter is dry. The detailed climatic account of this climatic type is given in the book on *India: Physical Environment*.

Tropical Wet and Dry Climate (Aw)

Tropical wet and dry climate occurs north and south of Af type climate regions. It borders with dry climate on the western part of the continent and Cf or Cw on the eastern part. Extensive Aw climate is found to the north and south of the Amazon forest in Brazil and adjoining parts

of Bolivia and Paraguay in South America, Sudan and south of Central Africa. The annual rainfall in this climate is considerably less than that in Af and Am climate types and is variable also. The wet season is shorter and the dry season is longer with the drought being more severe. Temperature is high throughout the year and diurnal ranges of temperature are the greatest in the dry season. Deciduous forest and tree-shredded grasslands occur in this climate.

Dry Climates : B

Dry climates are characterised by very low rainfall that is not adequate for the growth of plants. These climates cover a very large area of the planet extending over large latitudes from 15° - 60° north and south of the equator. At low latitudes, from 15° - 30° , they occur in the area of subtropical high where subsidence and inversion of temperature do not produce rainfall. On the western margin of the continents, adjoining the cold current, particularly over the west coast of South America, they extend more equatorwards and occur on the coast land. In middle latitudes, from 35° - 60° north and south of equator, they are confined to the interior of continents where maritime-humid winds do not reach and to areas often surrounded by mountains.

Dry climates are divided into steppe or semi-arid climate (BS) and desert climate (BW). They are further subdivided as subtropical steppe (BSh) and subtropical desert (BWh) at latitudes from 15° - 35° and mid-latitude steppe (BSk) and mid-latitude desert (BWk) at latitudes between 35° - 60° .

Subtropical Steppe (BSh) and Subtropical Desert (BWh) Climates

Subtropical steppe (BSh) and subtropical desert (BWh) have common precipitation and temperature characteristics. Located in the transition zone between humid and dry climates, subtropical steppe receives slightly more rainfall than the desert, adequate enough for the growth of sparse grasslands. The rainfall in both the climates is highly variable. The variability in the rainfall affects the life in the steppe much more than in the desert, more

often causing famine. Rain occurs in short intense thundershowers in deserts and is ineffective in building soil moisture. Fog is common in coastal deserts bordering cold currents. Maximum temperature in the summer is very high. The highest shade temperature of 58°C was recorded at *Al Aziziyah*, Libya on 13 September 1922. The annual and diurnal ranges of temperature are also high.

Warm Temperate (Mid-Latitude) Climates-C

Warm temperate (mid-latitude) climates extend from 30° - 50° of latitude mainly on the eastern and western margins of continents. These climates generally have warm summers with mild winters. They are grouped into four types: (i) Humid subtropical, i.e. dry in winter and hot in summer (Cwa); (ii) Mediterranean (Cs); (iii) Humid subtropical, i.e. no dry season and mild winter (Cfa); (iv) Marine west coast climate (Cfb).

Humid Subtropical Climate (Cwa)

Humid subtropical climate occurs poleward of Tropic of Cancer and Capricorn, mainly in North Indian plains and South China interior plains. The climate is similar to Aw climate except that the temperature in winter is warm.

Mediterranean Climate (Cs)

As the name suggests, Mediterranean climate occurs around Mediterranean sea, along the west coast of continents in subtropical latitudes between 30° - 40° latitudes e.g. — Central California, Central Chile, along the coast in south eastern and south western Australia. These areas come under the influence of sub tropical high in summer and westerly wind in winter. Hence, the climate is characterised by hot, dry summer and mild, rainy winter. Monthly average temperature in summer is around 25°C and in winter below 10°C . The annual precipitation ranges between 35 - 90 cm.

Humid Subtropical (Cfa) Climate

Humid subtropical climate lies on the eastern parts of the continent in subtropical latitudes. In this region the air masses are generally

unstable and cause rainfall throughout the year. They occur in eastern United States of America, southern and eastern China, southern Japan, northeastern Argentina, coastal south Africa and eastern coast of Australia. The annual averages of precipitation vary from 75-150 cm. Thunderstorms in summer and frontal precipitation in winter are common. Mean monthly temperature in summer is around 27°C, and in winter it varies from 5°-12° C. The daily range of temperature is small.

Marine West Coast Climate (Cfb)

Marine west coast climate is located poleward from the Mediterranean climate on the west coast of the continents. The main areas are: Northwestern Europe, west coast of North America, north of California, southern Chile, southeastern Australia and New Zealand. Due to marine influence, the temperature is moderate and in winter, it is warmer than for its latitude. The mean temperature in summer months ranges from 15°-20°C and in winter 4°-10°C. The annual and daily ranges of temperature are small. Precipitation occurs throughout the year. Precipitation varies greatly from 50-250cm.

Cold Snow Forest Climates (D)

Cold snow forest climates occur in the large continental area in the northern hemisphere between 40°-70° north latitudes in Europe, Asia and North America. Cold snow forest climates are divided into two types: (i) Df- cold climate with humid winter; (ii) Dw- cold climate with dry winter. The severity of winter is more pronounced in higher latitudes.

Cold Climate with Humid Winters (Df)

Cold climate with humid winter occurs poleward of marine west coast climate and mid latitude steppe. The winters are cold and snowy. The frost free season is short. The annual ranges of temperature are large. The weather changes are abrupt and short. Poleward, the winters are more severe.

Cold Climate with Dry Winters (Dw)

Cold climate with dry winter occurs mainly over Northeastern Asia. The development of pronounced winter anti cyclone and its weakening in summer sets in monsoon like reversal of wind in this region. Poleward summer temperatures are lower and winter temperatures are extremely low with many locations experiencing below freezing point temperatures for up to seven months in a year. Precipitation occurs in summer. The annual precipitation is low from 12-15 cm.

Polar Climates (E)

Polar climates exist poleward beyond 70° latitude. Polar climates consist of two types: (i) Tundra (ET); (ii) Ice Cap (EF).

Tundra Climate (ET)

The tundra climate (ET) is so called after the types of vegetation, like low growing mosses, lichens and flowering plants. This is the region of permafrost where the sub soil is permanently frozen. The short growing season and water logging support only low growing plants. During summer, the tundra regions have very long duration of day light.

Ice Cap Climate (EF)

The ice cap climate (EF) occurs over interior Greenland and Antarctica. Even in summer, the temperature is below freezing point. This area receives very little precipitation. The snow and ice get accumulated and the mounting pressure causes the deformation of the ice sheets and they break. They move as icebergs that float in the Arctic and Antarctic waters. Plateau Station , Antarctica ,79°S, portray this climate.

Highland Climates (H)

Highland climates are governed by topography. In high mountains, large changes in mean temperature occur over short distances. Precipitation types and intensity also vary spatially across high lands. There is vertical zonation of layering of climatic types with elevation in the mountain environment.

CLIMATE CHANGE

The earlier chapters on climate summarised our understanding of climate as it prevails now. The type of climate we experience now might be prevailing over the last 10,000 years with minor and occasionally wide fluctuations. The planet earth has witnessed many variations in climate since the beginning. Geological records show alteration of glacial and inter-glacial periods. The geomorphological features, especially in high altitudes and high latitudes, exhibit traces of advances and retreats of glaciers. The sediment deposits in glacial lakes also reveal the occurrence of warm and cold periods. The rings in the trees provide clues about wet and dry periods. Historical records describe the vagaries in climate. All these evidences indicate that change in climate is a natural and continuous process.

India also witnessed alternate wet and dry periods. Archaeological findings show that the Rajasthan desert experienced wet and cool climate around 8,000 B.C. The period 3,000-1,700 B.C. had higher rainfall. From about 2,000-1,700 B.C., this region was the centre of the Harappan civilisation. Dry conditions accentuated since then.

In the geological past, the earth was warm some 500-300 million years ago, through the Cambrian, Ordovician and Silurian periods. During the Pleistocene epoch, glacial and inter-glacial periods occurred, the last major peak glacial period was about 18,000 years ago. The present inter-glacial period started 10,000 years ago.

Climate in the recent past

Variability in climate occurs all the time. The nineties decade of the last century witnessed extreme weather events. The 1990s recorded the warmest temperature of the century and some of the worst floods around the world. The worst devastating drought in the Sahel region, south of the Sahara desert, from 1967-1977 is one such variability. During the 1930s, severe drought occurred in southwestern Great Plains of the United States, described as the *dust bowl*. Historical records of crop yield or

crop failures, of floods and migration of people tell about the effects of changing climate. A number of times Europe witnessed warm, wet, cold and dry periods, the significant episodes were the warm and dry conditions in the tenth and eleventh centuries, when the Vikings settled in Greenland. Europe witnessed "Little Ice Age" from 1550 to about 1850. From about 1885-1940 world temperature showed an upward trend. After 1940, the rate of increase in temperature slowed down.

Causes of Climate Change

The causes for climate change are many. They can be grouped into astronomical and terrestrial causes. The astronomical causes are the changes in solar output associated with sunspot activities. Sunspots are dark and cooler patches on the sun which increase and decrease in a cyclical manner. According to some meteorologists, when the number of sunspots increase, cooler and wetter weather and greater storminess occur. A decrease in sunspot numbers is associated with warm and drier conditions. Yet, these findings are not statistically significant.

An another astronomical theory is Millankovitch oscillations, which infer cycles in the variations in the earth's orbital characteristics around the sun, the wobbling of the earth and the changes in the earth's axial tilt. All these alter the amount of insolation received from the sun, which in turn, might have a bearing on the climate.

Volcanism is considered as another cause for climate change. Volcanic eruption throws up lots of aerosols into the atmosphere. These aerosols remain in the atmosphere for a considerable period of time reducing the sun's radiation reaching the Earth's surface. After the recent Pinatoba and El Cion volcanic eruptions, the average temperature of the earth fell to some extent for some years.

The most important anthropogenic effect on the climate is the increasing trend in the concentration of greenhouse gases in the atmosphere which is likely to cause global warming.

Global Warming

Due to the presence of greenhouse gases, the atmosphere is behaving like a *greenhouse*. The atmosphere also transmits the incoming solar radiation but absorbs the vast majority of long wave radiation emitted upwards by the earth's surface. The gases that absorb long wave radiation are called greenhouse gases. The processes that warm the atmosphere are often collectively referred to as the *greenhouse effect*.

The term *greenhouse* is derived from the analogy to a greenhouse used in cold areas for preserving heat. A *greenhouse* is made up of glass. The glass which is transparent to incoming short wave solar radiation is opaque to outgoing long wave radiation. The glass, therefore, allows in more radiation and prevents the long wave radiation going outside the glass house, causing the temperature inside the glasshouse structure warmer than outside. When you enter a car or a bus, during summers, where windows are closed, you feel more heat than outside. Likewise during winter the vehicles with closed doors and windows remain warmer than the temperature outside. This is another example of the *greenhouse effect*.

Greenhouse Gases(GHGs)

The primary GHGs of concern today are carbon dioxide (CO_2), Chlorofluorocarbons (CFCs), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Some other gases such as nitric oxide (NO) and carbon monoxide (CO) easily react with GHGs and affect their concentration in the atmosphere.

The effectiveness of any given GHG molecule will depend on the magnitude of the increase in its concentration, its life time in the atmosphere and the wavelength of radiation that it absorbs. The chlorofluorocarbons (CFCs) are highly effective. Ozone which absorbs ultra violet radiation in the stratosphere is very effective in absorbing terrestrial radiation when it is present in the lower troposphere. Another important point to be noted is that the more time the GHG molecule remains in the atmosphere, the longer

it will take for earth's atmospheric system to recover from any change brought about by the latter.

The *largest concentration* of GHGs in the atmosphere is *carbon dioxide*. The emission of CO_2 comes mainly from fossil fuel combustion (oil, gas and coal). Forests and oceans are the sinks for the carbon dioxide. Forests use CO_2 in their growth. So, deforestation due to changes in land use, also increases the concentration of CO_2 . The time taken for atmospheric CO_2 to adjust to changes in sources to sinks is 20-50 years. It is rising at about 0.5 per cent annually. Doubling of concentration of CO_2 over pre-industrial level is used as an index for estimating the changes in climate in climatic models.

Chlorofluorocarbons (CFCs) are products of human activity. *Ozone* occurs in the stratosphere where ultra-violet rays convert oxygen into ozone. Thus, ultra violet rays do not reach the earth's surface. The CFCs which drift into the stratosphere destroy the ozone. Large depletion of ozone occurs over Antarctica. *The depletion of ozone concentration in the stratosphere* is called the *ozone hole*. This allows the ultra violet rays to pass through the troposphere.

International efforts have been initiated for reducing the emission of GHGs into the atmosphere. The most important one is the *Kyoto protocol* proclaimed in 1997. This protocol went into effect in 2005, ratified by 141 nations. Kyoto protocol bounds the 35 industrialised countries to reduce their emissions by the year 2012 to 5 per cent less than the levels prevalent in the year 1990.

The increasing trend in the concentration of GHGs in the atmosphere may, in the long run, warm up the earth. Once the global warming sets in, it will be difficult to reverse it. The effect of global warming may not be uniform everywhere. Nevertheless, the adverse effect due to global warming will adversely affect the life supporting system. Rise in the sea level due to melting of glaciers and ice-caps and thermal expansion of the sea may inundate large parts of the coastal area and islands, leading to social problems. This is another cause for serious concern for the world

community. Efforts have already been initiated to control the emission of GHGs and to arrest the trend towards global warming. Let us hope the world community responds to this challenge and adopts a lifestyle that leaves behind a livable world for the generations to come.

One of the major concerns of the world today is global warming. Let us look at how much the planet has warmed up from the temperature records.

Temperature data are available from the middle of the 19th century mostly for western Europe. The reference period for this study is 1961-90. The temperature anomalies for the earlier and later periods are estimated from the average temperature for the period 1961-90. The annual average near-surface air temperature of the world is approximately 14°C. The time series show anomalies of

annual near surface temperature over land from 1856-2000, relative to the period 1961-90 as normal for the globe.

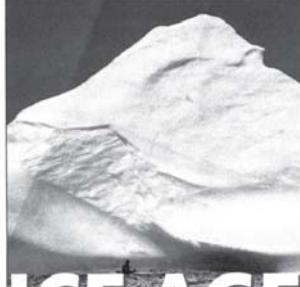
An increasing trend in temperature was discernible in the 20th century. The greatest warming of the 20th century was during the two periods, 1901-44 and 1977-99. Over each of these two periods, global temperatures rose by about 0.4°C. In between, there was a slight cooling, which was more marked in the Northern Hemisphere.

The globally averaged annual mean temperature at the end of the 20th century was about 0.6°C above that recorded at the end of the 19th century. The seven warmest years during the 1856-2000 were recorded in the last decade. The year 1998 was the warmest year, probably not only for the 20th century but also for the whole millennium.

Greenhouse gases rising alarmingly

Ancient Air Bubbles Buried In Antarctic Ice To Shed More Light On Global Warming

It has happened in the North Atlantic and may happen again. According to scientists, global warming could lead to prolonged chill



ICE AGE cometh

Air pollution biggest killer
Southeast Asia, says WHO

A smoky haze that shrouded parts of Southeast Asia this month, forcing schools and businesses to close, is just one element of a growing environmental problem that kills hundreds of thousands of people in the region annually, the World Health Organisation said.

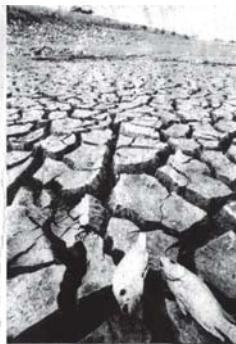
Air pollution, in major Southeast Asian and Chinese cities ranks among the worst in the world, causing breathing problems and seven million people who had a history



The research station for the European Project for Ice Coring in Antarctica.

did not get as far as humans have," said Richard B Alley, a geosciences professor at Pennsylvania State University who is an expert on ice cores. "We're changing the world really hugely — way past where it's been for a long time."

James White, a geology professor at the University of Colorado, Boulder, not involved with the study, said that although the ice-age evidence showed that levels of carbon dioxide and the other greenhouse gases rose and fell in response to warming and cooling, the gases could clearly take the lead as well.



This file photo shows dead fish lying on the dried bottom of the Ding An reservoir in China's Hainan island, an island on the edge of the vast Pacific. Hainan gets a large part of its rain during the typhoon season. The problem is, for two years now, there has not been a single typhoon, and

Gangotri is shrinking 23m every year

Geneva: Himalayan glaciers, including the Gangotri, are receding at among the fastest rates in the world due to global warming, threatening water shortages for millions of people in India, China and Nepal, a leading conservation group said on Monday.

The Worldwide Fund for Nature (WWF) said in a new study that Himalayan glaciers were receding 10-15 metres per year on average and that the rate was accelerating as global warming increases.

In India, the Gangotri glacier is receding at an average rate of 23 metres per year, the study said.

"Himalayan glaciers are among the fastest retreating glaciers globally due to the effects of global warming," the WWF said in a statement. "This will eventually result in water shortages for hundreds of millions of people who rely



This image shows how the Gangotri glacier terminus has retracted since 1780. The contour lines are approximate. (Image by Jesse Allen, Earth Observatory; based on data provided by the ASTER Science Team)

on glacier-dependent rivers in India, China and Nepal," it said.

Himalayan glaciers feed seven of Asia's greatest rivers — Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang Ho.



The rapid melting of Himalayan glaciers could increase the volume of meltwater, causing more frequent flooding, said Jennifer Francis, the WWF's programme director. "This situation is a warning sign that water levels are rising and sea levels are rising, and that's a concern for coastal communities around the world."

Write an explanatory note on "global warming".

EXERCISES**1. Multiple choice questions.**

- (i) Which one of the following is suitable for Koeppen's "A" type of climate?
 - (a) High rainfall in all the months
 - (b) Mean monthly temperature of the coldest month more than freezing point
 - (c) Mean monthly temperature of all the months more than 18° C
 - (d) Average temperature for all the months below 10° C
- (ii) Koeppen's system of classification of climates can be termed as :
 - (a) Applied (b) Systematic (c) Genetic (d) Empirical
- (iii) Most of the Indian Peninsula will be grouped according to Koeppen's system under:
 - (a) "Af" (b) "BSh" (c) "Cfb" (d) "Am"
- (iv) Which one of the following years is supposed to have recorded the warmest temperature the world over?
 - (a) 1990 (b) 1998 (c) 1885 (d) 1950
- (v) Which one of the following groups of four climates represents humid conditions?
 - (a) A—B—C—E
 - (b) A—C—D—E
 - (c) B—C—D—E
 - (d) A—C—D—F

2. Answer the following questions in about 30 words.

- (i) Which two climatic variables are used by Koeppen for classification of the climate?
- (ii) How is the "genetic" system of classification different from the "empirical one"?
- (iii) Which types of climates have very low range of temperature?
- (iv) What type of climatic conditions would prevail if the sun spots increase?

3. Answer the following questions in about 150 words.

- (i) Make a comparison of the climatic conditions between the "A" and "B" types of climate.
- (ii) What type of vegetation would you find in the "C" and "A" type(s) of climate?
- (iii) What do you understand by the term "Greenhouse Gases"? Make a list of greenhouse gases.

Project Work

Collect information about Kyoto declaration related to global climate changes.