Now, let us see the regional variations in precipitation. While snowfall occurs in the Himalayas, it only rains over the rest of the country. Similarly, variations are noticeable not only in the type of precipitation but also in its amount. While Cherrapunji and Mawsynram in the Khasi Hills of Meghalaya receive rainfall over 1,080 cm in a year, Jaisalmer in Rajasthan rarely gets more than 9 cm of rainfall during the same period.

Tura situated in the Garo Hills of Meghalaya may receive an amount of rainfall in a single day which is equal to 10 years of rainfall at Jaisalmer. While the annual precipitation is less than 10 cm in the north-west Himalayas and the western deserts, it exceeds 400 cm in Meghalaya.

The Ganga delta and the coastal plains of Odisha are hit by strong rain-bearing storms almost every third or fifth day in July and August while the Coromandal coast, a thousand km to the south, goes generally dry during these months. Most parts of the country get rainfall during June-September, but on the coastal areas of Tamil Nadu, it rains in the beginning of the winter season.

In spite of these differences and variations, the climate of India is monsoonal in rhythm and character.

Factors Determining the Climate of India

India's climate is controlled by a number of factors.

Latitude : You already know the latitudinal and longitudinal extent of the land of India. You also know that the Tropic of Cancer passes through the central part of India in east-west direction. Thus, northern part of the India lies in sub-tropical and temperate zone and the part lying south of the Tropic of Cancer falls in the tropical zone. The tropical zone being nearer to the equator, experiences high temperatures throughout the year with small daily and annual range. Area north of the Tropic of Cancer being away from the equator, experiences extreme climate with high daily and annual range of temperature.

The Himalayan Mountains : The lofty Himalayas in the north along with its extensions act as an effective climatic divide. The towering mountain chain provides an invincible shield to protect the subcontinent from the cold northern winds. These cold and chilly winds originate near the Arctic circle and blow across central and eastern Asia. The Himalayas also trap the monsoon winds, forcing them to shed their moisture within the subcontinent.

Distribution of Land and Water : India is flanked by the Indian Ocean on three sides in the south and girdled by a high and continuous mountain-wall in the north. As compared to the landmass, water heats up or cools down slowly. This differential heating of land and sea creates different air pressure zones in different seasons in and around the Indian subcontinent. Difference in air pressure causes reversal in the direction of monsoon winds.

Distance from the Sea : With a long coastline, large coastal areas have an equable climate. Areas in the interior of India are far away from the moderating influence of the sea. Such areas have extremes of climate. That is why, the people of Mumbai and the Konkan coast have hardly any idea of extremes of temperature and the seasonal rhythm of weather. On the other hand, the seasonal contrasts in weather at places in the interior of the country such as Delhi, Kanpur and Amritsar affect the entire sphere of life.

Altitude : Temperature decreases with height. Due to thin air, places in the mountains are cooler than places on the plains. For example, Agra and Darjiling are located on the same latitude, but temperature of January in Agra is 16° C whereas it is only 4° C in Darjiling.

Relief : The physiography or relief of India also affects the temperature, air pressure, direction and speed of wind and the amount and distribution of rainfall. The windward sides

Inter Tropical Convergence Zone (ITCZ)

The Inter Tropical Convergence Zone (ITCZ) is a low pressure zone located at the equator where trade winds converge, and so, it is a zone where air tends to ascend. In July, the ITCZ is located around 20° N-25° N latitudes (over the Gangetic plain), sometimes called the monsoon trough. This monsoon trough encourages the development of thermal low over north and northwest India. Due to the shift of ITCZ, the trade winds of the southern hemisphere cross the equator between 40° and 60° E longitudes and start blowing from southwest to northeast due to the Coriolis force. It becomes southwest monsoon. In winter, the ITCZ moves southward, and so the reversal of winds from northeast to south and southwest, takes place. They are called northeast monsoons.

of Western Ghats and Assam receive high rainfall during June-September whereas the southern plateau remains dry due to its leeward situation along the Western Ghats.

The Nature of Indian Monsoon

Monsoon is a familiar though a little known climatic phenomenon. Despite the observations spread over centuries, the monsoon continues to puzzle the scientists. Many attempts have been made to discover the exact nature and causation of monsoon, but so far, no single theory has been able to explain the monsoon fully. A real breakthrough has come recently when it was studied at the global rather than at regional level.

Systematic studies of the causes of rainfall in the South Asian region help to understand the causes and salient features of the monsoon, particularly some of its important aspects, such as:

(i) The onset of the monsoon.
(ii) Break in the monsoon.

Onset of the Monsoon

Towards the end of the nineteenth century, it was believed that the differential heating of land and sea during the summer months is the mechanism which sets the stage for the monsoon winds to drift towards the subcontinent. During April and May when the sun shines vertically over the Tropic of Cancer, the large landmass in the north of Indian ocean gets intensely heated. This causes the formation of an intense low pressure in the northwestern part of the subcontinent. Since the pressure in the Indian Ocean in the south of the landmass is high as water gets heated slowly, the low pressure cell attracts the southeast trades across the Equator. These conditions help in the northward shift in the position of the ITCZ. The southwest monsoon may thus, be seen as a continuation of the southeast trades deflected towards the Indian subcontinent after crossing the Equator. These winds cross the Equator between 40° E and 60° E longitudes.

Figure 4.1 : Onset of Monsoon

The shift in the position of the ITCZ is also related to the phenomenon of the withdrawal of the westerly jet stream from its position over the north Indian plain, south of the Himalayas. The easterly jet stream sets in along 15° N latitude only after the western jet stream has withdrawn itself from the region. This easterly jet stream is held responsible for the burst of the monsoon in India.

Entry of Monsoon into India : The southwest monsoon sets in over the Kerala coast by 1st June and moves swiftly to reach Mumbai and Kolkata between 10th and 13th June. By mid-July, southwest monsoon engulfs the entire subcontinent (Figure 4.2)

Break in the Monsoon

During the south-west monsoon period after having rains for a few days, if rain fails to occur for one or more weeks, it is known as break in the monsoon. These dry spells are quite common during the rainy season. These breaks in the different regions are due to different reasons:

(i) In northern India rains are likely to fail if the rain-bearing storms are not very frequent along the monsoon trough or the ITCZ over this region.

(ii) Over the west coast the dry spells are associated with days when winds blow parallel to the coast.

The Rhythm of Seasons

The climatic conditions of India can best be described in terms of an annual cycle of seasons. The meteorologists recognise the following four seasons :

(i) the cold weather season
(ii) the hot weather season
(iii) the southwest monsoon season
(iv) the retreating monsoon season.

The Cold Weather Season

Temperature : Usually, the cold weather season sets in by mid-November in northern India. December and January are the coldest months in the northern plain. The mean daily temperature remains below 21° C over most parts of northern India. The night temperature may be quite low, sometimes going below freezing point in Punjab and Rajasthan.

There are three main reasons for the excessive cold in north India during this season :

(i) States like Punjab, Haryana and Rajasthan being far away from the moderating influence of sea experience continental climate.

(ii) The snowfall in the nearby Himalayan ranges creates cold wave situation; and

(iii) Around February, the cold winds coming from the Caspian Sea and Turkmenistan

EI-Nino and the Indian Monsoon

EI-Nino is a complex weather system that appears once every three to seven years, bringing drought, floods and other weather extremes to different parts of the world.

The system involves oceanic and atmospheric phenomena with the appearance of warm currents off the coast of Peru in the Eastern Pacific and affects weather in many places including India. EI-Nino is merely an extension of the warm equatorial current which gets replaced temporarily by cold Peruvian current or Humbolt current (locate these currents in your atlas). This current increases the temperature of water on the Peruvian coast by 10° C. This results in:

(i) the distortion of equatorial atmospheric circulation;
(ii) irregularities in the evaporation of sea water;
(iii) reduction in the amount of planktons which further reduces the number of fish in the sea.

The word EI-Nino means 'Child Christ' because this current appears around Christmas in December. December is a summer month in Peru (Southern Hemisphere).

EI-Nino is used in India for forecasting long range monsoon rainfall. In 1990-91, there was a wild EI-Nino event and the onset of southwest monsoon was delayed over most parts of the country ranging from five to twelve days.

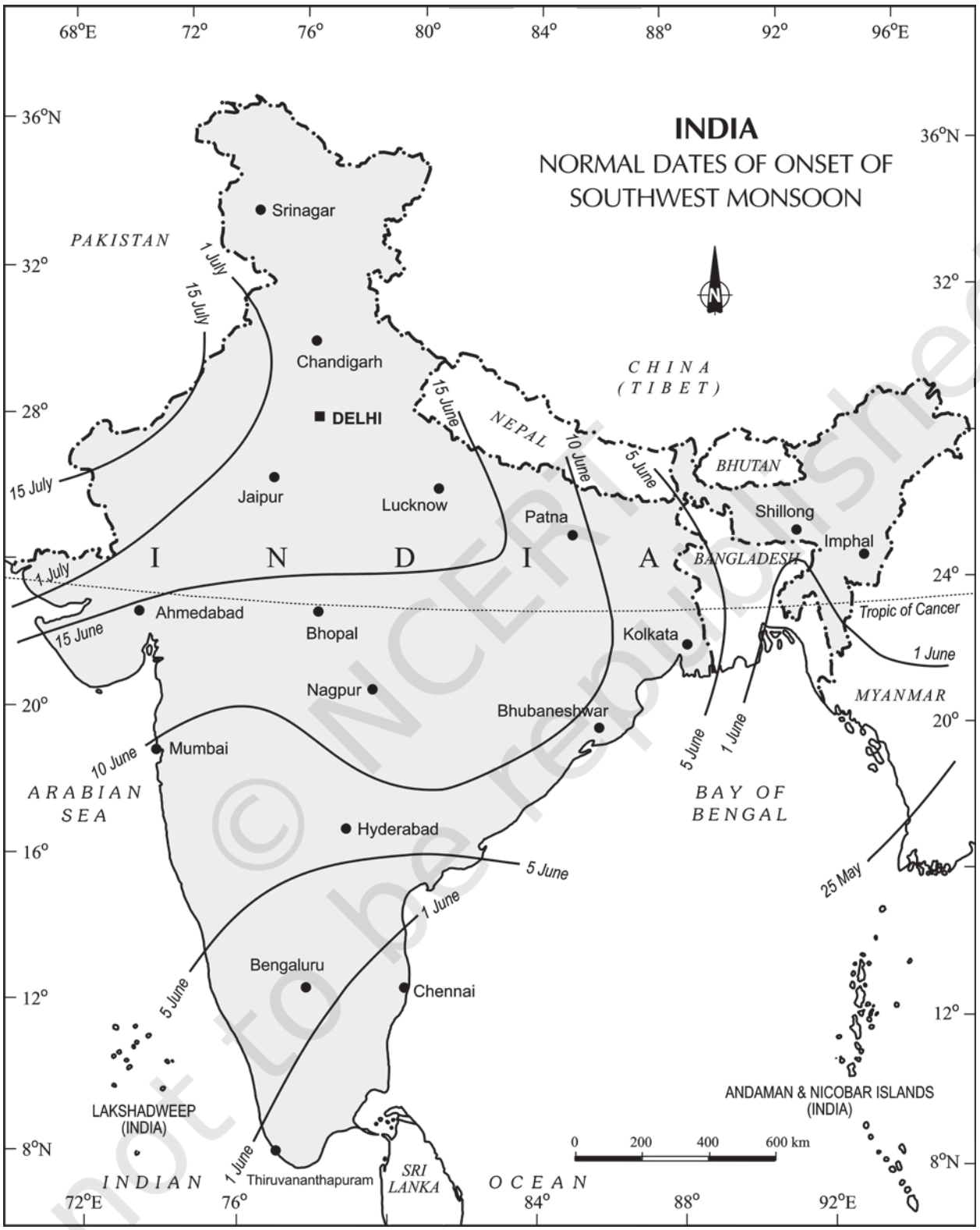

Figure 4.2 : India : Normal Dates of Onset of the Southwest Monsoon

bring cold wave along with frost and fog over the northwestern parts of India.

Understanding the Monsoon

Attempts have been made to understand the nature and mechanism of the monsoon on the basis of data collected on land, oceans and in the upper atmosphere. The intensity of southwest monsoon winds of southern oscillation can be measured, among others, by measuring the difference in pressure between Tahiti (roughly 20° S and 140° W) in French Polynesia in East Pacific and port Darwin (12° 30'S and 131° E) in northern Australia. Indian Meteorological Department (IMD) can forecast the possible behaviour of monsoons on the basis of 16 indicators.

The Peninsular region of India, however, does not have any well-defined cold weather season. There is hardly any seasonal change in the distribution pattern of the temperature in coastal areas because of moderating influence of the sea and the proximity to equator. For example, the mean maximum temperature for January at Thiruvanantapuram is as high as 21° C, and for June, it is 29.5° C. Temperatures at the hills of Western Ghats remain comparatively low.

Pressure and Winds : By the end of December (22nd December), the sun shines vertically over the Tropic of Capricorn in the southern hemisphere. The weather in this season is characterised by feeble high pressure conditions over the northern plain. In south India, the air pressure is slightly lower. The isobars of 1019 mb and 1013 mb pass through northwest India and far south, respectively.

As a result, winds start blowing from northwestern high pressure zone to the low air pressure zone over the Indian Ocean in the south.

Due to low pressure gradient, the light winds with a low velocity of about 3-5 km per hour begin to blow outwards. By and large, the topography of the region influences the wind direction. They are westerly or northwesterly down the Ganga Valley. They become northerly in the Ganga-Brahmaputra delta. Free from the influence of topography, they are clearly northeasterly over the Bay of Bengal.

During the winters, the weather in India is pleasant. The pleasant weather conditions, however, at intervals, get disturbed by shallow cyclonic depressions originating over the east Mediterranean Sea and travelling eastwards across West Asia, Iran, Afghanistan and Pakistan before they reach the northwestern parts of India. On their way, the moisture content gets augmented from the Caspian Sea in the north and the Persian Gulf in the south. What is the role of Westerly Jet Streams in steering these depressions in India?

Rainfall : Winter monsoons do not cause rainfall as they move from land to the sea. It is because firstly, they have little humidity; and secondly, due to anti cyclonic circulation on land, the possibility of rainfall from them reduces. So, most parts of India do not have rainfall in the winter season. However, there are some exceptions to it:

(i) In northwestern India, some weak temperate cyclones from the Mediterranean sea cause rainfall in Punjab, Haryana, Delhi and western Uttar Pradesh. Although the amount is meagre, it is highly beneficial for rabi crops. The precipitation is in the form of snowfall in the lower Himalayas. It is this snow that sustains the flow of water in the Himalayan rivers during the summer months. The precipitation goes on decreasing from west to east in the plains and from north to south in the mountains. The average winter rainfall in Delhi is around 53 mm. In Punjab and Bihar, rainfall remains

between 25 mm and 18 mm respectively.

(ii) Central parts of India and northern parts of southern Peninsula also get winter rainfall occasionally.

(iii) Arunachal Pradesh and Assam in the northeastern parts of India also have rains between 25 mm and 50 mm during these winter months.

(iv) During October and November, northeast monsoon while crossing over the Bay of Bengal, picks up moisture and causes torrential rainfall over the Tamil Nadu coast, southern Andhra Pradesh, southeast Karnataka and southeast Kerala.

The Hot Weather Season

Temperature: With the apparent northward movement of the sun towards the Tropic of Cancer in March, temperatures start rising in north India. April, May and June are the months of summer in north India. In most parts of India, temperatures recorded are between 30°-32° C. In March, the highest day temperature of about 38° C occurs in the Deccan Plateau while in April, temperature ranging between 38° C and 43° C are found in Gujarat and Madhya Pradesh. In May, the heat belt moves further north, and in the north-western part of India, temperatures around 48° C are not uncommon.

The hot weather season in south India is mild and not so intense as found in north India. The Peninsular situation of south India with moderating effect of the oceans keeps the temperatures lower than that prevailing in north India. So, temperatures remain between 26° C and 32° C. Due to altitude, the temperatures in the hills of Western Ghats remain below 25° C. In the coastal regions, the north-south extent of isotherms parallel to the coast confirms that temperature does not decrease from north to south rather it increases from the coast to the interior. The mean daily minimum temperature during the summer months also remains quite high and rarely goes below 26° C.

Pressure and Winds : The summer months are a period of excessive heat and falling air pressure in the northern half of the country. Because of the heating of the subcontinent, the ITCZ moves northwards occupying a position centred at 25° N in July. Roughly, this elongated low pressure monsoon trough extends over the Thar desert in the north-west to Patna and Chotanagpur plateau in the east-southeast. The location of the ITCZ attracts a surface circulation of the winds which are southwesterly on the west coast as well as along the coast of West Bengal and Bangladesh. They are easterly or south-easterly over north Bengal and Bihar. It has been discussed earlier that these currents of southwesterly monsoon are in reality 'displaced' equatorial easterlies. The influx of these winds by mid-June brings about a change in the weather towards the rainy season.

In the heart of the ITCZ in the northwest, the dry and hot winds known as *'Loo'*, blow in the afternoon, and very often, they continue to well into midnight. Dust storms in the evening are very common during May in Punjab, Haryana, Eastern Rajasthan and Uttar Pradesh. These temporary storms bring a welcome respite from the oppressing heat since they bring with them light rains and a pleasant cool breeze. Occasionally, the moisture-laden winds are attracted towards the periphery of the trough. A sudden contact between dry and moist air masses gives rise to local storms of great intensity. These local storms are associated with violent winds, torrential rains and even hailstorms.

Some Famous Local Storms of Hot Weather Season

(i) *Mango Shower :* Towards the end of summer, there are pre-monsoon showers which are a common phenomena in Kerala and coastal areas of Karnataka. Locally, they are known as mango showers since they help in the early ripening of mangoes.

(ii) *Blossom Shower :* With this shower, coffee flowers blossom in Kerala and nearby areas.

(iii) *Nor Westers :* These are dreaded evening thunderstorms in Bengal and Assam. Their notorious nature can be understood from the local nomenclature of *'Kalbaisakhi'*, a calamity of the month of *Baisakh*. These showers are useful for tea, jute and rice cultivation. In Assam, these storms are known as *"Bardoisila"*.

(iv) *Loo :* Hot, dry and oppressing winds blowing in the Northern plains from Punjab to Bihar with higher intensity between Delhi and Patna.

The Southwest Monsoon Season

As a result of rapid increase of temperature in May over the northwestern plains, the low pressure conditions over there get further intensified. By early June, they are powerful enough to attract the trade winds of Southern Hemisphere coming from the Indian Ocean. These southeast trade winds cross the equator and enter the Bay of Bengal and the Arabian Sea, only to be caught up in the air circulation over India. Passing over the equatorial warm currents, they bring with them moisture in abundance. After crossing the equator, they follow a southwesterly direction. That is why they are known as southwest monsoons.

The rain in the southwest monsoon season begins rather abruptly. One result of the first rain is that it brings down the temperature substantially. This sudden onset of the moisture-laden winds associated with violent thunder and lightening, is often termed as the "break" or "burst" of the monsoons. The monsoon may burst in the first week of June in the coastal areas of Kerala, Karnataka, Goa and Maharashtra while in the interior parts of the country, it may be delayed to the first week of July. The day temperature registers a decline of 5° C to 8° C between mid-June and mid-July.

As these winds approach the land, their southwesterly direction is modified by the relief and thermal low pressure over the northwest India. The monsoon approaches the landmass in two branches:

(i) The Arabian Sea branch
(ii) The Bay of Bengal branch.

Monsoon Winds of the Arabian Sea

The monsoon winds originating over the Arabian Sea further split into three branches:

(i) Its one branch is obstructed by the Western Ghats. These winds climb the slopes of the Western Ghats from 900-1200 m. Soon, they become cool, and as a result, the windward side of the Sahyadris and Western Coastal Plain receive very heavy rainfall ranging between 250 cm and 400 cm. After crossing the Western Ghats, these winds descend and get heated up. This reduces humidity in the winds. As a result, these winds cause little rainfall east of the Western Ghats. This region of low rainfall is known as the rain-shadow area. Find out the rainfall at Kozhikode, Mangalore, Pune and Bengaluru and note the difference.

(ii) Another branch of the Arabian sea monsoon strikes the coast north of Mumbai. Moving along the Narmada and Tapi river valleys, these winds cause rainfall in extensive areas of central India. The Chotanagpur plateau gets 15 cm rainfall from this part of the branch. Thereafter, they enter the Ganga plains and mingle with the Bay of Bengal branch.

(iii) A third branch of this monsoon wind strikes the Saurashtra Peninsula and the Kachchh. It then passes over west

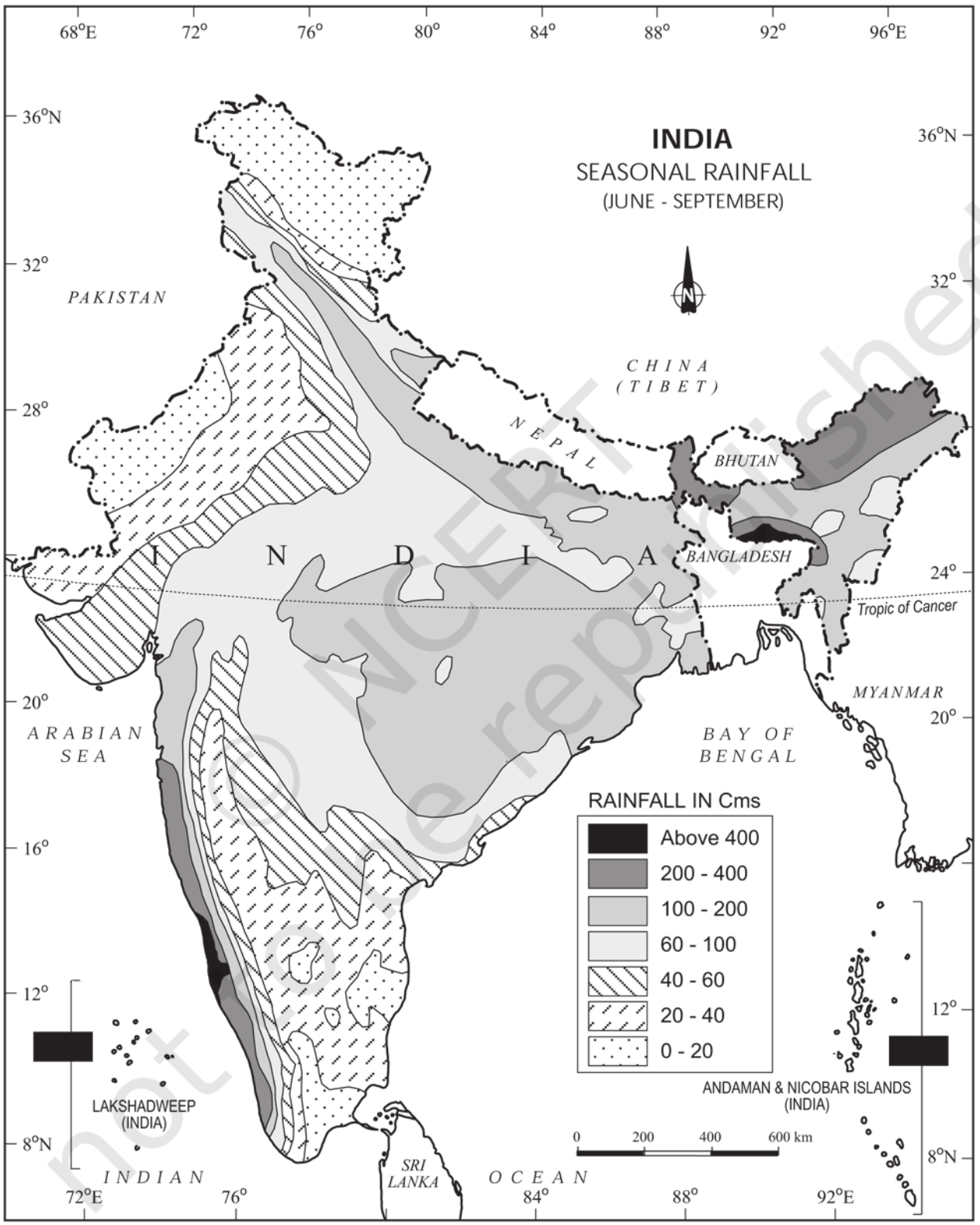

Figure 4.3 : India : Seasonal Rainfall (June-September)

Rajasthan and along the Aravalis, causing only a scanty rainfall. In Punjab and Haryana, it too joins the Bay of Bengal branch. These two branches, reinforced by each other, cause rains in the western Himalayas,

Monsoon Winds of the Bay of Bengal

The Bay of Bengal branch strikes the coast of Myanmar and part of southeast Bangladesh. But the Arakan Hills along the coast of Myanmar deflect a big portion of this branch towards the Indian subcontinent. The monsoon, therefore, enters West Bengal and Bangladesh from south and southeast instead of from the south-westerly direction. From here, this branch splits into two under the influence of the Himalayas and the thermal low is northwest India. Its one branch moves westward along the Ganga plains reaching as far as the Punjab plains. The other branch moves up the Brahmaputra valley in the north and the northeast, causing widespread rains. Its sub-branch strikes the Garo and Khasi hills of Meghalaya. Mawsynram, located on the crest of Khasi hills, receives the highest average annual rainfall in the world.

Here it is important to know why the Tamil Nadu coast remains dry during this season. There are two factors responsible for it:

(i) The Tamil Nadu coast is situated parallel to the Bay of Bengal branch of southwest monsoon.

(ii) It lies in the rainshadow area of the Arabian Sea branch of the south-west monsoon.

Season of Retreating Monsoon

The months of October and November are known for retreating monsoons. By the end of September, the southwest monsoon becomes weak as the low pressure trough of the Ganga plain starts moving southward in response to the southward march of the sun. The monsoon retreats from the western Rajasthan by the first week of September. It withdraws from Rajasthan, Gujarat, Western Ganga plain and the Central Highlands by the end of the month. By the beginning of October, the low pressure covers northern parts of the Bay of Bengal and by early November, it moves over Karnataka and Tamil Nadu. By the middle of December, the centre of low pressure is completely removed from the Peninsula.

The retreating southwest monsoon season is marked by clear skies and rise in temperature. The land is still moist. Owing to the conditions of high temperature and humidity, the weather becomes rather oppressive. This is commonly known as the 'October heat'. In the second half of October, the mercury begins to fall rapidly, particularly in northern India. The weather in the retreating monsoon is dry in north India but it is associated with rain in the eastern part of the Peninsula. Here, October and November are the rainiest months of the year.

The widespread rain in this season is associated with the passage of cyclonic depressions which originate over the Andaman Sea and manage to cross the eastern coast of the southern Peninsula. These tropical cyclones are very destructive. The thickly populated deltas of the Godavari, Krishna and Kaveri are their preferred targets. Every year cyclones bring disaster here. A few cyclonic storms also strike the coast of West Bengal, Bangladesh and Myanmar. A bulk of the rainfall of the Coromondal coast is derived from these depressions and cyclones. Such cyclonic storms are less frequent in the Arabian Sea.

Traditional Indian Seasons

In the Indian tradition, a year is divided into six two-monthly seasons. This cycle of seasons, which the common people in north and central India follow is based on their practical experience and age-old perception of weather phenomena. However, this system does not match with the seasons of south India where there is little variation in the seasons.

Seasons	*Months (According to the Indian Calendar)*	*Months (According to the Gregorian Calendar)*
Vasanta	Chaitra-Vaisakha	March-April
Grishma	Jyaistha-Asadha	May-June
Varsha	Sravana-Bhadra	July-August
Sharada	Asvina-Kartika	September-October
Hemanta	Margashirsa-Pausa	November-December
Shishira	Magha-Phalguna	January-February

Distribution of Rainfall

The average annual rainfall in India is about 125 cm, but it has great spatial variations .

Areas of High Rainfall : The highest rainfall occurs along the west coast, on the Western Ghats, as well as in the sub-Himalayan areas is the northeast and the hills of Meghalaya. Here the rainfall exceeds 200 cm. In some parts of Khasi and Jaintia hills, the rainfall exceeds 1,000 cm. In the Brahmaputra valley and the adjoining hills, the rainfall is less then 200 cm.

Areas of Medium Rainfall : Rainfall between 100-200 cm is received in the southern parts of Gujarat, east Tamil Nadu, northeastern Peninsula covering Odisha, Jharkhand, Bihar, eastern Madhya Pradesh, northern Ganga plain along the sub-Himalayas and the Cachar Valley and Manipur.

Areas of Low Rainfall : Western Uttar Pradesh, Delhi, Haryana, Punjab, Jammu and Kashmir, eastern Rajasthan, Gujarat and Deccan Plateau receive rainfall between 50-100 cm.

Areas of Inadequate Rainfall: Parts of the Peninsula, especially in Andhra Pradesh, Karnataka and Maharashtra, Ladakh and most of western Rajasthan receive rainfall below 50 cm.

Snowfall is restricted to the Himalayan region.

Identify the pattern of rainfall after consulting the rainfall map.

Monsoons and the Economic Life in India

(i) Monsoon is that axis around which revolves the entire agricultural cycle of India. It is because about 64 per cent people of India depend on agriculture for their livelihood and agriculture itself is based on southwest monsoon.

(ii) Except Himalayas all the parts of the country have temperature above the threashold level to grow the crops or plants throughout the year..

(iii) Regional variations in monsoon climate help in growing various types of crops.

(iv) Variability of rainfall brings droughts or floods every year in some parts of the country.

(v) Agricultural prosperity of India depends very much on timely and adequately distributed rainfall. If it fails, agriculture is adversely affected particularly in those regions where means of irrigation are not developed.

(vi) Sudden monsoon burst creates problem of soil erosion over large areas in India.

(vii) Winter rainfall by temperate cyclones in north India is highly beneficial for rabi crops.

(viii) Regional climatic variation in India is reflected in the vast variety of food, clothes and house types.

Global Warming

You know that change is the law of nature. Climate has also witnessed change in the past at the global as well as at local levels. It is changing even now but the change is imperceptible. A number of geological evidences suggest that once upon a time, large part of the earth was under ice cover. Now you might have read or heard the debate on global warming. Besides the natural causes, human activities such as large scale industrialisation and presence of polluting gas in the atmosphere are also important factors responsible for global warming. You might have heard about the "green house effect" while discussing global warming.

The temperature of the world is significantly increasing. Carbon dioxide produced by human activities is a major source of concern. This gas, released to the atmosphere in large quantities by burning of fossil fuel, is increasing gradually. Other gases like methane, chlorofluorocarbons, and nitrous oxide which are present in much smaller concentrations in the atmosphere, together with carbon dioxide are known as

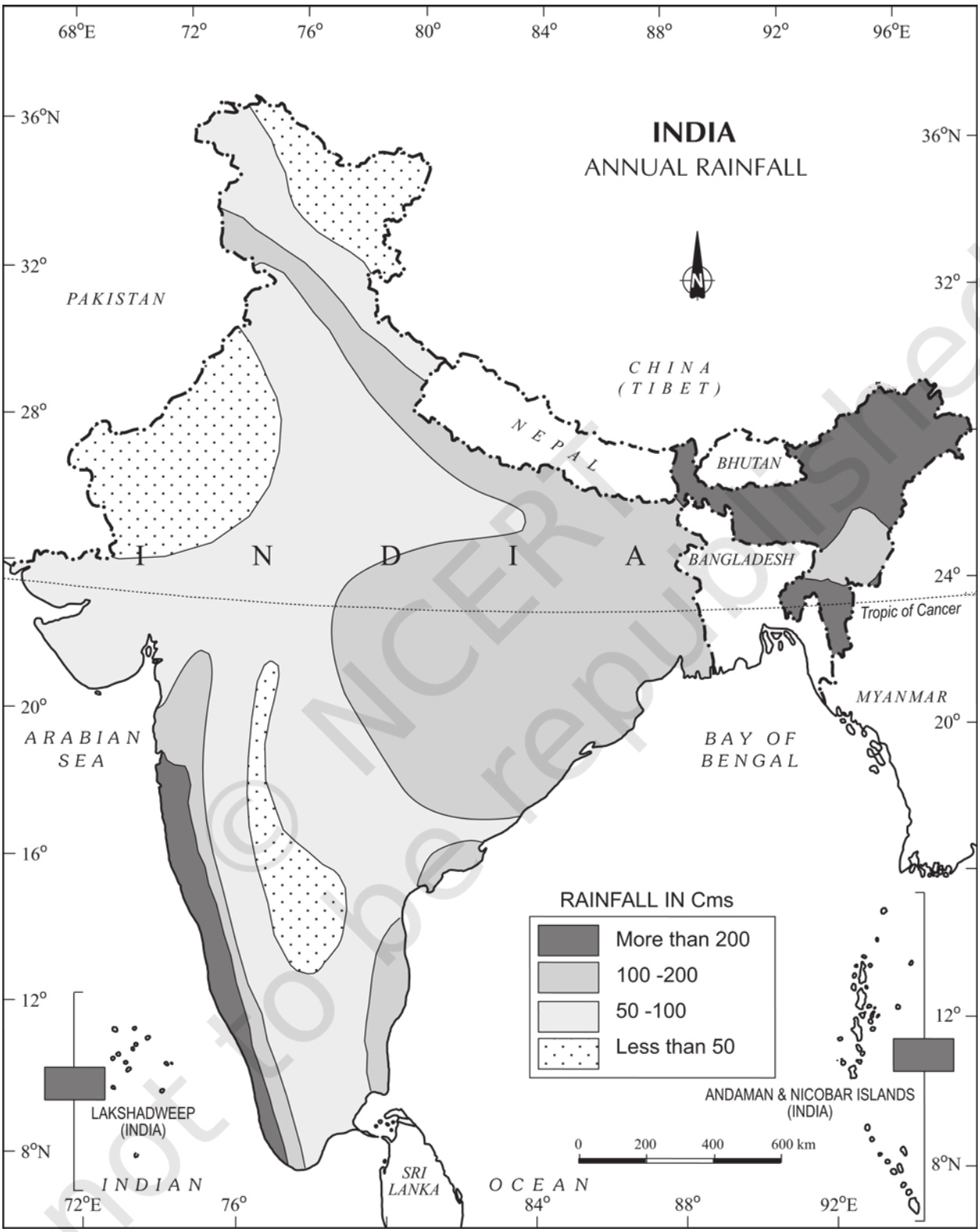

Figure 4.4 : India : Annual Rainfall

green house gases. These gases are better absorbers of long wave radiations than carbon dioxide, and so, are more effective at enhancing the green house effect. These gases have been contributing to global warming. It is said that due to global warming the polar ice caps and mountain glaciers would melt and the amount of water in the oceans would increase.

The mean annual surface temperature of the earth in the past 150 years has increased. It is projected that by the year 2,100, global temperature will increase by about 2° C. This rise in temperature will cause many other changes: one of these is a rise in sea level, as a result of melting of glaciers and sea-ice due to warming. According to the current prediction, on an average, the sea level will rise 48 cm by the end of twenty first century. This would increase the incidence of annual flooding. Climatic change would promote insect-borne diseases like malaria, and lead to shift in climatic boundaries, making some regions wetter and others drier. Agricultural pattern would shift and human population as well as the ecosystem would experience change. What would happen to the Indian sea coasts if the sea level rises 50 cm above the present one?

EXERCISES

1. Choose the right answer from the four alternatives given below.

   (i) What causes rainfall on the coastal areas of Tamil Nadu in the beginning of winters?

   (a) South-West monsoon (c) North-Eastern monsoon

   (b) Temperate cyclones (d) Local air circulation

   (ii) What is the proportion of area of India which receives annual rainfall less than 75 cm?

   (a) Half (c) Two-third

   (b) One-third (d) Three-fourth

   (iii) Which one of the following is not a fact regarding South India?

   (a) Diurnal range of temperature is less here.

   (b) Annual range of temperature is less here.

   (c) Temperatures here are high throughout the year.

   (d) Extreme climatic conditions are found here.

   (iv) Which one of the following phenomenon happens when the sun shines vertically over the Tropic of Capricorn in the southern hemisphere?

   (a) High pressure develops over North-western India due to low temperatures.

   (b) Low pressure develops over North-western India due to high temperatures.

   (c) No changes in temperature and pressure occur in north-western India.

   (d) 'Loo' blows in the North-western India.

2. Answer the following questions in about 30 words.
   (i) What is the Inter-Tropical Convergene Zone?
   (ii) What is meant by 'bursting of monsoon'? Name the place of India which gets the highest rainfall.
   (iii) Which type(s) of cyclones cause rainfall in north-western India during winter? Where do they originate?
3. Answer the following questions in not more than 125 words.
   (i) Notwithstanding the broad climatic unity, the climate of India has many regional variations. Elaborate this statement giving suitable examples.
   (ii) How many distinct seasons are found in India as per the Indian Meteorological Department? Discuss the weather conditions associated with any one season in detail.

Project/Activity

On the outline map of India, show the following:
   (i) Areas of winter rain
   (ii) Wind direction during the summer season
   (iii) Areas having less than 15° C temperature in January
   (iv) Isohyte of 100 cm.

CHAPTER

5

NATURAL VEGETATION

Have you ever been to a forest for a picnic? You might have surely gone to a park if you live in a city or to a mango, guava or coconut orchard, if you live in a village. How do you differentiate between the natural vegetation and the planted vegetation? The same variety may be found growing wild in the forest under natural conditions and the same tree may be the planted one in your garden under human supervision.

Natural vegetation refers to a plant community that has been left undisturbed over a long time, so as to allow its individual species to adjust themselves to climate and soil conditions as fully as possible.

India is a land of great variety of natural vegetation. Himalayan heights are marked with temperate vegetation; the Western Ghats and the Andaman Nicobar Islands have tropical rain forests, the deltaic regions have tropical forests and mangroves; the desert and semi desert areas of Rajasthan are known for cactii, a wide variety of bushes and thorny vegetation. Depending upon the variations in the climate and the soil, the vegetation of India changes from one region to another.

On the basis of certain common features such as predominant vegetation type and climatic regions, Indian forests can be divided into the following groups:

TYPES OF FORESTS

(i) Tropical Evergreen and Semi Evergreen forests
(ii) Tropical Deciduous forests
(iii) Tropical Thorn forests
(iv) Montane forests
(v) Littoral and Swamp forests.

Tropical Evergreen and Semi Evergreen Forests

These forests are found in the western slope of the Western Ghats, hills of the northeastern region and the Andaman and Nicobar Islands. They are found in warm and humid areas with an annual precipitation of over 200 cm and mean annual temperature above 22°C. Tropical evergreen forests are well stratified, with layers closer to the ground and are covered with shrubs and creepers, with short structured trees followed by tall variety of trees. In these forests, trees reach great heights up to 60 m or above. There is no definite time for trees to shed their leaves, flowering and fruition. As such these forests appear green all the year round. Species found in these forests include rosewood, mahogony, aini, ebony, etc.

The semi evergreen forests are found in the less rainy parts of these regions. Such forests have a mixture of evergreen and moist deciduous trees. The undergrowing climbers provide an evergreen character to these forests. Main species are white cedar, hollock and kail.

Figure 5.1 : Evergreen Forest

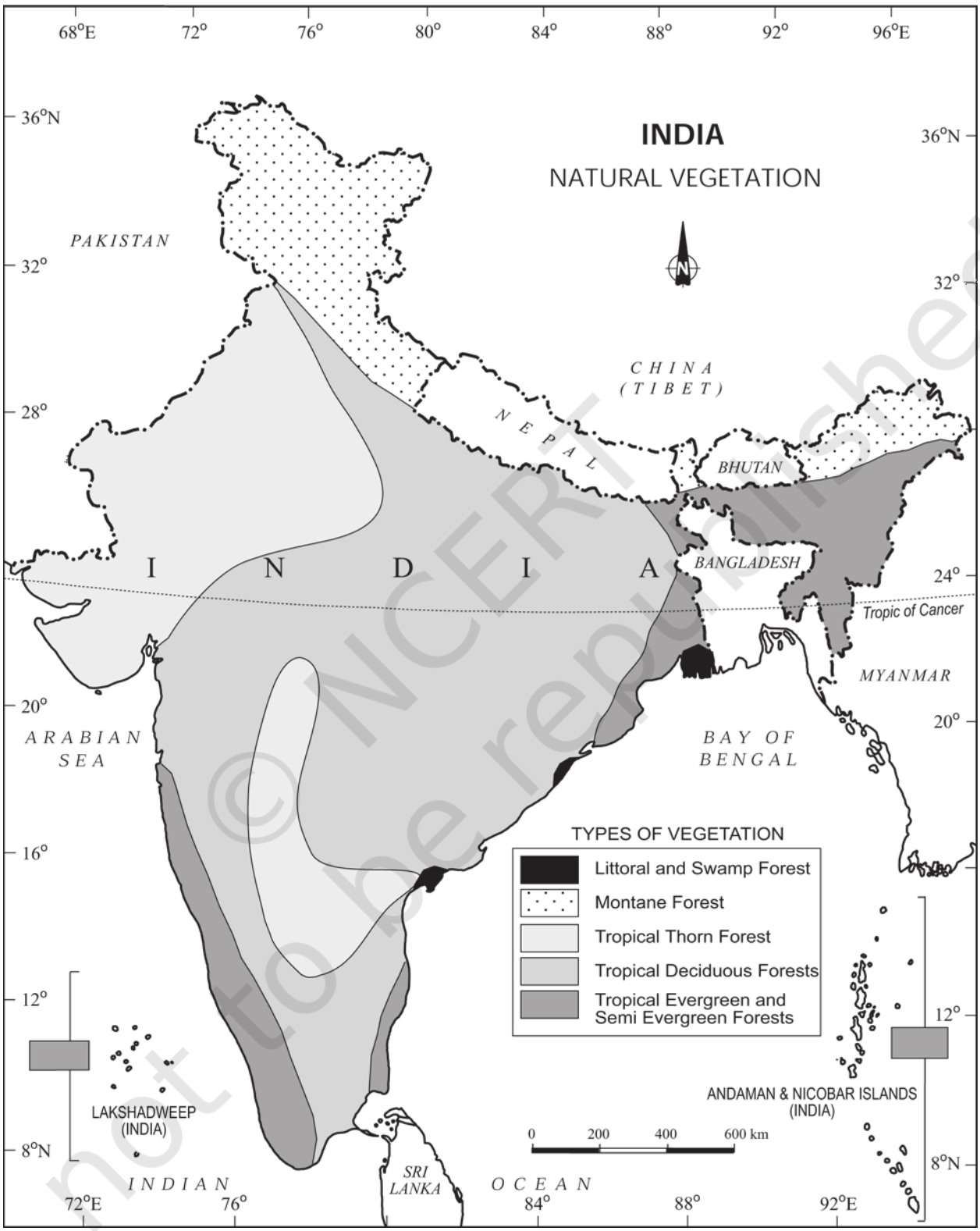

Figure 5.2 : Natural Vegetation

The British were aware of the economic value of the forests in India, hence, large scale exploitation of these forests was started. The structure of forests was also changed. The oak forests in Garhwal and Kumaon were replaced by pine (chirs) which was needed to lay railway lines. Forests were also cleared for introducing plantations of tea, rubber and coffee. The British also used timber for construction activities as it acts as an insulator of heat. The protectional use of forests was, thus, replaced by commercial use.

Tropical Deciduous Forests

These are the most widespread forests in India. They are also called the monsoon forests. They spread over regions which receive rainfall between 70-200 cm. On the basis of the availability of water, these forests are further divided into moist and dry deciduous.

Figure 5.3 : Deciduous Forests

The Moist deciduous forests are more pronounced in the regions which record rainfall between 100-200 cm. These forests are found in the northeastern states along the foothills of Himalayas, eastern slopes of the Western Ghats and Odisha. Teak, *sal, shisham, hurra, mahua, amla, semul, kusum,* and sandalwood etc. are the main species of these forests.

Dry deciduous forest covers vast areas of the country, where rainfall ranges between 70 -100 cm. On the wetter margins, it has a transition to the moist deciduous, while on the drier margins to thorn forests. These forests are found in rainier areas of the Peninsula and the plains of Uttar Pradesh and Bihar. In the higher rainfall regions of the Peninsular plateau and the northern Indian plain, these forests have a parkland landscape with open stretches in which teak and other trees interspersed with patches of grass are common. As the dry season begins, the trees shed their leaves completely and the forest appears like a vast grassland with naked trees all around. *Tendu, palas, amaltas, bel, khair,* axlewood, etc. are the common trees of these forests. In the western and southern part of Rajasthan, vegetation cover is very scanty due to low rainfall and overgrazing.

Tropical Thorn Forests

Tropical thorn forests occur in the areas which receive rainfall less than 50 cm. These consist of a variety of grasses and shrubs. It includes semi-arid areas of south west Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh. In these forests, plants remain leafless for most part of the year and give an expression of scrub vegetation. Important species found are *babool, ber*, and wild date palm, *khair, neem, khejri, palas*, etc. Tussocky grass grows upto a height of 2 m as the under growth.

Figure 5.4 : Tropical Thorn Forests

Montane Forests

In mountainous areas, the decrease in temperature with increasing altitude leads to a corresponding change in natural vegetation. Mountain forests can be classified into two types, the northern mountain forests and the southern mountain forests.

The Himalayan ranges show a succession of vegetation from the tropical to the tundra, which change in with the altitude. Deciduous forests are found in the foothills of the Himalayas. It is succeeded by the wet temperate type of forests between an altitude of 1,000-2,000 m. In the higher hill ranges of northeastern India, hilly areas of West Bengal and Uttaranchal, evergreen broad leaf trees such as oak and chestnut are predominant. Between 1,500-1,750 m, pine forests are also well-developed in this zone, with Chir Pine as a very useful commercial tree. Deodar, a highly valued endemic species grows mainly in the western part of the Himalayan range. Deodar is a durable wood mainly used in construction activity. Similarly, the *chinar* and the walnut, which sustain the famous Kashmir handicrafts, belong to this zone. Blue pine and spruce appear at altitudes of 2,225-3,048 m. At many places in this zone, temperate grasslands are also found. But in the higher reaches there is a transition to Alpine forests and pastures. Silver firs, junipers, pines, birch and rhododendrons, etc. occur between 3,000-4,000 m. However, these pastures are used extensively for transhumance by tribes like the Gujjars, the Bakarwals, the Bhotiyas and the Gaddis. The southern slopes of the Himalayas carry a thicker vegetation cover because of relatively higher precipitation than the drier north-facing slopes. At higher altitudes, mosses and lichens form part of the tundra vegetation.

Figure 5.5 : Montane Forests

The southern mountain forests include the forests found in three distinct areas of Peninsular India viz; the Western Ghats, the Vindhyas and the Nilgiris. As they are closer to the tropics, and only 1,500 m above the sea level, vegetation is temperate in the higher regions, and subtropical on the lower regions of the Western Ghats, especially in Kerala, Tamil Nadu and Karnataka. The temperate forests are called *Sholas* in the Nilgiris, Anaimalai and Palani hills. Some of the other trees of this forest of economic significance include, magnolia, laurel, cinchona and wattle. Such forests are also found in the Satpura and the Maikal ranges.

Littoral and Swamp Forests

India has a rich variety of wetland habitats. About 70 per cent of this comprises areas under paddy cultivation. The total area of wet land is 3.9 million hectares. Two sites — Chilika Lake (Odisha) and Keoladeo National Park (Bharatpur) are protected as water-fowl habitats under the Convention of Wetlands of International Importance (Ramsar Convention).

> An international convention is an agreement among member states of the United Nations.

The country's wetlands have been grouped into eight categories, viz. (i) the reservoirs of the Deccan Plateau in the south together with the lagoons and other wetlands of the southern west coast; (ii) the vast saline expanses of Rajasthan, Gujarat and the Gulf of Kachchh; (iii) freshwater lakes and reservoirs from Gujarat eastwards through Rajasthan (Keoladeo National Park) and Madhya Pradesh; (iv) the delta wetlands and lagoons of India's east coast (Chilika Lake); (v) the freshwater marshes of the Gangetic Plain; (vi) the floodplains of the Brahmaputra; the marshes and swamps in the hills of northeast India and the Himalayan foothills; (vii) the lakes and rivers of the montane region of Kashmir and Ladakh; and (viii) the mangrove forest and other wetlands of the island arcs of the Andaman and Nicobar Islands. Mangroves grow along the coasts in the salt marshes, tidal creeks, mud flats and estuaries.

They consist of a number of salt-tolerant species of plants. Crisscrossed by creeks of stagnant water and tidal flows, these forests give shelter to a wide variety of birds.

Figure 5.6 : Mangrove Forests

In India, the mangrove forests spread over 6,740 sq. km which is 7 per cent of the world's mangrove forests. They are highly developed in the Andaman and Nicobar Islands and the Sunderbans of West Bengal. Other areas of significance are the Mahanadi, the Godavari and the Krishna deltas. These forests too, are being encroached upon, and hence, need conservation.

Forest Conservation

Forests have an intricate interrelationship with life and environment. These provide numerous direct and indirect advantages to our economy and society. Hence, conservation of forest is of vital importance to the survival and prosperity of humankind. Accordingly, the Government of India proposed to have a nation-wide forest conservation policy, and adopted a forest policy in 1952, which was further modified in 1988. According to the new forest policy, the Government will emphasise sustainable forest management in order to conserve and expand forest reserve on the one hand, and to meet the needs of local people on the other.

The forest policy aimed at : (i) bringing 33 per cent of the geographical areas under forest cover; (ii) maintaining environmental stability and to restore forests where ecological balance was disturbed; (iii) conserving the natural heritage of the country, its biological diversity and genetic pool; (iv) checks soil erosion, extension of the desert lands and reduction of floods and droughts; (v) increasing the forest cover through social forestry and afforestation on degraded land; (vi) increasing the productivity of forests to make timber, fuel, fodder and food available to rural population dependant on forests, and encourage the substitution of wood; (vii) creating of a massive peoples movement involving women to encourage planting of trees, stop felling of trees and thus, reduce pressure on the existing forest.

Forests and Life

To a vast number of tribal people, the forest is a home, a livelihood, their very existence. It provides them food, fruits of all kinds, edible leaves, honey, nourishing roots and wild game. It provides them with material to build their houses and items for practising their arts. The importance of forests in tribal economy is well-known as they are the source of sustenance and livelihood for tribal communities. It is commonly believed that the tribal communities live in harmony with nature and protect forests.

Forest and tribals are very closely related. The age-old knowledge of tribals regarding forestry can be used in the development of forests. Rather than treating tribals as minor forest produce collectors they should be made growers of minor forest produce and encouraged to participate in conservation.

Based on the forest conservation policy the following steps were initiated:

Social Forestry

Social forestry means the management and protection of forests and afforestation on barren lands with the purpose of helping in the environmental, social and rural development.

The National Commission on Agriculture (1976) has classified social forestry into three

categories. These are Urban forestry, Rural forestry and Farm forestry.

Urban forestry pertains to the raising and management of trees on public and privately owned lands in and around urban centres such as green belts, parks, roadside avenues, industrial and commercial green belts, etc.

Rural forestry lays emphasis on promotion of agro-forestry and community-forestry.

Agro-forestry is the raising of trees and agriculture crops on the same land inclusive of the waste patches. It combines forestry with agriculture, thus, altering the simultaneous production of food, fodder, fuel, timber and fruit. Community forestry involves the raising of trees on public or community land such as the village pasture and temple land, roadside, canal bank, strips along railway lines, and schools etc. Community forestry programme aims at providing benefits to the community as a whole. Community forestry provides a means under which the people of landless classes can associate themselves in tree-raising and thus, get those benefits which otherwise are restricted for landowners.

Farm Forestry

Farm forestry is a term applied to the process under which farmers grow trees for commercial and non-commercial purposes on their farm lands.

Forest departments of various states distribute seedlings of trees free of cost to small and medium farmers. Several lands such as the margins of agricultural fields, grasslands and pastures, land around homes and cow sheds may be used for raising trees under non-commercial farm forestry.

Wildlife

You would have visited a zoo and may have seen animals and birds in captivity. Wildlife of India is a great natural heritage. It is estimated that about 4-5 per cent of all known plant and animal species on the earth are found in India. The main reason for this remarkable diversity of life forms is the great diversity of the ecosystem which this country has preserved and supported through the ages. Over the years, their habitat has been disturbed by human activities and as a result, their numbers have dwindled significantly. There are certain species that are at the brink of extinction.

Some of the important reasons of the declining of wildlife are as follows:

(i) Industrial and technological advancement brought about a rapid increase in the exploitation of forest resources.
(ii) More and more lands were cleared for agriculture, human settlement, roads, mining, reservoirs, etc.
(iii) Pressure on forests mounted due to lopping for fodder and fuelwood and removal of small timber by the local people.
(iv) Grazing by domestic cattle caused an adverse effect on wildlife and its habitat.
(v) Hunting was taken up as a sport by the elite and hundreds of wild animals were killed in a single hunt. Now commercial poaching is rampant.
(vi) Incidence of forest fire.

It is being felt that conservation of wildlife is of great significance to the national as well as the world heritage along with the promotion of ecotourism. What steps have been initiated by the government in this direction?

Wildlife Conservation in India

The protection of wildlife has a long tradition in India. Many stories of *Panchtantra* and *Jungle Books*, etc. have stood the test of time relating to the love for wildlife. These have a profound impact on young minds.

In 1972, a comprehensive Wildlife Act was enacted, which provides the main legal framework for conservation and protection of wildlife in India. The two main objectives of the Act are; to provide protection to the endangered species listed in the schedule of the Act and to provide legal support to the conservation areas of the country classified as National parks, sanctuaries and closed areas. This Act has been

comprehensively amended in 1991, making punishments more stringent and has also made provisions for the protection of specified plant species and conservation of endangered species of wild animals.

There are 101 National parks and 553 wildlife sanctuaries in the country (Appendix V).

Wildlife conservation has a very large ambit with unbounded potential for the well-being of humankind. However, this can be achieved only when every individual understands its significance and contributes his bit.

For the purpose of effective conservation of flora and fauna, special steps have been initiated by the Government of India in collaboration with UNESCO's 'Man and Biosphere Programme'.

Figure 5.7 : Elephants in their Natural Habitat

Table 5.1 : List of Biosphere Reserves

Sl. No.	*Name of the Biosphere Reserve and Total Geographical Area (km^2)*	*Date of Designation*	*Location in the States/UT*
1.	**Nilgiri (5520)**	01.08.1986	Part of Wynad, Nagarhole, Bandipur and Madumalai, Nilambur, Silent Valley and Siruvani Hills (Tamil Nadu, Kerala and Karnataka).
2.	**Nanda Devi (5860.69)**	18.01.1988	Part of Chamoli, Pithoragarh and Almora Districts in Uttarakhand.
3.	**Nokrek (820)**	01.09.1988	Part of East, West and South Garo Hill Districts in Meghalaya.
4.	Manas (2837)	14.03.1989	Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamrup and Darang Districts in Assam
5.	**Sunderban (9630)**	29.03.1989	Part of delta of Ganges and Brahamaputra river system in West Bengal.
6.	**Gulf of Mannar (10500)**	18.02.1989	Indian part of Gulf of Mannar extending from Rameswaram island in the North to Kaniyakumari in the South of Tamil Nadu.
7.	**Great Nicobar (885)**	06.01.1989	Southern most island of Andaman and Nicobar Islands.
8.	**Similipal (4374)**	21.06.1994	Part of Mayurbhanj District in Odisha.
9.	Dibru-Saikhowa (765)	28.07.1997	Part of Dibrugarh and Tinsukia Districts in Assam
10	Dehang Debang (5111.5)	02.09.1998	Part of Upper Siang, West Siang and Dibang Valley Districts in Arunachal Pradesh.
11.	**Pachmarhi (4981.72)**	03.03.1999	Part of Betul, Hoshangabad and Chhindwara Districts in Madhya Pradesh.
12.	**Khangchendzonga (2619.92)**	07.02.2000	Part of North and West Districts in Sikkim
13.	**Agasthyamalai (3500.36)**	12.11.2001	Part of Thirunelveli and Kanyakumari Districts in Tamil Nadu and Thiruvananthapuram, Kollam and Pathanmthitta districts in Kerala.
14.	**Achanakmar-Amarkantak (3835.51)**	30.03.2005	Part of Anuppur and Dindori Districts of Madhya Pradesh and Bilaspur district of Chhattisgarh
15.	Kachchh (12,454)	29.01.2008	Part of Kachchh, Rajkot, Surendranagar and Patan Districts in Gujarat.
16.	Cold Desert (7770)	28.08.2009	Pin Valley National Park and surroundings; Chandratal and Sarchu and Kibber Wildlife sanctuary in Himachal Pradesh.
17.	Seshachalam (4755.997)	20.09.2010	Seshachalam hill ranges in Eastern Ghatsencompassing part of Chittoor and Kadapa Districts in Andhra Pradesh.
18.	Panna (2998.98)	25.08.2011	Part of Pann and Chhattarpur Districts in Madhya Pradesh.

* Sites with bold letters have been included in the World Network of BRs of UNESCO.
Source : Annual Report 2018-19, Ministry of Environment and Forests, Government of India.

Figure 5.8 : India : Biosphere Reserves

Special schemes like Project Tiger (1973) and Project Elephant (1992) have been launched to conserve these species and their habitat in a sustainable manner.

Project Tiger has been implemented since 1973. The main objective of the scheme is to ensure maintenance of viable population of tigers in India for scientific, aesthetic, cultural and ecological values, and to preserve areas of biological importance as natural heritage for the benefit, education and enjoyment of the people. Initially, the Project Tiger was launched in nine tiger reserves, covering an area of 16,339 sq. km, which has now increased to 50 tiger reserves, encompassing 71,027.10 sq. km of core tiger habitats distributed in 18 states. The tiger population in the country has registered an increase from 1,411 in 2006 to 2,967 in 2020 which is 70 per cent of the global tiger population.

Project Elephant was launched in 1992 to assist states having free ranging population of wild elephants. It was aimed at ensuring long-term survival of identified viable population of elephants in their natural habitat. The project is being implemented in 16 states.

Apart from this, some other projects such as Crocodile Breeding Project, Project Hangul and conservation of Himalayan Musk deer have also been launched by the Government of India.

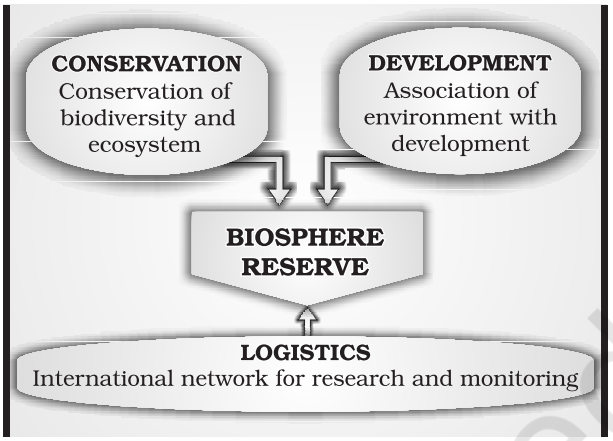

Figure 5.9 : Objectives of a Biosphere Reserve

Biosphere Reserves

A Biosphere Reserve is a unique and representative ecosystem of terrestrial and coastal areas which are internationally recognised within the framework of UNESCO's Man and Biosphere (MAB) Programme. The Biosphere Reserve aims at achieving the three objectives as depicted in Figure 5.9.

There are 18 Biosphere Reserves in India (Table 5.1, Figure 5.8). Eleven Biosphere Reserves have been recognised by the UNESCO on World Network of Biosphere Reserves.

EXERCISES

1. Choose the right answer from the four alternatives given below.
   (i) Sandalwood is an example of:
   (a) Evergreen forest (c) Deltaic forest
   (b) Deciduous forest (d) Thorny forest
   (ii) Which one of the following was the purpose of Project Tiger?
   (a) to kill tigers (c) to protect tigers from illegal hunting
   (b) to put tigers in the Zoo (d) to make films on tigers
   (iii) In which one of the following states is the Nandadevi Biosphere reserve situated?
   (a) Bihar (c) Uttarakhand
   (b) Uttar Pradesh (d) Odisha

(iv) How many of the Biosphere reserves from India are recognised by the UNESCO?

(a) One (c) Eleven

(b) Two (d) Four

(v) Which one of the following proportion of area of the country was targeted to be under forest in Forest Policy of India?

(a) 33 (c) 55

(b) 44 (d) 22

2. Answer the following questions in about 30 words.

(i) What is natural vegetation? Under what climatic conditions are tropical evergreen forests develop?

(ii) What do you understand by social forestry?

(iii) Define Biosphere reserves?

(iv) What is the difference between forest area and forest cover?

3. Answer the following questions in not more than 150 words.

(i) What steps have been taken up to conserve forests?

(ii) How can people's participation be effective in conserving forests and wildlife?

Project/Activity

1. On the outline map of India, mark and label the following.

(i) Areas having Mangrove forests.

(ii) Biosphere reserves of Nanda Devi, Sunderbans, Gulf of Mannar and Nilgiri.

(iii) Mark the location of Forest Survey of India Head Quarter.

2. List the trees, bush and shrub species found around your school. Write their local names and their uses.

UNIT IV

NATURAL HAZARDS AND DISASTERS: CAUSES, CONSEQUENCES AND MANAGEMENT

This unit deals with

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

CHAPTER

6

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, 1993 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. Concerted 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 6.2).

India is one of those countries which has experienced most of the natural disasters mentioned in Table 6.2. Every year it loses thousands of lives and property worth millions of rupees due to these natural calamities. In the following section, some of 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,

Figure 6.1 : A Damaged Building Due to an Earthquake

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 disadvantageous 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).*

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 union territories/states are Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, and the Darjeeling subdivision of West Bengal, and all the seven states of the northeast.

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 6.2).

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 6.2, 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, Ladakh, 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 6.1.

Table 6.1 : Effects of Earthquakes

On Ground	*On Manmade Structures*	*On Water*
Fissures	Cracking	Waves
Settlements	Slidings	Hydro-Dynamic Pressure
Landslides	Overturning	Tsunami
Liquefaction	Buckling	
Earth Pressure	Collapse	
Possible Chain-effects	Possible Chain-effects	Possible Chain-effects

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.

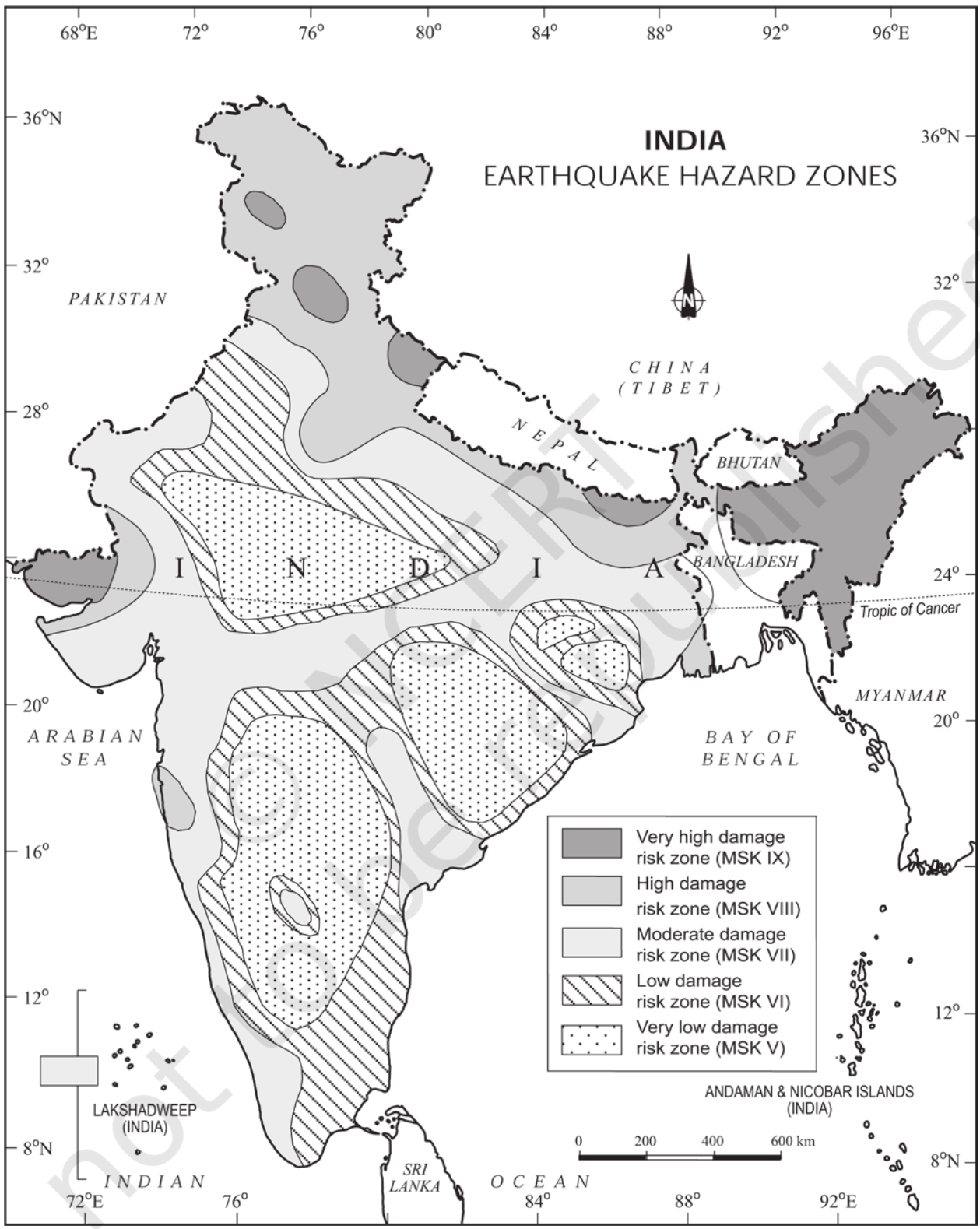

Figure 6.2 : India: Earthquake Hazard Zones

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.

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

Figure 6.3 : Tsunami Affected Area

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.

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.

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 disasterous 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

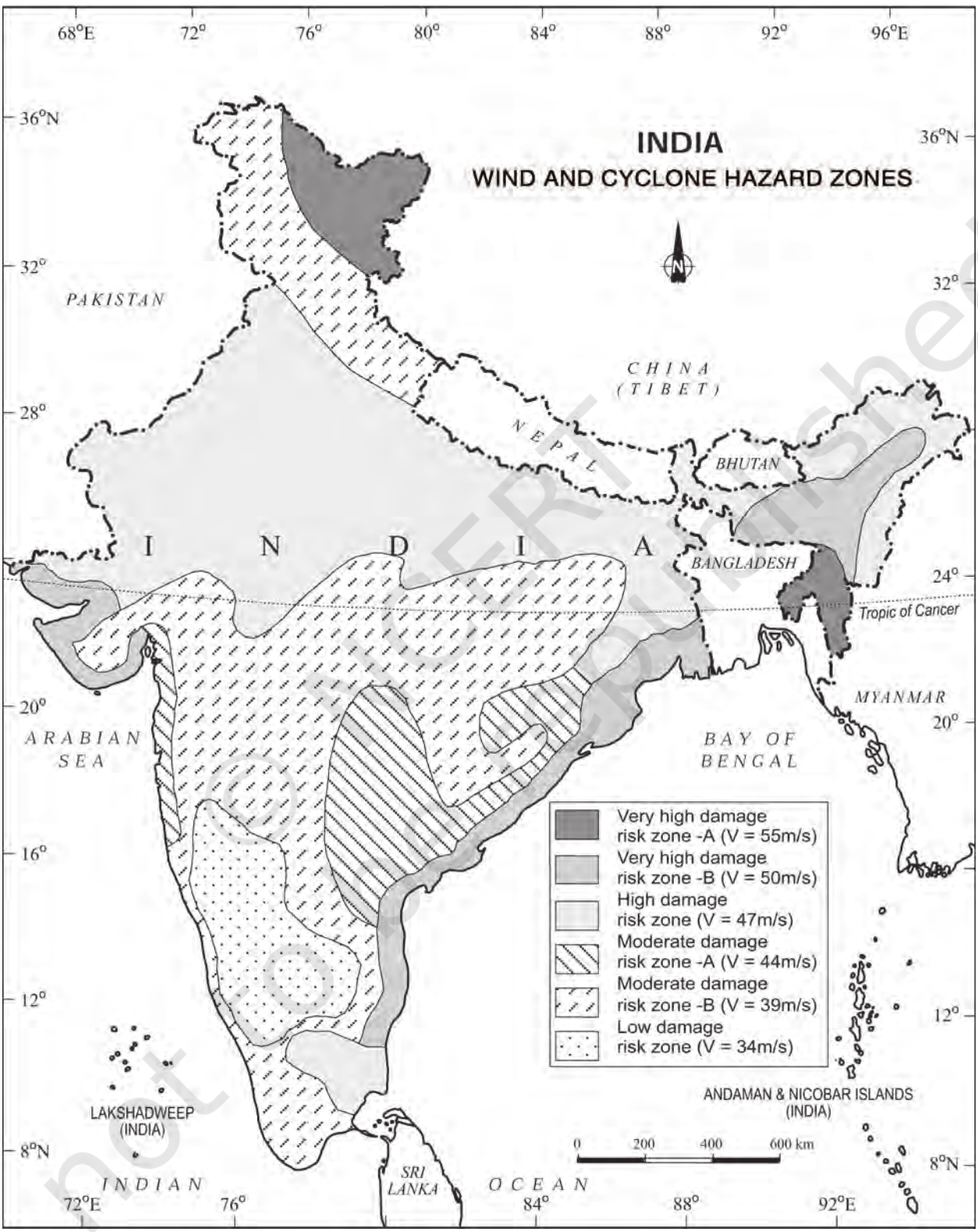

Figure 6.4 : Wind and Cyclone Hazard Zones

in increasing the intensity, magnitude and gravity of floods.

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 6.6 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 Odisha, 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.

Figure 6.5 : Brahmaputra During Flood

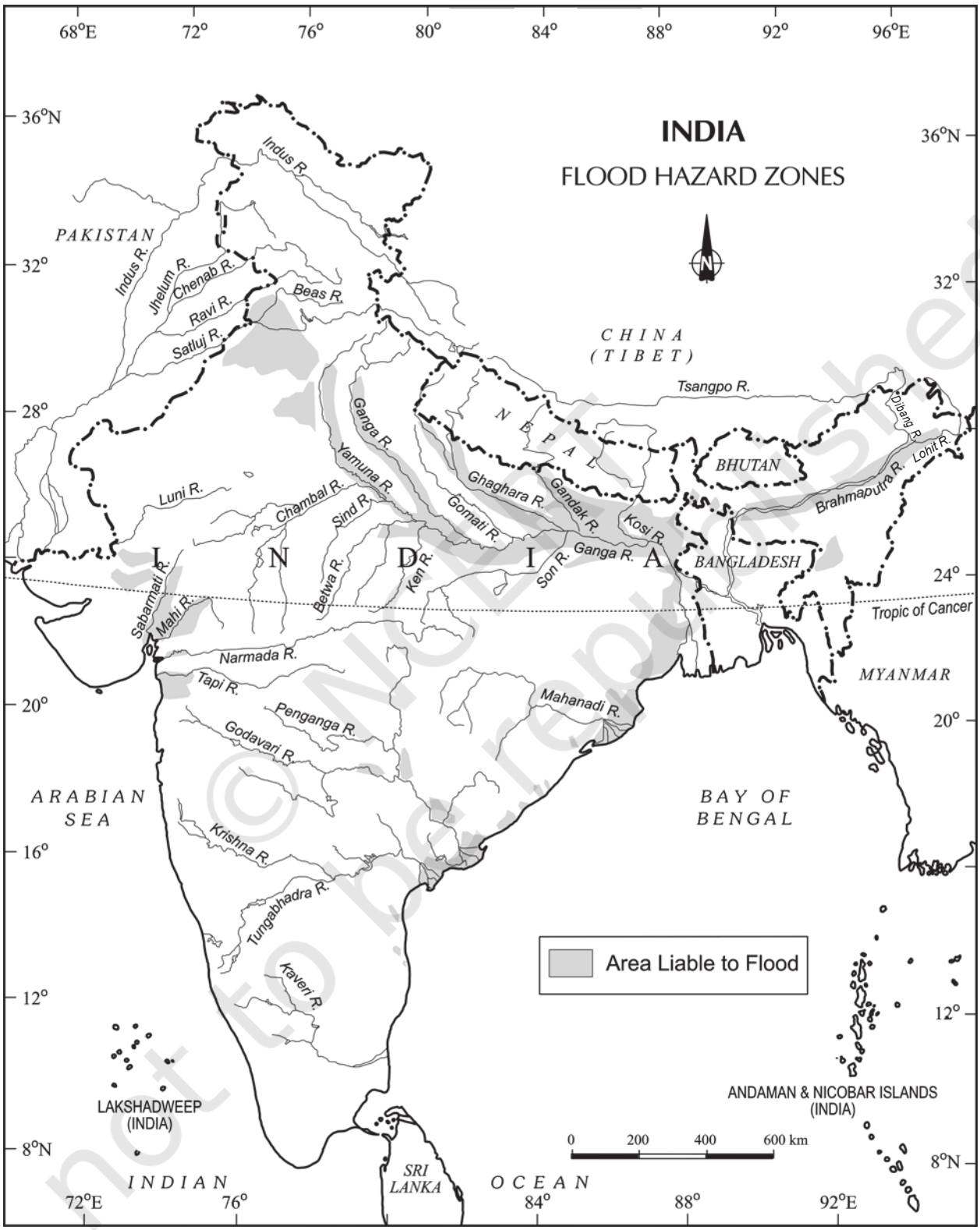

Figure 6.6 : Flood Hazard Zones

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, evapo-transpiration, 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.

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 6.7 that most parts of Rajasthan, particularly areas to the west of the Aravali hills, i.e. Marusthali 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 that 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 Odisha 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)*,

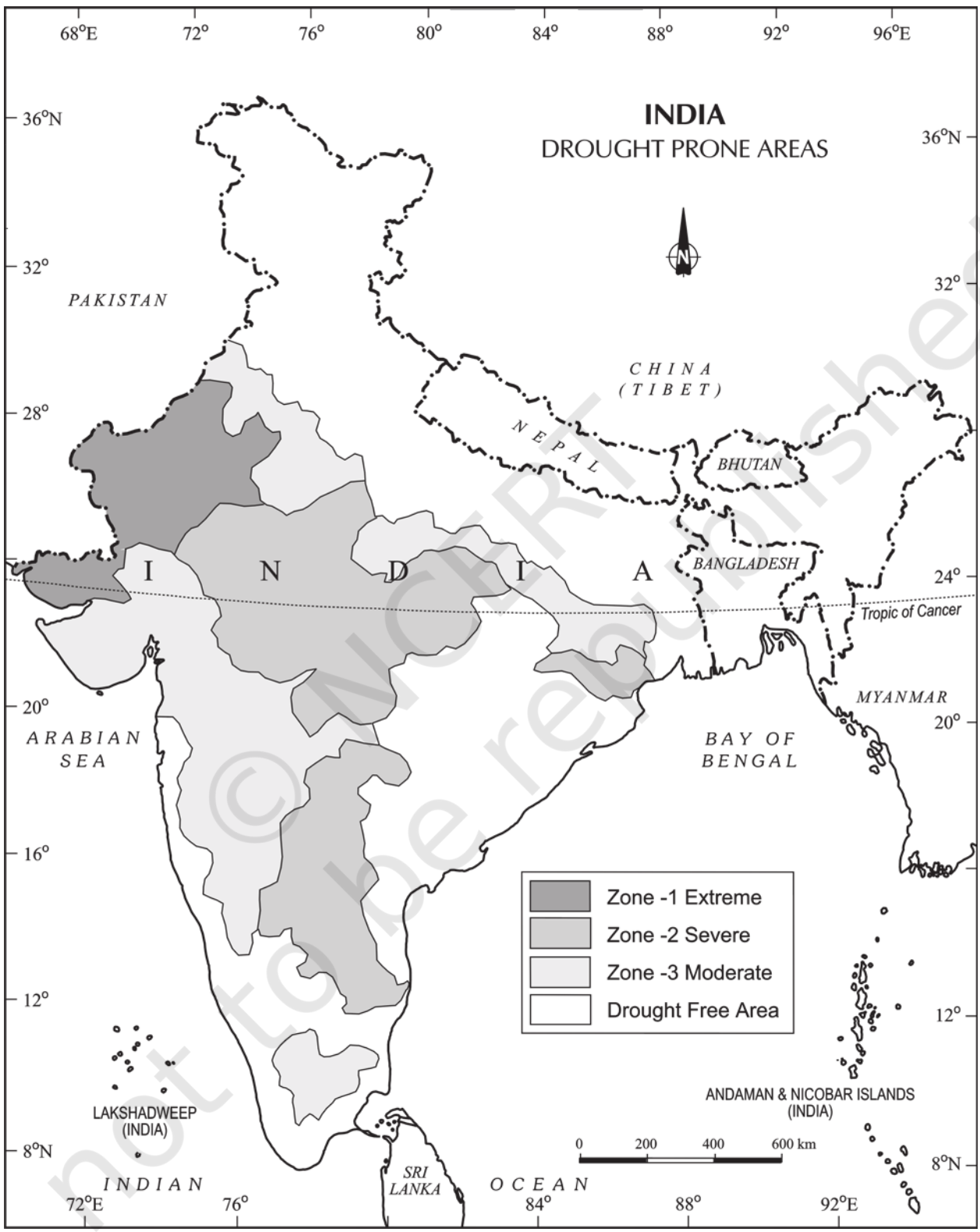

Figure 6.7 : Drought Prone Areas

Figure 6.8 : Drought

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

Figure 6.9 : Landslide

Eastern Ghats and Deccan plateau also experience occasional landslides. Landslides due to mining and subsidence are most common in states like Jharkhand, Odisha, 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 Uttaranchal 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?
   (vi) 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.
   (iii) 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
(ii) Tsunami
(iii) Odisha and Gujarat Cyclones
(iv) Inter-linking of rivers
(v) Tehri Dam/Sardar Sarovar
(vi) Bhuj/Latur Earthquakes
(vii) Life in a delta/riverine island
(viii) Prepare a model of rooftop rainwater harvesting

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.

FUNDAMENTALS OF PHYSICAL GEOGRAPHY

TEXTBOOK FOR CLASS XI

11092

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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Foreword

The National Curriculum Framework (NCF), 2005, recommends that children's life at school must be linked to their life outside the school. This principle marks a departure from the legacy of bookish learning which continues to shape our system and causes a gap between the school, home and community. The syllabi and textbooks developed on the basis of NCF signify an attempt to implement this basic idea. They also attempt to discourage rote learning and the maintenance of sharp boundaries between different subject areas. We hope these measures will take us significantly further in the direction of a child-centred system of education outlined in the National Policy on Education (1986).

The success of this effort depends on the steps that school principals and teachers will take to encourage children to reflect on their own learning and to pursue imaginative activities and questions. We must recognise that, given space, time and freedom, children generate new knowledge by engaging with the information passed on to them by adults. Treating the prescribed textbook as the sole basis of examination is one of the key reasons why other resources and sites of learning are ignored. Inculcating creativity and initiative is possible if we perceive and treat children as participants in learning, not as receivers of a fixed body of knowledge.

These aims imply considerable change in school routines and mode of functioning. Flexibility in the daily time-table is as necessary as rigour in implementing the annual calendar so that the required number of teaching days are actually devoted to teaching. The methods used for teaching and evaluation will also determine how effective this textbook proves for making children's life at school a happy experience, rather than a source of stress or boredom. Syllabus designers have tried to address the problem of curricular burden by restructuring and reorienting knowledge at different stages with greater consideration for child psychology and the time available for teaching. The textbook attempts to enhance this endeavour by giving higher priority and space to opportunities for contemplation and wondering, discussion in small groups, and activities requiring hands-on experience.

The National Council of Educational Research and Training (NCERT) appreciates the hard work done by the textbook development committee responsible for this book. We wish to thank the Chairperson of the advisory committee for textbooks in Social Sciences, at the higher secondary level, Professor Hari Vasudevan and the Chief Advisor for this book, Professor M.H. Qureshi for guiding the work of this committee. Several teachers contributed to the development of this textbook; we are grateful to their principals for making this possible. We are indebted to the institutions and organisations

which have generously permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the National Monitoring Committee, appointed by the Department of Secondary and Higher Education, Ministry of Human Resource Development under the Chairpersonship of Professor Mrinal Miri and Professor G.P. Deshpande, for their valuable time and contribution. As an organisation committed to systemic reform and continuous improvement in the quality of its products, NCERT welcomes comments and suggestions which will enable us to undertake further revision and refinement.

Director
National Council of
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Research and
Training

New Delhi

20 December 2005

Rationalisation of Content in the Textbooks

In view of the COVID-19 pandemic, it is imperative to reduce content load on students. The National Education Policy 2020, also emphasises reducing the content load and providing opportunities for experiential learning with creative mindset. In this background, the NCERT has undertaken the exercise to rationalise the textbooks across all classes. Learning Outcomes already developed by the NCERT across classes have been taken into consideration in this exercise.

Contents of the textbooks have been rationalised in view of the following:

- Overlapping with similar content included in other subject areas in the same class
- Similar content included in the lower or higher class in the same subject
- Difficulty level
- Content, which is easily accessible to students without much interventions from teachers and can be learned by children through self-learning or peer-learning
- Content, which is irrelevant in the present context

This present edition, is a reformatted version after carrying out the changes given above.

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Contents

CONSTITUTION OF INDIA

Part III (Articles 12 – 35)
(Subject to certain conditions, some exceptions
and reasonable restrictions)

guarantees these

Fundamental Rights

Right to Equality

- before law and equal protection of laws;
- irrespective of religion, race, caste, sex or place of birth;
- of opportunity in public employment;
- by abolition of untouchability and titles.

Right to Freedom

- of expression, assembly, association, movement, residence and profession;
- of certain protections in respect of conviction for offences;
- of protection of life and personal liberty;
- of free and compulsory education for children between the age of six and fourteen years;
- of protection against arrest and detention in certain cases.

Right against Exploitation

- for prohibition of traffic in human beings and forced labour;
- for prohibition of employment of children in hazardous jobs.

Right to Freedom of Religion

- freedom of conscience and free profession, practice and propagation of religion;
- freedom to manage religious affairs;
- freedom as to payment of taxes for promotion of any particular religion;
- freedom as to attendance at religious instruction or religious worship in educational institutions wholly maintained by the State.

Cultural and Educational Rights

- for protection of interests of minorities to conserve their language, script and culture;
- for minorities to establish and administer educational institutions of their choice.

Right to Constitutional Remedies

- by issuance of directions or orders or writs by the Supreme Court and High Courts for enforcement of these Fundamental Rights.

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*

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CHAPTER

1

GEOGRAPHY AS A DISCIPLINE

You have studied geography as one of the components of your Social Science 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.

(iii) 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

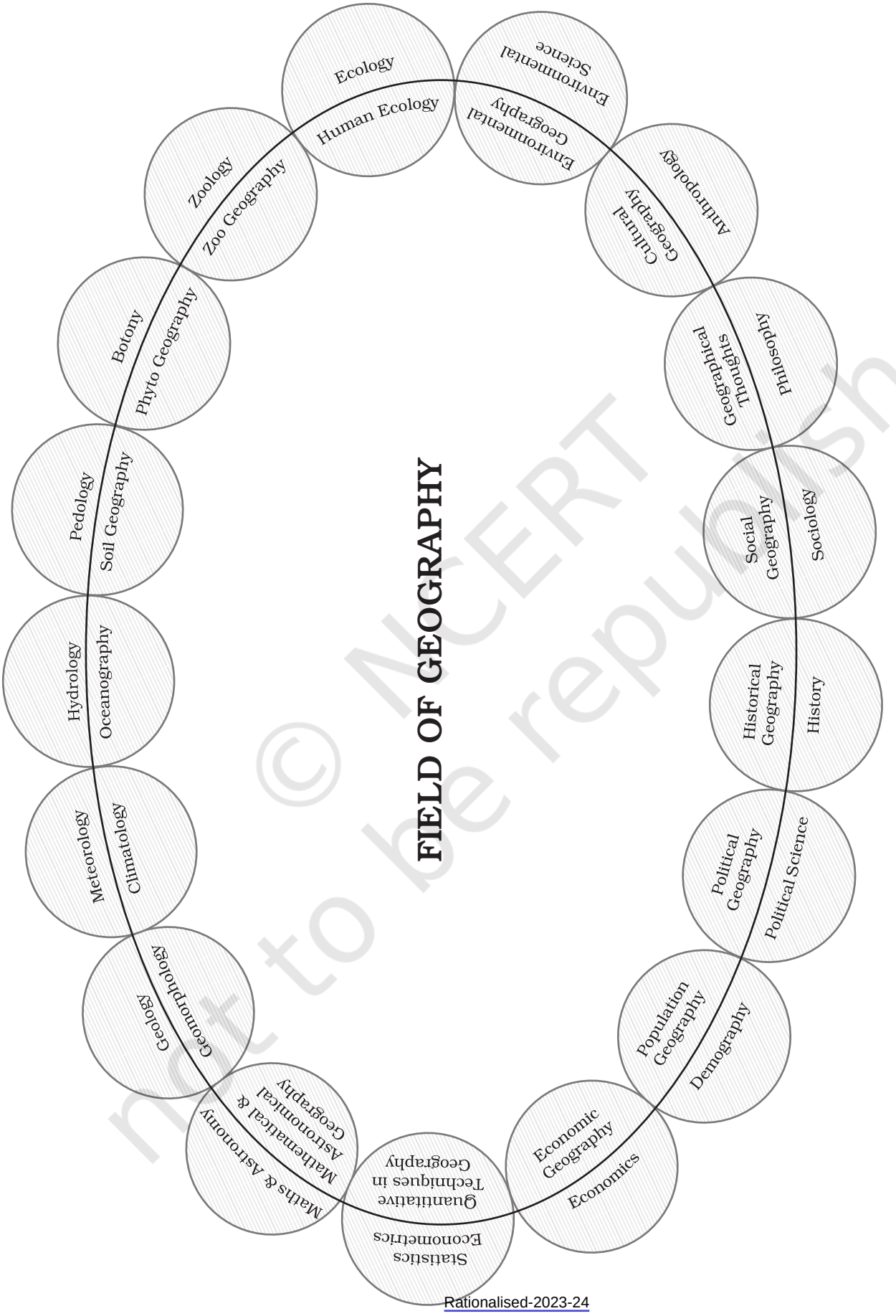


Figure 1.1 : Geography and its relation with other disciplines

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?

Figure1.1 amply depicts the linkages of geography with different natural and social sciences. This linkage can be put under two segments.

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.

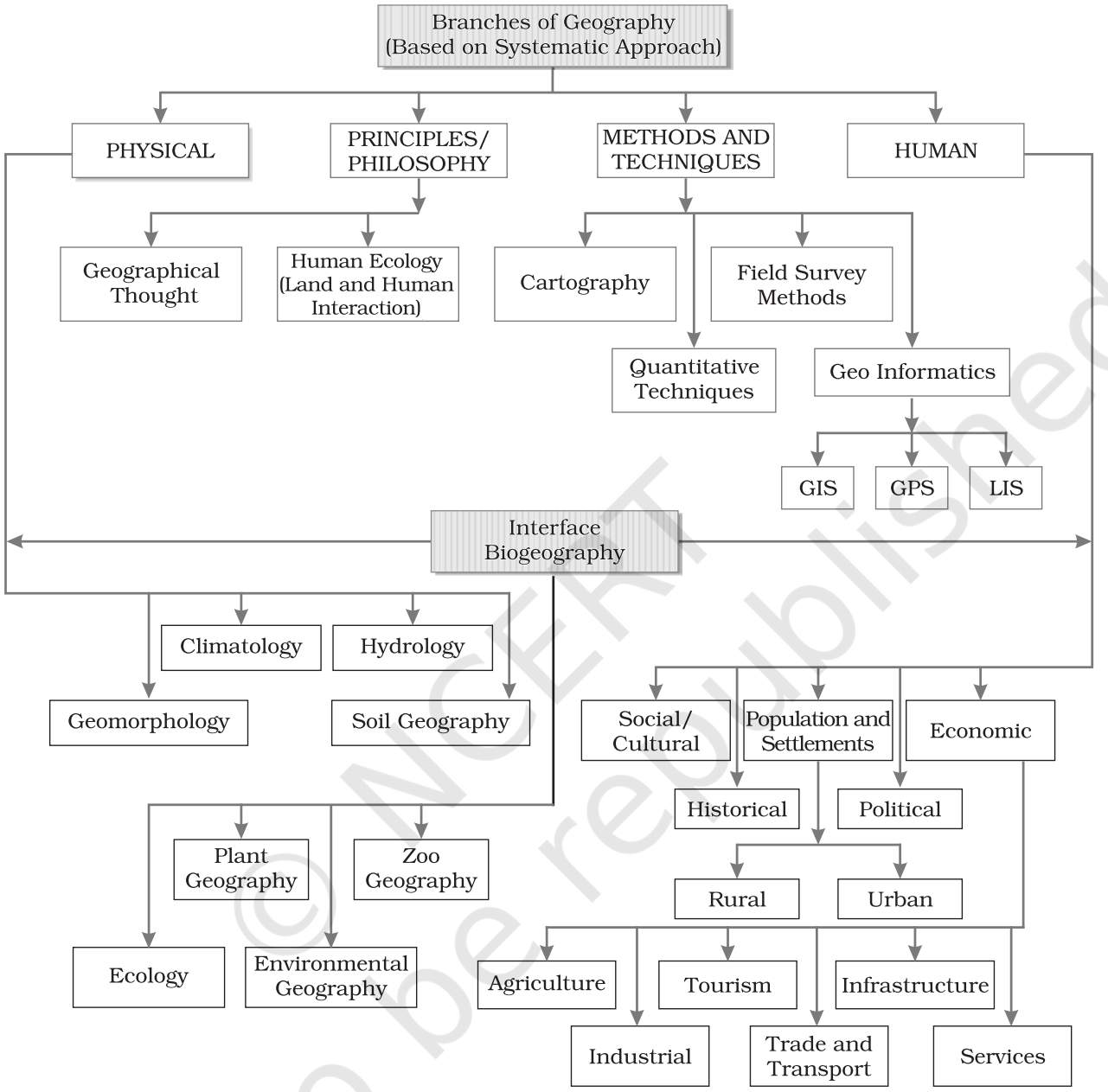


Figure 1.2 : Branches of geography based on systematic approach

(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

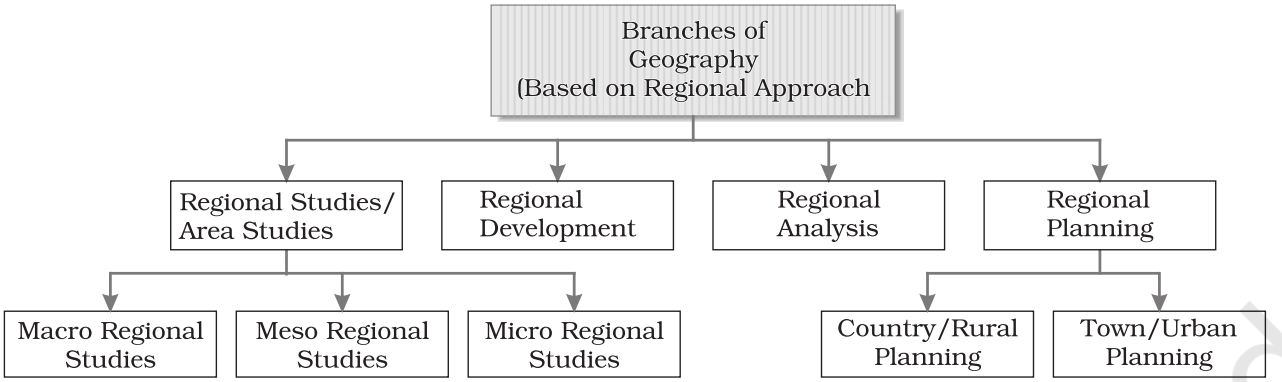


Figure 1.3 : Branches of geography based on regional approach

experience temporal changes and these form the concerns of historical gography.

(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 lead 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. 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 Uttaranchal.

UNIT II

THE EARTH

This unit deals with

- *Origin and evolution of the earth; Interior of the earth; Wegener's continental drift theory and plate tectonics; earthquakes and volcanoes*

11092CH02

CHAPTER

2

THE ORIGIN AND EVOLUTION OF THE EARTH

Do you remember the nursery rhyme "…Twinkle, twinkle little star…"?

Starry nights have always attracted us since the childhood. You may also have thought of these stars and had numerous questions in your mind. Questions such as how many stars are there in the sky? How did they come into existence? Can one reach the end of the sky? May be many more such questions are still there in your mind. In this chapter, you will learn how these "twinkling little stars" were formed. With that you will eventually also read the story of origin and evolution of the earth.

EARLY THEORIES

Origin of the Earth

A large number of hypotheses were put forth by different philosophers and scientists regarding the origin of the earth. One of the earlier and popular arguments was by German philosopher Immanuel Kant. Mathematician Laplace revised it in 1796. It is known as *Nebular Hypothesis*. The hypothesis considered that the planets were formed out of a cloud of material associated with a youthful sun, which was slowly rotating. In 1950, Otto Schmidt in Russia and Carl Weizascar in Germany somewhat revised the 'nebular hypothesis', though differing in details. They considered that the sun was surrounded by solar nebula containing mostly the hydrogen and helium along with what may be termed as dust. The friction and collision of particles led to formation of a disk-shaped cloud and the planets were formed through the process of accretion.

However, scientists in later period took up the problems of origin of universe rather than that of just the earth or the planets.

MODERN THEORIES

Origin of the Universe

The most popular argument regarding the origin of the universe is the *Big Bang Theory*. It is also called *expanding universe hypothesis*. Edwin Hubble, in 1920, provided evidence that the universe is expanding. As time passes, galaxies move further and further apart. You can experiment and find what does the expanding universe mean. Take a balloon and mark some points on it to represent the galaxies. Now, if you start inflating the balloon, the points marked on the balloon will appear to be moving away from each other as the balloon expands. Similarly, the distance between the galaxies is also found to be increasing and thereby, the universe is considered to be expanding. However, you will find that besides the increase in the distances between the points on the balloon, the points themselves are expanding. This is not in accordance with the fact. Scientists believe that though the space between the galaxies is increasing, observations do not support the expansion of galaxies. So, the balloon example is only partially correct.

The Big Bang Theory considers the following stages in the development of the universe.

(i) In the beginning, all matter forming the universe existed in one place in the form of a "tiny ball" (singular atom) with an

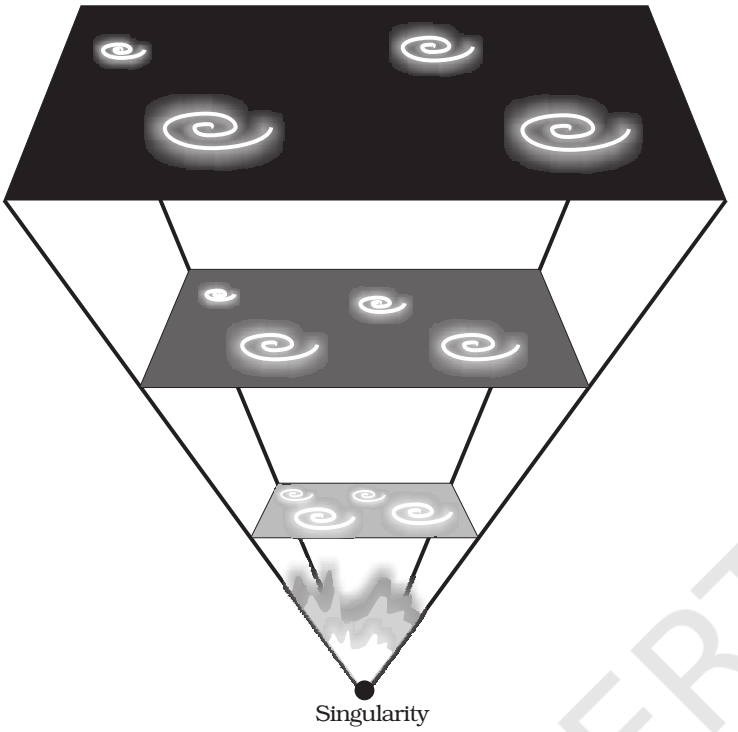


Figure 2.1 : The Big Bang

unimaginably small volume, infinite temperature and infinite density.

(ii) At the Big Bang the "tiny ball" exploded violently. This led to a huge expansion. It is now generally accepted that the event of big bang took place 13.7 billion years before the present. The expansion continues even to the present day. As it grew, some energy was converted into matter. There was particularly rapid expansion within fractions of a second after the bang. Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event, the first atom began to form.

(iii) Within 300,000 years from the Big Bang, temperature dropped to 4,500 K (Kelvin) and gave rise to atomic matter. The universe became transparent.

The expansion of universe means increase in space between the galaxies. An alternative to this was Hoyle's concept of *steady state*. It considered the universe to be roughly the same at any point of time. However, with greater evidence becoming available about the expanding universe, scientific community at present favours argument of expanding universe.

The Star Formation

The distribution of matter and energy was not even in the early universe. These initial density differences gave rise to differences in gravitational forces and it caused the matter to get drawn together. These formed the bases for development of galaxies. A *galaxy* contains a large number of stars. Galaxies spread over vast distances that are measured in thousands of *light-year*s. The diameters of individual galaxies range from 80,000-150,000 light years. A galaxy starts to form by accumulation of hydrogen gas in the form of a very large cloud called *nebula*. Eventually, growing nebula develops localised clumps of gas. These clumps continue to grow into even denser gaseous bodies, giving rise to formation of stars. The formation of stars is believed to have taken place some 5-6 billion years ago.

> A light year is a measure of distance and not of time. Light travels at a speed of 300,000 km/second. Considering this, the distances the light will travel in one year is taken to be one light year. This equals to 9.461 10^{12} km. The mean distance between the sun and the earth is 149,598,000 km. In terms of light years, it is 8.311minutes.

Formation of Planets

The following are considered to be the stages in the development of planets :

(i) The stars are localised lumps of gas within a nebula. The gravitational force within the lumps leads to the formation of a core to the gas cloud and a huge rotating disc of gas and dust develops around the gas core.

(ii) In the next stage, the gas cloud starts getting condensed and the matter around the core develops into small-rounded objects. These small-rounded objects by the process of cohesion develop into what is called *planetesimals*. Larger bodies start forming by collision, and gravitational attraction causes the material to stick together. Planetesimals are a large number of smaller bodies.

(iii) In the final stage, these large number of small planetesimals accrete to form a fewer large bodies in the form of planets.

Evolution of the Earth

Do you know that the planet earth initially was a barren, rocky and hot object with a thin atmosphere of hydrogen and helium. This is far from the present day picture of the earth. Hence, there must have been some events–processes, which may have caused this change from rocky, barren and hot earth to a beautiful planet with ample amount of water and conducive atmosphere favouring the existence of life. In the following section, you will find out how the period, between the 4,600 million years and the present, led to the evolution of life on the surface of the planet.

The earth has a layered structure. From the outermost end of the atmosphere to the centre of the earth, the material that exists is not uniform. The atmospheric matter has the least density. From the surface to deeper depths, the earth's interior has different zones and each of these contains materials with different characteristics.

How was the layered structure of the earth developed?

Evolution of Lithosphere

The earth was mostly in a volatile state during its primordial stage. Due to gradual increase in density the temperature inside has increased. As a result the material inside started getting separated depending on their densities. This allowed heavier materials (like iron) to sink towards the centre of the earth and the lighter ones to move towards the surface. With passage of time it cooled further and solidified and condensed into a smaller size. This later led to the development of the outer surface in the form of a crust. During the formation of the moon, due to the giant impact, the earth was further heated up. It is through the process of differentiation that the earth forming material got separated into different layers. Starting from the surface to the central parts, we have layers like the crust, mantle, outer core and inner core. From the crust to the core, the density of the material increases. We shall discuss in detail the properties of each of this layer in the next chapter.

Evolution of Atmosphere and Hydrosphere

The present composition of earth's atmosphere is chiefly contributed by nitrogen and oxygen. You will be dealing with the composition and structure of the earth's atmosphere in Chapter 8.

There are three stages in the evolution of the present atmosphere. The first stage is marked by the loss of primordial atmosphere. In the second stage, the hot interior of the earth contributed to the evolution of the atmosphere. Finally, the composition of the atmosphere was modified by the living world through the process of *photosynthesis*.

The early atmosphere, with hydrogen and helium, is supposed to have been stripped off as a result of the solar winds. This happened not only in case of the earth, but also in all the terrestrial planets, which were supposed to have lost their primordial atmosphere through the impact of solar winds.

During the cooling of the earth, gases and water vapour were released from the interior solid earth. This started the evolution of the present atmosphere. The early atmosphere largely contained water vapour, nitrogen, carbon dioxide, methane, ammonia and very little of free oxygen. The process through which the gases were outpoured from the interior is called *degassing*. Continuous volcanic eruptions contributed water vapour and gases to the atmosphere. As the earth cooled, the water vapour released started getting

condensed. The carbon dioxide in the atmosphere got dissolved in rainwater and the temperature further decreased causing more condensation and more rains. The rainwater falling onto the surface got collected in the depressions to give rise to oceans. The earth's oceans were formed within 500 million years from the formation of the earth. This tells us that the oceans are as old as 4,000 million years. Sometime around 3,800 million years ago, life began to evolve. However, around 2,500-3,000 million years before the present, the process of photosynthesis got evolved. Life was confined to the oceans for a long time. Oceans began to have the contribution of oxygen through the process of *photosynthesis*. Eventually, oceans were saturated with oxygen, and 2,000 million years ago, oxygen began to flood the atmosphere.

Origin of Life

The last phase in the evolution of the earth relates to the origin and evolution of life. It is undoubtedly clear that initially the earth or even the atmosphere of the earth was not conducive for the development of life. Modern scientists refer to the origin of life as a kind of chemical reaction, which first generated complex organic molecules and assembled them. This assemblage was such that they could duplicate themselves converting inanimate matter into living substance. The record of life that existed on this planet in different periods is found in rocks in the form of fossils. The microscopic structures closely related to the present form of blue algae have been found in geological formations much older than some 3,000 million years. It can be assumed that life began to evolve sometime 3,800 million years ago. The summary of evolution of life from unicellular bacteria to the modern man is given in the Geological Time Scale on page 18.

EXERCISES

1. Multiple choice questions.

   (i) Which one of the following figures represents the age of the earth?

   (a) 4.6 million years (c) 4.6 billion years

   (b) 13.7 billion years (d) 13.7 trillion years

   (ii) Which one of the following is not related to the formation or modification of the present atmosphere?

   (a) Solar winds (c) Degassing

   (b) Differentiation (d) Photosynthesis

   (iii) Life on the earth appeared around how many years before the present?

   (a) 13.7 billion (c) 4.6 billion

   (b) 3.8 million (d) 3.8 billion

2. Answer the following questions in about 30 words.

   (i) What is meant by the process of differentiation?

   (ii) What was the nature of the earth surface initially?

   (iii) What were the gases which initially formed the earth's atmosphere?

3. Answer the following questions in about 150 words.

   (i) Write an explanatory note on the 'Big Bang Theory'.

   (ii) List the stages in the evolution of the earth and explain each stage in brief.

Project Work

Collect information about the project "Stardust" (website: *www.sci.edu/public.html* and *www.nasm.edu*) along the following lines.

(i) Which is the agency that has launched this project?

(ii) Why are scientists interested in collecting Stardust?

(iii) Where from the Stardust is being collected?

11092CH03

CHAPTER

3

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.

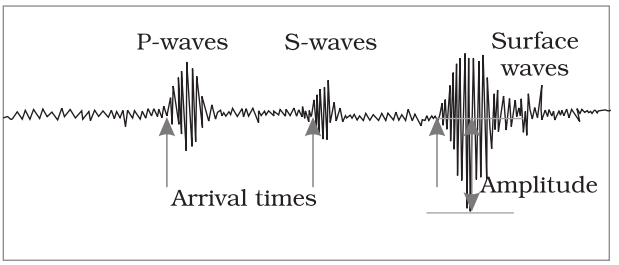


Figure 3.1 : Earthquake Waves

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.

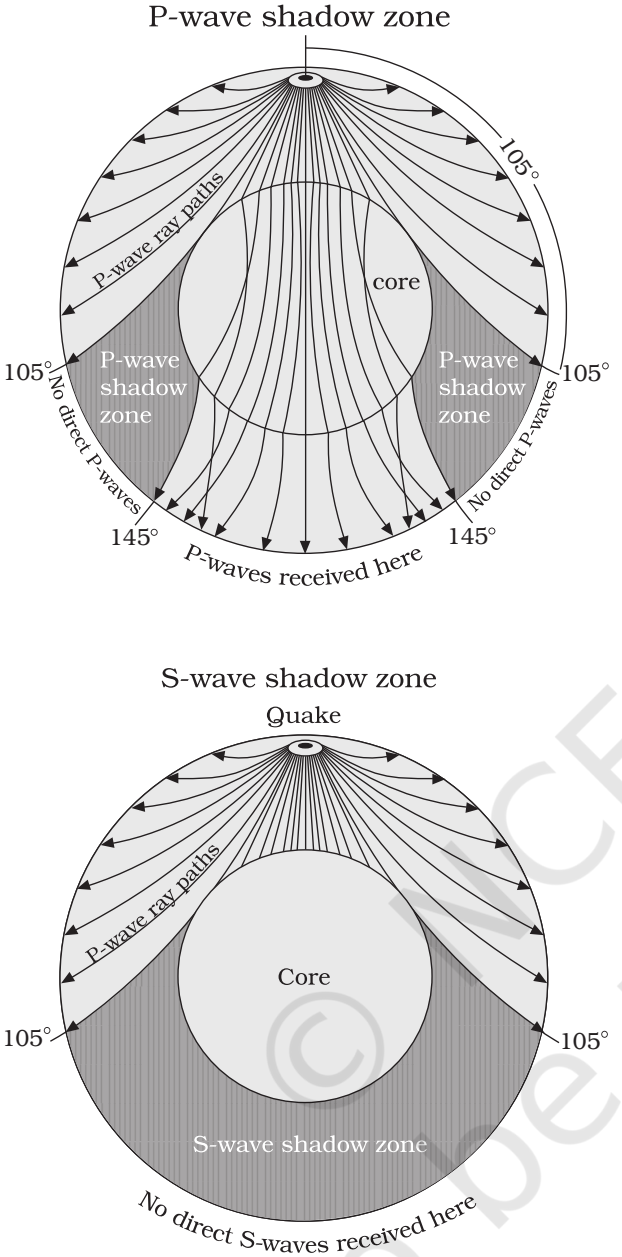


Figure 3.2 (a) and (b) : Earthquake Shadow Zones

(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 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.

A view of the destruction caused by tidal waves in Marina Beach, India

A view of the destruction caused by tidal waves in Thailand

People walk through debris of their houses destroyed by tidal waves on the coastal area in Colombo, Sri Lanka

A view of the destruction caused by tidal waves in Indonesia

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 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.

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

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.

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

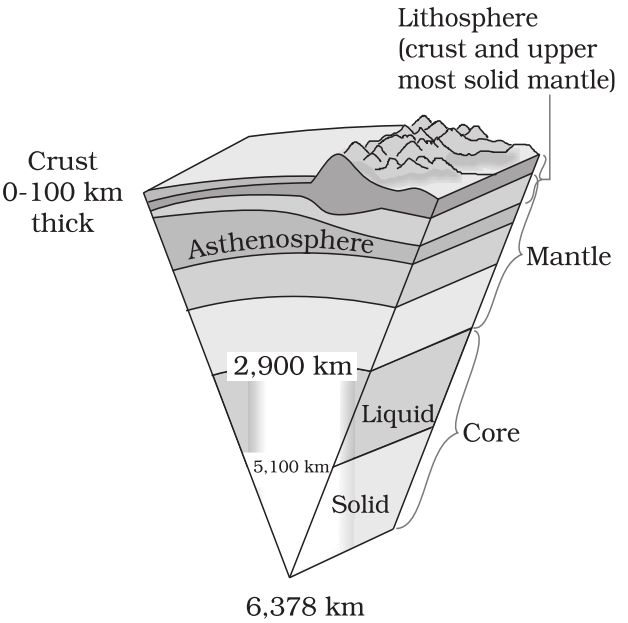


Figure 3.3 : The interior of the earth

its way to the surface during volcanic eruptions. 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 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.

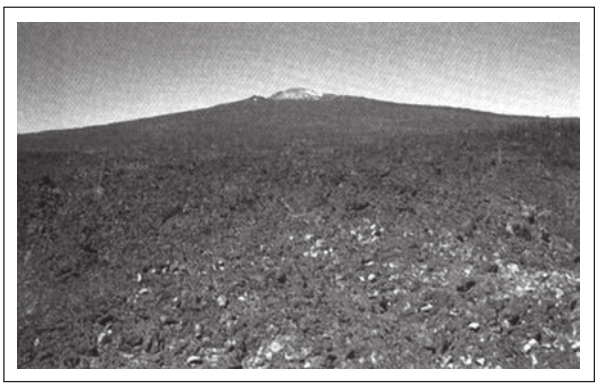
Volcanoes

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 3.4.

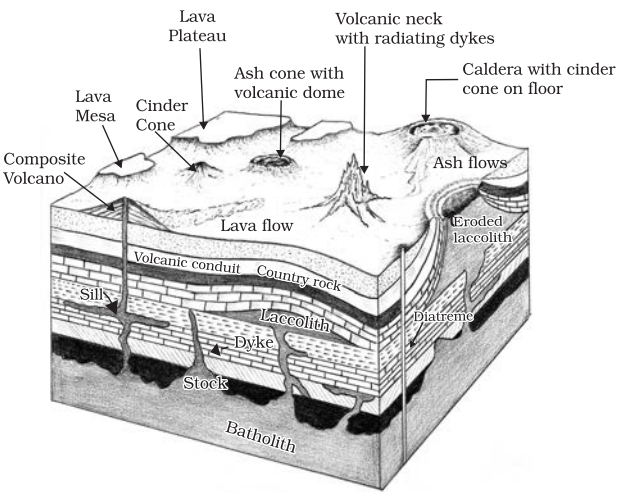


Figure 3.4 : Volcanic Landforms

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 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.

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CHAPTER

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 and mega ocean surrounded 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 counterparts in six different landmasses of the Southern Hemisphere. At the base, the system has thick tillite indicating extensive and prolonged glaciation. Counterparts of this succession are found in Africa, Falkland Island, Madagascar, Antarctica and Australia. 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 are presently 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–World War II 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–World War II 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 they are much younger than the continental areas. Rocks on either side of the crest of oceanic ridges and having equi-distant 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.

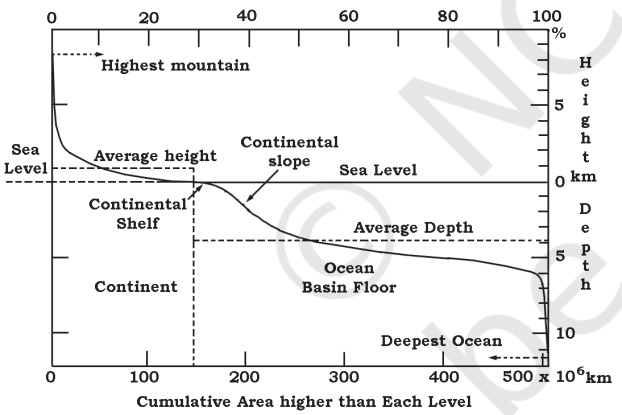


Figure 4.1 : Ocean Floor

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-oceanic 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

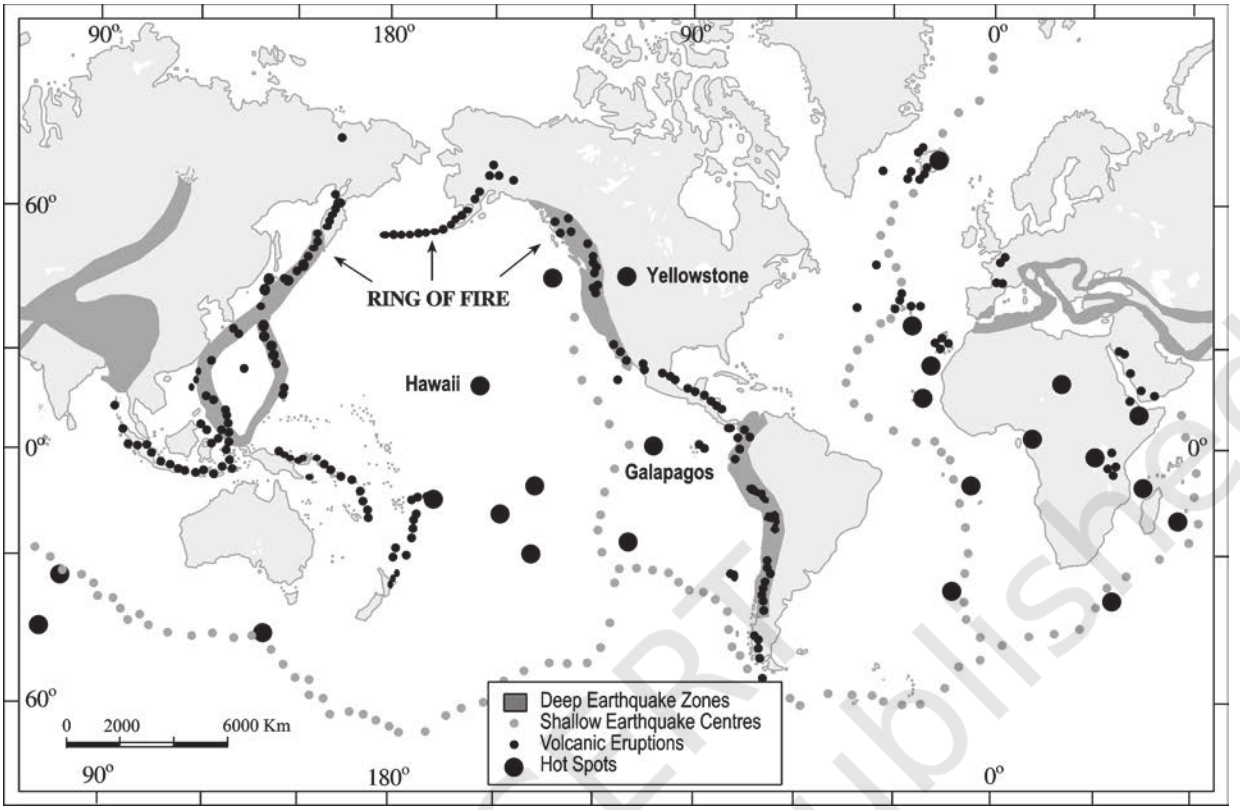


Figure 4. 2 : Distribution of earthquakes and volcanoes

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 have 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

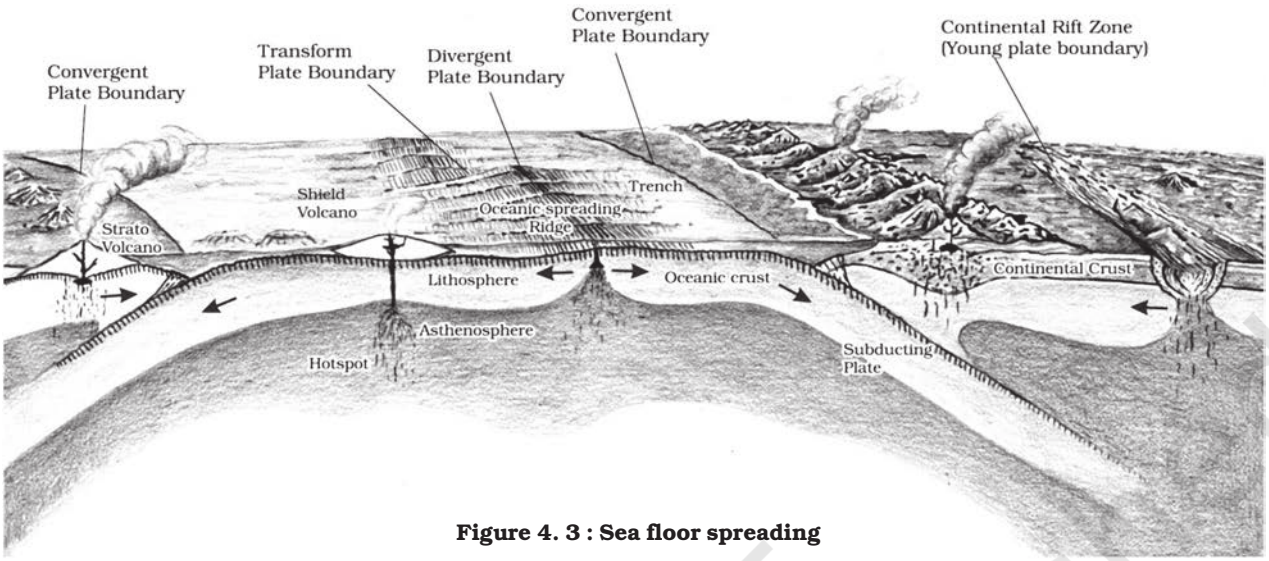


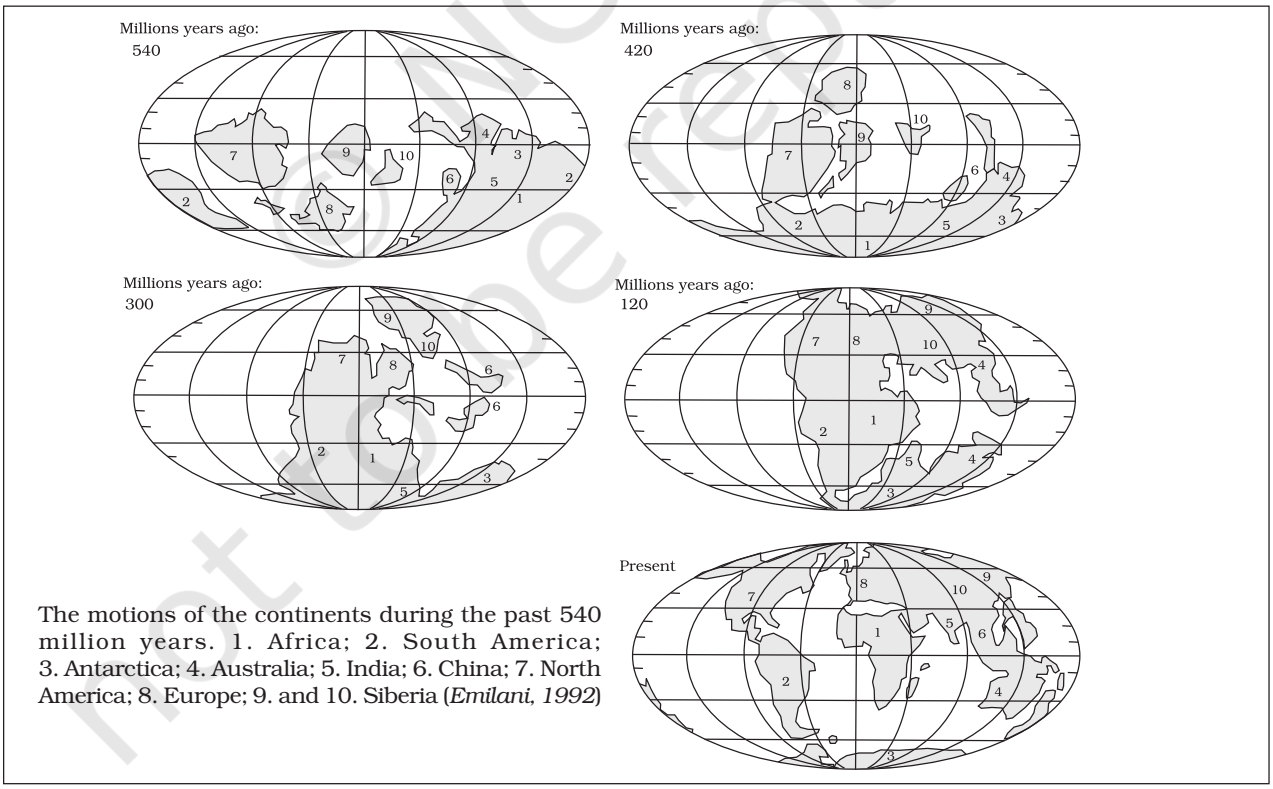
Figure 4. 3 : Sea floor spreading

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



The motions of the continents during the past 540 million years. 1. Africa; 2. South America; 3. Antarctica; 4. Australia; 5. India; 6. China; 7. North America; 8. Europe; 9. and 10. Siberia (*Emilani, 1992*)

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 and100 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

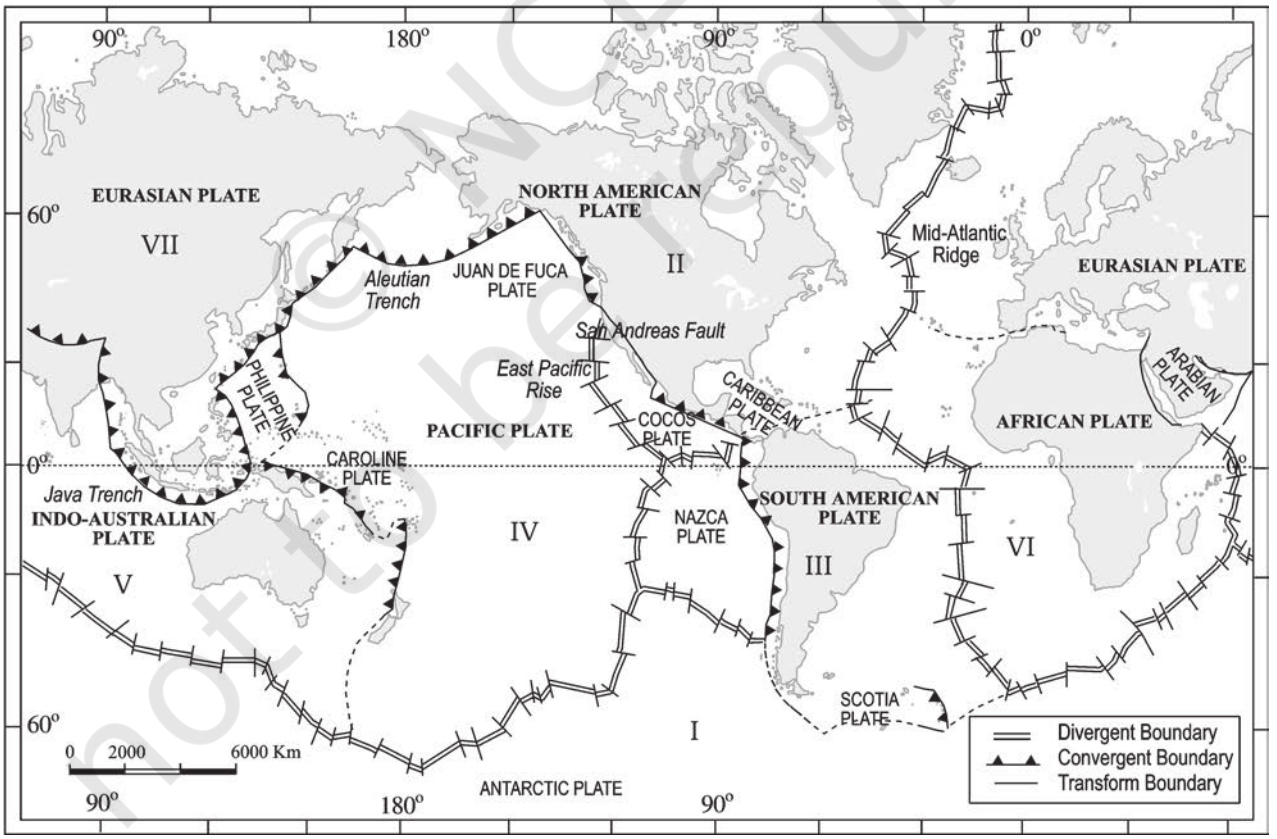


Figure 4.5 : Major and minor plates of the world

(v) *Caroline plate* : Between the Philippine and Indian plate (North of New Guinea)
(vi) *Fuji 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 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 (Fig 4.4). 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 dived 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 plate towards the Eurasian 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.

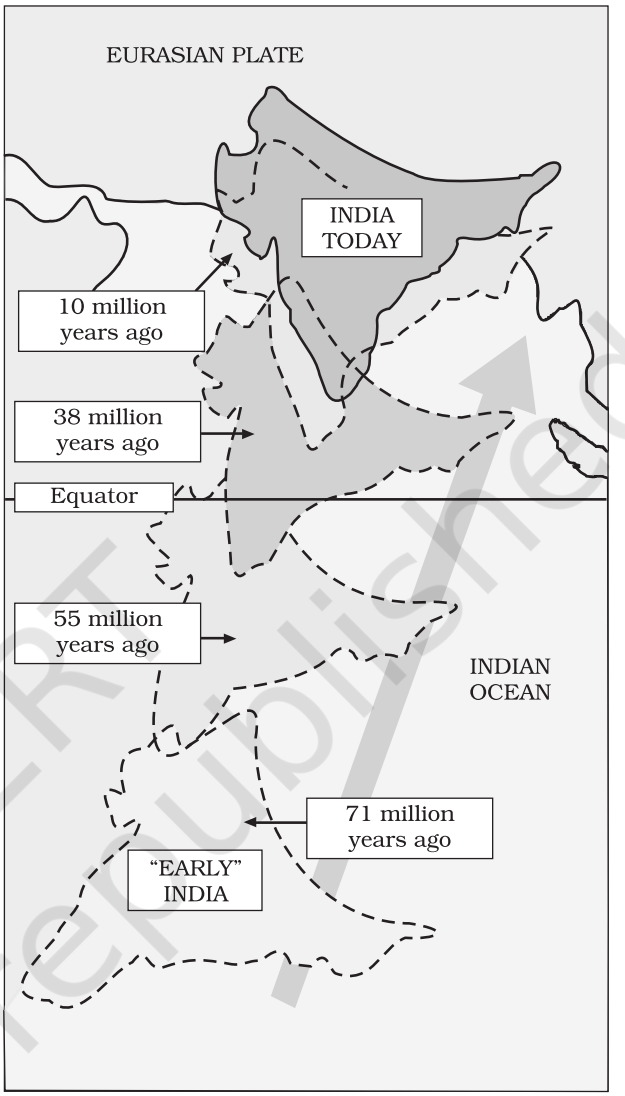


Figure 4.6 : Movement of the Indian plate

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

- *Landforms and their evolution*
- *Geomorphic processes — weathering, mass wasting, erosion and deposition; soils — formation*

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CHAPTER

5

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?

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 extensive damage to the environment through 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, and erosion is development of stresses in the body of the earth materials.

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 5.1) 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 owing to variations in thermal gradients created by latitudinal, seasonal, and land and water spread on the surface of the earth, the exogenic geomorphic processes vary from region to region. The density, type and distribution of vegetation which largely depend upon precipitation and temperature also exert

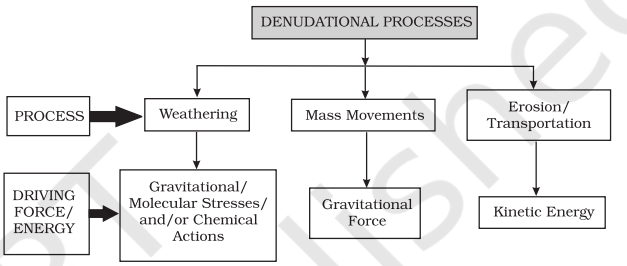

Figure 5.1 : Denudational processes and their driving forces

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?

sun (gravity assists)

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 5.2).

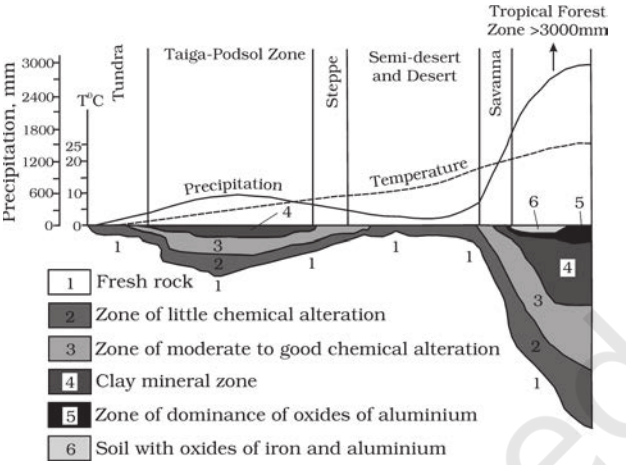

Figure 5.2 : Climatic regimes and depth of weathering mantles (adapted and modified from Strakhov, 1967)

> **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.

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.

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. Plant roots exert a tremendous pressure on the earth materials mechanically breaking them apart.

Special Effects of Weathering

Exfoliation

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 5.3). Exfoliation can occur due to expansion and contraction induced by temperature changes. Exfoliation domes and tors result due to unloading and thermal expansion respectively.

Fig.5.3 : Exfoliation (Flacking) and granular disintegration

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 bio-diversity 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 5.5 shows the relationships among different types of mass movements, their relative rates of movement and moisture limits.

Landslides

These are 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 5.4). Rapid rolling or sliding

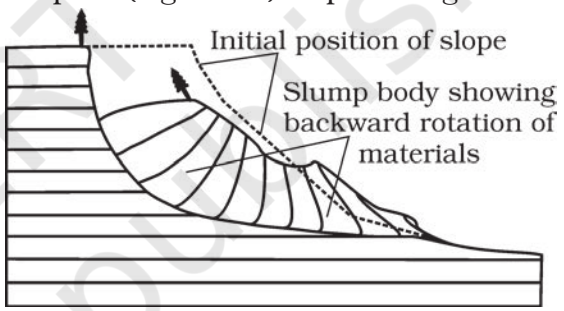

Figure 5.4 : Slumping of debris with backward rotation

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 5.5 shows landslide scars over steep slopes. Slides occur as planar failures along discontinuities like

Figure 5.5 : Landslide scars in Shiwalik Himalayan ranges near river Sarada at India-Nepal border, Uttar Pradesh

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 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 avalanches 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. They represent three states of matter — gaseous (wind), liquid (running water) and solid (glacier) respectively.

Can you compare the three climatically controlled agents?

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 these 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

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?

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.

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 considerations 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.

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 maturation 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.

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?

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.