3 FORMATION OF CONTINENTS AND OCEANS

What we have learnt

- There are seven continents on the surface of the earth and oceans occupy the space in between them.
- The crust of the earth can be bifurcated into sial and sima
- Some rocky portions of the continents are more than 3500 million years old.
- Portions of the sea floor older than 180 million years have not been discovered so far.
- The crust and the upper portion of the mantle together constitute the lithosphere of the earth.
- The rocks of the asthenosphere occurring just below the lithosphere are in partially molten condition.
- Earthquakes and volcanoes are found concentrated along certain linear zones of the earth's surface..

Can you believe that the various continents were connected to each other once upon a time! There was also an extensive ocean that surrounded that 'supercontinent'. In course of time that continent broke up and the fragments drifted to different directions. Man could not witness these events that took place several million years ago, because man was not originated at that time. You may now ask the question: How then did we come to know about these? Time has preserved records of these events in the rocks. When man's intelligence was combined with his enthusiasm, he could bring to light several secrets of the past. Let us have a brief discussion of these developments.

The origin of the concept of drifting continents

With the beginning of the 17th century,outlines of most of the continents had been made. The similarity between the east coast of South America and the west coast of Africa attracted the attention of early explorers and scientists.

Many people including the English philosopher Sir Francis Bacon, Flemish cartographer Abraham Ortelius and French scientist Françoise Placet the 17th century, pointed out similarity between the continental outlines on both sides of the Atlantic. This indicated that the continents of the western hemisphere were once united with Europe and Africa during some period in the long history of the Earth. In 1878, a scientist named Antonio Snider Pelligrini supported this view with substantive evidence. He observed similarities between the fossil plants of the coal deposits that formed during the Carboniferous Period in Europe and North America. However, these suggestions could not gain much recognition in the scientific world.

Ever since the beginning of the 20th century, several evidences have been obtained for the existence of a supercontinent in the southern hemisphere. In 1885, the Austrian geologist Edward Suess proposed the name Gondwanaland for that ancient supercontinent. It covered the present Indian Peninsula, the Islands of Sri Lanka and Madagascar, and the continents of Africa, South America and Antarctica. The similarity of the deposits left behind by ice sheets that covered extensive regions of these land masses between 380 to 250 million years ago (corresponding to the end of the Carboniferous Period and the beginning of the Permian period) as well as the similarity of the fossils of animals and plants that lived prior to that period in these areas, were the major evidences that indicated the existence of the gondwanaland.

Suess believed that, in addition to the gondwanaland yet another continent also existed in the southern hemisphere. It consisted of the

present day Australia and the Patagonia. He gave the name 'Antactics' to that continent. He also believed that, there probably existed two more continents in the northern hemisphere, during that time.

Suess also held the views that by the process of large scale faulting, extensive segments of landmass were detached from the ancestral continents and they subsequently floundered. These formed ocean floors and the remaining masses formed the present continents. However, where it was found that the density of the rocks of the ocean floor is more than that of the continents, the hypothesis of Sucess became unacceptable to the scientific world.

Continental Drift Theory

The German meteorologist Alfred Wegener (1860-1930) proposed the concept of "Continental Drift" and gave it a scientific base. It attracted the attention of the world of science. The similarity between the opposing coastlines of the continents of South America and Africa attracted his special attention. He was also impressed by the remarkable fit between the bulge of Brazil and the sea of Western Africa.

(i) Alfred Wegener formulated the hypothesis based on the following evidences. The similarity of the fossils collected from the continents on both sides of the Atlantic.

(ii) The evidences left by the ice age (glaciation) in the continents during the Permian Period and the subsequent Carboniferous Period, and

(iii) the pattern of global distribution of fold mountain chains.

In 1912, he presented the Continental Drift Theory before the scientific world in a meeting of the Frankfurt Geological Association, supported by numerous scientific evidences. Later in 1915, with additional evidences, he published his new theory in German language. He formulated his theory by incorporating the concept of gondwanaland of Suess. With the publication of an English translation of Wegener's work in 1924, the theory of continental drift became more popular in the scientific world.

Wegener held the view that the sialic portion of the crust which comprises the continental block , slides over the underlying sima. According to the continental drift theory, until the end of the Triassic Period, there was only a single huge landmass and an ocean that encircled it. 'Pangaea' was the name given by Wegener to that continent. For the ocean that surrounded Pangaea, he gave the name 'Panthalassa'.

About 200 million years ago Pangaea broke into two large continents and began to drift away from each other. Observe the(figure 3.1) and try to answer the questions given below.

- What was the name of the newly formed continent that existed in the northern hemisphere during that time?
- What was the name of the continent that existed in the southern hemisphere?

- What was the name given to the sea that lay in between the two continents?

According to the theory of Wegener, those two huge continents drifted away from each other. As a result of further breaking and subsequent lateral movement (drifting) of the continental masses, the seven continents assumed their present position.

From figure 3.1, study the displacements that have affected the continents and prepare a note. Draw the outline of a world map using a tracing table. Cut the continents out of that map and try to reassemble the continents and thus make an attempt to reconstruct the primordial supercontinent- Pangaea.

Wegener could not provide an adequate answer to the question of the nature of the force that was necessary to break the continents and drifting of the continental fragments. Wegener held the view that the gravitational pull of the sun and the moon that causes the phenomenon of tides on earth resulted in the drifting of continents towards the equator. The centrifugal force developing from the rotation of the earth resulted in the westward drift of the continents. However, a majority of the scientists of the time pointed out that these forces were not enough to cause the lateral drifting of continents. Moreover, Wegener could not provide an adequate explanation for the drifting of the continents. Later, in 1928, the well-known British geologist Arthur Holmes (1890-1965) suggested that perhaps the convection currents that develop in the mantle may be the driving force of drifting of continents.

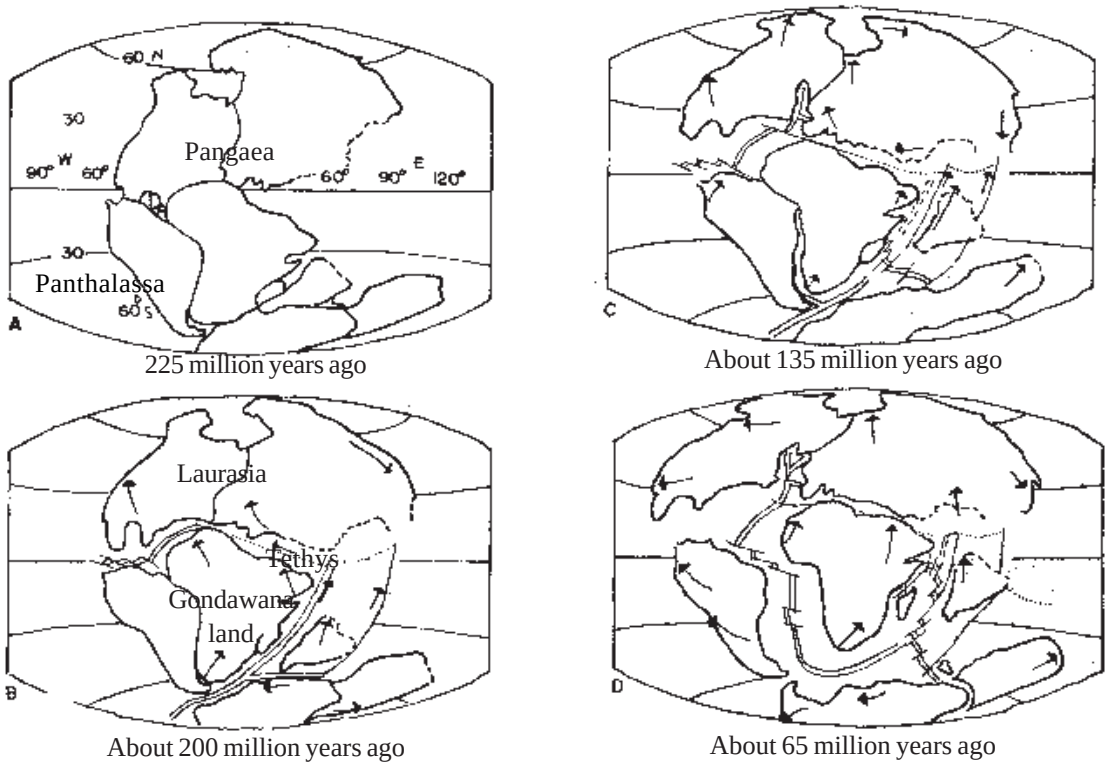


Figure 3.1

Our Wandering Continents

In 1934, Alexander du Toit, a Professor of Geology at Johannesburg University of South Africa gave a stronger foundation for the continental drift theory with the publication of his well-known book entitled ' Our Wandering Continents', supported by numerous evidences gathered from the southern continents. du Toit concluded that at first there were two continents -namely the gondwanaland and the Laurasia. He also supported the suggestion made by Arthur Holmes that convection currents originating inside the mantle could be the probable cause of the drifting of continents.

The Theory of Plate Tectonics

The Theory of Plate Tectonics, which was formulated in 1968, can be considered to be an integration or unification of earlier tectonic theories, such as those of continental drift, sea -floor spreading and polar wandering. Try to learn more about those theories from your teacher. Many scientists including Tuzo Wilson, Jack .E.Oliver, Bryan L.Isacks, William Morgan and several others made valuable contributions to the development of Plate Tectonics Theory in its present form.

The Theory of Plate Tectonics elucidates that Earth's outermost layer named the lithosphere has a thickness about 50 km to 100 km (including the crust and the upper mantle). Lithosphere consists of numerous large and small plates. These plates slide very slowly over the Earth's mantle, called asthenosphere, in response to some forces that originate at the interior of the Earth. Among these plates seven are very extensive. From the figure. (3.2) try to find out their names and prepare a list.

Major lithospheric plates are several thousands of square kilometres in areal extent. Why they are called 'plates' will become apparent when one compares their areas with their thickness.

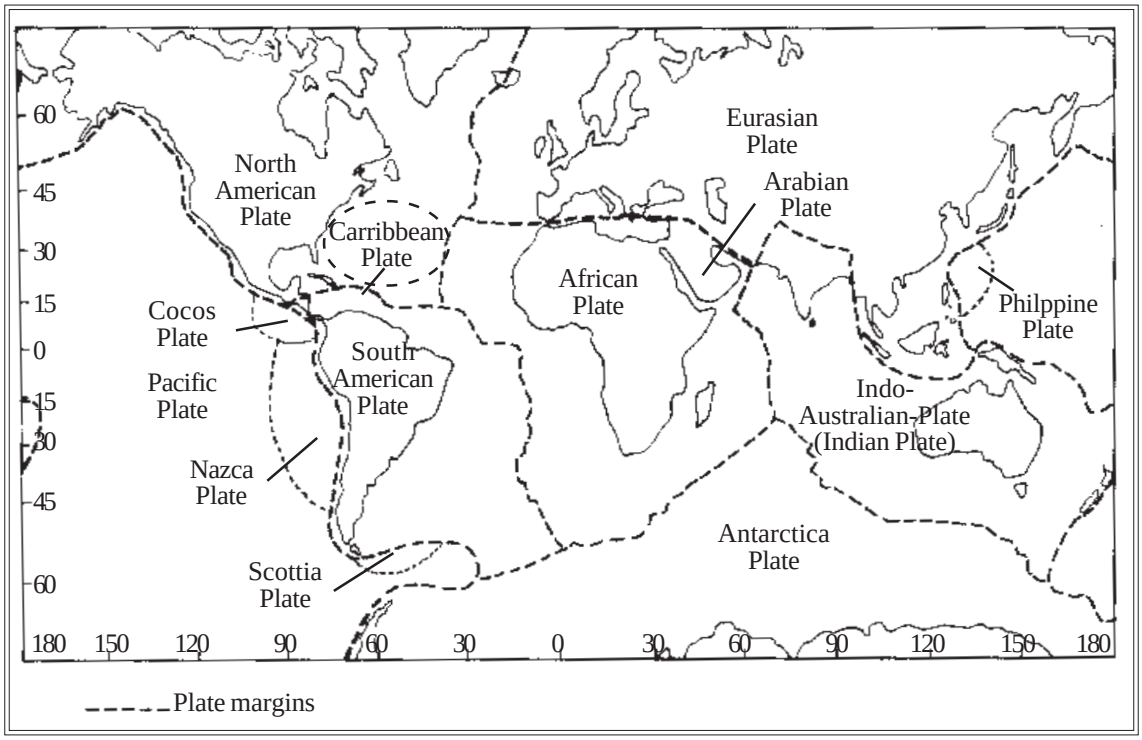
Lithospheric plates with relatively lesser areal extent include Cocos Plate, Nazca Plate, Caribbean Plate, Arabian Plate etc;

Although most of the plates comprise both continental and oceanic crusts, the Pacific plate is overlain only by oceanic crust.

The most extensive plate of the lithosphere is the Pacific plate. Its maximum width is about 14,000 km.

According to plate tectonics theory, lithospheric plates move very slowly in different directions. The margins of the lithospheric plates are zones which deserve our special attention. It has been noted that three types of plate margins can be recognised on the basis of the relative motions of plates with respect to adjacent plates. However, it should be noted that all the three types of margins need not be present in all plates.

1. Plate margins where two adjacent plates move away from each other- Divergent Margins.



Lithospheric Plates
figure 3.2

2. Plate margins where two plates meet each other - Convergent Margins.

3. Plate margins along which the plates slide past each other- Shear Margins.

As two adjoining plates slowly move away from each other, very long fissures develop in the lithosphere between them. Molten rock (magma) from the underlying mantle comes up through these fractures and cools down later. It consolidates and joins with the trailing edges of the plates and forms the youngest portions of the sea floor. The process of seafloor spreading takes place in this manner. Such plate margins passing through continents result in the formation of rift valleys. Most of the divergent plate margins pass through the crestal portions of the submarine mountain chains (midoceanic ridges). It has been estimated that the two plates on both sides of the midoceanic ridge of the Atlantic Ocean (The Mid-Atlantic Ridge) continually move apart at the rate of about 2.5 cm. per year. Earthquakes, faulting, and lava flows are very frequent along such plate margins.

In regions where divergent plate margins pass through the continents, large rift valleys develop. In course of time new sea floor forms within them and subsequently results in the drifting away of the sides of the rift valleys towards the opposite sides. The Krafla Rift Valley of Iceland and the rift valley zone of East Africa extending from Syria to Mozambique and further up to the Red Sea are formed in this manner. The Continent of Africa is gradually undergoing drifting as a result of the intrusion of magma from the mantle and the formation of new sea floor within the branching rift valley zone of that continent.

Gulf of California

The Gulf of California today occupies the region formed by the drifting that took place at about 30 million years ago of Baja California from the North American Plate along the northern extension of a divergent plate margin of the Pacific Ocean.

Where two plates come together and meet each other (convergent margins), the leading edge of one of the plates dives or sinks below the other and goes down into the mantle where it melts and forms part of the material of that mantle. Such zones of the Earth's crust where the margin of the lithospheric plates sinks into the mantle are called subduction zones.

There are three types of convergent plate margins.

1. ***Margins on both sides of which have sea floor:***
   The region of Mariana Trench in the Western Pacific Ocean is a zone where oceanic part of two lithospheric plates meet together. This is a plate margin where the Pacific plate is descending under the smaller Philippine plate.
2. ***Margin where seafloor of one plate meets the continental portion of adjacent plate:***
   Andes Mountain is an example for a convergent plate margin where there is seafloor on one side and continent on the other. In this zone the Pacific plate sinks below the South American plate .Many of the world's large destructive earthquakes occur along this type of plate margins.
3. ***Convergent margins where continents occur on both sides of the plate margin:***
   The Himalayan Mountains is an example of a convergent plate margin where continental portions of two plates meet together. The collision of the Indian Plate with the Eurasian Plate has produced the Himalayan Mountains and the Tibetan Plateau.

In some regions two lithospheric plates slide past one another in opposite directions, without converging or diverging. Such plate margins are called shear margins. As a result of this, these regions have developed into zones of faulting or shearing . The San Andreas Fault Zone of California is an example of such a plate margin. Shear margins are zones of tectonic activity characterized by frequent earthquakes. Some regions of the Earth are localities where three lithospheric plate margins meet together. Such plate margins are called 'triple junctions'.

The process of plate tectonics is making the Pacific Ocean smaller, the Atlantic Ocean larger and the Himalaya Mountains taller.

The pattern of distribution of continents and oceans we see today has evolved through the tectonic processes of repeated breaking, drifting and recombining of continental blocks. These processes have been taking place in the lithosphere without any interruption ever since the origin of the Earth. These process will most probably continue as long as our Earth exists.

SUMMARY

- It was the German meteorologist Alfred Wegener who gave a theoretical basis for the concept of continental drift.
- According to the Theory of continental drift there was only a single large continent on the surface of the Earth until the end of the Triassic Period.
- At about 200 million years ago, Pangaea broke up and formed into two continents named Gondwanaland and Laurasia.
- During the course of time earlier continents further fragmented and their portions drifted away from each other.
- Wegener failed in providing a scientifically sound explanation regarding the force that was necessary for drifting of continents.
- The Theory of Plate Tectonics has been formulated in 1968.
- The lithosphere of the Earth is made up of a number of large and small plates.
- Lithospheric plates slowly slide over the underlying asthenosphere.
- On the basis of relative motions of adjacent plates three types of plate margins have been recognised.
- Divergent plate margins in continents give rise to rift valleys.
- Convergent plate margins are of three types.
- Shear margins are those where adjacent plates move past each other in horizontal directions.
- Triple junctions are regions where three plates come into contact.

QUESTIONS

1. Write a note on the Continental Drift Theory of Alfred Wegener.
2. What was the explanation offered by Wegener regarding the force required for the drifting of continents?
3. Explain the Theory of Plate Tectonics.
4. Which are the seven major lithospheric plates?
5. Mark the locations of minor plates on a world map.
6. Name the lithospheric plate which consists solely of oceanic region.
7. What are the three types of plate margins?
8. Describe the tectonic processes that take place along the plate margins and their effects.
9. Elucidate with reference to Plate Tectonic Theory how the Himalaya Mountains were formed.
10. What is meant by 'triple junction'?
11. Name the type of plate margin with which subduction zones are associated?
12. What are the different kinds of convergent plate margins?
13. 'Continental regions are older than the sea floor'. Explain.
14. What is the basic difference between the Continental Drift Theory and the Plate Tectonics Theory?