UNIT 6

CONTINENTAL DRIFT, MOUNTAIN BUILDING AND PLATE TECTONICS

Structure

6.1 INTRODUCTION

You have studied materials of the Earth's crust in Unit 5 of this Block. In this unit you will learn about continental drift theory of Wegener, mountain building theories of Kober and Homes, and theory of plate tectonics. The continents are in motion relative to each other. After going through the Section 6.2, you will be able to define the 'Continental Drift' which is the movement of the Earth's continents relative to each other by appearing to drift across the ocean bed. This concept was independently and more precisely proposed by Alfred Wegener. The theories related to mountain building are propounded by various scientists explained in Section 6.3. Wegener's idea eventually helped to form the theory of plate tectonics. The theory of continental drift was supported by the theory of plate tectonics, which has been explained elaborately in Section 6.4. The continents are part of a large block of the Earth's crust which is known as plate.

Expected Learning Outcomes

After studying this unit, you should be able to:

- explain the basic idea of continental drift;
- explain the relationship between the theories of continental drift and plate tectonics;
- describe the origin and relationship of mountain building, Earthquake, volcanicity, tsunamis with plate tectonics.

6.2 CONTINENTAL DRIFT THEORY OF WEGENER

Density of the continental crust is lighter than all the layers of the Earth's interior and its density is 2.7g/cm3. Main composition of minerals of continental crust is Silica and Aluminum. That is why this layer is known as SIAL layer.

Oceanic crusts are heavier and its density is 3.0 g/cm3. The mineral compositions of the rocks are mainly Silica and Magnesium and so the layer is known as SIMA.

It is established fact that the Earth crust is made up of different parts, called plates, which move horizontally over the asthenosphere. This idea was later fully adopted and developed by Alfred Wegener in 1912 written in a book "The Origin of Continents and Oceans". This whole idea of the movements of continent crustal plates was termed as continental drift. The continents might have drifted which was first put forwarded by Abraham Ortelius in 1596. Let us now discuss about the continental drift theory. The 'Continental Drift Theory' of Alfred Wegener suggests that there might have been horizontal displacement of the continental masses on a global scale. Wegener assumed that there was only one super-continent named **Pangaea** meaning 'all lands'. It was surrounded by another super-ocean called **Panthalassa**. The northern part of Pangaea was called **Angaraland** and the southern part was called **Gondwanaland**. The northern and southern parts were separated by geosyncline, a long narrow shallow sea called **Tethys**, in which sediments were deposited. The minerals constituents silica and aluminum covering continental crust moved over the oceanic crust, which consists of silica and magnesium minerals. As you have already studied in Unit 5, there are two types of crusts i) continental crust also known as SIAL and ii) oceanic crust called as SIMA. The deep sea floor formed as the upper surface of SIMA is largely composed of basalt. During the Carboniferous period, the super continent Pangaea got broken and started drifting over SIMA.

Although, it was not well defined what may be the condition of the continents during pre-Carboniferous period but the postulation of a Carboniferous Pangaea does not mean that Wegner disbelieved in pre-Carboniferous drift. Major events before this time are known with much less certainty whereas the distribution of plants and animals can largely be explained by movements, which have taken place since the Carboniferous period (Steers, 1961). The Pangaea was disrupted during subsequent periods and broken landmasses drifted away from each other and thus the present position of the continents and ocean basins became possible.

6.2.1 Energy Responsible for Continental Drift

According to Wegener the continents after breaking away from the Pangaea moved in two directions: (i) Equator ward movement; and (ii) Westward movement. Refer to the Fig. 6.1 which explains how the present continents were once united in a single super continent as Pangaea.

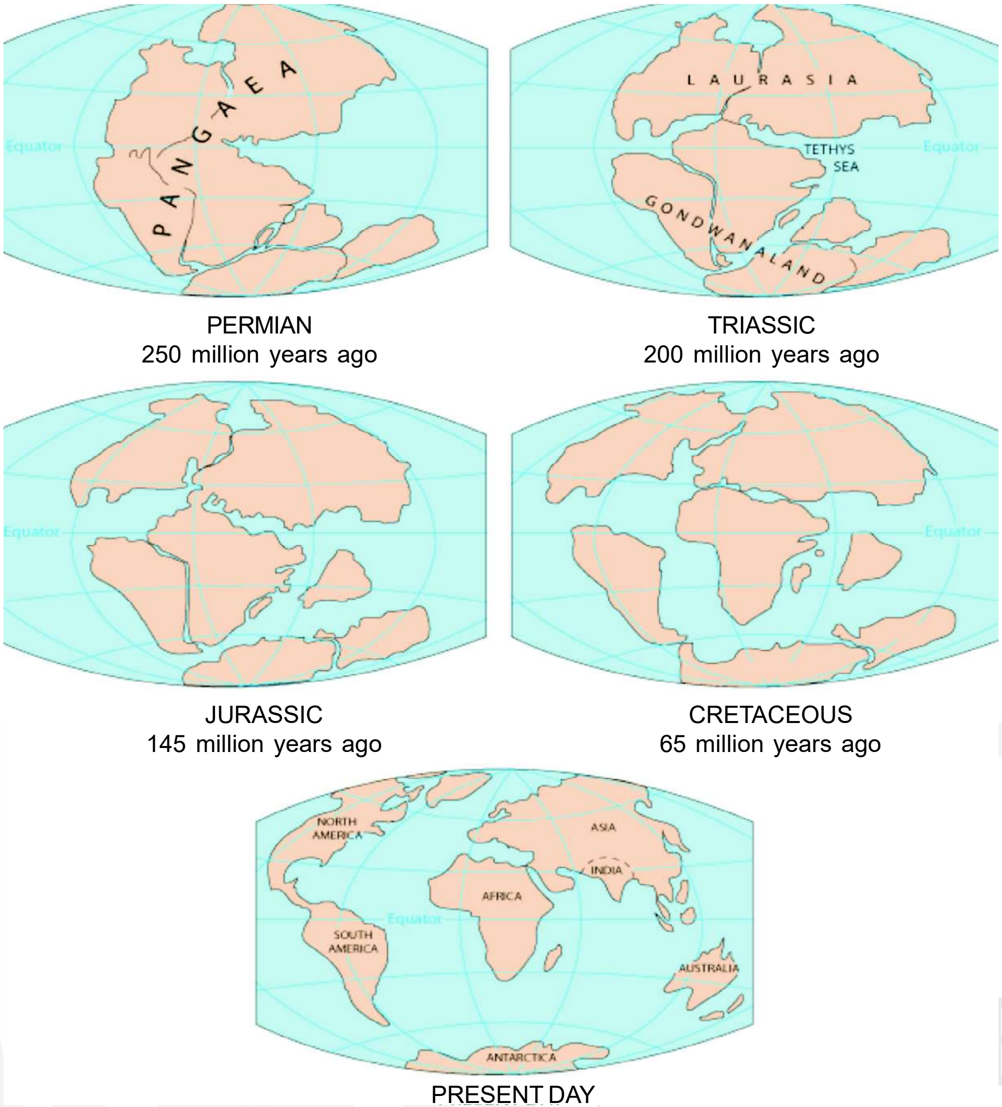

Fig. 6.1: Disruption of Pangaea and drifting of continents.
(*Source*: Illustration from USGS, 2012, URL: http:// pubs.usgs.gov)

The equator ward movement of southern part of broken Pangaea was mainly caused by gravitational differential force and force of buoyancy. The continental blocks are formed of lighter materials (SIAL) and are floating with friction on relatively denser oceanic crust (SIMA). Thus the equator ward movement of the continental blocks would depend on the relation of the centre of gravity and the centre of boundary of the floating continental mass. Generally, these two types of forces were operating on opposite directions. But because of the ellipsoidal form of the Earth, the resultant movements were directed toward the equator.

The westward movement of the continents was caused by the tidal force of the sun and the moon. According to Wegener, the maximum gravitational force of the sun and the moon was there when the moon was nearest to the Earth. The force dragged the SIAL over the interior of the Earth, SIMA towards the west.

This theory lacks the strength for explaining the potential force responsible for the movement of the continents. Such forces were extraordinarily small, but it is claimed that even these very small forces may be responsible to cause continental movement.

SAQ 1

Spend
5 mins

What are Pangaea and Panthalassa?

6.2.2 Mechanism of Continental Drift as Described by Holmes

It was Arthur Holmes, in 1919, who suggested the mechanism of continental drift in more scientific way. The theory says- (i) that the continents are drifting/ carried away by the **horizontal flow of hot magma** on which they sit, and (ii) the mantle is flowing because of its **convection current**. Holmes suggested that rocks in the interior of the Earth would buoyantly rise toward the surface from deep within the Earth when heated by radioactivity and then sink back down as they cool and become denser. He theorized that convection currents move through the mantle the same way heated air circulates through a room, and radically reshape the Earth's surface in the process. He proposed that upward convection might lift or even rupture the crust, that lateral movement could propel the crust sideways like a conveyor belt, and that is where convection turned downwards, the buoyant continents would crumple up and form mountains. Holmes also understood the importance of convection as a mechanism for loss of heat from the Earth and of cooling its deep interior. Not until after World War II, could scientists produce the hard evidence to support Holmes's fundamental concept. Holmes' theories have continued to be reinforced by new data from seismologists, mineral physicists and geochemists (Earth: Inside and out, 2000).

6.3 THEORIES OF MOUNTAIN BUILDING

Wegener also attempted to solve the problem of the origin of folded mountains of Tertiary period on the basis of his Continental Drift Theory. The frontal edges of westward drifting continental blocks of North and South America were crumpled and folded against the resistance of the rocks of the sea floor and thus the western cordilleras of the North and South America (Rockies, Andes and other mountains) were formed. Similarly, the Alpine ranges of Eurasia were folded due to equatorward movement of Eurasia and Africa together with Peninsular India. Here, Wegener postulated contradicting view points. According to Wegener, SIAL was floating upon SIMA without any friction and resistance but during the later part of his theory he pointed out that mountains were formed at the frontal edge of floating and drifting continental blocks due to friction and résistance offered by SIMA.

6.3.1 Geosynclinal Orogen Theory of Kober

Kober not only attempted to explain the origin of mountains on the basis of his Geosynclinal Theory but he also attempted to elaborate the various aspects of mountain building, e.g. formation of mountains, their geological history and evolution and development.

Kober's Geosynclinal Theory is based on the forces of the contraction produced by the cooling of the Earth. The force of contraction generated due to cooling of the rigid masses or forelands which squeeze buckle and fold the sediments into mountain ranges.

Base of the Theory

According to Kober, there were mobile zones of water in the places of present day mountains. He called those mobile zones of water as geosynclines or *Orogen*. The mobile zones of geocycline were surrounded by rigid masses which were termed by Kober as **'Kratogen'**. Kober identified six major periods of mountain building. Three mountain building periods, about which very little is known, are reported to have occurred during Pre-Cambrian period. Palaeozoic era saw two major mountain building periods-the Caledonian orogenesis was completed by the end of Silurian period and the Variscan orogeny was culminated in Permo-Carboniferous period. The last (6th) orogenic activity known as Alpine orogeny was completed during Tertiary epoch.

Mechanism of the Theory

According to him, the whole process of mountain building passes through three closely linked stages of ***lithogenesis, orogenesis*** and ***gliptogenesis***. The geosynclines are long and wide mobile zones of water which are bordered by rigid masses which have been named by Kober as ***forelands*** or ***kratogen***. These upstanding land masses or forelands are subjected to continuous erosion by fluvial processes and eroded materials are deposited in the geosynclines. This process of sediment deposition is called sedimentation. The ever-increasing weight of the deposited sediments due to gradual sedimentation put enormous pressure on the beds of geosynclines, resulting gradual subsidence of the beds of the geosynclines.

The second stage of mountain formation is called the stage of orogenesis. Both the forelands started moving towards each other because of horizontal movement cause by the force of contraction resulting from the cooling of the Earth. The compressive force generated by the movement of foreland causes contraction, squeezing and ultimately folding of sediments deposited in the geosyncline to form folded mountain ranges. If the compressive forces are normal and of the moderate intensity, only the marginal sediments of the

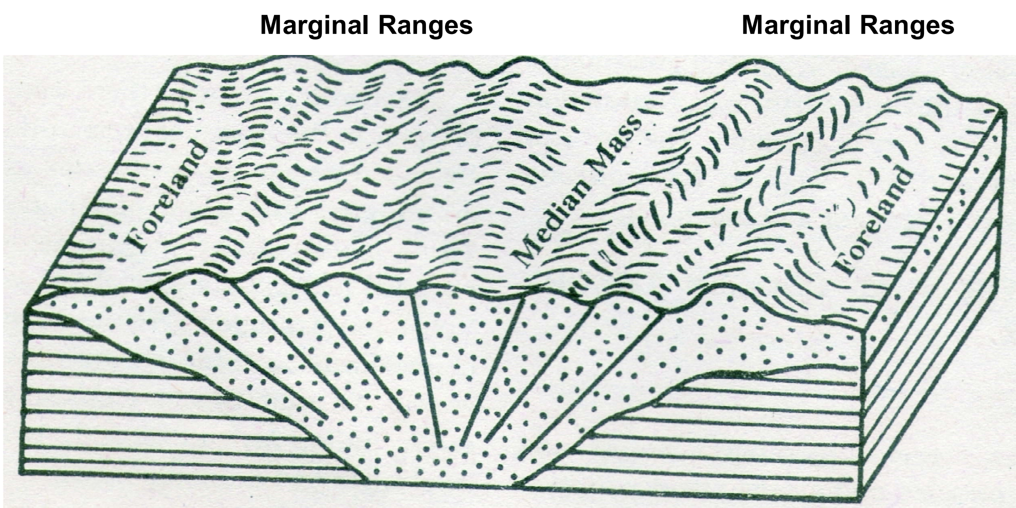

Fig. 6.2: Kober's Geosynclinal Theory of Mountain Building.
(*Source*: Savindra Singh, 2012, Physical Geography)

geosynclines are folded to form two marginal ranges and middle portion of the geosynclines remains unaffected by folding activity. This unfolded middle portion is called ***Zwischengebirge*** or median mass (Fig. 6.2). According to Kober, the Alpine mountain chain of Europe can be explained on the basis of median masses.

Third stage of mountain building is characterised by gradual rise of mountains and their denudation by fluvial and other processes. Continuous denudation result into gradually lowering of the height of mountains.

6.3.2 Convection Current Theory of Holmes

Arthur Holmes postulated his thermal convection current theory during 1928-29 to explain the intricate problems of the origin of major relief features of the Earth's surface. The driving force of mountain building implied by Arthur Holmes is provided by thermal convection current originating from deep within the Earth.

Base of the Theory

The origin of convective current within the Earth depends on the presence of radioactive elements in the rocks. The disintegration of radioactive elements generates huge heat which melts the rock as magma and thus causes convection current. According to Holmes, concentration of radioactive elements in the crust is also there but the generated temperature is not so high because there is gradual loss of heat through conduction and radiation from the upper surface at the rate of 60 calories per square centimeter per year. Though there is very low concentration of radioactive elements in the substratum but the gradual accumulation of heat produced by the radioactive elements cause convective currents. Ascending convective current originates under the crust near the equator because of greater thickness of crust, whereas descending convective currents are originated under the polar crust because of its shallow depth.

Mechanism of the Theory

The convective currents are divided into two major groups on the basis of their location i) convective currents of rising columns; and ii) convective currents of falling columns.

According to Holmes, the equatorial crust was stretched and ruptured due to divergence of rising convective currents which carried the ruptured crustal block towards the north and south and a syncline was created as Tethys Sea between two blocks. This phase is called **Opening of Tethys**. Again two sets of convergent or downward moving currents pull Laurasia and Gondowanaland towards each other and thus Tethys was compressed and folded into Alpine mountains including Himalyas. This phase is called **Closing of Tethys**. Geosynclines are formed due to subsidence of crustal blocks mainly continental slabs due to compressive force generated by convergent convective current moving laterally together under continental and oceanic crust. According to Holmes, the cyclic pattern of convective current and related mountain building pass through three phases or stages.

In the first stage, the rising convective current of two centers converge under the continental slabs and thus form geosynclines due to compression coming from the convergence of two sets of lateral currents. As the sediments are pressed downward into geosynclines, these go further downward and are intensely heated and metamorphosed. Metamorphism of sediment causes rise in their density which further cause downward movement of the metamorphosed materials. This stage is called **Lithogenesis**.

The second stage is marked by phenomenal increase in the velocity of convective currents. The main cause for this convective current is the downward movement of cold materials in the falling column and upward movement of hot materials in the rising columns of convective currents. The high velocity convergent convective current buckle geosyncline sediments and thus initiate the process of mountain building. This stage, thus, is called the stage of **Orogenesis** (Fig. 6.3).

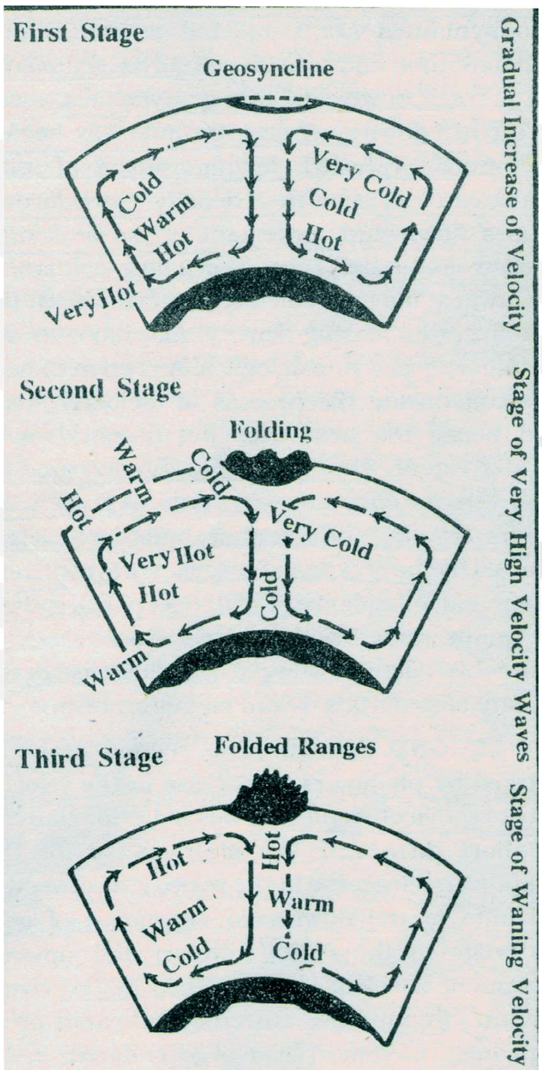

Fig. 6.3: Successive stage of Thermal Convective Currents under the Crust and Mountain Building.
(*Source*: Savindra Singh, Physical Geography)

The third stage is characterised by waning phase of thermal convective currents due to incoming hot materials in the falling column and upward movement of colder materials in the rising columns. The termination of the mechanism of convective current yields several results, e.g. (i) the materials of the falling columns start rising because of decrease in the pressure at the top of the falling column due to the end of deposition of materials. This mechanism causes further rise in the mountains. (ii) the metamorphosed rock (Eclogite) with increased density being heavier depressed downward and gets melted due to immense heat and thus it expands. This expansion in the volume of molten Eclogite causes further rise in the mountains. This stage is known as the stage of **Gliptogenesis**.

6.3.3 Plate Tectonic Theory and Mountain Building

Mountain building can be explained by the theory of Plate Tectonics. The theory tells that the result of plate convergence and its involvement in sedimentation, deformation, igneous activities, erosion and isostatic balance leads to formation of mountains. There are four different types of plate convergence (Fig 6.4):

1) Convergence of two oceanic plates,
2) Convergence of oceanic and continental plates,
3) Convergence of two continental plates and
4) Continent- Arc collision

Convergence of two Oceanic Plates and Mountain Building

Two oceanic plates may converge at the destructive plate boundary where one oceanic plate, which is heavier and denser compared to other oceanic plate, subducts in the trench beneath the lighter low density plate. The resultant compression leads to the formation of island festoons and Island-arcs. The best examples of this type are the Japanese Islands and Philippines Island. The ocean crust, along with its sediments, is thrust beneath and the rocks on the continental side of the trench are metamorphosed under high pressure condition. The molten magma rises up and forms a pile of volcanic rocks. The continuous pilling of volcanic rocks raises them above the ocean floor are finally exposes them above the sea level to form Island arcs.

Convergence of two Continental Plates and Mountain Building

When convergence and collision takes place, the continental plate having denser materials is subducted under the continental plate having relatively lighter materials. This brings about huge lateral compression in the sediment deposited in the geosyncline situated between two converging continental plates as well as the sediment laying on the margins of the continents. This compressional force is squeezed the fold and further deforms the sediments. Due to this, the folded mountains are formed.

The Alpine -Himalayan mountain system provides the best example in the formation of mountains by continent-continent collision. In the Mesozoic era there existed a long geosyncline, known as the Tethys Sea, between Lauratia in the north and Gondowana land in the south. After the Mesozoic era, Gondwanaland started breaking up and Deccan shield started moving northward at the approximate rate of 16 cm per year. The result of converge of these two land masses was that the Tethys sea became narrower and ultimately closed. The marine sediments and the crust of the Tethys seas suffered from compression

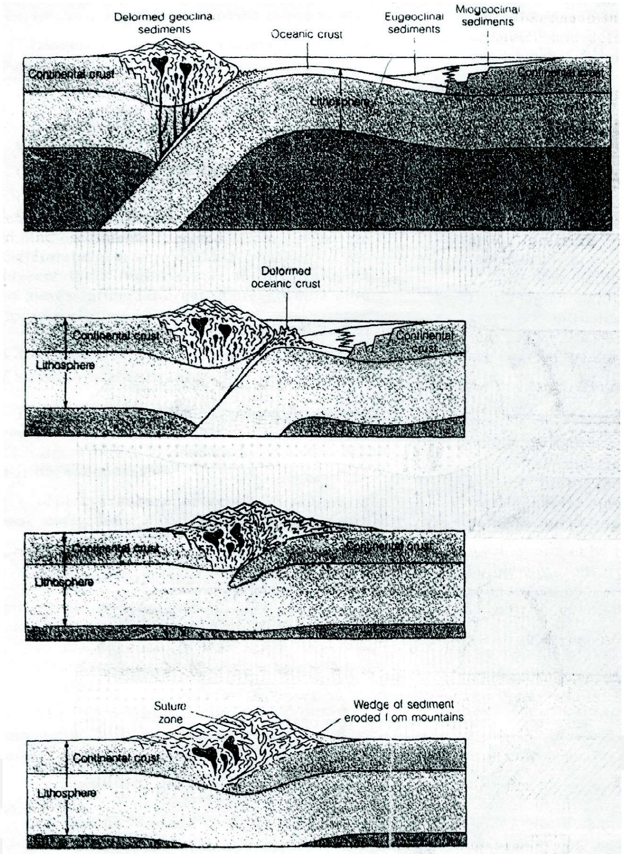

Fig. 6.4: Continent-Continent Collision and Complex Mountain Range.

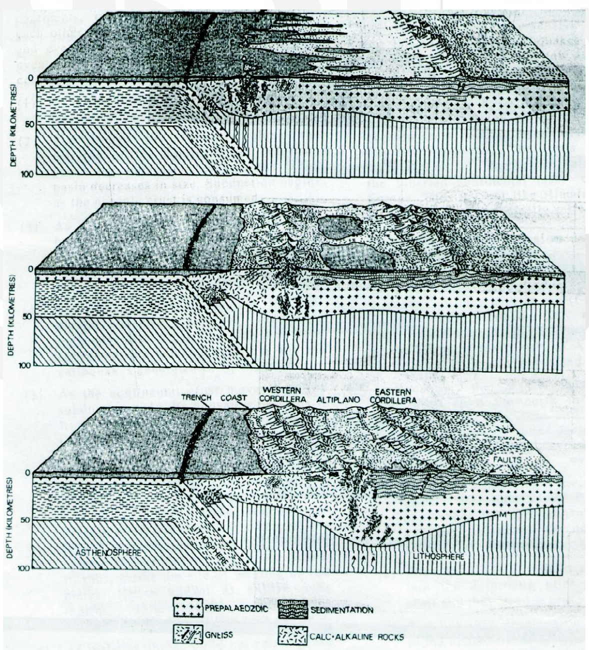

Fig. 6.5: Ocean-Continent and Mountain Building.

as a result of convergence of the two continental plates and these led to the folding of the rock strata and the Himalayas were born.

Convergence of Continental-Oceanic Plates and Mountain Building

Continent-ocean collision is the most prevalent of all the collisions as most of the mountains encircling the American coast of the Pacific Ocean formed by this type of collision. Convergence and collision generate intense compression force and the sediment deposited on the continental margin is squeezed and folded. The Rocky Mountains of western North America and the Andes of western South America are the best examples of mountain building by continent- ocean plate collision.

Continent - Arc collision

Continent-Arc collision occurs when a continental plate collides with an arc. This kind of situation exists in New Guinea where the mountains were formed about 20 million years ago due to convergence of the Islands arc lying to the north edge of Australia. As such, the northern part of the Island is an old Island arc while the southern part of the Island is a part of Australia.

SAQ 2

Spend 5 mins

What are major theories of mountain building?

6.4 PLATE TECTONIC THEORY

Let us now study the modern theory of **Plate Tectonics**. The concept of plate tectonics may be considered as a revival of the Continental Drift Theory. The Plate Tectonics theory tells that the Earth's outer layer consists of several rigid lithospheric plates consisting of continental (SIAL) as well as oceanic crust (SIMA) and the uppermost part of the mantle. Plates are defined as broad rigid segments of lithosphere consisting of continental and oceanic crust including the rigid upper part of upper mantle which floats on the underlying hot viscous asthenosphere. The rigid continental plates are 100-150 km thick where as the thickness of the oceanic crust ranges from 6 to 100 km. These plates are unable to deform except in response to very strong or prolonged forces. The plates are drifting or moving relative to each other and in the process huge pressure is generated along the margins or boundaries of the plates which are responsible for almost all the major geomorphic and tectonic features on the Earth's crust. The present shape and distribution of the continents and oceans can be described with seven major and over twenty minor lithospheric plates. The major plates are: African Plate, Pacific Plate, North American Plate, Antarctic Plate, Eurasian Plate, Indo-Australian Plate and South American Plate. The important other minor plates are: Cocos Plate, Filipino Plate, Juan de Fuca Plate, Caribbean Plate, Scotia Plate, Nazca Plate, Arabian Plate, etc. Refer to the figure 6.6, which shows the distribution of major and minor plates of the Earth.

You will understand that there are mainly three types of identified plate boundaries and margins: divergent or constructive plate boundaries, convergent or destructive plate boundaries, and transform or lateral plate boundaries. The divergent plate boundaries are mostly seen in the deep sea along the **mid oceanic ridges** and the process is known as "**sea floor spreading**". In this sea floor spreading process new oceanic crust is constructed.

i) **Divergent or constructive plate boundaries**: Two plates moving in opposite direction is called divergence. So, it is a zone of divergence characterized by continuous upwelling of mountain material resulting into the formation of new oceanic crust.

ii) **Convergent or destructive plate boundaries**: The boundary of two or more crustal blocks or plates is known as convergent plate boundary. Here the plates are dragged down through trenches along subduction zones into the mantle. The denser crustal plate goes down the lighter one and melts or gets destroyed into the mantle. The convergent plate boundaries can further be divided into three types:

a) Ocean - Ocean convergent plate boundary is marked by the formation of island arcs. Example of this type of plate boundary is seen along the Japan in the Pacific Ocean.

b) Ocean - Continent convergent plate boundary is seen all along the Pacific Ocean boundary. This is marked by the generation of volcanic arcs on the continents. Due to this volcanic activity, the Pacific Ocean boundary is named as 'Ring of Fire'.

c) Continent - Continent convergent plate boundary is seen between the Indian Plate (forming Indian sub-continent) and Eurasia Plate (forming Europe and Asia). The zone is marked by the development of huge mountain ranges, e.g., Himalaya.

iii) **Transform or lateral plate boundaries**: These are formed where two crustal plates slide past one another. In this case plates are neither created nor destroyed, but severe Earthquake is experienced.

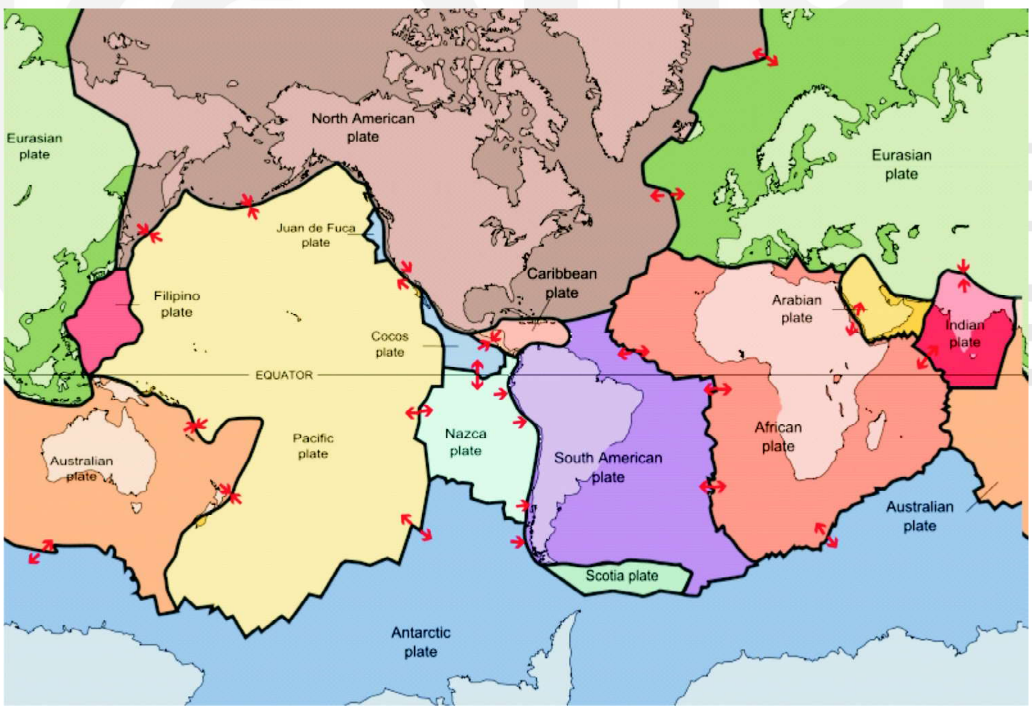

Fig. 6.6: Distribution of Plates of the Earth
(*Source*: http://www.indiana.edu/~g105lab/1425chap13.htm)

6.4.1 Mechanism of Plate Movement

There are various forces that act upon the plates to make them move. Three classes of possible mechanisms are namely convection current, slab pull, and ridge push. Now let us discuss about all three stages of mechanism in detail.

1. Convection Current

Convection current involves the whole mantle having large amount of radio activity which causes huge heat concentration in the mantle. As the current ascend from below, they diverge and spread laterally along the lower part of the plates. Convection current causes the lithosphere to split and the plate may move laterally along the direction of the convection current. The high heat flow along the mid-oceanic ridges provides evidence to this process. Convectional current is only found in Asthenosphere where the size of convection cells are said to be smaller. The other type of mantle convection involves jet like plumes are called mantle plume of low density materials from the core mantle boundary. As the plume reaches the lithosphere, it spreads out laterally doming surfacial zones of the Earth and moving them along in the direction of radial flow. Mantle plumes are thought to be responsible for the initial breaking of the Pangaea. Refer to Fig. 6.7, which illustrates the mechanism responsible for various plate movements.

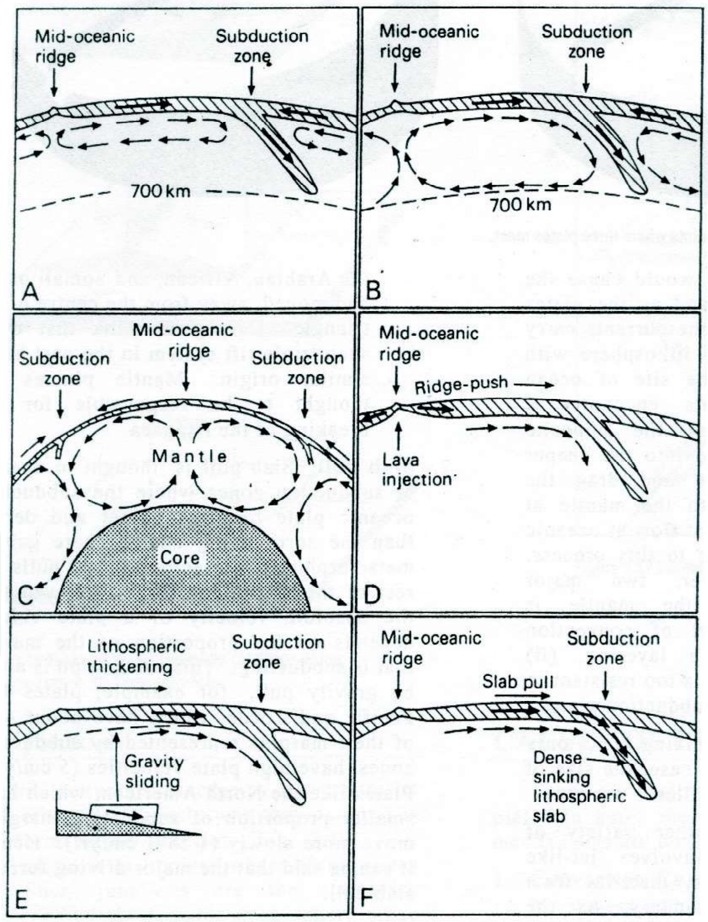

Fig 6.7: Mechanism of Plate Movements.

2. Slab Pull

In the convergent boundary, the denser plate slides down the lighter plate causing subduction. The subducted portion of the plate causes slab pull. This force accounts for most of the overall forces acting on plate tectonics. Besides this, the 'ridge push' force adds about 5 to 10 per cent of the overall force for plate movement.

3. Ridge Push

The magma coming out of the mid-oceanic ridges causes the 'Ridge Push'. Before the nineties, this force was considered to be the leading contributor for moving the plates around the Earth. There have been two main models of ridge push proposed by Earth scientists, namely gravity wedging and gravity sliding. We know that mid-oceanic ridges rise thousands of metres above the ocean floor. New sea floor or oceanic plate is created along the mid-oceanic ridges, it is very hot and thin as well as much higher in elevation than the abyssal plains and trenches. The newly created plate will effectively slide down the slope and try to move towards the subduction zone causing sea floor spreading. The oceanic plate gets thicker and denser as it progresses away from the spreading centre, the ridge push force increases towards the subduction zone (Fig 6.7).

With the advancement of the Plate Tectonic Theory, the Continental Drift Theory has got enormous improvement. Continental Drift Theory says that the continents are in motion while according to plate tectonics not only the continents but the sea floor are also spreading. The generation of new oceanic crust at mid-oceanic ridges seems to be compensated by the consumption of old oceanic crust along subduction zones. So, the crustal block is to move outward from the mid-oceanic ridges.

According to Plate Tectonic Theory, it is not SIAL that is in motion, floating over SIMA but the lithospheric block (Plate) over the asthenosphere. The Continental Drift Theory talked about the gravitational and tidal forces as the chief mechanism for the movement of the continents which were largely inadequate while Plate Tectonic Theory gave five different mechanisms for the movement of the continents. The theory explains almost every aspects on the geo-tectonic features of the Earth as well as the continental drift hypothesis. Therefore, we can infer that the Plate Tectonic Theory is the latest and modern concept of Continental Drift Theory.

SAQ 3

What are three classes of mechanism of plate movement?

Spend 5 mins

6.4.2 Plate Tectonic Theory: Mountain Building, Volcanism, Earthquake and Tsunamis

The theory of plate tectonics explains why different types of Earth movements, epirogenic and orogenic takes place which involves the processes of mountain building, Earthquake, volcanism and tsunamis, etc.

Plate Tectonics and Mountain Building

All the great mountain ranges of the world can be explained with the plate tectonic theory. Two plates result huge compression along their convergent plate boundary, which finally leads to formation of folded mountains. The Rockies, the Andes, the Alpine Himalayan belt, etc. are active folded mountains formed in Tertiary Period. Other mountains, namely Applachians in USA and Urals in Russia are zones where plate tectonics was active earlier and these mountains represent the zone of welding between two different plates.

Plate Tectonics and Volcanism

The worldwide distribution of volcanoes and their occurrence at specific place is related to different types of plate boundaries and their movements. Volcanic activity will take place when two plates converge as evident with the Pacific and the Eurasian plate; and the Nazca and the South American plates. The subduction of the plate is also resulted from the activity of melting and volcanism. It is proved with the portion of the molten Pacific and Nazca is thrown by the volcanoes of Mayon and Luzon in Philippines; Misti in Peru; Chimboroza and Cotopaxi in Andes, etc. whereas subducted African plate releases fire in Iran, Caucasus and Italy. Divergence leads to quite type of basaltic eruption which is seen along all the mid-oceanic ridges. There are two types of associations of volcanic activity with plate tectonics: plate margin volcanism and intra-plate volcanism.

The 2004 Indian Ocean Earthquake and resultant Tsunami was due to an under-sea mega-thrust Earthquake that occurred at 00:58:53 UTC on Sunday, 26 December 2004, with an epicentre off the west coast of Sumatra, Indonesia. The Tsunami killed over 230,000 people in fourteen countries.

There are two types of plate boundaries where volcanic activities take place. i.e. constructive or divergent plate boundary and destructive margin or convergent plate boundary. Volcanism in central parts of plates beyond constructive and destructive margins is not common, but it can be explained as the surface expression of local thermal variation or hot spots in the mantle.

Plate Tectonics and Earthquake

Nature and movements of plate boundaries are responsible for the major Earthquakes. Frequent Earthquakes take place at the diverging as well as converging plate boundaries. Mid-oceanic ridges are common manifestation of the divergent plate margins. The oceanic ridges are offsets by many transform faults. Movement along this transform faults generate Earthquakes which have a shallow foci. Convergent plate boundaries are characterized by subduction of one plate under another and the zone is characterized by most widespread and intense Earthquake. Tensional Earthquake occurs on the oceanic side of the trench, where normal faulting occurs form tensional stresses generated by the initial bending of the plates. At intermediate depths, Earthquakes are caused by extension or compression, depending on the pacific characteristics of seduction zone.

Plate Tectonics and Tsunami

The movements of under-sea convergence or destructive plate margins are instigated to the creation of tsunamis. Tsunami occurs when there is rapid vertical movement in the oceanic crust that results in a displacement (rise or drop) in the overlying water. Due to this displacement in the ocean floor that can set off a tsunami. You may know that Earthquake is the result of plate tectonics. Tsunamis are the result of an Earthquake event which displaces sea water. Instead, most tsunamis tend to act like tide, with a rise in sea level that surges onto the coast with very strong currents. However, unlike a rising tide, there can be a rapid retreat of sea level prior to the huge surge i.e. tsunami (USGS, 2005). A tsunami is a series of ocean waves generated by sudden displacements in the sea floor, landslides, or volcanic activity. In the deep ocean, the tsunami wave may only be a few inches high. The tsunami wave may come gently ashore or may increase in height to become a fast moving wall of turbulent water several meters high (http://www.tsunami.noaa.gov).

SAQ 4

Spend 5 mins

Try to find relationship between volcanism and plate boundary?

6.4.3 Evidences of Continental Drift and Underlying Plate Tectonics

Evidences for continental drift and the underlying plate tectonics are as follows:

1. Most of the continents/shapes look like they were separated from a single great continent (Pangaea). They exist as pieces of a jig-saw puzzle. For example, have a look at the Figure 6.8, the shape of the east coast of North and South America matches with the shape of the west coast of Africa and Europe.

2. Geologically, both the coasts of Atlantic are also identical. The geological structure of the eastern coast of South America and western coast of Africa are more or less similar.

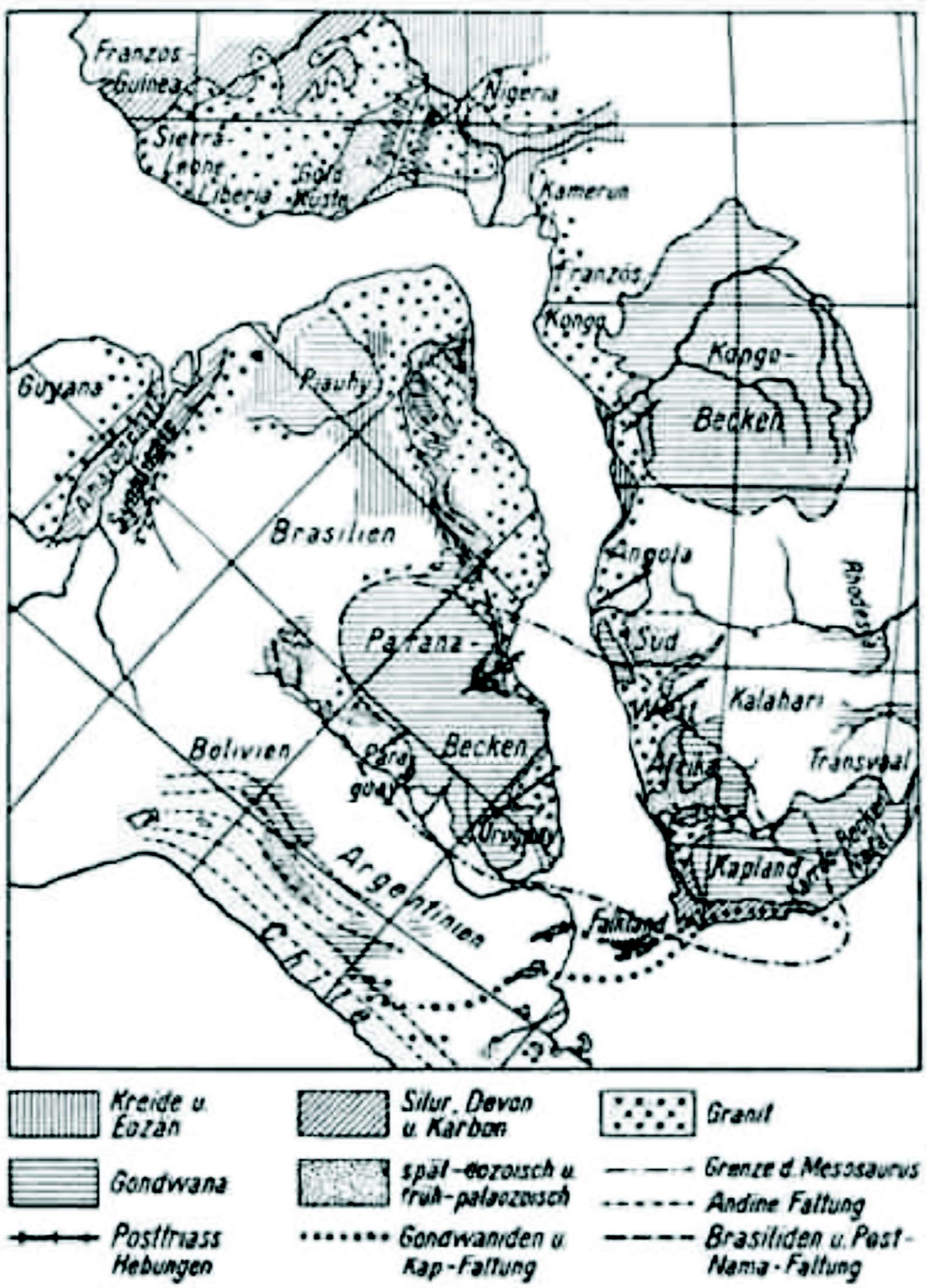

Fig. 6.8: Match of geology between eastern South America and western Africa
(*Source*: http://www.scientus.org/Wegener-Continental-Drift.html)

3. Many fossil comparisons along the edges of continents look like they fit together, which suggests species' similarities of that would only make sense, if the two continents were joined together at some point in the past.
4. There is a large amount of seismic, volcanic, and geothermal activities along the conjectured plate boundaries. The concentration is striking, and indeed this plot serves to define the plate boundaries extremely well.
5. There are ridges, such as the Mid-Atlantic Ridge where plates are separating that are produced by upwelling lava between the plates. Likewise, there are mountain ranges being formed where plates are pushing against each other (e.g., the Himalaya, which is still growing).
6. The upwelling of lava or magma in the mid-oceanic ridge forms a new crustal plate. So, it is certain that they are young in geological age. This has been scientifically proven.
7. Evidences for the disintegration of Pangaea in several crustal plates and their movement as continents are now extensive. Similar plant and animal fossils are found around different continental shores, suggesting that they are certainly joined together. The fossils of Mesosaurus, a freshwater reptile, found both in Brazil and South Africa are one of the important examples. Another is the discovery of fossils of the land reptile known as Lystrosaurus from rocks of the same age from locations in South America, Africa, and Antarctica (Fig. 6.9). There are also living evidences, may be the same animals being found on two continents. Some Earthworm families are also found in South America and Africa.

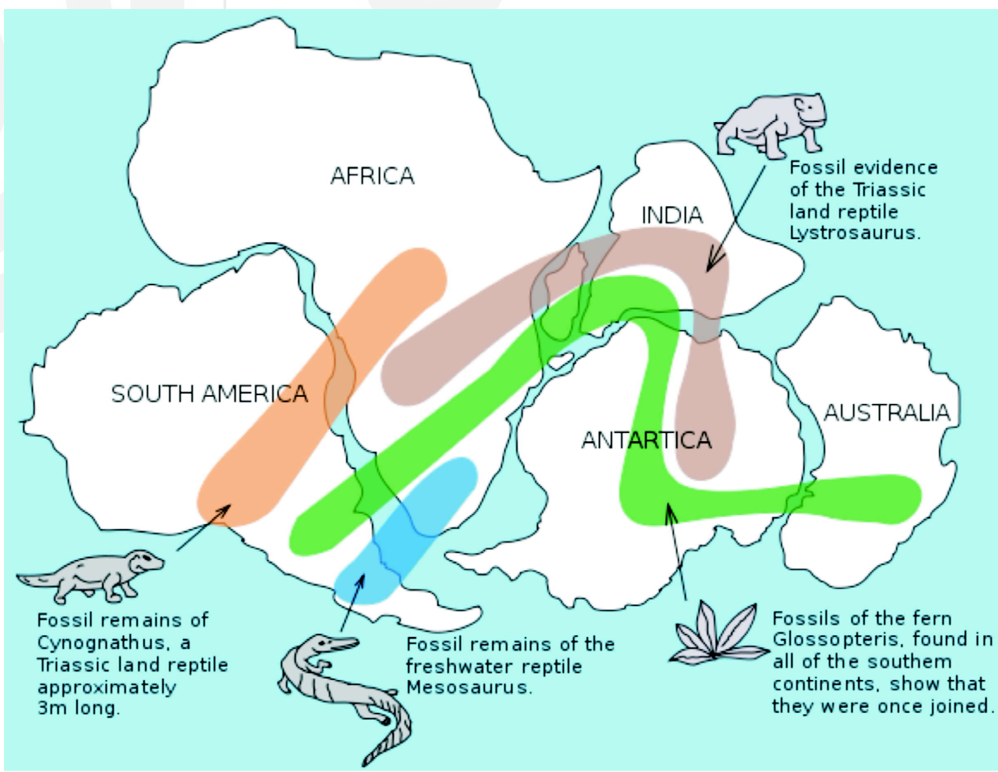

Fig. 6.9: Fossil Pattern Distribution of Fossil Pattern in Different Continents
Source: USGS (http://en.wikipedia.org).

6. 5 SUMMARY

Thus, in this unit, you have studied and learned the following key points and theories as follows:

- Wegener proposed the continental drift theory which suggests that the continental masses get displaced in horizontal manner on a global scale. He named Pangaea for the super-continent Panthalassa for the surrounded super-ocean. The Angaraland and Gondwanaland separated by a long narrow shallow sea which he called Tethys.
- There are two types of crusts i) continental crust (SIAL) and ii) oceanic crust (SIMA). The deep sea floor formed as the upper surface of SIMA. It was assumed that the super continent Pangaea got broken and started drifting over SIMA.
- According to the Wegener, the continents are moving by the action of tidal force of the sun and the moon. When the moon is nearest to the Earth then the maximum gravitational force occur between the sun and the moon. It results for moving of the SIAL over the interior of the Earth.This theory lacks the strength for explaining the potential force responsible for the movement of the continents.
- Plate tectonic theory explains that the crust is divided into various lithospheric plates which move in different directions on the Earth. There are three types of plate boundaries namely divergent (plates move in opposite direction), convergent (two plates come together) and transform (slide past one another). The mechanism involved in the plate tectonic theory is thought to be convection current, slab pull, and ridge push.
- You have learnt about the mountain building theories with detailed explanation of features of Geosyncline, convectional currents and plate movements. You have also learnt about the views of different geographers on mountain building like Kober's Geosyncline Theory and Convection Current Theory of Arthur Holms.

You will further study in detail about endogenetic and exogenetic forces. Endogenetic forces originated from beneath of the Earth and are responsible for creation of various topographical features. Whereas, exogenetic processes are responsible for landscape sculpture.

6.6 TERMINAL QUESTIONS

1. Explain elaborately theory of continental drift as defined by Wegner.
2. Briefly present the geosynclinal orogen Theory of Kober.
3. Explain the mountain building theory of Holmes.
4. Discuss the Plate Tectonic Theory and mountain building, earthquakes, volcanism and tsunamis.

6. 7 ANSWERS

Self-Assessment Questions

1. Wegner assumed that there was only one super-continent before the present form and shape of the continents that he called Pangaea whereas the super-continent Pangaea was surrounded by a super-ocean called Panthalassa.
2. The major theories of mountain building are:

   Mountain Building Theory based on Continental Drift Theory of Wegener;

Geosynclinal Orogen Theory of Kober; Convection Current Theory of Holmes; and Mountain Building according to Plate Tectonics Theory.

3. Three classes of mechanism of plate movements are:
   i) Convection Current
   ii) Slab Pull
   iii) Ridge Push
4. Plate boundary and volcanism are closely associated as the majority of volcanoes are situated mainly at plate boundaries

Terminal Questions

1. Refer to Sec. 6.2.
2. Kober attempted to explain the origin of the mountains on the basis of his Geosynclinal Theory and elaborated various aspects of mountain building e.g. formation of mountains, their geological history and evolution and development. Further refer to Sub-sec. 6.3.1.
3. Refer to Sec. 6.3.2
4. Refer to Sec. 6.4

6. 8 REFERENCES/FURTHER READING

1. Butzer, K. W. (1976). "Geomorphology from the Earth" New York: *Harper & Row Publishers*.
2. Carlson, R.L., Hilde T.W.C., and Uyeda, S. (1983). "The driving mechanism of plate tectonics: Relation to age of the lithosphere at trench". *Geophys. Res. Lett*., 10: 297-300., GeoRL.10.297C. doi:10.1029/GL010i004p00297.
3. Clinton, P., Conrad, Susan Bilek, Carolina, (2004). "Great Earthquakes and slab pull: interaction between seismic coupling and plate-slab coupling". *Earth and Planetary Science Letters*, 218:109-122.
4. Lallemand, S., Heuret A., and Boutelier D. (2005). "On the relationships between slab dip, back-arc stress, upper plate absolute motion, and crustal nature in subduction zones". *Geochemistry Geophysics Geosystems*, 6.
5. Lake, P. (1966). *Physical Geography*. London: Macmillan and Co Ltd.
6. Majid, H. (2007). *Fundamentals of Physical Geography*. New Delhi: Rawat Publication.
7. Monkhouse, F.J. (1984). *Principles of Physical Geography*. London: Hodder and Stoughton.
8. Mussett A.E., and Khan M.A. (2000). Looking into the Earth; An Introduction to Geological Geophysics. *Cambridge University Press*.
9. Singh, S. (2012). Physical Geography. Allahabad: Prayag Pustak Bhavan.
10. Sparks, B.W. (1971). *Rocks and Relief*. London: Longmans.
11. Strahler, A. H., and Strahler, A.N. (1992). *Modern Physical Geography*. John Wiley and Sons, Pvt. Ltd.
12. USGS: Historical perspective on plate tectonics, last updated, 19 September 2011.