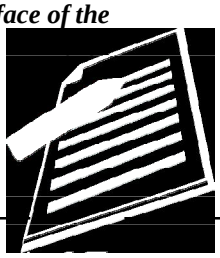


3

DYNAMIC SURFACE OF THE EARTH

In the previous lesson, we have learnt that the interior of the earth is very hot. Earthquakes and volcanoes are concentrated along a few narrow belts. The type and density of rocks of the crust are variable. The surface features are dynamic in character. This dynamism is due to two forces — endogenetic and exogenetic. Endogenetic forces are those which are caused from below the surface. Due to this, an area may get elevated or gets submerged. These forces try to make the surface irregular while exogenetic froces are those which operate from above the surface. They try to eliminate the irregularities of the surface through the process of denudation about which we will be reading in lesson. In this lesson we will be studying about the endogenetic forces.

OBJECTIVES

After studying this lesson, you will be able to :

- define isostasy;
- describe the variation in relief features on the earth's surface;
- explain the isostatic adjustment by various experiments;
- explain the views of Airy and Pratt and distinguish between the ideas of both;
- explain the concept of continental drift;
- enumerate the evidences of continental drift;
- explain the concept of plate tectonics;
- identify and locate different plates on the world map;

Notes

- explain the mechanism of plate movement;
- identify various plate boundaries and associated features;
- explain the distribution of land and water on the globe and
- associate earthquakes and volcanoes with plate boundaries.

3.1 CONCEPT OF ISOSTASY

The term "Isostasy" is derived from "Isostasios", a word of Greek language meaning the state of being in balance. You already know and must have seen that the mountain have many peaks and relatively great heights. Similarly plateau and plain have flat surfaces. They have moderate and lower height, respectively. On the contrary oceanic beds and trenches have greater depths. There is a great difference in height among these features. You also know that the earth is rotating while keeping perfect balance among its various features. Thus, our earth is considered to be in isostatic equilibrium.

Example:- Suppose you are holding one stick each in your both hands vertically with varying heights, say 5' and 15' and you are moving in a particular direction. Do you have any difficulty in maintaining a balance in congruence with your body as well as two sticks together? Definitely, smaller stick will be easy to make a balance than the longer one. It is just because of the centre of gravity. The centre of gravity with smaller stick will be nearer to your holding hand in comparasion to the longer stick. In the same way smaller surface features like plains are more stable than the tall mountains.

A. Isosatic Balance: views of Airy

Airy, a geologist, considered the density of different columns (plains, plateaus, mountains, etc.) to be the same. Hence, he proposed the idea of **'uniform density with varying thickness'**. We know that the upper crust of the earth is made up of lighter material. In this layer, silica and aluminium are found in abundance, hence it is known as 'Sial'. It is less denser than the lower one. Airy assumed that the Sialic crust is floating over the Sima (silica and magnesium, lower denser layer). Crustal layer is uniform in terms of density with varying length of columns. Therefore, those columns are projecting down into the asthenosphere depending upon the proportions of the column. It is due to this reason that the root has developed or the sima has been displaced from below.

To prove this concept, Airy took an example of wooden blocks of various sizes and immersed them into water (Figure 3.1). All blocks are of same density. They get immersed differently in proportion to their sizes. In the same way higher features with great height seen on the surface of the earth have deeper roots whereas short in length has shorter roots beneath. It is the concept of root which is sustaining the higher elevation. He is of the openion

that the landmasses are floating like a boat in the substratum (magmatic asthenosphere). According to this concept, the root beneath the Mt. Everest would be 8848X8 = 70784 metre below the sea level. On this bases Airy has been criticized that the root is not possible to be at such a great depth. Because the root material will melt due to higher temperature found at that depth.

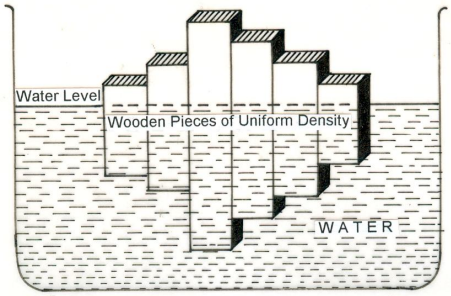


Fig. 3.1(a) :Illustration of the concept of Airy on isostasy

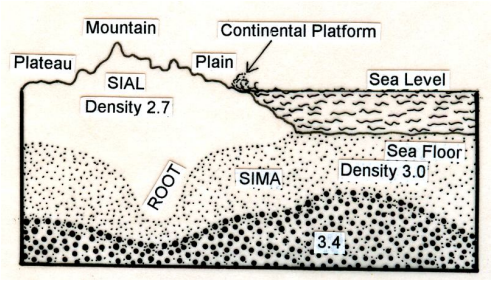


Fig. 3.1(b) : Condition of Isostary (based on A. Holmes and D.L. Holmes)

B. Isostatic Balance: views of Pratt

Pratt considered landblocks of various heights to be different in terms of their density. The taller landmass has lesser density and smaller height features to be denser. In other words, there is an inverse relationship between height and density. If there is a higher column, density will be lesser and if there is a shorter column, density will be higher. Assuming this to be true, he accepted that all blocks of different height get compensated at a certain depth into the substratum. In this way a line is being demarcated above which there is equal pressure with varying heights. Thus, he denounced the root concept of Airy and accepted the 'concept of a level of compensation'. For proving his concept he took a number of metal bars of varying density with same weight and put them into mercury (Figure 3.2). In this way they form a line by all those bars, which he regarded to be the level of compensation.

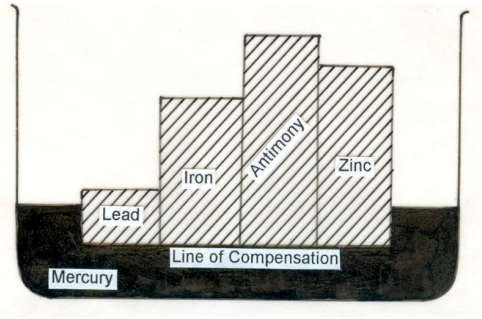


Fig. 3.2a Experiment of the concept of Pratt on Isostasy.

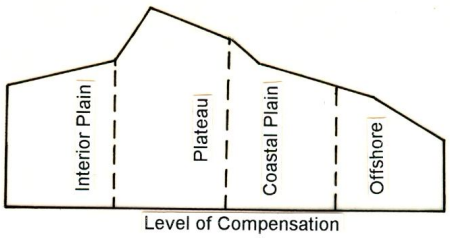


Fig. 3.2b. Illustration of Lithospheric block being compensated

Differences between the views of Airy and Pratt

The differences between the views of Airy and Pratt can more clearly be presented in a tabular form:-

	Views of Airy	Views of Pratt
1.	Uniform density of crustal material.	Varying density of crustal material.
2.	Varying depth upto which root penetrates.	Uniform depth upto which crustal material reaches.
3.	Deeper root below the mountain and smaller beneath plain. (Figure 3.1)	No root formation, but a level of Compensation. (Figure 3.2)

C. Global Isostatic Adjustment

It is quite apparent that there is no complete isostatic balance over the globe. The earth is unstable. Endogenetic forces often disturb the crustal balance. The regular earthquakes and volcanic eruptions along a particular belt do not signify any balance but a sort of adjustment is needed continuously. Endogenetic forces and their tectonic effects are the causes of imbalance on the surface but nature always tries to make an isostatic adjustment with itself.

Exogenetic forces are trying to eliminate the differences on the surface of the earth and in this process they are peeling off, transporting down to far flung places, and depositing them. In this process, isostatic balance is maintained by the underneath flowage of material by subsidence at the place of deposition and upliftment at the peeling of place in their proportion to the denudation (Figure 3.3).

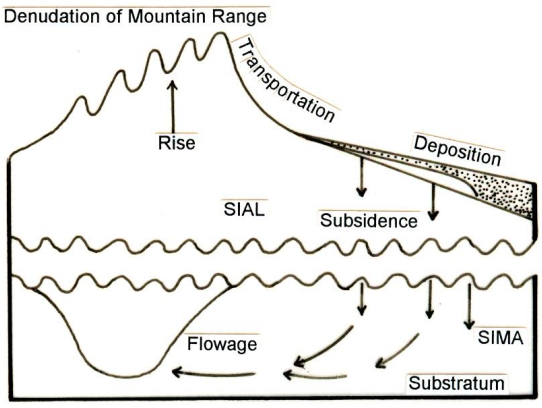
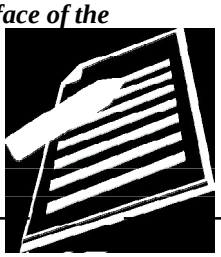


Fig. 3.3 : Mechanism of isostatic adjustment



INTEXT QUESTIONS 3.1

Fill in the blanks:-

1. Isostasy means _____.

2. Airy considered the density of different columns to be _____.

3. Pratt considered landblocks of various height to be different in terms of their _____.

4. According to Airy there is _____ root below the mountain and _____ beneath plain.

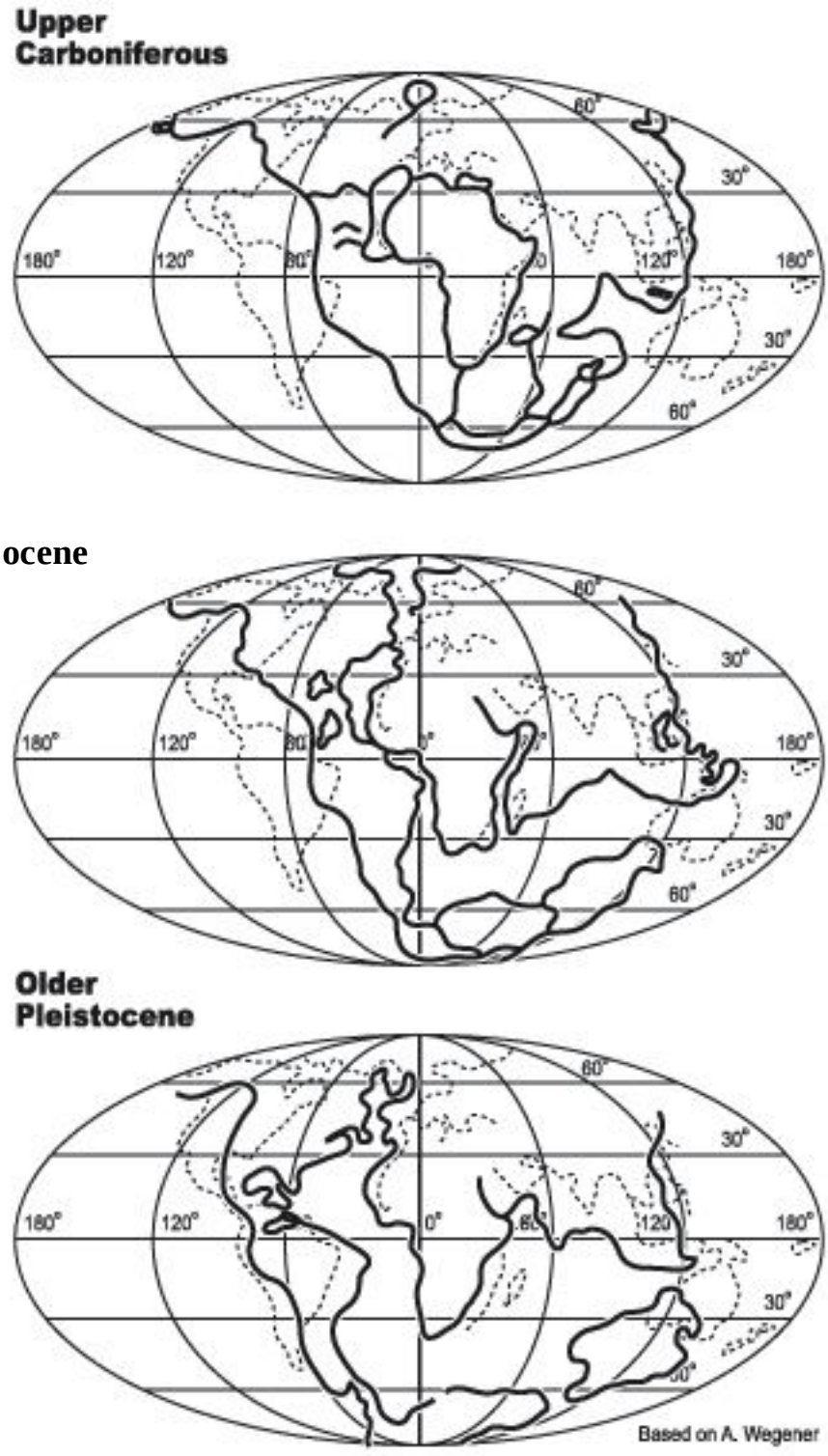
5. Pratt postulated the concept of _____ root formation but a _____ of compensation.

6. Endogenetic forces often _____ the crustal balance.

7. Regular earthquakes and volcanic eruptions along a particular belt does not signify _____ but a sort of continuous_____ _____.

3.2 CONTINENTAL DRIFT

According to Alfred Wegener, the entire landmass of the globe was together about 280 million years ago. It was termed as Pangea, a super continent. The huge water body surrounding the Pangea was known as Panthalasa. From 280 to 150 million years ago, Pangea was broken latitudinally into northern and southern parts known as Laurasia (Angaraland) and Gondwanaland, respectively. Both of them drifted away and in between a shallow sea emerged by filling up the water from Panthalasa. It was known as Tethys sea. Later on Laurasia and Gondwanaland rifted and finally drifted to form the present day distribution of land and water on the earth (Figure 3.4).



Pangea

Fig. 3.4 Pangea

Evidences of Drift

Wegener gave a number of evidences in support of the unification of land-mass in geologic past. They are such which cannot be negated even today.

a. Jig-saw-fit:- Eastern coast of South America is identical to Western coast of Africa which fits to a certain depth in the ocean. To a certain extent coastal areas and continental shelves have been modified by oceanic waves through denudation (Figure 3.5)

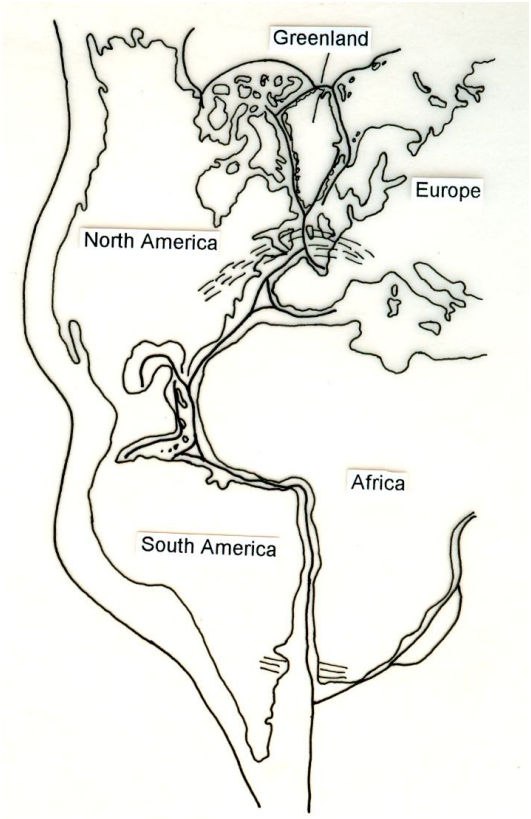


Fig. 3.5 Wegners map of continental drift-Fitting of the continents bording the Atlantic Ocean

b. Geological similarities:- The mountain systems of Southern Atalantic coast in South America and Africa show the similarity of the extension in both continents.

c. Coal and Vegetation evidences:- The distribution of coal and vegetation over South America, Africa, India and Australia proves that they were together in geological past. The classical glacial deposits during carboniferous period over these landmasses resemble each other which tells the story of togetherness. Today they lie in different climatic zones.

Notes

Apart from above evidences put forward by Wegener, other evidences (known later) are also there which support the idea of continental drift.

d. **Evidences from paleomagnetism :–** Paleomagnetism is the study of the direction of pole through ages. Magnetically susceptible minerals like haematite, pyrhotite magnetite etc. get aligned with the magnetic pole of the earth and recorded in the solidification of magma during that time. It is found that periodic changes have occurred and poles have wandered which is not possible for the entire earth. Hence, it is the twist and turn of the landblock and not for the entire earth which has again explained that the continents have shifted their positions.

e. **Sea floor spreading :–** Along the mid Atlantic ridge, magma comes out at the sea bed and gets solidified. A new zone is formed and this process is continuing since millions of years. It is leading for diversion of continental block, and hence the size of the Atlantic ocean is increasing which is termed as sea floor spreading. It is the classical example of the shifting of continents. The explanation of continental drift through sea floor spreading and the study of paleomagnetism is commonly known as Plate Tectonics. (Figure 3.6)

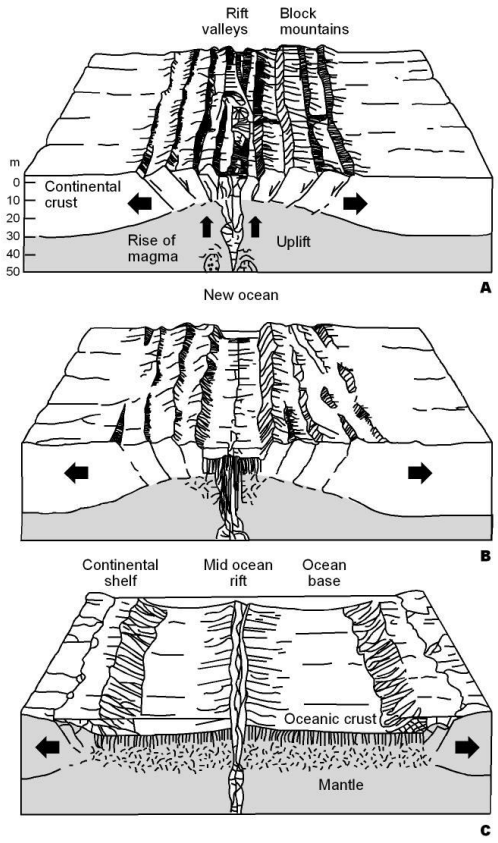
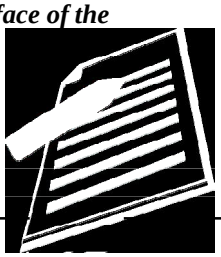


Fig. 3.6 Stages in continental rapture and the opening-up of a new basin



INTEXT QUESTIONS 3.2

1. Fill in the blanks:-
   a. Alfred Wegener termed the supercontinent as _____.
   b. Premordial ocean was known as _____.
   c. Pangaea was broken into two _____ in the north and _____ in the south.
   d. North and South America drifted towards _____.
   e. Tethys sea emerged between _____ and _____ by filling up of the water of _____.
2. Name three evidences of continental drift put forwarded by Wegener -
   a. _____
   b. _____
   c. _____
3. Name two evidences of continental drift, but not mentioned by Wegener
   a. _____
   b. _____

3.3 PLATE TECTONICS

The uppermost outer solid and rigid layer of the earth is called crust. Its thickness varies considerably. It is as little as 5 km thick beneath the oceans at some places but under some mountain ranges it extends upto a depth of 70 km. Below the crust denser rocks are found, known as mantle crust. This upper part of mantle upto an average depth of 100 km from the surface is solid. This solid mantle plus upper crust form a comparatively rigid block termed as lithosphere. Mantle is partially molten between 100 to 250 km depth. This zone is said to be asthenosphere, also known as Mohr discontinuity, a simplification of Mohorovicic, the name of the seismologist who discovered it. All these things you have already read in the previous lesson.

The lithosphere is broken into several blocks. These blocks are known as plates, which are moving over asthenosphere. There are seven major plates. (Figure 3.7)

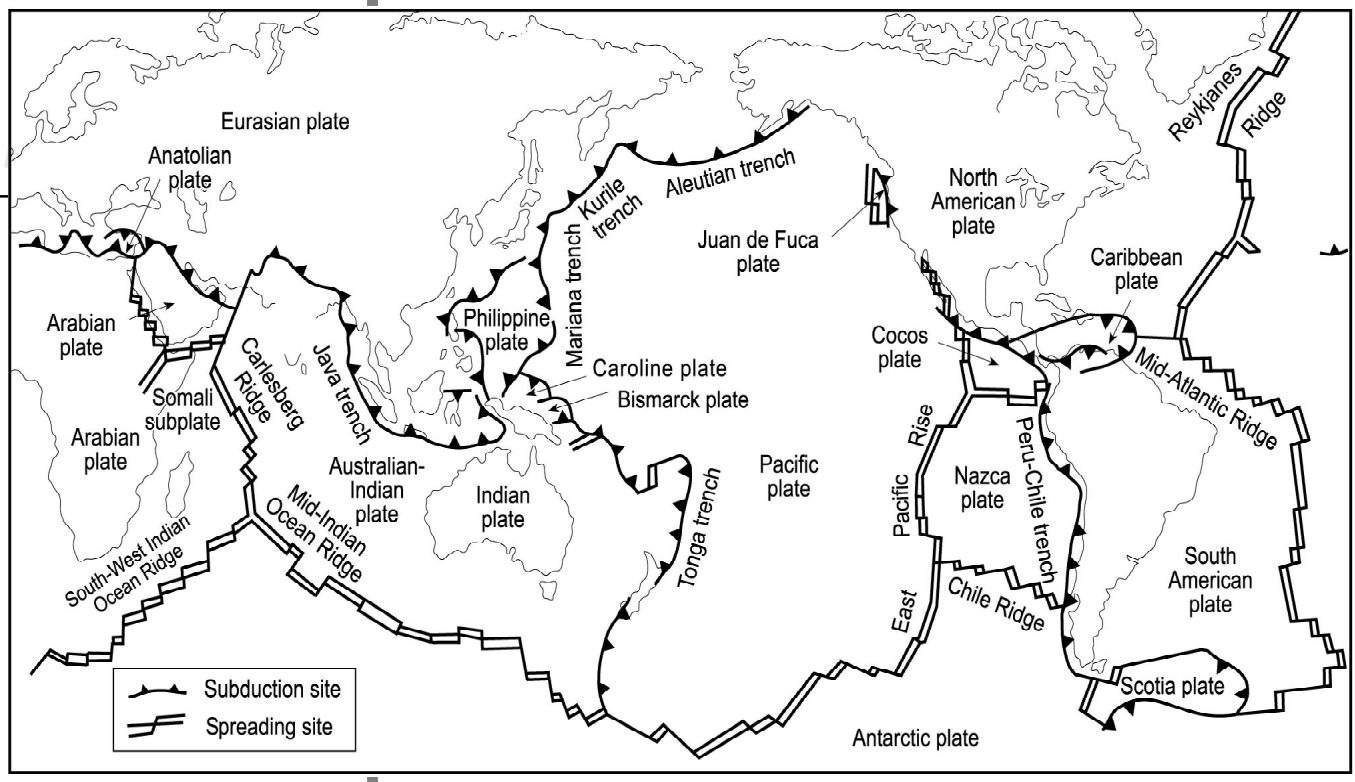


Fig. 3.7 Tectonic plates, spreading sites and subduction sites

1. Eurasian plate,
2. African plate,
3. Indo-Australian plate,
4. Pacific plate,
5. North American plate,
6. South American plate and
7. Antarctic plate.

Apart from these major plates minor plates are about 20 in number, a few important among them are :-

Arabian plate,
Philippine plate,
Cocos plate,
Nazca plate,
Caribbean plate,
Scotia plate, etc.

The major and minor plates constitute the whole surface of the earth.

Plate tectonics is a method or way of understanding the land-water distribution of the earth. Tectonics is a sort of movement of plates. Through the movement,

internal forces are explained which are responsible for the distribution of earth's crust, formation of mountain chains and distribtion of earthquakes and volcanism.

Mechanism of plate Movement

Arthur Holmes, a British geologist, in 1928 – 1929, proposed that convectional currents exist underneath the lithosphere. The centre of convectional current is not exactly known, but it is believed that it has an average depth of about 100 to 250 km below the surface. The inception of the current is initiated by heat generation due to radio-active minerals. Due to integration and disintegration of atomic minerals heat is produced and hence the melting of surrounding rocks. In this way currents start operating. These currents are classified into rising and falling with divergence and convergence activities, respectively.

With rising convectional current, transport of hot and viscous matter takes place upwardly. After reaching about 100 kms below the surface that current gets diverged leading to split into the upper part. The molten material penetrates into the split and thus creation of new surface and the draft of the mammoth plate in opposition direction. It happens below the mid-oceanic ridge. On the other hand two sets of diverging thermal convectional currents brings two plates together and it is called convergent boundary where subduction takes place. Plates of lithosphere are constantly in motion because of convectional currents. Their relative motion depends upon the force operating over them.

Plate boundaries are very important and significant structural features. Boundaries are very distinct and easy to identify. They are associated with newly formed mountain systems, oceanic ridges and trenches. Plates are moving continuously and have relative direction of movement. Based on the direction of movement three types of plate boundaries can, easily, be identified. (Figure 3.8)

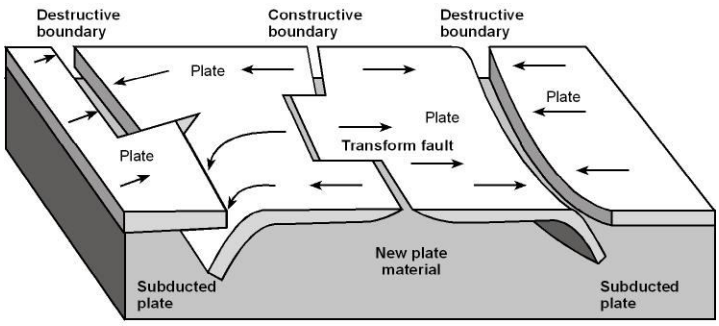


Fig. 3.8 Types of plate boundaries

(i) Divergent boundary
(ii) Convergent boundary
(iii) Fracture or transform boundary fault

The convectional current are caused due to radio-activity. These currents get diverted on approaching the crust layer. Diverging currents produce tension at the contact-zone of crust leading to fracture. Maganatic material penetrates into the fractroges and gets solidified. This continuous process pushes the blocks in opposite direction and creates a new zone, known as “zone of construction”.

At convergent boundary, two adjacent plates come further and further closer to each other and collide. When both sides are of continental nature, a mountain formation is evident. When one of the two is continental and the other maritime again mountain comes into being along the boundary. In this case, continental plate overnides the maritime. When both plates are of maritime, both of them break, subduct and penetrate below and, hence, trenches are formed. Along this boundary earthquakes and volcanic activities are prominent. In all these three situations, surface area is reduced, therefore, this is also known as “zone of destruction”.

Transform fault is the one when two adjacent plates slide past each other. Direction of movement may be along or against but they move parallel to each other. Therefore, neither there is any construction of fresh area nor it has any destruction. Hence, it is known as “zone of preservation”.

Plates are not a permanent features but they vary in size and shape. Plates can split or get welded with adjoining plate. Almost all tectonic activities occur along the plate boundaries.

Prior to the advent of plate tectonic theory, the continental drift theory which was proposed by Wegener was criticized, particularly about the forces. In fact, it was outrightly rejected inspite of apparent evidences. But further reserches about the material of sea floor and paleomagnetism supported the theory but the proposition of plate tectornic theory in 1960’s has solved the problem of the mechanism of movement.

Plate Tectonics Vs Earthquakes and Volcanoes

The distribution of earthquakes and volcanoes over the globe (Figure 3.9) clearly reveals that they are strongly associated with the boundaries of plates. Plate boundaries are the zones where every sort of tectonic activity does take place. The release of energy created because of the movement of plates is manifested in this zone in the form of earthquakes and volcanic eruption.

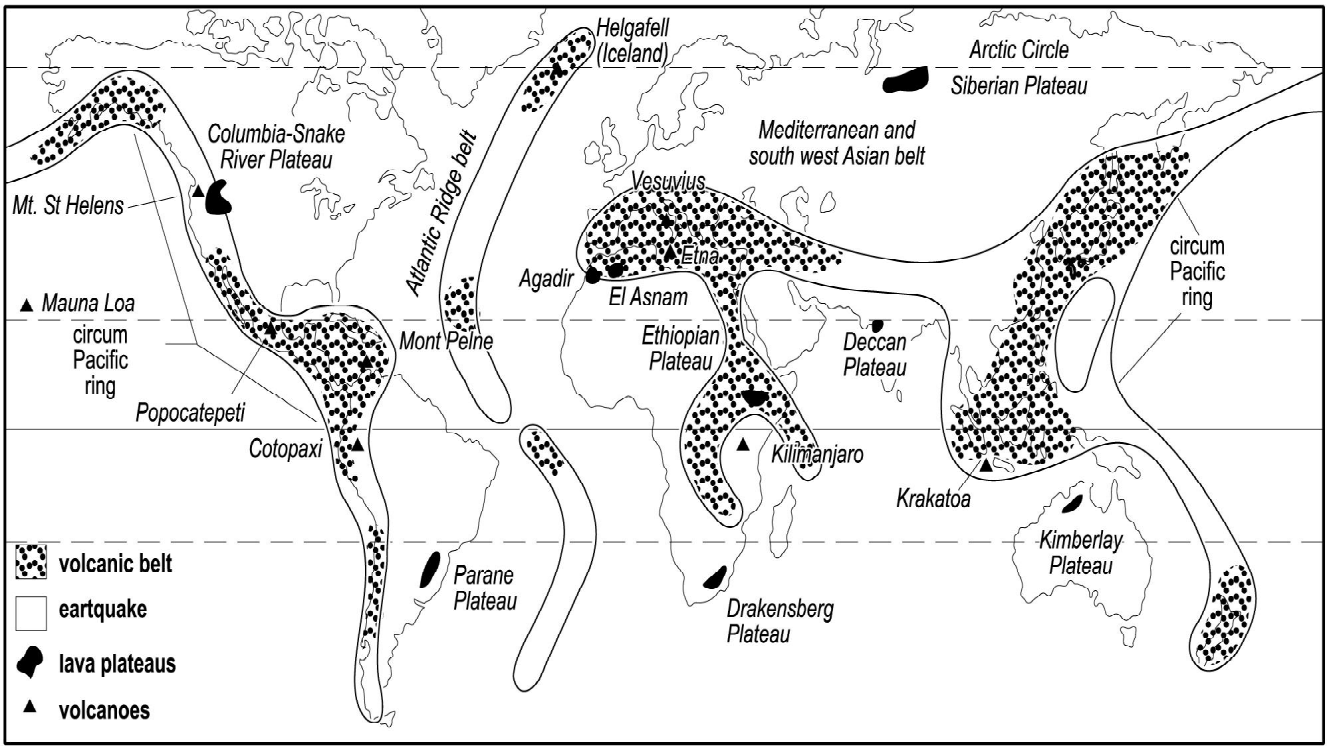


Fig. 3.9 The Major Earthquake and volcanic belts of the world

INTEXT QUESTIONS 3.3

1. Fill in the blanks:-
   a. The uppermost outer _____ layer of the earth is called _____.
   b. Crust and upper part of mantle upto an average depth of _____ is _____.
   c. Lithosphere includes _____ and _____.
   d. Tectonics is sort of _____ of lithospheric plate.
   e. The concept of convectional current was first explained by _____ in _____.
   f. Convectional currents are classified into _____ and _____; they _____ and _____, respectively.
   g. Plate boundaries are associated with _____, _____ and _____.
2. Name seven major plates
   a. _____
   b. _____
   c. _____
   d. _____
   e. _____

f. _____

g. _____

3. Name some important minor plates –

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

4. Enumerate different types of plate boundaries

a. _____

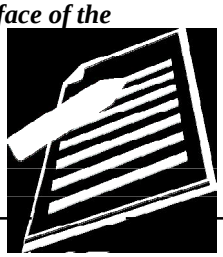
b. _____

c. _____

WHAT YOU HAVE LEARNT

The surface of the earth is dynamic. This dynamism is due to the forces operating from inside the surface (endogenetic forces) as well as on the surface/atmospheric forces (exogenetic forces). It is existing on the earth while itself is rotating and revoling. The surface is irregular. Hence, a sort of dynamic equalibrium is always in operation which is termed as isostasy. Apart from many scholars the views of Airy and Pratt are more distinct. Airy propounded the idea of uniform density of all rocks on the surface but has its roots depending upon the height of the column. A greater root will be found beneath the higher and lofy body of mountains and having smaller root under lower columns like plateau or plain. Pratt accepted that the rocks found on the earth have different densities. At a particulars depth, the weight of all columns of varying height will be compensated. Hence, higher column of mass will have lower density and lower column will have higher density. Therefore, both of them are explaining the same problem of isostatic balance, but with different perspective.

The distribution of land and water on earth surface is not static. It has changed, it is changing and it will change in future too. This changed position is said to be continental drift in crude way which was conceived by Wegener, but the mechanism explained by him was not scientific. Therefore, his ideas of continental drift was denounced inspite of his strong unfutile and testifying evidences.



With the concept of convectional current theory of Holmes and proposition of plate tectonics, a new thinking came in understanding the surface of the earth. Study on paleomagnetism as well as sea floor spreading have supported the plate tectonics theory. According to this theory, the earth surface is made up of several broken blocks of enormous size with great depth considered to be a plate. There are seven bigger size plates and twenty seven smaller size plates. As per the concept of convectional current, their movement takes place in three possible ways. First, two adjacent plates move away (divergent) and where a new zone is constructed. Second, two adjacent plates come closer (convergent) and get subducted and where a zone is destroyed. Third, in which two adjacent plates slide past each other (fracture) where the margins of both plates are preserved. Because of these different tectonic activities, earthquakes and volcanoes are associated with plate margins.

TERMINAL QUESTIONS

1. What is isostasy?
2. Explain the concept of isostasy according to Airy.
3. Explain the isostatic balance of the earth as proposed by Pratt.
4. Differentiate the ideas between Airy and Pratt.
5. Discuss the isostatic balance at global level.
6. Discuss the evidences of continental drift.
7. What is plate? Explain the mechanism of plate movement.
8. Discuss the activities at plate margins.
9. Describe the distribution of earthquakes and volcanoes with the help of plate boundaries.

ANSWERS TO INTEXT QUESTIONS

3.1

1. the state of being balance
2. same
3. density
4. deeper, lower
5. no, level
6. disturb
7. any balance, adjustment is needed.

3.2

1. a. Pangeea
   b. Panthalasa
   c. Laurasia (Angaraland), Gondwanaland
   d. West
   e. Angaraland, Gondwanaland, Panthalasa

2. a. Jig-saw-fit
   b. geological similarities
   c. coal evidences

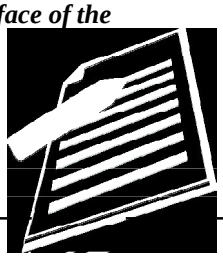
3 a. evidences from paleomagnetism
   b. sea floor spreading

3.3

1. a. solid and rigid, plate
   b. 100 km, solid
   c. upper solid mantle, crust
   d. movement
   e. Arthur Holmes, 1928-29
   f. Rising, falling; diverge, converge
   g. Newly formed mountain systems, oceanic ridges, trenches

2. a. Eurasian plate
   b. African plate
   c. Indo-Australian plate
   d. Pacific plate
   e. North American plate
   f. South American plate
   g. Antarctic plate

3. a. Arabian plate
   b. Philippine plate
   c. Cocos plate
   d. Nazca plate
   e. Caribbean plate
   f. Scotia plate



4. a. divergent boundaries
   b. convergent boundaries
   c. fracture or transform fault/boundaries

HINTS TO TERMINAL QUESTIONS

1. Please refer to section 3.1
2. Please refer to section A of 3.1
3. Please refer to section B of 3.1
4. Please refer to section C of 3.1
5. Please refer to section 3.2
6. Please refer to section 3.2, Evidence of drift.
7. Please refer to section 3.3
8. Please refer to section 3.3
9. Please refer to section 3.3