UNIT 14

PLATE TECTONICS

Structure

14.1 INTRODUCTION

Earthquakes, volcanic activities, sea-floor spreading, continental drift, convection currents and other similar activities combinedly point to dynamic nature of the Earth. Its dynamism is manifested through visible and invisible activities and these are very slow (few cm/year) rate; spreading of ocean floor) to very fast (volcanic eruptions, earthquakes) in operations. A large variety of dynamic activities are interlinked and movements of the rigid lithospheric plates play controlling roles. The drift of continents, sea-floor spreading and palaeomagnetism provide solid evidences that Earth is made-up of the rigid plates that are in continuous motion. The resulting tectonic activities are also responsible for formation of beautiful major sculptures like mountains, oceans and other landforms as by-products in due course of time. Plate tectonics is a unifying theory for geology because this logically explains the formation of tectonics features on the Earth's surface. While studying the earlier units, you are now well aware about the major geotectonic features found on the Earth.

In this unit, we will discuss development of plate tectonics theory, lithosphere and asthenosphere. We also discuss three types of plate movements; associated tectonics features and mechanisms of plate tectonics.

Expected Learning Outcomes

After reading this unit, you will be able to:

- define theory of plate tectonics;
- describe historical background for the development of the theory of plate tectonics;
- write about concept of asthenosphere and lithosphere;
- discuss lithospheric plates and their movement types;
- describe driving forces acting behind the plate movements; and
- explain mantle plume, triple junctions and hotspots.

14.2 PLATE TECTONICS

The theory of plate tectonics states that the relatively thin rigid lithosphere of the Earth is composed of seven major plates and numerous smaller plates, all of which are in motion in different directions over the asthenosphere. It is a well accepted theory in geology because it explains almost all large-scale geological structures and processes operating on the Earth (McConnell and Abe, 2015). Therefore, plate tectonics theory is known as unifying theory or principle of geology.

Historical Background

It took more than fifty years for evolving the of concept of plate tectonics on the foundation of continental drift which was gradually reinforced by a series of astonishing developments of new ideas like of sea-floor spreading and gathering of evidences by tens of scientists and groups. Therefore, the credit of development of the theory of plate tectonics does not go to a single person, rather it developed through a chain incorporation of observations, discoveries, data and discussions. The initial focus of geoscientists was on identification and description of rocks, minerals, fossils and they used to think Earth as a whole possesses limited mobility, which is well marked in rocks in the form of folds and faults and continents were believed to be stationary. This idea was commonly known as **Fixist hypothesis** (Moores and Twiss, 1995). According to this hypothesis, the vertical motions were predominantly the accepted movements and isostasy was chiefly the driving force behind the vertical motion.

In 1909, the Yugoslav seismologist, A. Mohorovicic, discovered the sharp increase in primary wave velocity at the base of the crust. Later, the German seismologist, B. Gutenberg in 1914, first recognised the core-mantle structure of the Earth. In meantime, French geophysicist, B. Brunhes, discovered reversely magnetised basalt in 1909 and Japanese geophysicist, M. Matuyama in 1928, proposed that the Earth's magnetic field was in reversed in polarity during the major part of the Quaternary and only 7 lakh years ago reverse polarity was replaced or changed into normal polarity. These studies though later proved to be very important and revolutionary, but there was no unifying model of the existence in the early twentieth century.

The direct challenge to the fixist model came in 1912 and 1915 with Wegener's continental drift hypothesis. Wegener's hypothesis created a great deal of interest worldwide. The controversy came for discordance in 1926, where in a meeting of American Association of Petroleum Geologists in New York, where Wegener could not convincingly explain the driving force and mechanism of continental drift. After the New York meeting, the continental drift hypothesis was out of scene for long time, but a South African geologist A. Du Toit strongly supported the idea in his book 'Our Wandering Continents' which got published in 1937, but the hypothesis' breath was revived in 1950's when it got support from the palaeomagnetic studies.

In early 1930s, the Dutch geophysicist F.A. Veining-Meinesz and his team made a surprising discovery that deep sea trenches in the Caribbean and in Indonesia were see associated with negative gravity anomaly and seemed to violate the laws of isostasy. The British geologist, Arthurs Holmes, proposed the idea that because of down going convection currents the crust is down buckling into the mantle. At about the same time in 1928, the Japanese seismologist, K. Wadati, recognised earthquake sources beneath Japan are located along an inclined planar zone near the trenches. Vening-Meinesz took with him an American geologist, Harry Hess, in his marine expeditions. Later, Hess published the compilation and synthesis of the detailed topographic characteristics of the western Pacific Ocean including trenches off Japan, the Marianas and the Philippines. In the late 1940s and early 1950s, the American seismologist, Hugo Benioff, recognised the presence of inclined seismic zone in the Pacific dipping into the mantle, thus, confirming the early discovery of Wadati.

In the late 1950s, Gutenberg discovered a zone of low seismic velocity approximately 100 km depth in the mantle. The pace of new discoveries and problems accelerated with the identification of thousands of kilometers long fracture zones in the oceans in late 1950s and early 1960s. During this time period, palaeomagnetism ended the isolated developments when it was recognised that Europe and North America had different polar wander paths. The simplest explanation was that the continents had moved relative to one another. This was a blow to the fixist and support to the continental drift hypothesis. In 1958, the Australian tectonist, S.W. Carey, tried to fit the continents on a spherical table and accepted the drift theory with drifting away of continents from the mid-oceanic ridges. He also proposed many other tectonic relationships that were subsequently confirmed. He also propounded his idea that the Earth is expanding, which is the root cause of continental drifting, though this idea of Earth's expansion could not gain popularity.

In 1963, important synthesis came independently from L.W. Morley in Canada and from F.J. Vine and D.H. Mathews in Cambridge, England. It is popularly known as Vine-Mathews-Morley hypothesis proposes that there were several polarity reversals in the Earth's magnetic field, which the ocean-floors have preserved in strips like a tape recorder on the both sides of the Mid-oceanic ridges symmetrically. The Canadian geophysicist, J.T. Wilson in 1965 proposed the idea of transform fault, which disrupts the mid-oceanic ridges. Based on seismicity maps of 1960 to 1968, the American seismologists, M. Barazangi and L. Dorman in 1969, showed a pronounced concentration of seismicity in the narrow zones along the mid-oceanic ridges and in planar zone dipping beneath the island arcs to the depth up to 700 km. This map made it clear how tectonically active the Earth is and also that the tectonics of the Earth is characterised by rigid-body motion of large plates on a sphere. It also made clear that the deformation and seismic activities are concentrated along the boundaries of the plates, where they interact with one another. A global conference in December 1969 was organised by William R. Dickinson in California that explored the application of plate tectonics to continental geology and orogeny and also for ancient continental geology. Now it is clear that continental drift was not a single episode of Earth's history, but an inherent and continuous process.

14.3 LITHOSPHERE AND ASTHENOSPHERE

We are familiar with a commonly followed three layers structure namely, the core, mantle and crust of the Earth's interior, which are largely based on chemical composition and density of Earth's interior obtained by indirect means e.g. by seismic waves. The Earth is also classified as core, lower mantle, mesosphere, asthenosphere and lithosphere on the basis of different sets of physical properties and behaviour of the rock material present inside the Earth.

After awareness of the core and lower mantle layers, now, let us get acquainted with the term asthenosphere and lithosphere for proper understanding of plate tectonics.

Lithosphere

Lithosphere (lithos, meaning rocks) is the outermost layer of the Earth and lies above the asthenosphere. It is composed of Earth's crust (both oceanic and continental) and rigid and relatively cool part of the upper mantle (Fig. 14.1). Lithosphere is physically considered as strong and rigid region that deforms in elastic way (Kearey and others, 2009). The thickness of lithosphere above the astheonsphere is not uniform and varies from palce to place on the Earth. The average the thickness of lithosphere is 100 km and may go upto 300 km below the orogenic mountains. The thickness of lithosphere is less than 50 km below the oceanic crust.

The lithosphere is not a single shell, but consists of many different large segments or blocks of lithosphere, which are called as **lithospheric plates**, **tectonic plates** or simply **plates**. These plates are considered rigid bodies floating over the asthenosphere and tectonic deformations generally take place at the boundaries of the plates because of the interactions one plate with other plate(s). The boundaries of present-day plates are chiefly drawn along densely concentrated, linear shaped earthquakes foci area and loci of active and dormant volcanoes. The lithospheric plates move horizontally over the asthenosphere.

Asthenosphere

Asthenosphere (asthenes, meaning without strength) is the part of upper mantle (Fig. 14.1). It is also known as Low Velocity Zone (LVZ) because the velocity of seismic waves decreases in this zone. Asthenosphere lies below the lithosphere at an average depth of 100 km and extending to a depth of 350 to

650 km. The asthenosphere is hot, soft, semi-viscous in nature and consists of very little molten rock material around mineral grains. This zone allows the lithospheric plate to float and move over it. The upper boundary of the asthenosphere may lie about 60 km below the oceanic crust while the base of the asthenosphere is can be as deep as 700 km (Kearey and others, 2009). The average thickness of asthenosphere however, lies between 180 to 220 km. The asthenosphere is thought to play critical role in movements of the plates on the Earth's surface.

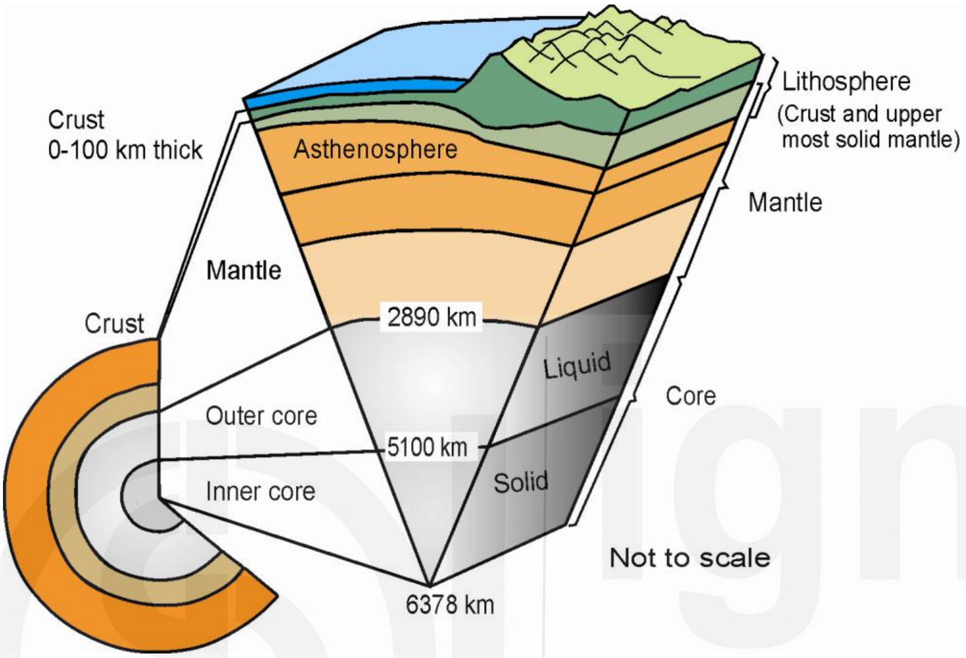

Fig. 14.1: Internal structure of the Earth showing lithosphere and asthenosphere. (Source: https://igs.indiana.edu/Geothermal/)

14.4 PLATES AND THEIR TYPES

As mentioned above, lithospheric plates are portions, blocks or segments of the lithosphere. The demarcation of boundary of a single plate helps to find whether it is oceanic, continental or continent-oceanic plate and whether it is a small or larger plate. Composition-wise plates are of the following three types:

- Oceanic plate: It is comprised entirely of an oceanic crust.
- Continental plate: It is wholly composed of continental crust.
- Continent-oceanic plate: It is comprised partially of oceanic and partially of continental crust.

It may be noted that the lithosphere of the Earth is made up of a mosaic of discrete relatively rigid plates. There are seven major plates and several minor plates (Fig. 14.2). The names of seven major plates are:

1) Indo-Australian plate
2) Eurasian plate
3) North American plate
4) South American plate
5) African plate

6) Pacific plate

7) Antarctic plate

The Nazca plate, Cocos plate, Scotia plate, Philippines Sea plate, Iran plate, Chinese plate, Arabian plate, Nubian plate and Somali plate are the names of a few minor plates.

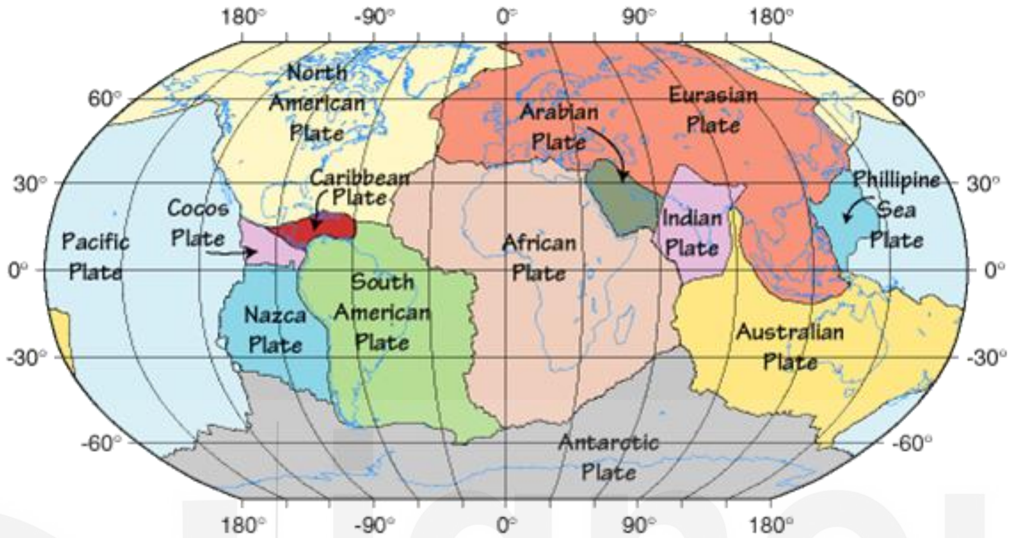

Fig. 14.2: Major plates of the world. (Source: http://eqseis.geosc.psu.edu/~cammon)

Nature of the Plates: The thickness of the plates is controlled by 1400°C isotherm. This isotherm represents the temperature of partial melting that transforms the mantle into quasi plastic medium. Thus lithospheric plates are made up of both crust and upper mantle. The thickness of oceanic plate increases as we go away from the spreading ridges. The average thickness of oceanic plate is about 60 km and for continental plate, the average thickness is about 100 km.

As a result of plate tectonics, the total area of ocean plate has gradually decreased and that of the continental plate has increased. In the current configuration, the seven major plates exceed an area of about 10^7 km^2. Six intermediate sized plates namely Arabia, Caribbean, Cocos, Nazca, Philippines and Scotia currently range in area from 10^6 to 10^7 km^2. Numerous plates exist that are smaller than 10^5 km^2 such as Indonesia, Fiji, Bismarck etc. such plates have been called as **micro-plates**.

As per the concepts of the plate tectonics, the plates move apart from a divergent boundary and get converge along a convergent boundary. New crust is generated along the accreting of constructive plate margins and destroyed in mantle along subduction zone. The phenomenon of plate tectonics is able to explain many problems of earthquakes, volcanoes, island arcs, trenches, mountains etc.

Plate Boundary/ Plate Margin: Plate boundary is the surface trace of the zone of motion between two plates. Plate boundary is rarely a sharp plane; normally it is several km wide regions or zones. Two plate margins meet at a common plate boundary. Plate margin is marginal part of a particular plate. The plate margins or plate boundaries are of the following four types (Fig. 14.3):

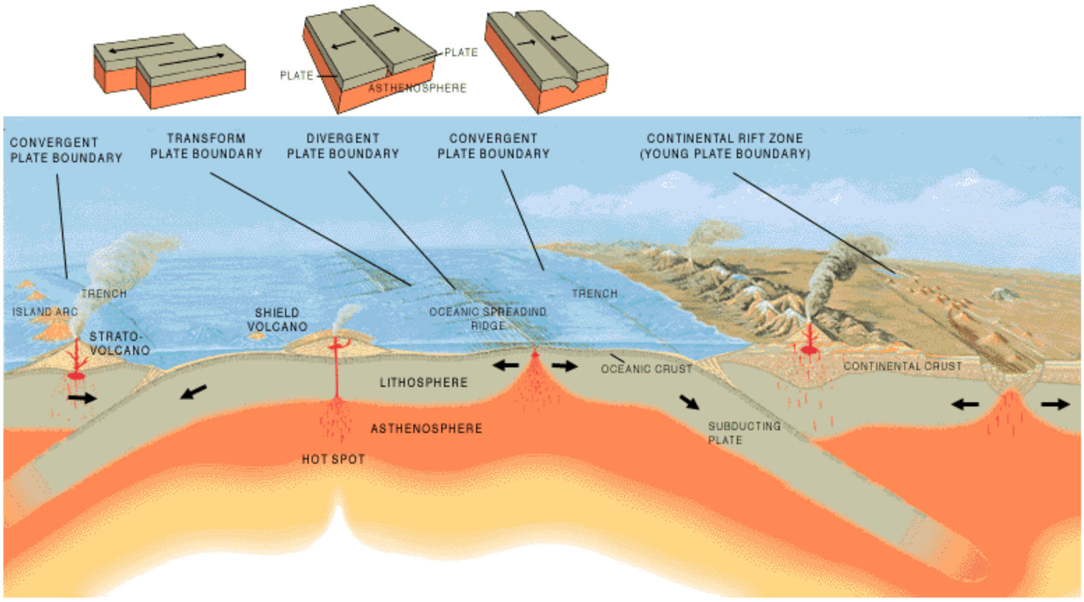

Fig. 14.3: Schematic showing three types of plate boundaries. (Source: https://g105lab.sitehost.iu.edu/1425chap13.htm)

a) **Constructive** or **divergent** or **accreting plate margin**: Constructive plate boundary represents zone of divergence where there is continuous upwelling of molten rocks (i.e. lava) and thus, new (oceanic) crust is formed. This type of boundary occurs at the mid oceanic ridges.

b) **Destructiv**e or **convergent** or **consuming plate margin**: Here two plates converge towards each other, one plate which is heavier in density buckles down or subducts (subducting plate) below the lighter plate (over-riding plate or stationary plate) and is consumed or destroyed in the mantle. The zone where subduction occurs is called as **subduction** or **Benioff Zone**.

c) **Conservative** or **shear** or **transform fault margin**: Here two plates neither converge or diverge and only slide or shear past each other along transform faults.

d) Recently, a fourth type of plate margins have been recognised as **'Plate Boundary Zone**' where the plate margin is not a single line, but rather a zone where many microplates in between two major plates, play their role in the tectonics. For example, the zone between African and Eurasian plates.

Before proceeding further, let us have a short break to check your progress.

SAQ 1

a) Name seven major plates of the globe.

b) What is asthenosphere?

c) Which plate boundary is called conservative type?

14.5 RATES OF THE PLATE MOVEMENTS

We often become curious that if the tectonic plates are moving continuously why don't we experience this motion? Or do we experience the movement at the time of earthquakes only? Or how do geologists find the rate of movement of the tectonic plates? Well, our curiosity may find the answer when we go through the followings.

The current plate movements can be tracked directly by means of ground-based or space-based geodetic measurements. However, because plate motions are global in scale, they are best measured by satellite-based methods. Global Positioning System (GPS) has been the most useful for studying the Earth's crustal movements. By repeatedly measuring distances between specific points, geologists can determine if there has been active movement along faults or between plates.

Evidence of the past rates of the plate movement also can be obtained from geological mapping of markers. If a rock formation of known age (marker rock) mapped on one side of a plate boundary can be matched with the same formation on the other side of the boundary, then measuring the distance between offset across the structure or distance between the rock formation and the axis, can give an estimate of the average rate of plate motion. This is a simple and effective technique, which is used to determine the rates of plate motion at divergent boundaries, for example, the Mid-Atlantic Ridge and transform boundaries such as the San Andreas Fault.

We know that the ocean-floor have records of the Earth's magnetic normal and reversed polarity events in the form of linear strips. Therefore, knowing the approximate duration of the reversal, we can also calculate the average rate of plate movement during a given time span. These average rates of plate separations can range widely. The Arctic Ridge has the slowest rate (less than 2.5 cm/year). 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/year).

14.6 MECHANISMS OF THE PLATE TECTONICS

The general theory of plate tectonics takes the following assumptions:

a) Sea-floor spreading occurs and new oceanic crust is continuously generated at irregular line source (i.e. along the active Mid-oceanic ridges).

b) The Earth is of constant surface area or if not, the changes at a rate, which is small by comparison with the rate of generation of new surface area by spreading.

c) Once formed, new crust forms part of a rigid plate which may or may not incorporate continental material.

An important question is that why do plates move? Or which cause plates to move? It is important to note that the driving forces for plate tectonics are still not accurately identified. However, many hypotheses have been proposed for explaining the mechanism of the motion of the plates. Some of them are described below:

- **Convection current hypothesis**: According to this hypothesis, the convection currents operating in mantle cause movement of plates along them.

- **The plates drag the mantle**: This hypothesis argues that because asthenosphere cannot be separated by lithosphere, hence, it is the plate movement which drags the mantle.
- **Gravity slide**: According to this hypothesis, it is the Earth's gravity that causes plates to slide towards asthenosphere; hence, the lateral movements of the plates are generated.
- **Mantle plumes**: It states that mantle plumes arising from lower mantle and at core-mantle boundary create hotspots and drive the plate in radial direction.

In recent times, the mantle plumes and hotspots model have gained much popularity for the driving forces for plate tectonics. Lets us discuss this model in details.

Mantle Plumes and Hotspots

The mantle plume model was originally proposed by an American Geophysicist, W.J. Morgan in 1971. This model assumes a 'plume' to be important source of heat transfer from lower to upper mantle. A mantle plume is a rising column of hot material a few hundred km in diameter that comes upward from lower mantle or from the core-lower mantle boundary into asthenosphere and spreads out like thunderhead beneath the lithospheric plates (Fig. 14.4). The complementary return flow, due to mantle convection current, would involve a uniform sinking of entire mantle below the asthenosphere, which is in addition to the down flow associated with subduction zones.

The lateral spreading of plume material in the asthenosphere produces radial shear stress on the base of the overlying lithosphere. If a number of plumes are aligned in a line, then flow in the asthenosphere would be laterally away from the line of plumes, and the resulting shear stresses would act to pull the lithosphere apart. Thus, a spreading center is created along the line of plume.

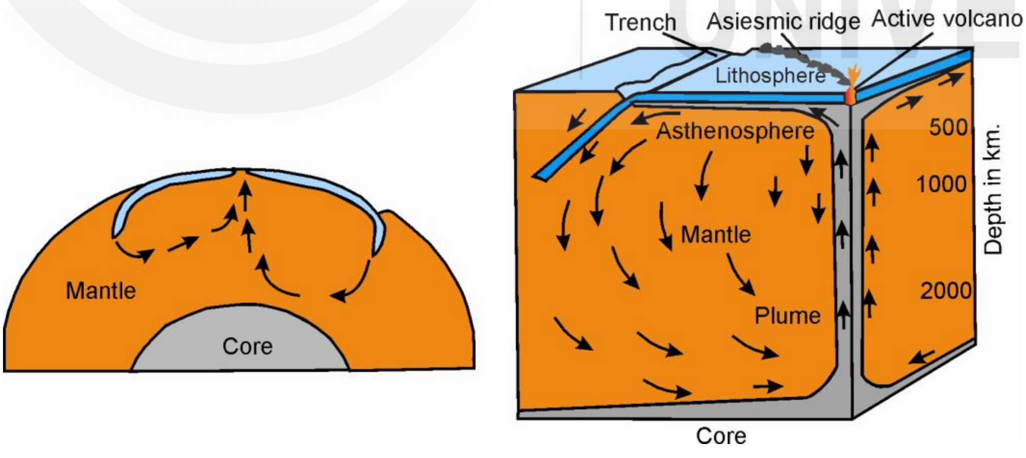

Fig. 14.4: Mantle plume: a) Convection currents in mantle; and b) Plume rise in lower mantle creating hot spot on Earth's surface. Lava outpouring on hot spots form active volcanic mounds which in due course of time due to movement of plate become aseismic ridge. (Source: redrawn after Moores and Twiss, 1995)

The mantle plumes are upwelling from the lower mantle and are immobile in nature. They complete their life cycle in more than a hundred million years and their surface manifestations are known as **hotspots**. The hotspots are stationary, intra-plate and long-lived volcanic regions on the Earth's surface that are fed from the by underlying mantle. These places are anomalously hot compared with the surroundings and give rise to localised regions of volcanic activity. Hotspot volcanoes are considered to have a fundamentally different origin from island arc volcanoes because the later form over subduction zones at converging plate boundaries. The hotspots also differ from the volcanism over the divergent boundary along Mid-Oceanic Ridge (MOR) because the MOR have source of magma at shallower depth. Hotspots may occur over a single plate and such type of setting is known as intra-plate sitting.

The Deccan traps of peninsular of India is a result of massive volcanic eruption that took place about 66 million years ago, when the Indian plate crossed oven the present Reunion hotspot situated in the African plate. Kerguelen is another hotspot located in the Indian Ocean and its volcanic eruption some 118-112 million years ago led to the formation of the Rajmahal traps of the eastern India. Hotspots are also used as reference frames to analyse the finite plate motions. Most of the hotspots over the Earth's surface have been located in the oceanic regions (Fig. 14.5), though hotspots have also been observed over the continents.

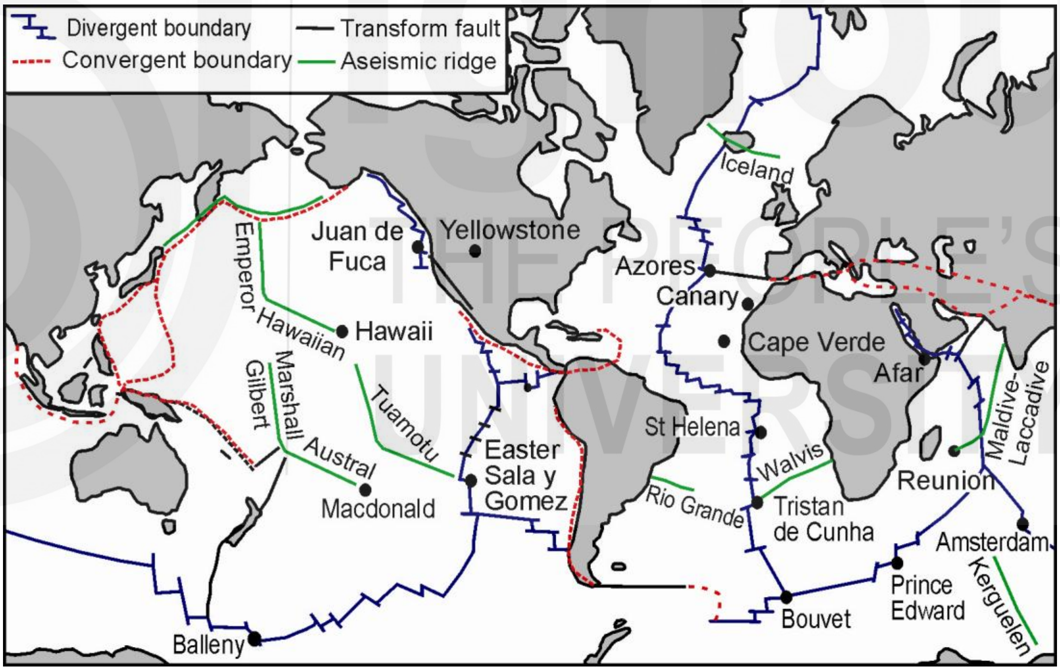

Fig. 14.5: Map of hotspots. Note that the hotspot volcanism is not related to the Mid-Oceanic ridges or island arc volcanisms. (Source: redrawn after Moores and Twiss, 1995)

The hotspots are often found associated with the aseismic ridges, which are formed due to outpouring of magma on a plate surface over a considerable time period (Fig.14.5). Aseismic ridges are long, linear and mountainous topographic elevations found in the oceans and usually have anomalously thick oceanic crust. Earthquakes do not occur within aseismic ridges, and it is this feature that distinguishes them from oceanic spreading centers. Two ridges namely the Ninety Degree East and Eighty Five East ridges are present in Bay of Bengal and extending into Indian Ocean.

SAQ 2

a) Name the most popular model for mechanism of plate movements.

b) What is hotspot? Name one example of hotspot in the Pacific Ocean

c) Why ridges created by hotspots are called aseismic ridges?

14.7 TRIPLE JUNCTIONS AND THEIR PRESENT-DAY EXAMPLES

The lithosphere is a mosaic of inter-locking plates and most of the tectonic activities are found along the boundary of the two interacting plates, however, there are several places where three different plates come together.

The place where three plates meet is known as **triple junction**. In other words, the contact region of three plates represents a triple junction. You are already aware that plate boundaries are a junction where two plates meet together. You are also aware that ridges usually associated with divergent plate margins, trenches with convergent plate margins and strike-slip fault with transform faults. Based on the combinations of these three basic types, the triple junctions broadly classified into three types, as given below (Fig. 14.6):

- **Ridge-Ridge-Ridge (RRR) triple junction**: It a place where three ocean ridges meet together (Fig. 14.6a). Common example of RRR triple junctions is in the South Atlantic Ocean where ridges of three plates namely, South American, Antarctic and African meet.
- **Trench-Trench-Trench (TTT) triple junction**: It is the triple junction between three oceanic trenches (Fig. 14.6b). It occurs in central Japan.
- **Ridge-Ridge-Fault (RRF) triple junction**: It is a triple junction between two oceanic ridges and one transform fault (Fig. 14.6c).

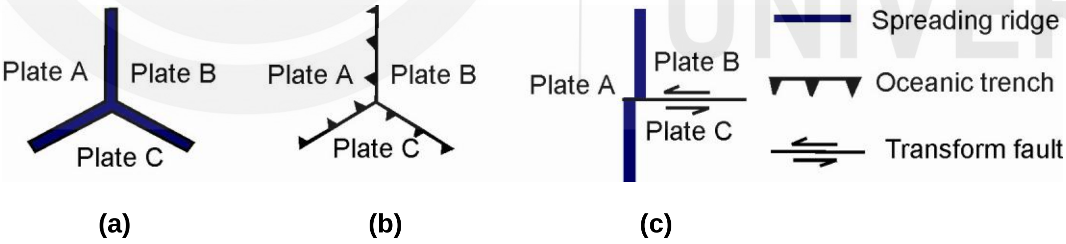

Fig. 14.6: Types of triple junctions: a) RRR triple junction; b) TTT triple junction; and c) RRF triple junction. (Source: https://www.open.edu/openlearn/science-maths-technology/science/geology/plate-tectonics/content-section-3.9#)

Other types of triple junction are Trench-Trench-Fault (TTF), Trench-Trench-Ridge (TTR), Fault-Fault-Ridge (FFR), Fault-Fault-Trench (FFT) and Ridge-Trench-Fault (RTF).

A triple junction is stable or unstable depends on geometry of the plates, relative velocities of the plates and orientations of the plate boundaries (Moores and Twiss, 1995). In stable triple junction, the configuration of junction does not change with time. But, in case of unstable triple junction the configuration of junction evolves with time. RRR triple junction is an example of stable triple junction. The TTT triple junction is an unstable triple junction. Some of the common present-day triple junctions with their types are listed in Table 14.1.

Table 14.1: Present-day examples of triple junctions. R stands for Ridge, F for Fault and T for Trench.

Triple junction type	Name of triple junction	Locatio n	Plates involved	Ridge/Fault/Trench Involved
RRR	Afar triple junction	Ethiopia, Africa	Nubian, Somalian and Arabian plates	Red Sea Rift, Aden Ridge and East African Rift
RRR	Azores triple junction	Atlantic Ocean	North American, Eurasian and African plates	Mid-Atlantic Ridge and Terceira Rift
RRR	Bouvet triple junction	Atlantic Ocean	South American, African and Antarctic plates	Mid-Atlantic Ridge, Southwest Indian Ridge, and South American-Antarctic Ridge
RRR	Indian Ocean (Rodrigues) triple junction	Indian Ocean	African, Indo-Australian and Antarctic plates	Central Indian Ridge, Southwest Indian Ridge and Southeast Indian Ridge
RRR	Galapagos triple junction	Pacific Ocean	Pacific, Cocos andNazca plates	East Pacific Rise and Galapagos Rise
FFF	Karliova triple junction	Near Turkey	Arabian, Eurasian and Anatolian (Turkish) plates	North Anatolian Fault and East Anatolian Fault
TTT	Boso triple junction	Pacific Ocean	North American Pacific and Philippines Sea plates	Sagami, Izu-Bonin and Japan Trenches
TTR	Chile triple junction	Pacific Ocean	S America, Nazca and Antarctic plates	Chile Rise, South American Plate and Peru-Chile Trench
FFT	Mendocino triple junction	Pacific Ocean	North American, Pacific and Gorda plate	Gorda and North American plates and Mendocino and San Andreas Faults
RRF	Macquarie triple junction	Pacific Ocean	Indo-Australian, Pacific and Antarctic plates	Macquarie Ridge Complex and numerous other fractures zones

14.8 ACTIVITY

Given below is the global tectonic map (Fig. 14.7). Plot the location of the following:

a) Reunion, Kerguelen, Hawaii, Macdonald, Iceland and Afar hotspots.

b) Bouvet and Azores triple junctions.

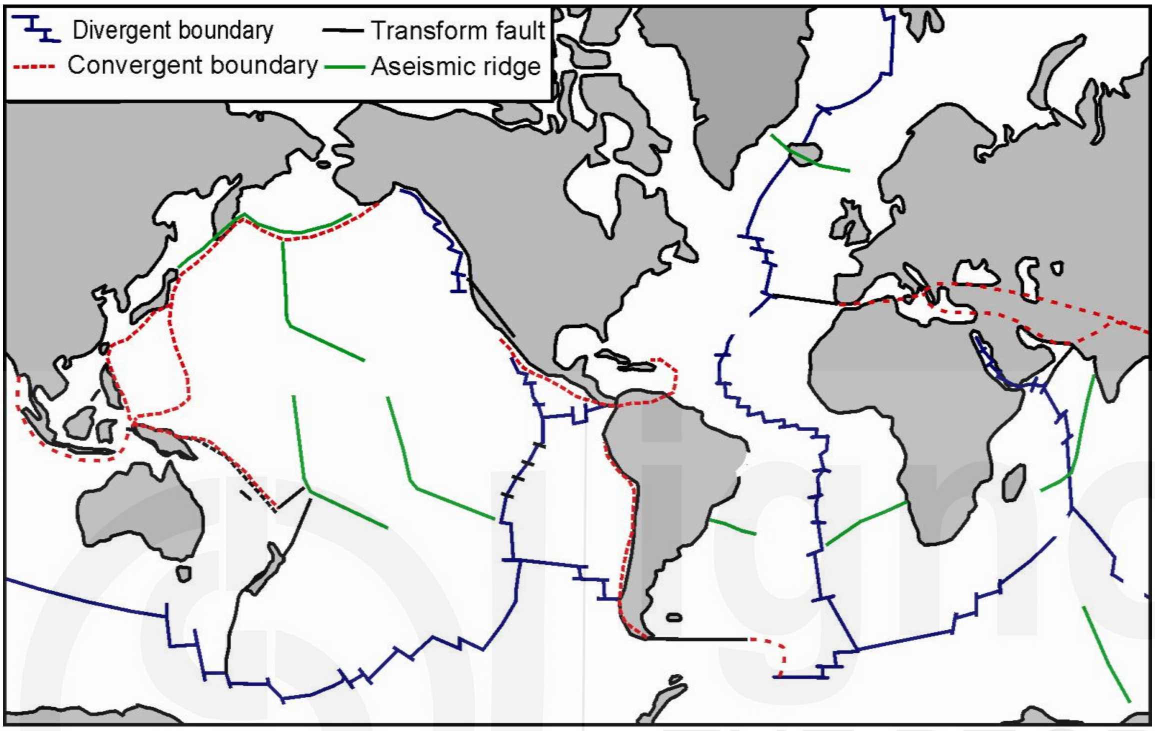

Fig. 14.7: Map showing main tectonic features.

14.9 SUMMARY

Let us summarise what we have read in this unit:

- The evolution of the theory of plate tectonics has been a journey passing through different hypotheses like continental drift, sea-floor spreading, palaeomagnetism and convection currents proposed in the early part of 20th century.
- The theory of plate tectonics in fact developed through the unifications of theories, observations and contribution coming from geological, palaeontological, seismological, oceanographic, palaeomagnetism gravitational, meteorological and many other studies carried out over decades.
- The tectonic plates are a segment of lithosphere that float and move over the asthenosphere. The boundaries of these rigid plates have been marked by focused concentration of earthquakes and volcanic activities because of interaction of one plate with the other.
- A tectonic plate may comprise totally oceanic, totally continental or partially continental and partially oceanic segment of the lithosphere.

- New crusts are created where two plates diverge from each other and where the two plates converge in motion the crust get destroyed by subducting under another plate.
- Along the transform fault the crust is neither created nor destroyed, therefore this plate boundary is known as conservative plate boundary.
- Convection currents in the mantle are probably the chief forces that drive the plates.
- Hotspots are the places on the Earth's surface where a linear stream of magma called plume comes from lower mantle or core-mantle boundary, outpours lava without any significant seismic activity. These volcanoes form linear topographic ridges called aseismic ridges.
- Mantle plume is the most popular model to explain the movements of the plates.
- Many geotectonic features such as mountains, trenches island arcs, aseismic ridges and activities like earthquakes and volcanoes can be satisfactorily explained by the theory of plate tectonics.
- Triple junctions are the places where three plates come together.

14.10 TERMINAL QUESTIONS

1. With near diagrams, explain the constitution of lithosphere and asthenosphere. Also discuss their role in plate tectonics.
2. What is mantle plume? Explain its contribution in volcanism, plate movements and earthquakes.
3. What do you understand by triple junction in plate tectonics?
4. On the world map given below (Fig. 14.8) show the locations of the following: African plate, Indo-Australian plate, Nazca plate, South American plate, Antarctic plates, Mid Atlantic Ridge and Hawaii-Emperor Aseismic Ridge.

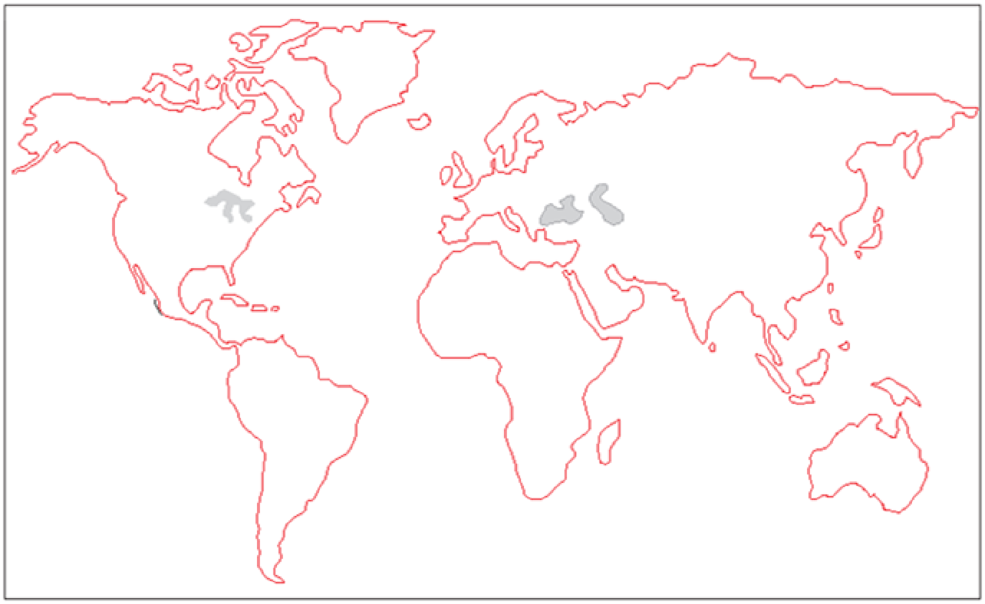

Fig. 14.8: Blank map of the world.

14.11 REFERENCES

- Kearey, P., Klepeis, K.A. and Vine, F.J. (2009) Global Tectonics, Wiley India Pvt. Ltd, New Delhi.
- McConnell, R.L. and Abel, D.C. (2015) Environmental Geology Today, Jones and Bartlett Learning, Burlington.
- Moores, E.M. and Twiss, R.J. (1995) Tectonics, W.H. Freeman and Company, New York.

14.12 FURTHER/SUGGESTED READINGS

- Condie, K.C. (2003) Plate Tectonics and Crustal Evolution, Butterworth-Heinemann, Oxford.
- Foulger, G.R. (2010) Plates vs Plumes, Wiley-Blackwell, Sussex.
- Gass, I.G., Smith, P.J. and Wilson, R.C.L. (1979) Understanding the Earth, The Artemis Press Limited, Sussex.
- Kearey, P. and Vine, F.J. (1996) Global Tectonics (2nd Edition), Blackwell Science, Oxford.

14.13 ANSWERS

Self Assessment Question 1

a) The seven major plates of the globe are Eurasian plate, North American plate, South American plate, African plate, Indo-Australian plate, Pacific plate and Antarctic plate.

b) Asthenosphere is the part of upper mantle that lies below the lithosphere at an average depth of 100 km and extending to a depth of 350 to 650 km. The asthenosphere is hot, semi-viscous in nature and consists of partially molten rock. This zone allows the lithospheric plate to float and move over it. The asthenosphere is thought to play critical role in movements of the plates on the Earth's surface.

c) The transform fault is called conservative plate boundary because along the transform fault the crust is neither created nor destroyed.

Self Assessment Question 2

a) Mantle plume is the most popular model for mechanism of plate movements.

b) Hotspots are the surface manifestations of mantle plumes. The hotspots are volcanic regions on the Earth's surface that are thought to be fed by underlying mantle. Hawaii is a most common hotspot of the Pacific Ocean and it has formed a volcanic island known as Hawaiian island.

c) The ridges created by hotspots are long, linear and mountainous topographic elevations found in the oceans. They usually have anomalously thick oceanic crust and earthquakes do not occur in these ridges. Hence, these ridges are known as aseismic ridges.

Terminal Questions

1. Please refer to section 14.3.
2. Please refer to section 14.6
3. Please refer to section 14.7.
4. Consult Fig. 14.2.