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Lecture-1

Physical Geography and its Branches

Physical geography is that branch of systematic geography (physical and human) that examines the natural processes occurring at the earth's surface that provide the physical setting for human activities. Physical geography differs from other sciences in that it focuses on the world around us from changes in daily weather conditions to landforms we travel every day. Physical geography is not only the agglomeration of different branches of earth and natural sciences like geomorphology, climatology, meteorology, pedology, geology etc. but it also studies the patterns of interactions between human activities and physical environment. Physical geography can be defined differently as follows:

- 1. Physical geography is the study of forces that influence the surface of earth.*
- 2. Physical geography is to study natural phenomena.*
- 3. Physical geography is the study of physical processes and patterns in the natural environment that shape the surface of the earth and their associated variability over space and time.*
- 4. Physical geography studies the spatial patterns and spatial relationships of environmental components of the globe in regional context, it also studies the causes of regional patterns of such relationships.*

The main purpose of studying physical geography is to explain the spatial characteristics of the various natural phenomena associated with geomorphology, climatology, oceanography, pedology, biogeography etc.

Branches of Physical geography

There are five fields or branches of physical geography varying from geomorphology to biogeography as highlighted below:

1. Geomorphology: It is the science of earth surface processes and landforms. In other words it is the scientific study of surface involving interpretative description of landforms, their origin and development and nature and mechanism of geomorphological processes which evolve the landforms. Modern geomorphology also focuses on modeling landform shaping processes to predict both short-term (rapid) changes such as landslides, floods, coastal storm, erosion, and long term (slower) changes, such as soil erosion in agricultural areas or as a result of strip mining.

2. Climatology: Climatology is the science that describes and explains the variability of atmospheric conditions (heat and moisture) over space and time. According to Critchfield,

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climatology is the science which studies the nature of climate, the causes and interpretation of its spatial variations and its association with the elements of natural environment and human activities. In simple words it is the systematic and regional study of atmospheric conditions i.e. weather and climate. Climatology is concerned with climate change, both in past and future.

3. Oceanography: The science of hydrosphere i.e. oceans and seas is called oceanography which includes the consideration, description and analysis of both physical and biological aspects of hydrosphere. It is concerned with the study of various types of Oceanic component and processes related to ocean floor depths, currents, corals reefs, and continental drifts etc. The study of oceanography has gained much importance during the current times because of the economic and strategic importance of oceans and seas. Today more focus is on applied oceanography which includes the consideration of delineation, mapping, exploration, utilization and management of marine abiotic as well as biotic resources.

4. Pedology: is the study of the distribution of soil types and properties and the processes of soil formation. It is related to both geomorphic processes of rock break up and weathering, and to biological processes of growth, activity and decay of organisms living in the soil. Since both geomorphic and biological processes are influenced by the surface temperature and availability of moisture, broad-scale soil patterns are often related to climate.

5. Biogeography: is the science of the distributions of organisms at varying spatial and temporal scales, as well as the processes that produce these distribution patterns. Local distribution of plants and animals typically depend on the suitability of the habitat that supports them. In this application biogeography is closely aligned with ecology. Over broader scales and time periods, the migration, evolution and extinction of plants and animals are key processes that determine their spatial distribution patterns. Thus, bio-geographers often seek to reconstruct past patterns of plants and animal communities from fossil evidence of various kinds.

In addition to these five main fields of physical geography, two others are strongly involved with applications of physical geography – water resources and hazards assessment.

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Lecture-2

Earth's Interior

The knowledge of the internal structure and composition of the earth has been remained a matter of great controversy among the geologists and geo-physicists. Today, there is a lot of knowledge available about the earth's interior. The most ambitious human effort to penetrate Earth's interior was made by the former Soviet Union, which drilled a super-deep research well, named the Kola Well, near Murmansk, Russia. This was an attempt to penetrate the crust and reach the upper mantle. The reported depth of the Kola Well is a little more than 7.5 miles (12 km.). The main sources for the study of earth's interior includes

1. Evidences based on Artificial Sources

a. Density: *The average density of Earth is about 5.52 g/cm^3 and the average density of Earth's crust is about $2.6 \text{ to } 3.3 \text{ g/cm}^3$.* This indicates higher density below the crust and because the acceleration due to gravity is quite uniform everywhere therefore mass is distributed uniformly in the form of concentric layers. It is estimated that the relative density of the rocks of the interior part of the earth is about 11 to 13.

b. Pressure: Pressure in itself is not responsible for the increase in density; rather the core is composed of intrinsically heavy metallic materials of high density.

c. Temperature: there is a rise of 1°C with every 32 meters of depth. This rate of increase is uniform everywhere on the earth. The temperature at the depth of 50 km should be around 1500 degree C. It is, therefore, clear that the solid layer of the Earth is a thin film over the otherwise molten material. Evidences based upon temperature indicate that middle layer exists between 1200 to 2900 km of depth. The lowest layer is considered to be 2900 to 6378 km deep.

d. Meteorites: Meteorites (hitting earth) allow us to determine the density, mineralogy and chemistry of the nickel iron core of bodies having a similar composition to that of the earth.

2. Natural sources

a. Vulcanicity: Some geologists on the basis of upwelling and spread of hot and liquid lava on the earth's surface during volcanic eruptions believe that there is at least a layer below the earth's surface which is in liquid state.

b. Evidences from Seismology: It has been experimentally proved that three types of waves are produced at the time of earthquake. These waves are also known as seismic waves. These include,

1. **Primary** (Longitudinal or Compressional or 'P') waves-to and fro motion of particles in line of the propagation of the ray. These waves can pass through both the solid and the liquid medium

2. **Secondary** (transverse or distortional or S) waves-particles move at right angles to the rays. These waves cannot pass through the liquid.

3. **Surface (Long-Period or 'L') waves:** Affect only the surface of the earth and covers the longest distance of all seismic waves. It has lower speed than P and S waves but is of **most violent and destructive nature**. These waves get reflected and refracted while passing through a body having heterogeneous composition and varying density zones at the discontinuities.

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P-wave velocity depends on the elasticity, rigidity, and density of the material. By contrast, S-wave velocity depends only on the rigidity and density of the material. In most rock types P-waves travel between 1.7 and 1.8 times more quickly than S-waves; therefore, P-waves always arrive first at seismographic stations. P-waves travel by a series of compressions and expansions of the material through which they travel. The slower S-waves, also called shear waves, move like a wave in a rope. This movement makes the S-wave more destructive to structures like buildings and highway overpasses during earthquakes. Because S-waves can travel only through solids and cannot travel through Earth's outer core, seismologists concluded that Earth's outer core must be liquid or at least must have the properties of a fluid. This proves that there are various layers of different densities and medium which split the waves in many parts. It is meant that earth is made up of various shells.

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Lecture-3

Structure of Earth's interior

The Crust: It is the outermost part of the earth. It is brittle in nature. The thickness of the crust varies under the oceanic and continental areas. The main thickness of oceanic crust is 5 to 8 km and that of continental is around 30 km. the continental crust is thicker in the areas of major mountain systems. It is as much as 70 km thick in the Himalayan region. It is made up of heavier rocks having density of 3 g/cm^3 . This type of rock found in the oceanic crust is basalt. The mean density of material in oceanic crust is 2.7 g/cm^3 .

The Mantle: The portion of the interior beyond the crust is called the mantle. It is separated from the crust by a boundary, *called Moho's discontinuity*. The mantle is about 2900 km thick. It is divided into two sections: the upper mantle and the Lower mantle. These are separated by another boundary, called *Repetti discontinuity*, after which the rocks of the mantle become soft and pliable due to pressure and heat. The upper portion of the mantle is called asthenosphere. It is the main source of magma that finds its way to the surface during volcanic eruptions. It has a density (3.4 g/cm^3) higher than the crust. The crust and upper part of mantle are called lithosphere. Its thickness ranges from 10 to 200 km.

The mantle is important in many ways. It accounts for nearly half of the radius of earth, 83 per cent of its volume and 67 per cent of its mass. The dynamic processes which determine the movement of crust plates are powered by the mantle.

The Core: The innermost layer of the earth is called the *core*. Being composed of mostly metal, it is also known as the metallic core. It is separated from the mantle by a boundary called **Gutenberg – Wiechert discontinuity**. The core is also divided into two parts- the inner core and the outer core. The inner core is a solid and is composed of iron and nickel. The density of this core is about 13 gm/cm^3 . The inner core is about 1300 km thick and is surrounded by an outer core of around 2080 km. The outer core appears to be molten. *The inner core and the outer core are separated by Lehmann or transition discontinuity.*

Chemically the earth can be divided into following layers:

1. SiAl

- ❖ Just below outer sedimentary cover.
- ❖ Composed mainly of granites
- ❖ Density- 2.9 g/cm^3
- ❖ 50 to 300 km thick.
- ❖ Rich in silica and aluminium (Silicates mainly present are those of sodium, potassium and aluminum.)
- ❖ It forms the continental layer.
- ❖ Acidic in nature

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2. SiMa

- ❖ Below SiAl
- ❖ Composed mainly of basalt
- ❖ Source of magma and lava
- ❖ Rich in silica and magnesium
- ❖ Density-2.9 to 4.7 g/cm³
- ❖ Thickness-1000 to 2000 km
- ❖ Basic in nature
- ❖ Silicate mainly present are those of magnesium, calcium and Iron.

3. NiFe

- ❖ Below SiMa
- ❖ Rich in nickel and iron
- ❖ Very high density
- ❖ Diameter of this layer-6880 km
- ❖ Indicates magnetic property of the earth's interior

Mechanical Divisions of Earth

Prof. Edward Suess divides the earth's interior into three parts

(1) **Lithosphere**: The lithosphere is the solid layer composed of the crust and the upper mantle (40 to 100 km). Its relative density ranges from 2.75 to 2.90. It is composed of Silicon and Aluminum. It is called **SIAL** by Suess. This layer is mainly composed of granite. It is divided into several large fragments called plates. It moves over Asthenosphere, which is a 100 km thick layer found at the top of the lower mantle. It is a low velocity zone (that is slow speed of seismic ways in this zone) and plastic or less viscous (softer, more pliable) in nature.

(ii) **Pyrosphere**: this is the middle layer, surrounds the core on all sides. Its relative density ranges from 2.9 to 4.75. It is composed of Silicon and Magnesium. Suess calls it **SIMA**.

(iii) **Barysphere**: It comprises core. Outer layer is liquid in state where as the inner core is solid. The rocks of this layer are composed of Iron and Nickel. The relative density of these rocks is about 11 to 13. Suess calls this layer as **NIFE**.

Discontinuities:

Many such discontinuities are expressed as follows-

1. **Gutenberg discontinuity**-Between outer liquid core and the solid mantle
2. **Mohorovicic discontinuity**-Between crust and mantle.
3. **Conrad discontinuity**-Between oceanic (Basaltic or SIMA layer) and continental (Granites or SIAL layer) Crust-Up to 30 – 40 km beneath the continents (greater depth in mountainous regions). 10 km deep beneath the oceans.

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Lecture-4

Wegener's Theory of Continental Drift

The theory of continental theory is an attempt to explain the present arrangement of continents and ocean basins. Continental drift is the large scale horizontal displacement of continents with respect to each other and with respect to ocean basins during one or more episodes of geological time.

It is worthy to mention here that though the credit for the development of continental drift goes to Alfred Wegener, there were a number of earlier scholars who also talked about continental drift in one way or the other. These scholars were Abraham Ortelius, Sir Francis Bacon, Antonio Snider Pellinerigi, F.B Taylor etc.

However the, Alfred Wegener, a German meteorologist and geophysicist is considered by most scientists to be the pioneer of the modern continental drift theory. He presented his ideas in 1912. As Wegener was a meteorologist and geophysicist, he was interested to investigate the relative distribution of land and sea and the climatic anomaly of the past and with this thing in mind he concluded about the drift of continents, which he presented in his book 'origin of continents and oceans', which was first published in German in the year 1915 and was later translated into English in 1924.

As already mentioned, the main theme of Wegener's theory was based on climatic changes reported in the past history. Wegener believed on three system of earth's layers; SIAL, SIMA and NIFE. He believed that SIAL being lighter and uppermost floats over a denser SIMA and NIFE. Assuming on the basis of paleo- climatology, paleo-botany and geology that all the landmasses were united together which he called "Pangaea" surrounded by a huge water body called "panthallassa". According to Wegener Pangaea started breaking about 300 million years ago and about 200 million years ago (Mesozoic era) first split took place, which divided the continent into two main landmasses namely Laurasia (Europe, Asia, North America and Greenland) in the north and Gondwanaland (South America, Africa, India, Australia and Antarctica) in the south. These two blocks were separated by a long shallow inland sea called sea of Tethys.

According to Wegener, again 70 million years ago, the second drift took place in which the drift was westward and equator ward to southwards. The equator ward drift was due to force of gravity and buoyancy and westwards due to tidal currents because of the earth's motion. In this drift the centrally located sea of Tethys was filled and the blocks of plates of America drifted westwards and mountain ranges of Rockies and Andes were formed with rubbing of pacific plates. Meanwhile, the peninsular India broke from Gondwanaland and was attracted towards Laurasia being larger one. So the mountain ranges of the Himalayas, Suleiman, Hindukush, Armenia, Atlas and Alps were buckled (raised) from the materials of sea of Tethys whose remaining portion still exists in the form of Meditterean Sea, Black Sea and Caspian Sea.

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The Gondwanaland's split portion of Australia moved towards east forming east mountainous region of Australia. In the same manner, Antarctica also moved southwards forming the present position of continents and ocean basins.

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Evidences in support of Continental Drift Theory

Some of the evidences that are used to support the continental drift theory are the following:

1. Like a jigsaw puzzle, there is a near perfect match of the coastlines of distant continents, such as South America and Africa.
2. Found in continents separated by oceans are identical remains of fossils of certain species of plants and animals.
3. Coal deposits in Antarctica showed that this continent has experienced warm climate. That was the time when it was part of the supercontinent Pangaea.
4. Identical rock formations were found on opposite shores of the Atlantic. This is proof that these shores were once part of the continent.
5. North and South America continue to move away from Europe at the rate of 4 cm/year. India continues to move into Asia at the rate of 5 cm/year. As a consequence, Mount Everest and the Himalayan mountain ranges grow higher by 1 cm/year.

Criticism

One of the main objections to Wegner's hypothesis stemmed from his inability to provide a driving mechanism for continental drift. Wegner proposed two possible energy sources for drift.

1. The Tidal force/influence of the moon was presumed by Wegner to be strong enough to give the continents a westward motion. However, the prominent Physicist Harold Jeffrey's quickly countered with the argument that the tidal friction of the magnitude needed to displace the continents would bring the earth's rotation to a halt in a matter of few years.
2. Further Wegner proposed that the larger and sturdier continents broke through the oceanic crust, much like icebreakers cut through ice.

However no evidence existed to suggest that the ocean floor was weak enough to permit passage of the continents without themselves being appreciably deformed in the process.

The hypothesis was criticized largely on grounds of its inability to suggest a satisfactory means of engineering continental movements. It must be conceded that the cumulative evidence supporting the theory of continental drift was massive and the theory was very attractive. If all the points in the theory could be established and an adequate motive force discovered then as Professor Shand has said, "We would have to credit prof. Wegner with the greatest piece of geological synthesis that has ever been accomplished" (1933).

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Wegner himself in response to his critics said “Scientists still do not appear to understand sufficiently that all earth Sciences must contribute evidence towards unraveling the state of our planet in earlier times, and the truth of the matter can only be reached by combining all this evidence”.

Although most of Wegner’s contemporaries opposed his views, even to the point of openly ridiculing him, a few considered his ideas plausible. Amongst the noted supporter were. Arthur Holmes (1928) contributed to the cause by proposing a plausible driving mechanism for continental drift. Since the time he first proposed, he kept on modifying his hypothesis and in his book Physical Geology (1966) he suggested that convection currents operating within the Mantle were responsible for propelling the continents across the globe.

Although, even to this day geologists are not in agreement on the exact nature of the driving mechanism, the concept proposed by Holmes is still one of the most appealing. Wegner also in 1929 suggested thermal convection currents.

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Lecture-6

Concept of sea-floor spreading

The concept of sea floor spreading was put forward by Harry. H. Hess in 1960. He was professor of the Princeton University. Sea floor spreading is the process by which crust is formed along mid oceanic ridges. This concept of sea floor spreading made continental drift a fact. Until 1950's, the evidences regarding continental drift were obtained from the continents only, but after 1950's the scientists from different fields obtained observations from the ocean basins and it led a revolution in science. Number of investigations, experiments and observations were made from the ocean floor. On the basis of these observations Harry. H. Hess gave his concept of sea floor spreading but it was already given by Arthur Holmes in his concept of convection current cells (CCC) in 1930.

Harry. H. Hess was impressed by two observation of sea floor spreading obtained by marine geologists, geo-chemists, geophysicists etc. these are

1. All the oceans have a common feature i.e. they have mid oceanic ridges except north-west pacific. Which are continuous and run for about 60000 kms across all the world oceans.
2. The oceanic crust is much less thick only (7kms) than the continental crust (35-40kms).

Harry. H. Hess postulated that hot and molten material (due to CCC) from the mantle of the earth comes up continuously through the cracks centered at the mid oceanic ridges. The molten material spreads on both sides of ridges, cools down and solidifies and forms new basaltic crust. As the process of volcanic activity is continuous, the molten material comes up continuously pushing again and again far apart the oceanic crust along mid oceanic ridges and forming new basaltic crust and the process goes on. So much younger and younger oceanic crust is being formed. It leads the movement of oceanic floor i.e. basaltic oceanic crust which lies under the granitic continental crust. So, continents and ocean basins are moving and are not permanent. Here, we come to know that as the sea floor is being formed continuously in all the oceans and the earth's surface area is expanding. Areas in which new crust is being formed along mid-oceanic ridges by rising of magma are called spreading centers. The spreading rate along mid oceanic ridges is 1cm/year.

Hess proposed: -

1. Ocean ridges are located above upwelling portions of large convection cells in the mantle.

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2. As rising material from the mantle spreads laterally, Sea floor is carried in a conveyer belt fashion away from the ridge crest.

3. Tensional tears at the ridge crest produced by diverging lateral currents provide pathway for magma to intrude and generate new oceanic crust. Thus, as the sea floor moves away from the ridge crest, newly formed crust replaces it.

4. He further proposed that the downward limbs of these convection cells are located beneath the deep ocean trenches. Here, according to Hess, the older portions of the sea floor are gradually consumed as they descend into the mantle. As one researcher summarized “No wonder the ocean floor was young it was constantly being renewed”.

Evidences in support of sea floor spreading

1. Occurrence of earthquakes along the crust of the mid oceanic ridges.
2. The dearth of sediments at the crust of mid oceanic ridges and active volcanic islands like Iceland and Canary islands.
3. Thickness of sediments increases away from the mid oceanic ridges.
4. There is reversal in the main magnetic field of the earth known as magnetic di-pole (magnetic field).
5. The normal and reverse magnetic anomalies are found in alternate manner on either side of mid-oceanic ridges.

Inferences

1. There is continuous spreading of sea floor.
2. The basaltic crust is continuously formed along mid oceanic ridges.
3. The newly formed basaltic layer is divided in to two equal halves and thus displaced from the mid-oceanic ridges.
4. Alternate strips of positive and negative anomalies are found on either side of mid-oceanic ridges.

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Lecture-7

Theory of plate tectonics

Meaning & Concept:-

The word Tectonic is derived from Greek word 'tekton' means 'builder' applied to all internal forces which build up or form the features of the earth crust, including both Diastrophism and vulcanicity.

The rigid lithospheric slabs or rigid and solid crustal layers are technically called Plates.

The study of whole mechanism of evolution, nature and motions of plates, deformation within plates and interactions of plates margins with each other is collectively called as Plate tectonics. Plate tectonics tells us that it is not only the continents that are in motion, but the ocean as well. This is so because the top crust of the earth is not an unbroken shell of granite and basalt, but a mosaic of several rigid segments called plates. In other words, the whole process of plate motion and resultant deformation is referred to as plate tectonics. These plates include not only the earth's solid upper crust, but also parts of the denser mantle below. They have an average thickness of hundred kilometers. They float on the plastic upper mantle of the earth called Asthenosphere and carry the continents and oceans on the backs like mammoth rafts.

The term "plate" was first used by Tuzo Wilson of the University of Toronto in 1965. Mechanize of Cambridge and Parker of America in 1967 arrived at certain conclusion similar to Wilson and gave the concept of plate tectonics. On the other hand, Morgon (1967) of Princeton University was working on the same issue, gave this concept independently. Some books wrote Morgon was the person who firstly gave this concept of plate tectonics.

Finally it was Le-Pichan in (1973) who gave a detailed history of the concept of plate tectonics on the basis of the studies of others. He only presented it in a collective form. He made a statement which is the central theme of plate tectonics.

"Lithosphere the outer shell of earth, consists of number of rigid plates which are in relative motion".

This statement has two parts one referring to plates called geometric part and the other referring to tectonics called as kinematic part.

Geometric part

Lithosphere comprises of crust and upper mantle, resting on plastic plasmic layer called asthenosphere. It is made up of mosaic of plates.

Plates are:-

- Rigid (they are hard).

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- Can be of any size (different sizes).
- Can be of any nature, either completely continental, completely oceanic or partly continental and partly oceanic.

These plates does not go through any kind of deformation. There does not take place any kind of activity such as volcanic or seismic. The activities occur along the edges of the plates which are weaker parts called plate margins (collectively called plate boundaries). Two plate boundaries meet at a common plate boundary.

There are seven major plates and more than twenty minor plates.

Major plates:

1. African Plate. 2. North American Plate. 3. South American Plate. 4. Antarctica Plate. 5. Australian Plate. 6. Eurasian Plate. 7. Pacific Plate.

Minor Plates

1. Arabian Plate. 2. Bismark Plate. 3. Caribbean Plate. 4. Carolina Plate. 5. Cocos Plate. 6. Juan De Fuca Plate. 7. Nazca or East Pacific Plate. 8. Philippines Plate. 9. Scotia Plate. 10. Persian Plate. 11. Anatolian Plate. 12. China Plate.13.Fiji Plate. Etc.

Kinematic part

This part states that plates are in constant relative motion. These plates can undergo three possible movements.

1. Move away from one another.
2. Move towards one another.
3. Slide past one another.

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Lecture-8

Plate margins or Boundaries & Earth movements

It may be highlighted that tectonically plate boundaries or plate margins are most significant because all the tectonic activities occur along plate margins e.g., seismic activities, vulcanicity, mountain building and faulting etc. There are three types of plate boundaries on the basis of direction of their movement with relation to each other.

- i) Convergent plate boundaries.
- ii) Divergent plate boundaries.
- iii) Transform plate boundaries.

Along these boundaries various kinds of tectonic features are formed. They are discussed in the following lines.

Convergent plate margin : are also called as ‘destructive plate margins’ or ‘consuming plate margin’ because two plates moves toward each other (face to face) or two plate converge along a line and collide where in leading edge of one plate (of relatively lighter material) overrides the other plate (of relatively denser material) and the overridden plate is subducted or thrust into upper mantle and thus a part of the crust is lost in the mantle, this is why the convergent plate margin is called as destructive plate margin and also called as collision zone or Subduction zone or Benioff zone (after the scientist Hugo Benioff).

The following Important geological phenomenon takes place along the convergent boundary.

- i) Occurrence of volcanic activity in the oceanic area near the trench. For example ring of fires in Pacific Ocean.
- ii) Formation of seas and island i.e. seas in Pacific Ocean including Japan, Philippines etc.
- iii) Earthquakes occurrence; and
- iv) Formation of Fold Mountains and trenches.

Divergent Plate Margin:- also called as constructive plate margin or accreting plate boundaries. Through this passage of fracture, molten materials are up welling and deposited both sides of the fracture. Such margins occur usually in ocean and along the mid-oceanic ridges. Along the mid-oceanic ridge especially in Atlantic Ocean, due to deposition of new ejected molten material, new oceanic floor is created. The creation of new ocean floor is described as ocean floor spreading. Hence the divergent margin is also called as constructive margin as new crust is formed. The following events are associated along this margin.

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- i) Formation of rift or fracture
- ii) Upwelling of molten materials from the mantle.
- iii) Formation of ocean floor spreading.
- iv) Occurrence of fissure type volcanic eruption.

Transform Margin:- are also called as conservative plate margin or shear plate margins and parallel/ transform fault boundaries where two plates are moving a part in opposite direction from a common line. These are called conservative because crust is neither created nor destroyed. All the plates from two sides (both converging and diverging plates) moves parallel to each other and slide along common margin. Such margin is called as Transform margin because transform fault is formed. Plates in this process may join ridge to ridge, a ridge to trench or a trench to trench. A ridge trench transform will always change length with time, A trench to trench transform may either lengthen, shrink or remain constant depending on which of plates, that form of subduction system, is the down going plate and the transform which join two ridge will change in length with time.

The following events taking place along the transform plate margin.

- i) Formation of Transform Faults.
- ii) Earthquakes.

The conservative plate margin includes no volcanic activities, Seismic events, creation of ridges and valley, fracture zone etc.

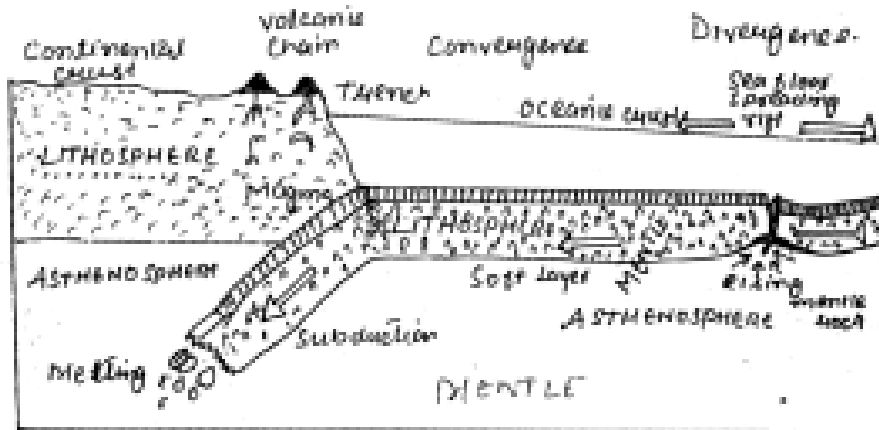


Fig. Diagrammatic presentation of different types of plate margins.

Evidences in support of plate tectonics

The following evidences prove the theory. These are

1. Older rocks form the continents while younger rocks are present on the ocean floor. On continents, rocks of up to 3.5 billion years old can be found while the oldest rock on the ocean floor is not more than 75 million years old. As we move towards ridges, still

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younger rocks appear. This points to an affective spread of sea floor along oceanic ridges which are also the plate margins.

2. The normal temperature gradient on the sea floor is $9.4^{\circ}/300$ meter but near the ridges it becomes higher, indicating an upwelling of magmatic material from the mantle.
3. In trenches, where subduction has taken place (convergent edge), the value of gravitational constant "g" is less. This indicated a loss of material.

For instances gravity measurements around the Indonesian islands have indicated that large gravity anomalies are associated with the oceanic trenches bordering Indonesia. The mass deficiency which caused this negative gravity anomaly can be explained by the lighter earth's crust being pulled down into the mantle by sinking convection currents.

4. The orientation of iron grains on older rocks (for instance, investigation revealing, such an evidence on the ocean floor south west of Iceland in 1960s) shows an orientation which points to the existence of south pole, once upon a time, somewhere between the present day Africa (natal island) and Antarctica.

The fact that all plate boundary regions are areas of earthquake and volcanic disturbances goes to prove the theory of plate tectonics.

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Mechanism of plate tectonics

Whatever be the motion of plates, an enormous amount of energy is required to move the plates. A number of attempts were made to measure the energy required to move the plates. Leon and Knoff were of the opinion that about 10^{26} ergs of energy is required to move the plates per year. Where from such huge amount of energy comes continuously.

Some possible reasons which contribute to it are:-

- According to Kirchoff due to decay of radioactive elements like uranium, thorium, strontium, gallium, radium etc. present in the asthenosphere, a huge amount of energy is released, it is everlasting source of energy.
- Gravity model also explains the plate motion. According to it everything having mass has gravity (so earth) which gives rise to push and pull effects which cause the movement of plates. During rising of magma, the plates are pushed along mid oceanic ridges, on the other side plates converge and get sub-ducted. As it is sub-ducted, the earth's gravity is highest pulls it and it gets in to mantle. So plates move in this way.
- Mechanize and Knoff gave the concept of hotspots to explain the plate tectonics, whenever there is change in phase energy is generated inside the earth.

Huge amount of radiogenic heat generates convectional currents. As the temperature inside the earth is very high the lower part of the mantle material gets heated and rises upwards and strikes the crust. If the crustal material is weak it comes as a volcano and if it is hard it gets deflected right and left and moves plates in the direction of deflection. It cools down after moving some distance and goes down into mantle again and this process is continuous. And where it hits the lithosphere divergence occurs and where it moves down convergence occurs.

- Tidal force are also responsible for plate movements. The gravitational pull of heavenly bodies like sun and moon generates this tidal force.

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Lecture-10

Concept of Isostasy

The term isostasy has been derived from two Greek words “iso” and “statis”, iso means equal and statis meaning standing. Thus this means the tendency of the earth’s crust to attain equilibrium or simply a state of equal balance. This concept of isostasy was first proposed by an American geologist Dutton in 1889. Later many other geologists made a lot of contribution to the development of this concept. The most reputed geologist who worked on this concept of isostasy were Airy, Pratt, Hiscenman and Jolly.

The concept of isostasy is based on the principle of buoyancy first outlined by Archimedes.

“Buoyancy is the ability of an object to float in a fluid by displacing a volume of that fluid equal in mass to floating objects own mass”.

Based on Archimedes principle Dutton observed that earth is made of two kinds of landmasses one are elevated ones and the other are depressed parts have an equal density and float on the molten layer called asthenosphere. The elevated areas extend deeper into the asthenosphere because of their higher elevation and the depressed areas do not go deeper into the asthenosphere because of their confined size. Therefore a balance is thought to exist in all the elevated and depressed parts of the earth. This balance is termed as isopiesitic balance and the phenomenon is known as isostasy. This balance is upset due to erosion, weathering, mass wasting, land-sliding, deposition of sediments, melting of glaciers or accumulation of snow.

This isopiesitic balance is always maintained by the earth through the process of either elevating a part of it or subsiding a part of it causing vertical movements.

Airys concept

Sir. B. George airy, a geologist and astronomer of Royal society of USA, put forward his opinion on Duttons theory of isostasy in (1851-1892). According to Airry, the continental blocks or lithospheric blocks are lighter and of same density. These crustal blocks have different surface area. Airry pointed out the example of Indian Himalayas and the Gangantic plains and observed these crustal blocks have similar density and different surface area are floating on, a semi-solid, semi-liquid , mobile in character mantle or simply asthenosphere.

Airy based his theory on the simple law of floatation. He quotes the example of ice-bergs and explained that one part of the ice-berg is seen above the surface of water and nine parts below the surface of water (Archimedes principle 1:9). Airry derived the same principle on crustal blocks and so said all the crustal blocks are floating on SIMA (mantle or asthenosphere) corresponding to the proportion of sinking explained in Archimedes principle. The Mount Everest is 9 km above the sea level but it is about 80 kms sunk into SiMa leading to the process of root formation for attaining equilibrium, balancing in such a way is known as hydrostatic balance. Airry demonstrated the following experiment in support of his theory. He

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brought a trough filled with water and floated wooden blocks of equal density but of unequal surface area and observed that higher in elevation the blocks deeper into the water and lower in elevation the block lower sunk into the water in such a way to stand equally attaining equilibrium.

Pratts theory of Isostasy

J. H. Pratt formulated his hypothesis on isostasy in 1898. He was professionally a physicist and was interested in geology he worked as a professor of physics at Chicago University USA for about 19 years, but retired on account of ill health at the age of 48 years. After retirement he vigorously worked on the Dutton's concept of isostasy. According to Pratt the earth consists of several crustal blocks of different density. It is the density of these crustal blocks which determines the height and expansion of these crustal blocks. Pratt proposed that higher and more expanded crustal blocks consist of the material of higher density. According to Pratt, mountains, plains and plateaus are the crustal blocks of lighter density. These mountain blocks have lower density than plains and plateaus. All those crustal blocks of different density float on a viscous layer known as SiMa (asthenosphere).

He rejected the concept of Airy for equal standing of crustal blocks based on the law of floatation. Pratt based his concept on the law of compensation. According to him the law of compensation proposed by Hickman, Bowe, and Holmes. When the crustal blocks of different densities are floated on a viscous liquid upto a uniform depth. But the height of crustal blocks above the level of viscous liquid will inversely vary proportional to their height. This is why we find relief features of diverse height on earth.

However he does not agree with the Airy's concept of root formation. Pratt illustrates his concept with the help of an experiment Pratt floated different blocks of platinum, zinc, iron and lead in a trough (jar filled with mercury). All these blocks have different density, such as platinum (21.5), lead (11.4), zinc (7.1) and iron (7.4). These blocks were floated on the viscous mercury of density (26.5) on floating these blocks Pratt observed that these blocks sink in to the mercury to a uniform depth and their height above the mercury level was different. Pratt concluded that the crustal blocks are in the same way standing on asthenosphere.

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Lecture-11

Definition and nature of earthquake.

Earthquakes are the most prominent evidence of present day earth movements. An earthquake is a vibratory motion of the ground surface, ranging from a faint tremor to wild motion capable of shaking buildings apart. In other words, an earthquake is a form of energy of wave motion transmitted through the surface layer of the earth in widening circles from a point of sudden energy release, the focus. The point within the earth where earthquakes are generated is called **focus or hypocenter**. The point on the earth's surface directly or vertically above the focus is called the epicenter and experience the seismic event first. The science of studying earthquakes is known as **seismology**. Hence, all the phenomena related to the emergence and manifestation of earthquakes are called seismic. The magnitude or energy released by an earthquake is measured with the help of **Richter Scale**. Its values range from 1 and 09. Elastic Rebound Theory explains the mode and cause of earthquake.

Earthquake waves or seismic waves

Earthquakes generate pulses of energy called **seismic waves**. Four types of earthquake waves are found. Three were discovered by **R. D Oldham** and one later, by **Augustas E. H. Love**. Basically, they may be divided into two chief kinds of seismic waves:

1. Body waves

2. Surface waves.

1. Body Waves: The fastest seismic waves, move through the earth. Slower surface waves travel along the surface of the earth. Body waves tend to cause the most earth-quake damage. There are two kinds of body waves:

(I). *P-waves/ Compressional/ longitudinal waves*

(II). *S- waves/ Transverse/ Shear waves.*

(I). P-waves/ Compressional/ longitudinal waves

As the waves pass through the earth, they cause particles of rock to move in different ways. Compressional waves *push and pull* the rock. They cause buildings and other structures to contract and expand. Compressional waves can travel through **solids, liquids, or gases**. Compressional or longitudinal waves are the fastest seismic waves, and they arrive first at a distant point. For this reason, compressional waves are also **called primary (P) waves**. They have shortest wavelength among the four. Their velocity is 5 to 12 km/sec. They can travel through liquids (outer core) and solids (crust, mantle and inner core) but travel faster in denser solid media. These waves are like **sound waves** and cause any rock in their path to compress and then expand in the same direction as the waves are traveling. Primary waves undergo refraction and reflection at the margin of earth's outer lighter shell and inner dense core.

(II). S- waves/ Transverse/ Shear waves.

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Secondary or S waves which are of medium wavelength and high frequency, are also *called Shake or Shear waves*. Shear waves make rocks bend or slide from side to side, and buildings shake. Shear waves, which travel slower and arrive later, are called *secondary (S) waves*. Shear waves also called as transverse waves travel through all solid parts of earth but not the liquid part of the core. It is also called *distortional wave*. Their velocity is about 3 to 4 km/sec.

2. Surface Waves or L - Waves: are long and slow waves. They are of long wavelength and low frequency. These are confined to the skin of the earth's crust, thereby, causing most of the earthquake structural damage. These waves cover the longest distance of all seismic waves. There are two kinds of surface waves: Love waves and Rayleigh waves.

Love waves, named after A.E.H Love in 1911, travel through the earth's surface horizontally and move the ground from side to side. Typical Love waves travel at about 4.4 kilometers per second.

Rayleigh waves, named after Lord Rayleigh in 1885, makes the surface of the earth roll like waves on the ocean. *Rayleigh waves, the slowest of the seismic waves*, move at about 3.7 kilometers per second.

Causes of earthquakes

Earthquakes may arise for a variety of reasons. Some tensional earthquakes clearly arise from faulting. Some others arise due to converging hard lithospheric converging plates. Others may result from tearing of the lithosphere under high pressure.

Types of earthquakes on the basis of cause:

In accordance with the factors or causes conditioning them, earthquakes can be divided into three main types:

(i) Volcanic Earthquakes

These are connected with the processes of volcanism. They develop only in the regions of contemporary volcanic activity. They emerge as a result of deep explosions of gases, emitted from the magma and hydraulic shocks of magma. But there are many places where there are no signs of volcanoes but are visited by earthquakes. Hence, volcanic activity can be considered to be a local cause of volcanic activity. The earthquake caused by Krakatao (1883) and Katmai (1912) were experienced only at a small distance from the volcanic areas.

(ii) Denudational Earthquakes

They result from the collapses of considerable masses of rocks, mainly in mountainous region. They are also called earthquakes due to collapse. For example earthquakes due to large landslides or sinking of underground karst caves.

(iii) Tectonical Earthquakes

Earthquakes belonging to this group are characterized by maximum force and account for **95 per cent** of all the earthquakes that are registered. These earthquakes result due to the displacement or dislocation of individual blocks of lithosphere due to short relaxation of

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mechanical stresses that have continuously been accumulated on them. This is best explained by the Elastic Rebound Theory.

Types of earthquakes on the basis of depth/focus.

Depending on the depth (focus) at which they emerge, earthquakes are classified as:

- (i) **Surface Earthquake:** Earthquakes having a focus at the depth *of upto 10 kms* are known as surface earthquakes.
- (ii) **Normal earthquakes:** Earthquakes having a focus at the depth of *10 to 70 kms* are known as normal earthquakes.
- (iii) **Intermediate Earthquakes:** Their depth /focus ranges from *70 to 300 kms*. They accounts for about *18 per cent* of the total earthquakes.
- (iv) **Deep focus earthquakes:** Their depth of focus *exceeds 300 kms*. They are very inconsiderable and are mainly recorded within the confines of Far East. The focus of Deep-Focus earthquakes is placed at 760 km.

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Lecture-12

Measurement of Earthquakes

There are many scales devised for the measurement of earthquake intensity. Out of these Mercalli and Richter are most well-known.

1. Richter scale: Probably the best-known gauge of earth-quake intensity is the local Richter magnitude scale, developed in 1935 by United States seismologist *Charles Francis Richter*. This scale, commonly known as the Richter scale, measures the ground motion caused by an earthquake. It is a logarithmic scale that runs from 0 to 9, though no upper limit exists. There are about 10 times as many quakes for every decrease in Richter magnitude by one unit. For example, a magnitude 7 quake is 10 times more powerful than a magnitude 6 quake, 100 times more powerful than a magnitude 5 quake, 1000 times more powerful than a magnitude 4 quake, and so on. Until 1979 an earthquake of magnitude 8.5 was thought to be the most powerful possible; since then, however, improvements in seismic measuring techniques have enabled seismologists to refine the scale, and 9.5 is now considered to be the practical limit. Every increase of one number in magnitude means the energy release of the quake is 32 times greater. For example, an earthquake of magnitude 7.0 releases 32 times as much energy as an earthquake measuring 6.0. The largest earthquake ever recorded on the moment magnitude scale measured 9.5. It was an inter-plate earthquake that occurred along the Pacific coast of Chile in South America in 1960.

2. Mercalli Scale: It is a qualitative scale. Hence it is not considered to be accurate from the point of view of scientific measurement. Its scale is dependent upon the experiences gained by human sensory organs and the devastating effects of the earthquakes. It was introduced in 1800's by the Italian seismologist Giuseppe Mercalli, measures the intensity of shaking with gradations from I to XII. Intensity I on this scale is defined as an event felt by very few people, whereas intensity XII is a catastrophic event that causes total destruction. Intensities II to III on the Mercalli scale are roughly equal to magnitudes 3 to 4 on the Richter scale, and XI to XII to 8 to 9.

Distribution of earthquakes/ seismic zones of the world

The observation of earthquakes that have been made in course of time has provided an opportunity for the scientists to single out the seismic zones of the world. Earthquakes are mainly felt in the following seismic regions.

(i) The Circum-Pacific Seismic Belt

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This belt is also called as Ring of Fire and corresponds to approximately 68 per cent of all the earthquakes. It has been found that 80 per cent of shallow, 90 per cent of medium and all the deep focus-earthquakes originated in this belt. It includes the western coast of North and South America, the Aleutians, Kamachatka, the Kurilis, Japan, the Philippines and a strip through the East Indies to New Zealand.

(ii) The Mediterranean or Alpine and Trans Asiatic Belt

This seismic zone accounts for **21 per cent** of all the earthquakes. This belt is characterized by larger earthquakes of shallow origin and some of the intermediate origin. This belt extends along the Alpine mountain system of Europe and North Africa, through Asia Minor and the Caucasus, Iran and Pakistan to the Himalayan mountain system including Tibet, the Pamir and China.

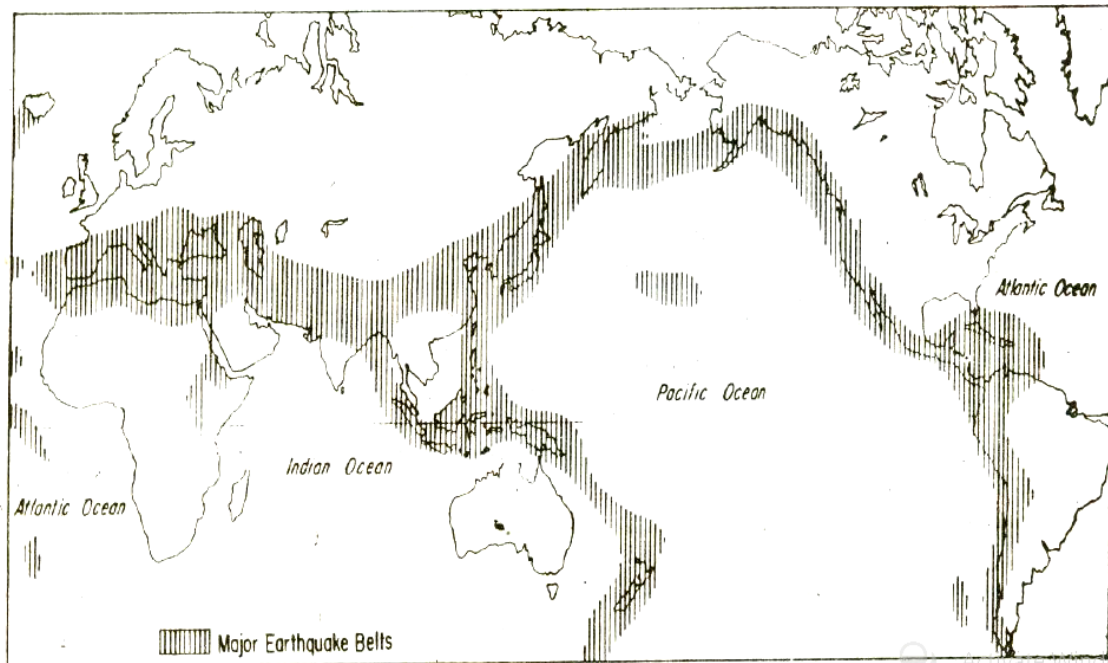
(iii) The Atlantic Belt

This belt runs from north to south through the middle of the Atlantic Ocean. It contains mostly the earthquakes of shallow origin. These constitute major fracture zones where the plates diverge and new oceanic crust is being formed by the up welling of magma on the mid-ocean ridges.

Earthquake distribution in India

In India, the earthquake region is connected with the Himalayas. The region follows the junction of Tertiary rocks with the older rocks. The most important earthquake areas of India are

- (i) Zone of maximum Intensity -- The Himalayan Region
- (ii) Zone of Minimum Intensity – The Northern Plain Region



- (iii) Zone of Less Intensity – The Peninsular Region

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Environmental implications of earthquakes

A. Disadvantages

- (i) Landslides swamps fields and houses in the hilly regions.
- (ii) Earthquakes results in emergence and subsidence of land.
- (iii) Earthquakes cause great damage to buildings, roads, railways, dams, bridges etc. it becomes difficult to send supplies to the victims.
- (iv) The rivers are dammed. It creates floods which inundates fields, towns etc.
- (v) Fires are caused in the areas of earthquakes.
- (vi) Glaciers are breached and their avalanches scatter to far off places.
- (vii) Underground water is also affected. Lakes and swamps are created at many places.
- (viii) The water recedes from the sea ports under the influence of earthquake waves.

B. Advantages

- (i) New waterfalls and streams are created on the account of the disturbances of the underground water.
- (ii) Due to submergence of sea bottoms, deep gulfs are formed.
- (iv) New soil is formed due to breakdown of rocks.
- (v) New mineral areas are uncovered.
- (vi) Rivers adopt new courses that are fruitful for agriculture.