



Distance Learning Programme

UPPCS Mains

World Geography





drishti

WORLD GEOGRAPHY


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Interior of the Earth

Study of interior of earth is generally undertaken by geologists and specialists in Earth Science. Our current information comes from studies of the paths and characteristics of earthquake waves travelling through the Earth, as well as from laboratory experiments on surface minerals and rocks at high pressure and temperature. Other important data on the Earth's interior come from geological observation of surface rocks and studies of the Earth's motions in the Solar System, its gravity and magnetic fields, and the flow of heat from inside the Earth. Most of the knowledge about the earth's interior is largely based on indirect sources. Yet, a part of the information is obtained through direct observations and analysis of materials.

Direct Sources

Direct sources include rock materials from mining areas and molten magma from volcanic eruptions. Surface rock or the rocks we get from mining areas such as gold mines in South Africa are as deep as 3-4 km. Besides, scientists are working on "Deep Ocean Drilling Project" and "Integrated Ocean Drilling Project". The deepest drill at Kola, in Arctic Ocean, has reached a depth of 12 km. These projects have provided information about interior of Earth through analysis of materials collected at different depths.

Indirect Sources

Evidence from Meteorites

Meteorites from asteroids and even from other planets help scientists understand all planets in our solar system, particularly the processes taking place deep inside. Although no one has ever been to the center of Earth, we know from meteorites that Earth has a center, or core, made of nickel and iron metal. The other planets have metal cores as well. During planetary formation, metal sinks to the center of the body, while lighter material formed a rocky crust and mantle around the outside.

Evidences from Temperature, Pressure and Density of Earth's Interior

The temperature increases towards the centre of the earth and the rate of increase of temperature is not uniform from the surface towards the earth's centre. In the beginning, this increase is at an average rate of 10°C for every 32 meters increase in depth. At such a constant rate of increase in temperature the earth's interior should be in a molten state. Yet it is not so because the rocks buried under the pressure of several kilometer thickness of overlying rocks melt at higher temperature than similar rocks at the surface. The pressure near the centre is considered 3 to 4 million times the pressure of atmosphere at sea level. The molten material under tremendous pressure conditions acquires the property of a solid and is probably in a plastic state. Due to increase in pressure and presence of heavier

materials towards the earth's centre, the density of earth's layers also goes on increasing. Hence, the materials of the innermost part of the earth are very dense.

Evidences from Seismology (Indirect Source)

Seismic waves are the waves of energy caused by sudden breaking of rocks within the earth or an explosion. They are the energy waves that travel through the earth and are recorded on seismographs. Study of seismic waves provides complete picture of composition of the earth.

These waves are of two types – body waves and surface waves:

- **Body Waves:** Body waves are generated due to the release of energy at the focus and move in all directions travelling through the body of the earth. Body waves consist of Primary Waves (P-waves) and Secondary Waves (S-waves).

- **Primary Waves (P-waves):** P-waves are first to arrive at the surface as they are fastest. The waves are similar to sound waves (longitudinal wave). They travel through gaseous, liquid and solid materials. P-waves cause rocks to squeeze and stretch.

- **Secondary Waves (S-waves):**

S-waves can travel only through solid materials. This characteristic of the S-waves has helped scientists to understand the structure of the interior of the earth. S waves cannot pass through liquids, as they get absorbed. They are slower than P-waves and transverse in nature.

- **Surface Waves:** When body waves interact with surface rocks new set of waves are generated which are called surface waves. The surface waves are restricted to the earth's surface. These waves are more destructive. They cause displacement of rocks, and hence, the collapse of structures occurs. These waves are of two types – Love waves and Rayleigh waves.

- **Love Waves:** Love wave causes surface motions similar to that of S-waves, but with no vertical component.

- **Rayleigh Waves:** Rayleigh wave makes a material particle oscillate in an elliptic path in the vertical plane (with horizontal motion along direction of energy transmission).

- **Concept of Shadow Zone:** In geophysics, the refraction or reflection of seismic waves is used for research into the structure of the earth's interior; these waves are refracted, reflected and absorbed when it passes through earth's interiors. There is a change in velocity and course of the waves on crossing the boundaries of different zones inside the earth which are recorded by seismograph giving some idea about earth's interior. There are specific areas on the earth surface where waves do not get recorded on the seismograph; such zones are called as shadow zones. The seismographs located beyond 145° from epicenter, record the arrival of P-waves, but not that of S-waves. We can recall that S-waves can only travel through solid medium. This indicates that interior

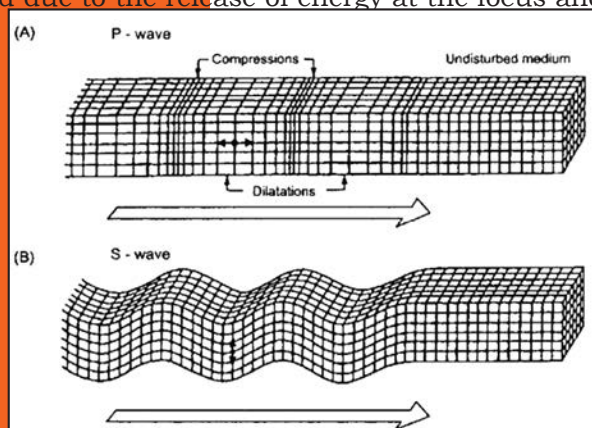


Fig: P and S Waves

of earth has different mediums. A zone between 105° and 145° from epicenter was identified as the shadow zone for both the types of waves. The entire zone beyond 105° does not receive S-waves. The shadow zone of S-wave is much larger than that of the P-waves.

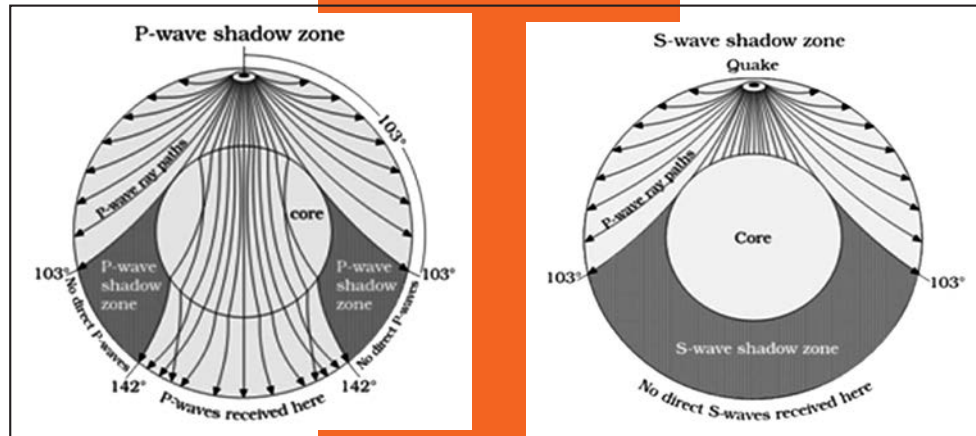


Fig: Earthquake Shadow Zones

Composition of the Earth

The interior structure of the Earth is layered like spherical shells, just like an onion. The shadow zones identified along with curving of the seismic waves helps in identification of three different layers of earth's interior. Earth has an outer silicate solid crust, a highly viscous mantle, a liquid outer core that is much less viscous than the mantle, and a solid inner core.

Crust

The crust ranges from 5-70 km in depth and is the outermost layer. The thin parts are the oceanic crust, which underlie the ocean basins (5–10 km) and are composed of dense (mafic) iron magnesium (Mg) silicate igneous rocks, like basalt. This is known as SIMA (Silica + Magnesium). The thicker crust is continental crust, which is less dense and composed of (felsic) sodium, potassium, aluminium and silicate rocks like granite. This is known as SIAL (Silica + Aluminium). Crust can be divided into two parts: upper crust (up to 30 km) and lower crust (30 to 70 km) based on the velocity of P waves, which suddenly increases in lower crust. The change in density is responsible for change in the speed of P waves.

Mantle

The mantle is composed of silicate rocks that are rich in iron and magnesium relative to the overlying crust. Crust mantle boundary is called the Mohorovicic discontinuity or Moho. The mantle is composed of silicate rocks that are rich in iron and magnesium relative to the overlying crust. Earth's mantle extends to a depth of 2,890 km, making it the thickest layer of Earth. The upper mantle is divided into the lithospheric mantle and the asthenosphere. The upper and lower mantle is separated by the transition zone. The lowest part of the mantle next to the core-mantle boundary is known as the D layer.

Core

The earthquake wave velocities helped in understanding the existence of the core of the earth. The core mantle boundary is called Gutenberg Discontinuity located at the depth of 2900km. The core is divided into two parts, a “solid” inner core with a radius of ~1,220 km and a liquid outer core extending beyond it, to a radius of ~3,400 km. Hence, the Inner core exists from 5150 km to 6400 km. The density of material at the mantle core boundary is around 5 g/cm³. At the centre of the earth at 6,300 km, the density value is around 13 g/cm³. The inner core is made up of very heavy material mostly constituted of Nickel and Iron, known as **NIFE**.

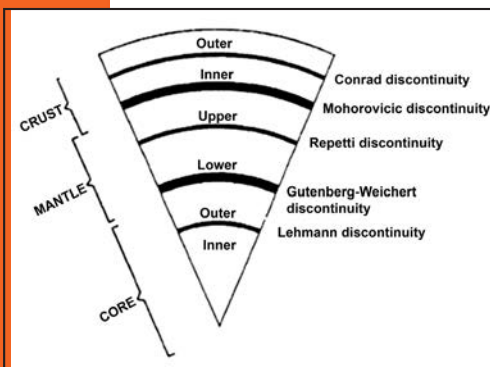


Fig: Discontinuities

| Discontinuities | Between Layers |
|-----------------|-------------------------------|
| Conrad | Continental and Oceanic Crust |
| Mohorovicic | Crust and Mantle |
| Repetti | Upper and Lower Mantle |
| Gutenberg | Mantle and Outer Core |
| Lehmann | Outer and Inner Core |

Geomorphic Processes

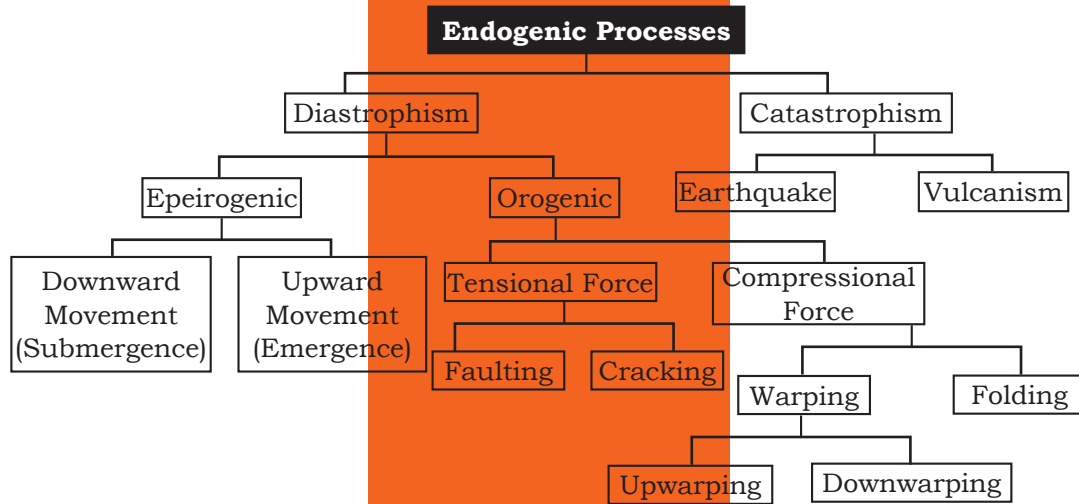
It is a natural process through which the endogenic and exogenic forces causing physical stresses and chemical actions on earth materials bring about changes in the configuration on the surface of the earth. It can be either endogenetic/endogenic processes or exogenetic/exogenic processes.

Exogenetic Processes

The exogenetic process derive their energy from atmosphere determined by the ultimate energy from the sun and also the gradients created by tectonic factors. Weathering, mass wasting, erosion and deposition are exogenic geomorphic processes which are later discussed in unit 5 of this Booklet.

Endogenetic/Endogenic Processes

The geomorphic processes which are caused by the energy emanating from within the earth are called endogenic geomorphic processes. This energy is mostly generated by radioactivity, rotational and tidal friction, and primordial heat from the origin of the earth. Endogenic processes are outcome of endogenic forces. Due to variations in geothermal gradients and heat flow from within, crustal thickness and strength, the impacts of endogenic process are not uniform and hence the tectonically controlled original crustal surface is uneven. Endogenic processes are further classified into diastrophism (Slow processes) and catastrophism (Sudden processes).



Diastrophism

All processes that move, elevate or build up portions of the earth's crust are known as diastrophism. This is slow process acting over a long period of time and produces landform of higher magnitude and amplitude. They are classified into two groups.

- **Epeirogenic Processes:** It involves uplift or warping of large parts of the earth's crust. It is known as continent building process. Endogenetic force in this process acts along vertical section from earth's centre to the surface. **Emergence** and **submergence** of the coastline are two important impacts of the epeirogenic process. Eastern coast of India is emergent coast while that of western coast is submergent coast.
- **Orogenic Processes:** The geomorphic processes which involve mountain building through severe folding and affect long and narrow belts of the earth's crust is called orogenic processes. It acts along the horizontal axis and they are responsible for Fold Mountains as well as oceanic ridges. These movements are more localized in comparison to epeirogenic, and involve tangential forces i.e. horizontal movement, resulting in **compression** and **tension** of the crust. Orogenic movements occur in episodes, widely spaced in geologic time and, world-wide in extent. During the long intervals between two consecutive periods of orogeny, the earth's crust remains stable or subject to slow epeirogenic uplift or subsidence. **Folding**, **faulting** and **continental drift** constitute horizontal movements.

Folding

Wave like bends are formed in crustal rocks due to the tangential compressive force resulting from horizontal movement caused by the endogenetic force originating deep within the earth. Such bends are called 'folds' where in some parts are bent up and some parts are bent down. The up folds are termed anticlines (crests) and the down folds the synclines (troughs).

Fold Mountains

These mountains are result of large scale earth movements under stress sets in the earth's crust. Stress lead to generation of compressive forces that produce folding along

the lines of weakness. These mountains are also rich storehouse of minerals including tin, copper, gold and petroleum. All the major mountain systems of the world including Himalayas, Alps, Andes, and Rockies etc are young fold mountains.

Faults

When the crustal rocks are displaced due to tensional movement caused by the endogenetic forces along a plane the resultant structure is called a fault. The different types of faults are:

Normal Fault

If the displacement of the rock blocks is down to the direction of the dip then the resultant fault is called Normal fault. Normal faults are formed due to the displacement of both the rock blocks in opposite directions due to tensional force.

Reverse Fault

Reverse faults are formed due to the movement of the fractured rock blocks towards each other. In reverse faults, the rock beds on the upper side are displaced up the fault plane relatively to the rock beds below. During the reverse faulting the horizontal stress is maximum on the rock, while the vertical Stress is minimum.

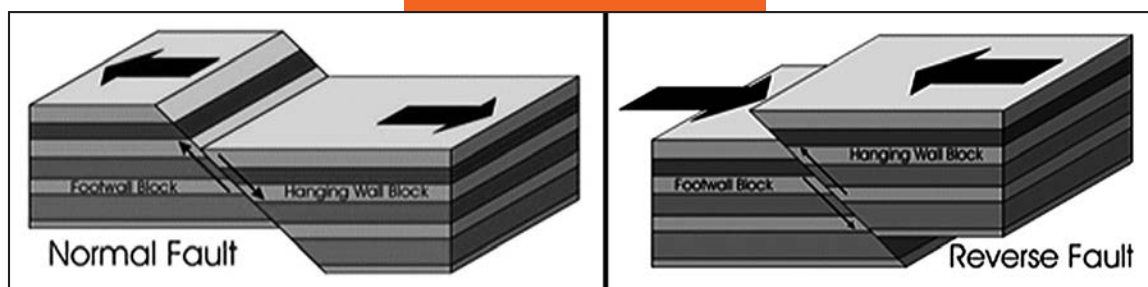


Fig: Normal and Reverse Fault

Rift Valley

Rift valley is a major relief feature resulting from faulting activities. It represents a trough, depression or basin between two crustal parts. Rift valleys are formed due to displacement of crustal parts and subsidence of middle portion between two normal faults by horizontal and vertical movements motored by endogenetic forces. **Rhine rift valley** is the best example of rift valley. Some of the other rift valleys are Jordan River valley, Death Valley of southern Californian and Dead Sea in Asia. A rift valley may be formed in two ways:

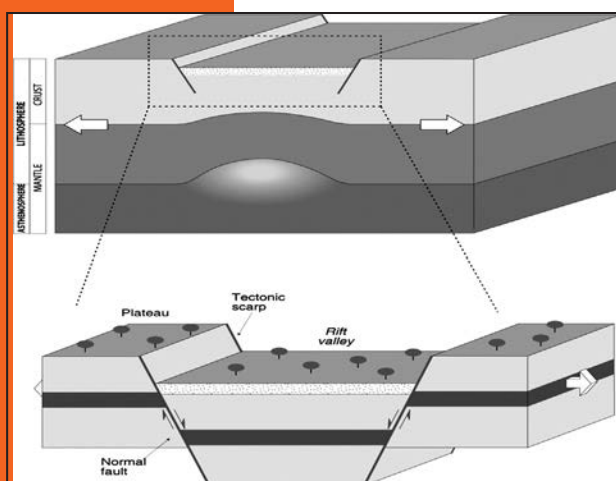


Fig: Rift Valley Formation