Physical geography Chapter 1: Structure of the earth, continental drift and earthquakes

In the universe we live on planet earth,

- is the third planet from the Sun at a distance of about 93 million miles (150 million km).
- is spherical with a radius of about 6,400 kilometers;
- is the biggest of the terrestrial planets and the fifth largest planet overall
- has a total surface Area of about 510 000 000 square km; 21% of which is land and 71%of which is covered by water.
- Has a mass of 60,000 billion tones
- The sun is the main source of energy (light and heat)
- has average temperature of $15^0$C

**Earth structure**

- The structure of the earth is divided into four major components: the crust, the mantle, the outer core, and the inner core.
- Each layer has a unique chemical composition, physical state, and can impact life on Earth's surface.
- Movements in the mantle caused by variations in heat from the core, cause the plates to shift, which can cause earthquakes and volcanic eruptions.
- These natural hazards then change our landscape, and in some cases, threaten lives and property.

**Spinning and Rotation of the earth**

- The earth spins on its axis once in 24 hours producing night and day,
- The Earth revolves in orbit around the sun in 365 days, 6 hours, 9 minutes leading to changes in seasons.

## Theories of continental drift

- Continental drift is the hypothesis that the Earth's continents have moved over geologic time relative to each other and are still moving even today. The several theories of continental drift include

1. **F.B Tailor's theory of continental drift**

- According to Tailor, originally, there were two land masses Lauratia and Gondwanaland located near the north and south poles respectively.
- These moved towards the equator because the moon came closer to the earth and exerted powerful tidal and gravitational forces on them.
- Lauratia equator ward movement resulted into tensional force near the North Pole. This caused stretching, splitting and rupturing of the landmass leading to formation of Baffin Bay, Labrador Sea and Davis Strait.
- Similarly, the displacements of the Gondwanaland from the South Pole towards the equator led to splinting of the mass into Great Australian Bight and Ross Sea around Antarctic Continent.
- Arctic sea was formed between Greenland and Siberia due to equator ward movement of Lauratia.
- Atlantic and Indian oceans were supposed to have been formed because of filling of gaps between the drifting continents with water.
- Taylor assumed that the landmasses began to move in lobe form while drifting through the zones of lesser resistance. Thus, mountains and island arcs were formed in the frontal part of the moving lobes.
- The Himalayas, Caucasus and Alps are considered to have been formed during equator ward movement of the Lauratia and Gondwanaland from the north and south poles respectively while the Rockies and Andes were formed due to westward movement of the land- masses.

**Criticism of F.B Tailor's theory of continental drift**

- Tailor failed to explain why the moon came close to the earth at that time.
- It doubtable if the moon could exert that strong force to pull the two super continents together. If at all the moon came closer and exerted such a strong force, the earth's rotation would have stopped within one year but this was not evidence.
- According to Tailor, mountain building was through tidal attraction. He failed to explain the origin of mountains e.g. Caledonian which existed before tidal attraction.

2. **Theory of sea flow spreading**

- Seafloor spreading is a geologic process in which tectonic plates—large slabs of Earth's lithosphere—split apart from each other.
- It was advance by an American geologist named Henry Hess who based his theory after studying the bed of the Atlantic Ocean in which he observed presence of ridges between Africa and America.
- Seafloor spreading occurs when the sea floor move apart along both sides of a mid-ocean ridge as new crust is added by volcanic activity. As a result, ocean floors move like a conveyor belt, carrying continents along with them.

**The Evidence in support of seafloor spreading**

- Pillow-shaped rocks found on the ocean floor could only have formed when molten material hardened quickly after erupting underwater. It has been found that the youngest rocks are in the center of the ridges proving that sea-floor spreading really has taken place
- The magnetic polarity of the seafloor changes. The center of the ridge is of normal polarity. Stripes of normal and reverse polarity are found symmetrical on both sides of the ridge.

## 3. Alfred Wegner's theory of continental drift

**Assumptions**

- Wegner's theory assumed that there was one giant Sialic landmass (super continent) known as Pangaea, which was located in the south near the present day South Pole, surrounded by a huge expanse of water (Ocean) known as Panthalassa
- During the Precambrian period (Permian times about 250million years) Pangaea begun rifting and drifting northwards.
- Pangaea cracked and broke into land masses i.e. Laurasia and Gondwanaland were separated by a narrow sea of Tethys (universal sea).
- At about l35million years ago, Gondwanaland and Laurasia drifted north wards leading to the closure of the Tethys Sea in the East
- Laurasia split into North America, Eurasia and Green land, Iceland while Gondwanaland split into Africa, South America, India, Austria and Antarctica.
- During the drifting the Oceans between the continental blocks became wider, forming the present day ocean basins like Atlantic, pacific etc.
- In the North, Eurasia drifted East wards.
- In the South, Africa moved to attain its present locations astride the equator.
- South America drifted westwards and Northern wards to join north America
- India drifted northwards to join Eurasia. Australia drifted eastwards, away from Antarctica about 65million years ago.

**Relevancy/Evidences to support Wegner's theory**

- **Jigsaw/Visual fit of continents**. There is a close fitting (Jigsaw puzzle) of the continental coastlines across the Atlantic ocean i.e. the East coast of South America and West coast of Africa have good visual fit (each fit into one another) not only at the surface but also at 2000m deep.
- **Geometric fit of continents**. The west coastline of Africa and the Eastern coastline of South America fit almost exactly on each other if rotated at an angle of $57^0$ with rotational point $40^0$N and $30^0$ E
- **Matching geological/similarity in rocks** and rocks bearing minerals which appear continuous. E.g. Africa and South America have rocks with a convincing boundary joined between Accra and Saolouis in Brazil, the coal bearing rocks of Eurasia and North America (the Appalachiana). The gold bearing rocks of West Africa (Ghana) and South America (Guyana).
- **Similar oil beds**. Oil beds in Brazil are similar to those of Angola in Africa.
- **Matching orogenic zones/belts.** The alignment of the belts of fold mountains matches across the joint of Africa and America e.g. folded ranges in Falkland Islands and Argentina are similar in age and structure to those of the south west cape of South Africa-the cape ranges.
- **Glacial evidence (Dwyka Tillite)** thick deposits of tillite (fossilized glacial moraine) in Eastern Brazil, Paraguay and Argentina, are exactly like those of South Africa and Australia implying that the continents at one time were near or too close to each other.
- **Similar sedimentary Basins**. A long part of North Eastern Brazil coast, South Nigeria and Cameroon, similar sedimentary rocks sequences exist and the low beds of that basin match exactly on both continents.
- **Similarity in plant and animal species** in Australia and south Africa; Africa And South America
- **Palaeomagnetic evidence;** Palaeomagnetism refers to ancient or fossil magnetism in rocks. It's based on the fact that igneous rocks when cooled retain some magnetic properties which at the

time of their formation, can become magnetized parallel to the Earth's magnetic field. For instance studies indicated that India, Australia, South America, the magnetic properties in the magnetized rocks no longer point in the north-south direction as it should be suggesting that during the course of drifting, rocks were twisted and changed direction.

- **Existence of laterites** in North America and Europe proves that these continents experienced tropical climatic conditions for formation of laterites. But with time drifted to the temperate region.
- **Existence of coral reefs** in the Green land, Britain, North America and yet coral reefs form in hot climatic conditions.
- **Salt evaporites/beds** in cold parts of U.S.A, Britain, Germany and Russia is evidence for continental drift from tropics because salt evaporites occur in tropics
- **Proximity of continental** land masses to the North Pole than in South Pole.
- **Existence of Fold Mountains justifies** the theory of continental drift. Fold mountains form when there are compressional forces acting in the same direction e.g. Mt. Himalaya
- **Identical fossils** on different continents for example the ancient reptile mesosaurus are only found in southern Africa and South America yet it is not evident that it swam across Atlantic ocean

**Lesson 2 of 2**

**Plate tectonics**

- Plate tectonics is a scientific theory that explains how major landforms and water bodies are created as a result of Earth's subterranean movements.
- Plate tectonics theory suggests that that the Earth's outer shell/crust is divided into several rigid plates/sections called tectonic plates. These float and glide over the mantle leading to changes in the earth's surface
- There are seven major plates: African, Antarctic, Eurasian, Indo-Australian, North American, Pacific and South American.

**The theory of plate-tectonics**

- It is the most modern theory of continental drift
- It explains the movement and distribution of present day continents, ocean basins and land forms.
- It proposes that the earth crust is divided into individual separate parts/tectonic plates by geochemical reactions and radioactivity in the earth's interior. These float and move/glide on the top of Earth's interior mantle.
- The movements of the tectonic plates results in the movement of continents /land masses and water bodies and change their positions relative to each other.
- Generally all plates move northwards, others like America move westwards while Africa, Europe, Asia, Australia move north eastwards.
- There are 3 types of plate movements/boundaries caused by convection currents which influence the distribution of continents i.e.
  (i) Divergent movements occurs when tectonic plates move away from one another leading to faulting, rifting and warping of crustal land masses.
  On the sea floor, divergent movements produce Under-water Mountains known as the mid-ocean ridge for example the mid-Atlantic ridge and islands
  (ii) Convergent movements occur when tectonic plates to move towards one another and getting closer; when collision occurred fold mountains were formed e.g. the Himalayas due to the collision of India and Asia.
  (iii) Continents may move towards Oceanic plates causing subduction of denser simatic rocks. Collision of plates and subduction leads to formation of trenches, volcanic and fold mountains e.g. Nazca , Java and Tonga trenches etc.
- Oceanic crust may move towards each other causing narrowing of Ocean Basins and continents move nearer leading to formation of trenches and volcanic arcs e.g. Pacific and Eurasia plates moved towards each other Marina trench and Japan volcanic arc were formed.
- Plate tectonism is responsible for land forms due to vulcanicity, faulting and warping.

**Definitions**
**Tectonic plates**
**Tectonic plates** are blocks of continental and ocean crust. The earth's surface is divided into blocks of continental and oceanic crust.

**Characteristics of tectonic plates**

- Plates are relatively light and therefore float on the denser rocks of the mantle and asthenosphere.
- Plates are mobile and move extremely slow on rocks of the upper mantle and driven by convective currents generated by radioactivity and geochemical reactions in the core and the mantle.
- A given plate is so rigid that if one part move, the rest move

**Continental crust (SIAL)**

Continental Crust Continental crust is made up of very old light rocks (average density 2.6) of different granites. SISAL stands for silicate and aluminum, the most abundant minerals in continental crust.

**Oceanic Crust (SIMA)**

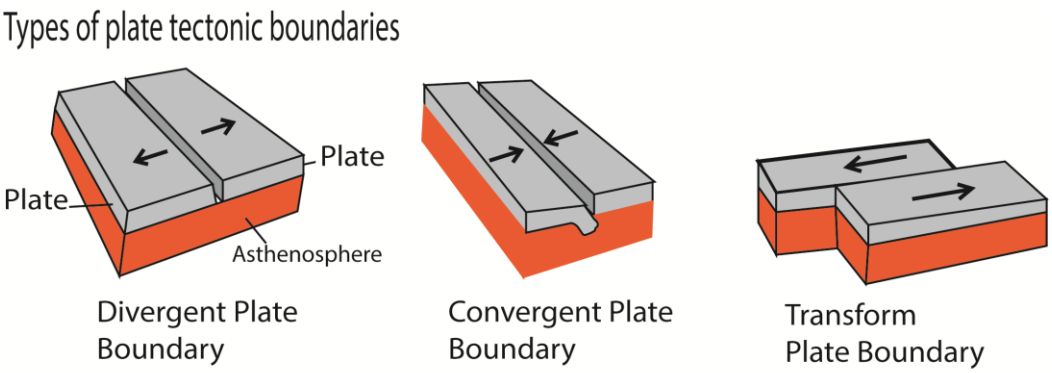
Oceanic crust is made up of heavy basalt rocks (average density 3) and thickness between 5-10 kilometers (3-6 miles). SIMA stands for silicate and magnesium, the most abundant minerals in oceanic crust.

**Types of plate tectonic boundaries**

- A **divergent boundary (constructive plate boundary/margin)** occurs when two tectonic plates move away from each other widening the gap between the plates. Along these boundaries, earthquakes are common and magma (molten rock) rises from the Earth's mantle to the surface, solidifying to create new oceanic crust. Examples include divergent tectonic boundaries include The Mid-Atlantic Ridge.
- A **convergent boundary** occurs when two plates come together narrowing the gap between the plates. The impact of the colliding plates can cause the edges of one or both plates to buckle up into a mountain ranges or one of the plates may bend down into a deep seafloor trench. A chain of volcanoes often forms parallel to convergent plate boundaries and powerful earthquakes are common along these boundaries. The Pacific Ring of Fire is an example of a convergent plate boundary.

  At **convergent plate boundaries**, oceanic crust is often forced down into the mantle where it begins to melt. Magma rises into and through the other plate, solidifying into granite, the rock that makes up the continents. Thus, at convergent boundaries, continental crust is created and oceanic crust is destroyed.
- A **transform plate boundary (transform plate margin)** occurs when two plates sliding parallel past each other. One of the most famous transform plate boundaries occurs at the San Andreas Fault zone, which extends underwater.

  Natural or human-made structures that cross a transform boundary are offset — split into pieces and carried in opposite directions. Rocks that line the boundary are pulverized as the plates grind along, creating a linear fault valley or undersea canyon. Earthquakes are common along these faults. In contrast to convergent and divergent boundaries, crust is cracked and broken at transform margins, but is not created or destroyed.




## Lateral and vertical Earth movement

**Lateral earth movements**

- They are diastrophic or deforming ( i.e. folding, faulting, warping, fracturing) movements that operate horizontally within the earth crust.
- They are caused by internal forces i.e. tensional forces (divergent forces) and compressional forces (convergent forces}, with resulting strains and stresses in the rocks.
- They lead to folding and faulting of the coast.

While

**Vertical earth movements**

- They are diastrophic or deforming (i.e. folding, faulting, warping, fracturing) movements that operate vertically exerting a pushing force onto the crust either upward or downward along a radius from the centre of the earth to the surface.
- They usually occur on a large scale hence called epeirogenic (slow large scale uplift) and may involve vertical uplift or subsidence.
- On local scale, vertical earth movements lead to isostatic readjustment especially around the coast leading the relative changes in the sea level.

## Earthquake

An **earthquake** is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves/vibration/tremors.

Most earthquakes occur within the crust of the earth and not at the surface. The point from which the shock waves originate is known as the focus and the point directly above on the surface is known as the epicenter. The shock waves pass very rapidly through the rocks to the surface where the shaking can cause destruction of life and property.

The Richter magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs.

**Causes earthquakes**

Earthquakes are caused due to sudden tectonic movements in the earth's crust. When the tectonic plates slide over one another, or collide there is a cause of orogeny which results in earthquakes and volcanoes. These disturbances cause vibrations that spread in all directions

The energy that drives earthquake is generated by radioactivity and geochemical reactions leading to the development of convective currents.

**Body waves** are seismic waves generated during earthquakes and travel through the earth's interior, spreading from the focus in all direction. They can be p-waves/longitudinal waves or s-waves of transverse waves.

**Surface waves** are seismic waves that travel on the surface away from epicenter. They are classified as Love waves (transverse waves) or Rayleigh waves (longitudinal waves) both of which are destructive to property and lives.

Effect of earthquake

- Destruction of lives and property
- Advancement of technology to construction of earthquake resistant properties
- Triggered technology for understanding different land forms
- Employment such as in education

Revision questions

1. Discuss any four theories which have been put forward to ascertain the occurrence of continental drift.
2. (a) What is meant by the term plate tectonic?
   (b) How does the theory of plate tectonic explain the present day distribution of continents?
3. Examine the evidences outlined to justify occurrence of continental drift.
4. Explain the relevance of Wegner's theory of continental drift to understanding of the present day distribution of continents and oceans.
5. (a) Distinguish between lateral and vertical earth movements.
   (b) Explain the relevance of plate tectonic theory in understanding the present day distribution of ocean and land masses.