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SENIOR FIVE TERM 1

TOPIC 2/3: The Origin of Continents and Ocean Basins

Competency: The learner demonstrates an understanding of the role of theories in exploring geomorphic concepts by critically evaluating the continental drift theory based on scientific evidence to inform further geographical inquiry and to acquire problem-solving skills.

A **continent** is a large, continuous mass of land on Earth, usually separated by oceans and distinguished by geography, culture, and history. Most English-speaking countries recognize **seven continents**: Asia, Africa, North America, South America, Antarctica, Europe, and Australia/Oceania

An **ocean basin** is a large, saucer-like depression on Earth's surface that holds the oceans. They cover about **71% of Earth's surface**, with an average depth of **16,000 feet (≈4,900 m)**

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 forces responsible for the drifting of continents

- (i) **Mantle convection currents:** Heat from Earth's core causes molten rock in the mantle to circulate. These convection currents drag the tectonic plates (and continents) above them, causing movement.
- (ii) **Ridge push:** At mid-ocean ridges, magma rises and solidifies, creating new crust. The elevated ridge exerts a force that pushes plates away from the ridge.
- (iii) **Slab pull:** At subduction zones, a dense oceanic plate sinks into the mantle. The sinking slab pulls the rest of the plate along, driving continental drift.
- (iv) **Gravitational forces:** Gravity helps in the downward movement of plates at subduction zones. It also influences the sliding of plates away from elevated ridges.
- (v) **Earth's rotation (minor factor):** Early theories suggested centrifugal force from Earth's rotation contributed, but modern science sees this as negligible compared to mantle dynamics.

Theories of continental drift

The several theories of continental drift include

(i) F.B Taylor's theory of continental drift

- According to Taylor **1908** (published in 1910), 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 Taylor's theory of continental drift

The moon-capture tidal force mechanism was incorrect and lacked sufficient evidence.

Significance of F.B Taylor's theory of continental drift:

F.B Taylor was the first to link mountain building to continental collisions and provided an early alternative to fixed-continent theories, influencing Alfred Wegener.

(ii) Theory of sea flow spreading

The Seafloor Spreading Theory, proposed by Harry Hess in the 1960s, explains that new oceanic crust is formed at mid-ocean ridges by rising magma, which pushes older crust outwards like a conveyor belt, eventually sinking back into the mantle at deep-sea

trenches. This process is driven by convection currents in the mantle and is a key mechanism for plate tectonics.

Key Ideas

- **Mid-ocean ridges** are underwater mountain chains where magma rises from the mantle.
- As magma cools, it solidifies into **new oceanic crust**.
- This crust gradually moves away from the ridge, pushing continents apart.
- At **subduction zones**, old oceanic crust sinks back into the mantle, balancing Earth's surface area.

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.
- **Age of oceanic rocks:** Rocks near ridges are younger, while those farther away are older.
- **Magnetic striping:** Rocks on either side of ridges show symmetrical patterns of magnetic polarity reversals, recording Earth's geomagnetic history.
- **Ocean floor mapping:** Revealed ridges, trenches, and fracture zones consistent with spreading.
- **Heat flow studies:** Higher heat near ridges, lower farther away.

(iii) Alfred Wegner's theory of continental drift

Alfred Wegener's theory of continental drift (c. 1912) proposed that all continents were once a supercontinent (Pangaea) that broke apart and moved to their current positions, supported by evidence like matching coastlines, similar fossils, and geological features across continents.

Relevancy/Evidence for Continental Drift

- (i) **Jigsaw Puzzle Fit:** Continents, particularly South America and Africa, look like they would fit together.
- (ii) **Fossil Correlation:** Identical plant and animal fossils (e.g., *Lystrosaurus*, *Mesosaurus Glossopteris*) are found on now-distant continents, suggesting a previous land bridge or connection.
- (iii) **Rock and Mountain Correlation:** Similar rock types, geological structures, and ancient mountain belts (like the Appalachians and Caledonides) appear on opposite sides of the Atlantic.
- (iv) **Paleoclimate Data:**

- Glacial deposits (tillites, striations) found in tropical regions (Africa, India, South America) showed evidence of past widespread glaciation, suggesting these continents were once closer to the poles.
- Ancient coal deposits and coral reefs (tropical indicators) found in colder regions (Europe, North America) implied they were once in warmer climates.
- (v) **Similar oil beds.** Oil beds in Brazil are similar to those of Angola in Africa.
- (vi) **Similarity in plant and animal species** in Australia and south Africa; Africa And South America
- (vii) **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.
- (viii) **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.
- (ix) **Existence of coral reefs** in the Green land, Britain, North America and yet coral reefs form in hot climatic conditions.
- (x) **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
- (xi) **Proximity of continental** land masses to the North Pole than in South Pole.

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 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 moves, 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. SIAL stands for silicate and aluminum, the most abundant minerals in continental crust.

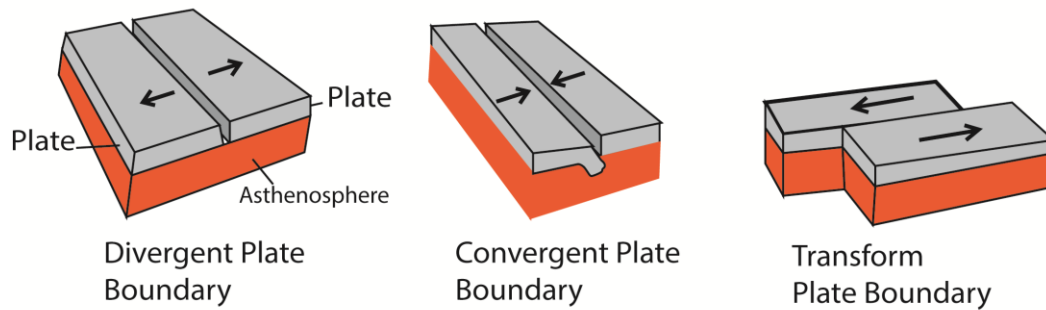
Oceanic Crust (SIMA)

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.

Types of plate tectonic boundaries



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

Effects of Continental Drift on Relief (Landforms)

- (i) **Mountain building:** When continents collide, they form Fold Mountains. Example: The Himalayas formed from the collision of the Indian and Eurasian plates.
- (ii) **Rift valleys:** When plates move apart, deep valleys form. Example: The East African Rift Valley.
- (iii) **Plateaus:** Uplift caused by tectonic forces creates high flat regions. Example: The Deccan Plateau in India.
- (iv) **Ocean basins:** Continental drift widens or narrows ocean basins. Example: The Atlantic Ocean basin widened as South America drifted away from Africa.

Effects of Continental Drift on Landscape (Surface Features)

- (i) Volcanoes: Movement of plates creates volcanic activity along boundaries. Example: Mount Kilimanjaro in Tanzania.
- (ii) Earthquakes: Friction between moving plates causes earthquakes, reshaping landscapes. Example: Rift Valley earthquakes in East Africa.
- (iii) Islands: Volcanic activity from drifting plates forms islands. Example: Hawaiian Islands formed by volcanic hotspots.
- (iv) Coastlines: Continental drift alters coastlines, creating bays, gulfs, and peninsulas. Example: The Gulf of Aden formed as Arabia drifted away from Africa.

Effect of continental drift on human activities and development

Effects of continental drift on Human Activities

- (i) **Agriculture:** Continental drift created fertile plains and valleys (e.g., East African Rift Valley), which support farming. Volcanic soils from tectonic activity are highly fertile, benefiting crops.
- (ii) **Settlement patterns:** Mountain ranges, coastlines, and rift valleys influence where people live. For example, river valleys formed by tectonic shifts (like the Nile) became centers of civilization.
- (iii) **Transportation and trade:** Continental drift shaped coastlines, harbors, and straits, which are vital for shipping and global trade. Narrow seas (e.g., Mediterranean) facilitated cultural exchange and commerce.
- (iv) **Natural hazards:** Earthquakes and volcanoes from plate movement threaten human settlements. Regions like Japan and Indonesia face frequent disasters, affecting development and infrastructure.
- (v) **Energy and mineral resources:** Continental drift concentrated oil, gas, coal, and mineral deposits in certain regions. Human development relies heavily on these resources for industry and energy.

Effects of continental drift on Human Development

- (i) **Cultural diversity:** Separation of continents led to isolated human populations, fostering diverse languages, traditions, and societies.
- (ii) **Economic growth:** Access to resources shaped economies — e.g., Middle East oil reserves, African minerals.
- (iii) **Urbanization:** Cities often developed near tectonic features like rivers, fertile valleys, and coasts.
- (iv) **Climate and environment:** Continental drift altered ocean currents and wind patterns, influencing climate zones. This affects agriculture, water supply, and habitability.

Speculated Future of Continents

- (i) **Atlantic Ocean widening:** The Americas continue drifting westward away from Europe and Africa. The Atlantic Ocean will grow larger, while the Pacific shrinks.
- (ii) **Pacific Ocean shrinking:** Subduction zones around the Pacific (“Ring of Fire”) are pulling oceanic plates under continents. This could eventually close the Pacific Ocean entirely.
- (iii) **Africa moving north:** Africa is drifting northward toward Europe. In ~50 million years, Africa may collide with Europe, closing the Mediterranean Sea and forming new mountain ranges (similar to the Alps).
- (iv) **Australia drifting north:** Australia is moving toward Southeast Asia. It may eventually merge with Asia, altering coastlines and ecosystems.

- (v) **New supercontinent formation:** Scientists predict that in ~200–250 million years, continents may merge into a new supercontinent. Possible scenarios include:
- **Pangaea Ultima:** Atlantic closes, Americas collide with Africa and Europe.
 - **Novopangaea:** Pacific closes, continents cluster around the opposite side of Earth.
 - **Aurica:** Atlantic and Pacific both close, forming a ring-shaped supercontinent.

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.

Thank You

Dr. Bbosa Science