THEORY OF PLATE TECTONICS AND CONTINENTAL DRIFT

The surface of the lithosphere is fractured into a number of tectonic plates (also known as lithospheric or crustal plates) which are in constant motion. As these plates move and collide, the lithosphere buckles, warps, and is torn apart. When this occurs, the Earth's surface shakes with great force, like that which accompanies earthquakes.

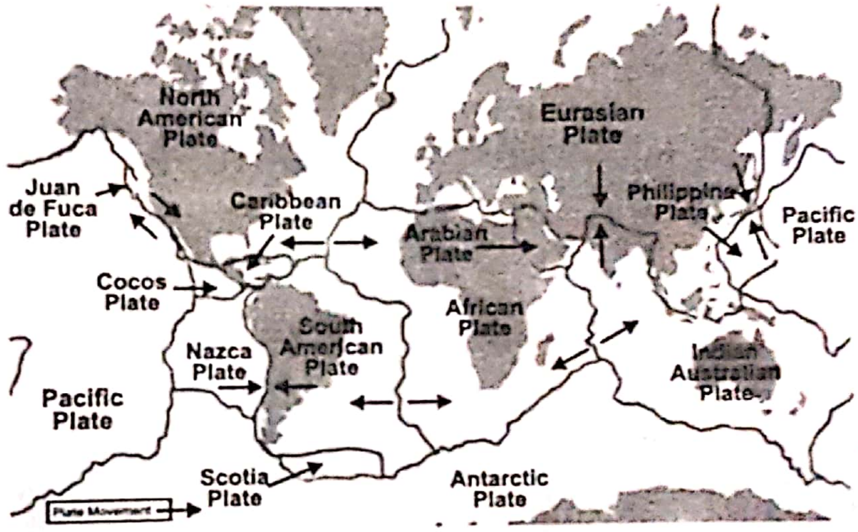


Figure: Plate distribution map

According to plate tectonics theory, the outermost part of the Earth's interior is made up of two layers: the lithosphere, comprising the crust, and the solidified uppermost part of the mantle. Below the lithosphere lies the asthenosphere, which forms the inner part of the mantle. The asthenosphere behaves like a superheated and extremely viscous liquid.

The lithosphere essentially floats on the asthenosphere and is broken up into what are called tectonic plates. These plates are rigid segments that move in relation to one another at one of three types of plate boundaries: convergent, divergent and transform. Earthquakes, volcanic activity, mountain-building, and oceanic trench formation can occur along these plate boundaries.

The main plates are:

Plate name	Area10^6 km^2	Covering
African Plate	61.3	Africa
Antarctic Plate	60.9	Antarctica

Australian Plate	47.2	Australia
Eurasian Plate	67.8	Asia and Europe
North American Plate	75.9	North America and north-east Siberia
South American Plate	43.6	South America
Pacific Plate	103.3	Pacific Ocean

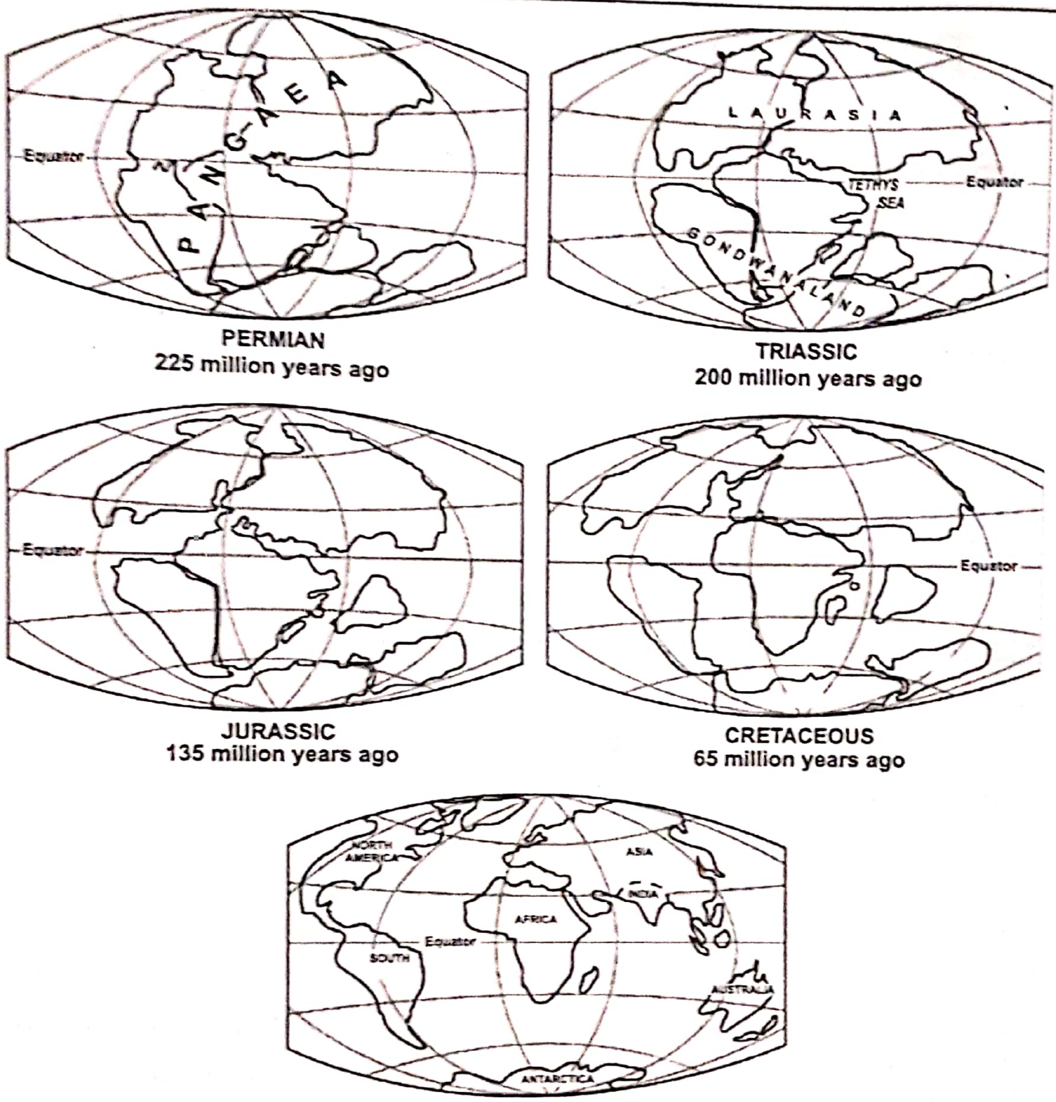


Figure: Continental journey from Pangaea to present day continents

Notable minor plates include the Indian Plate, the Arabian Plate, the Caribbean Plate, the Nazca Plate off the west coast of South America and the Scotia Plate in the southern Atlantic Ocean. The Australian Plate actually fused with Indian Plate between 50 and 55 million years ago. The fastest moving plates are the oceanic plates, with the Cocos Plate advancing at a rate of 75 mm/yr (3.0 in/yr) and the Pacific Plate moving 52–69 mm/yr (2.1–2.7 in/yr). At the other extreme, the slowest-moving plate is the Eurasian Plate, progressing at a typical rate of about 21 mm/yr (0.8 in/yr).

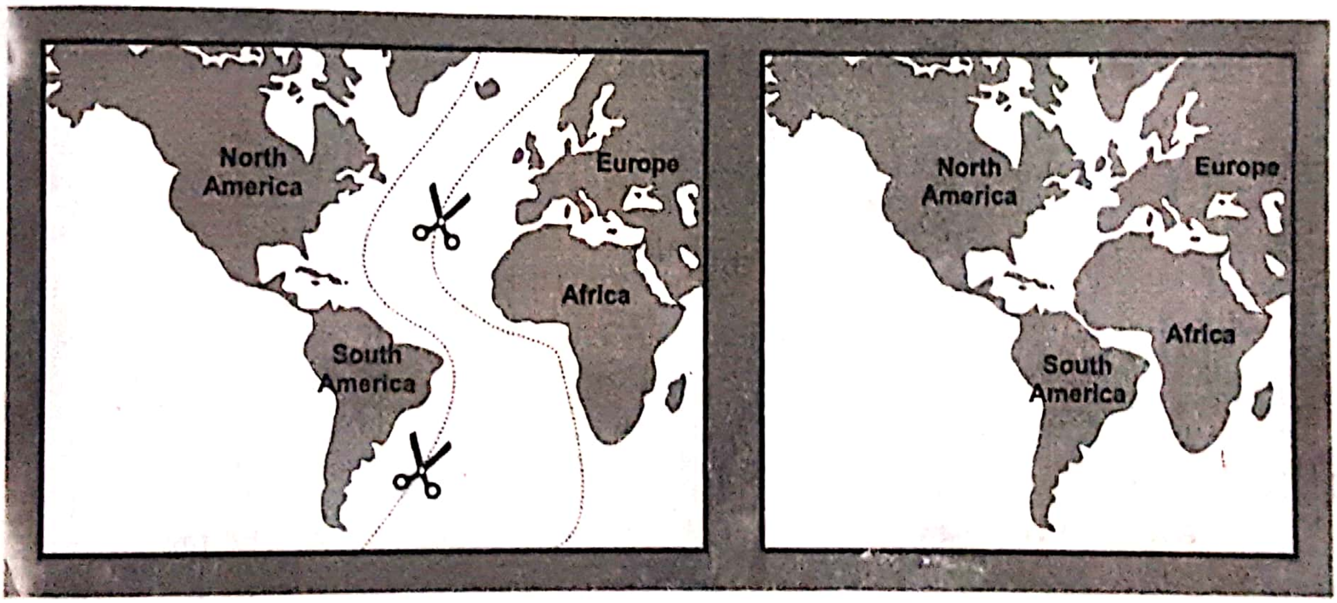
PLATE TECTONICS

Plate tectonics refers to the process of plate formation, movement and destruction. It finds its foundations in two theories, continental drift and sea-floor spreading. **Continental drift** describes the movements of continents over the Earth's surface. Sea-floor spreading refers to the creation of new oceanic plate material and movement away from the mid ocean ridge. It was Alfred Wegener, in the early 1900's, who brought forth the concept that the "shell" of the Earth's surface was fractured, and these "pieces" drifted about. Wegener was able to piece together several bits of information which led to his conclusion that the present configuration of the continents is not the same as it was in the past. In fact, the continents were one "super-continent" called **Pangaea** in the past.

PLATE TECTONICS KEEP THE PLANET COMFORTABLE

Earth is the only planet in the Solar System with plate tectonics. The outer crust of the Earth is broken up into regions known as tectonic plates. This process is very important. When microscopic plants in the ocean die, they fall to the bottom of the ocean. Over long periods of time, the remnants of this life, rich in carbon, are carried back into the interior of the Earth and recycled. This pulls carbon out of the atmosphere, which makes sure we don't get a runaway greenhouse effect, like what happened on Venus.
Without the plate tectonics, there'd be no way to recycle this carbon, and the Earth would overheat.

Carefully examine the east coast of South America and then let your eyes drift to the west coast of Africa. It looks like you could "fit" South America up against Africa like a puzzle. The same can be said for the fit between North America, Africa, and Europe **(Figure 1)**

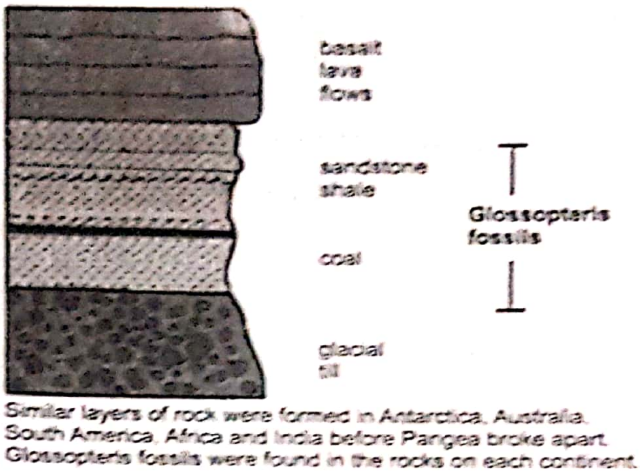


(Figure 1) Fit of continental land masses

Looking for the Evidence

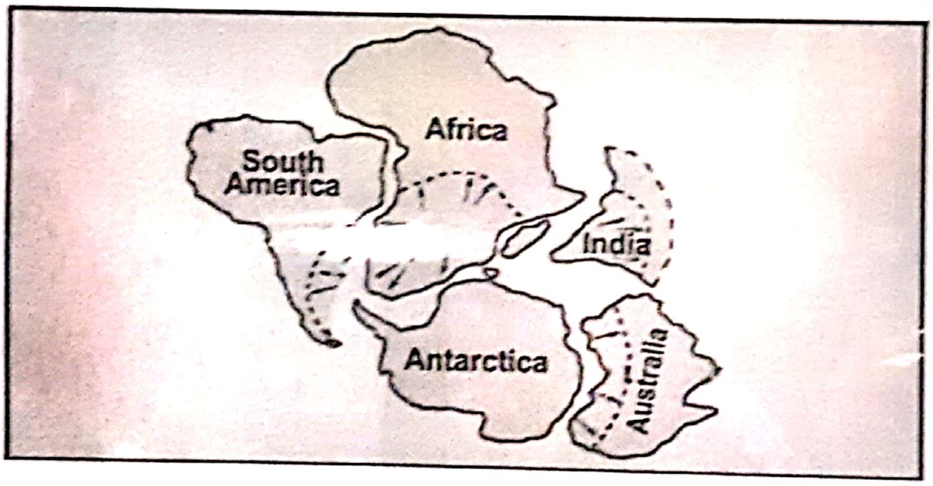
If the continents were in one piece at some time in the past, we should find similar fossils and rocks on both continents which is precisely what Wegener discovered.

By studying the geologic record, the fossil record and climatic record, he found remarkable similarities between Africa and South America. **Fossils of the same species of plants and animals** were found in similar geologic formations in different parts of the world, most notably South America, Africa, and India For example, fossils of the Glossopteris, an ancient fern, are found in South America, Africa, Antarctica, India, and Australia. It was hypothesized that such a distribution could only come about if the continents were all part of the one super-continent.



(Figure 2) Simplified stratigraphic profile for portions of South America, Antarctica, Australia, Africa and India

Examining the stratigraphy (vertical sequences) of the rock record, Wegener could point to further evidence for Pangaea and continental drift. Wegener noted that the rock sequences in South America, Africa, India and Australia are very similar. Wegener showed that the same three bottom layers occurred on each of the continents. Such a strong similarity in the rock record of these localities, now separated by great geographic distance, lent credence to Wegener's notion of continental drift.

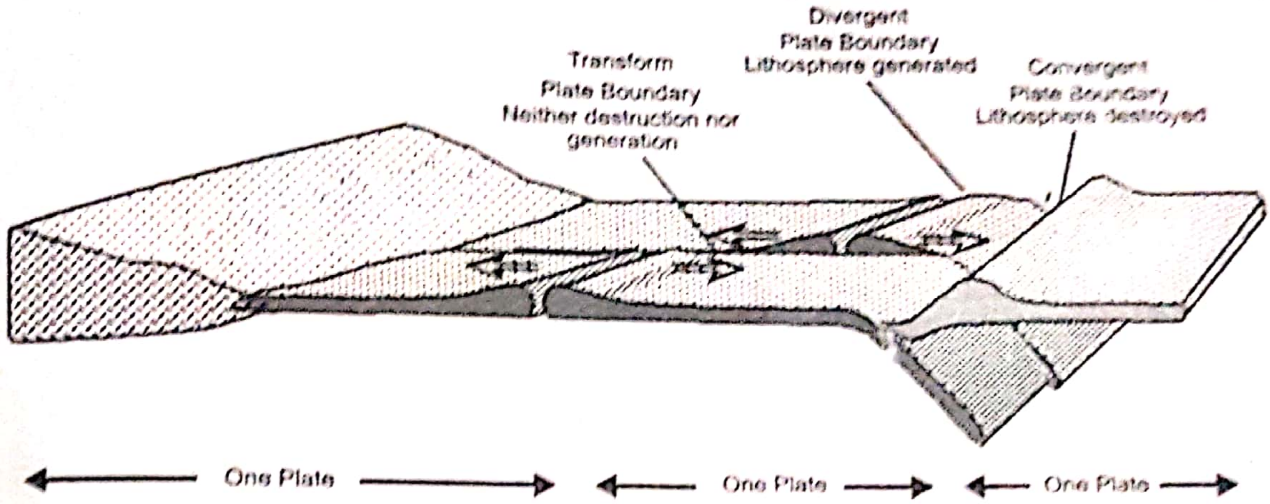


(Figure 3) The distribution of glacial features can be best explained if the continents were part of Pangaea. Grooves carved by glaciers (shown by arrows) provided evidence for continental drift.

The occurrence of glacial features (Figure 3) in the geologic record of South America, Africa, India and Australia provides further evidence for the notion of continental drift. Glaciers affected all or part of these continents at the same time in Earth's history.

TYPES OF PLATE BOUNDARIES

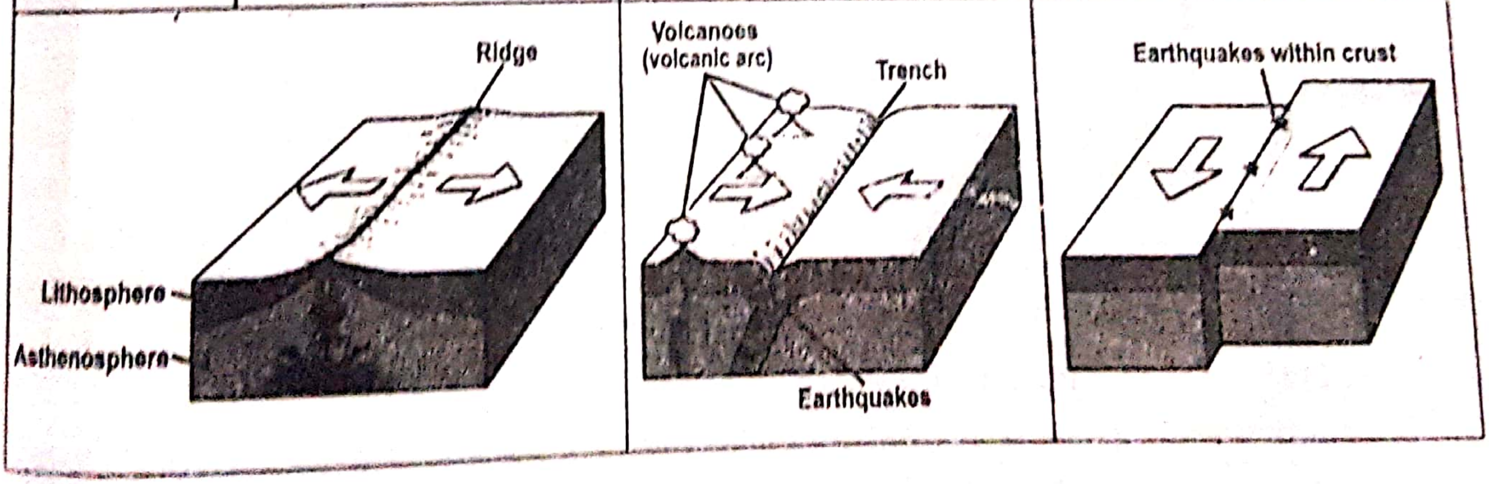
Three types of plate boundaries are recognized and are depicted in **Figure 4**. A Spreading boundary occurs where plates are moving away (diverging) from one another, like along the mid-ocean ridge. Here, new crust is formed. Convergent boundaries are located where subduction is active and the lithosphere is being "consumed". This occurs where two plates collide with one another. Transform boundaries occur where plates are grinding past one another, like the San Andreas Fault.



(Figure 4) Tectonic settings

The boundaries where plates meet are known as plate margins. The type of geologic activity that occurs when two plates interact is dependent on the nature of the plate interaction and of the margins. Plate margins come in three varieties: oceanic-oceanic, continental-continental, and continental-oceanic.

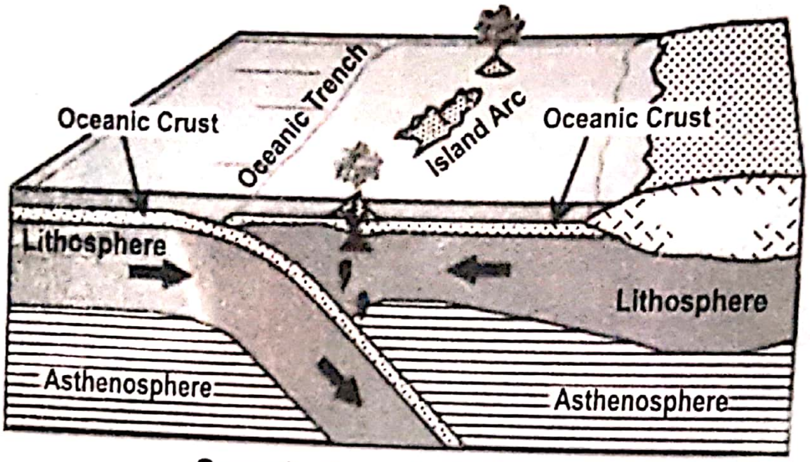
Type of Margin	Divergent	Convergent	Transform
Motion	Spreading	Subduction	Lateral Sliding
Effect	Constructive (oceanic lithosphere created)	Destructive (oceanic lithosphere destroyed)	Conservative (lithosphere neither created or destroyed)
Topography	Ridge/Rift	Trench	No major effect
Volcanic activity	Yes	Yes	No



1. Convergent Motion

a. Oceanic-Oceanic Plate Convergence

When two oceanic plates converge, one of the plates subducts or sinks underneath the other, forming a deep depression called an ocean trench. The subducted plate sinks downward into the mantle where it begins to melt. Molten rock from the melting plate rises toward the surface and forms a chain of volcanic islands, or a volcanic island arc, behind the ocean trench. Japanese archipelago formed as a result of this convergence.

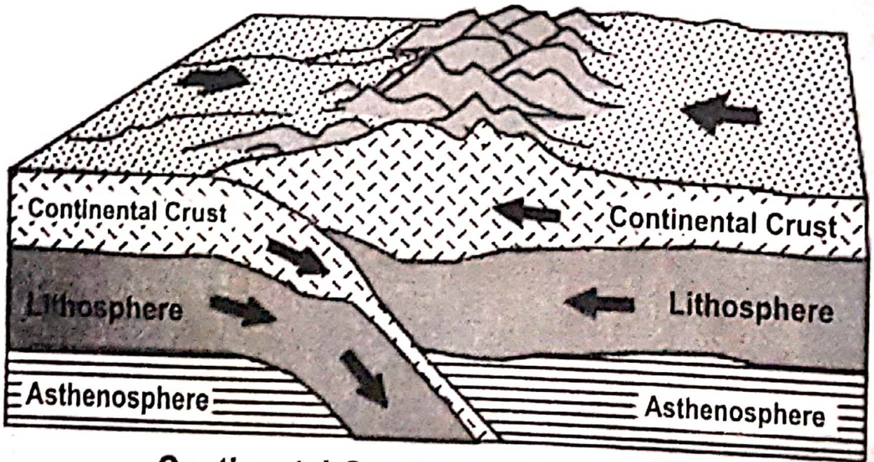


Oceanic-Oceanic Convergence

b. Continental-Continental Plate Convergence

Continental-continental convergent plates act quite differently than oceanic-oceanic plates. Continental crust is too light to be carried downward into a trench. At continental-continental convergent margins neither plate subducts. The two continental plates converge, buckle, and compress to form complex mountains ranges of great height. Convergence of this sort produced the Himalayas when the Indian-Australian plate collided with the Eurasian plate.

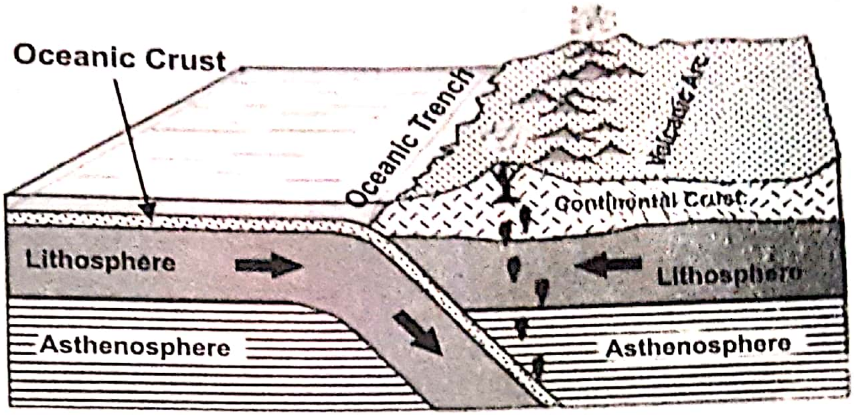
> **FAST FACT**
>
> The Pacific plate is entirely under the Pacific Ocean and has no continental areas.



Continental-Continental Convergence

c. Continental-Oceanic Plate Convergence

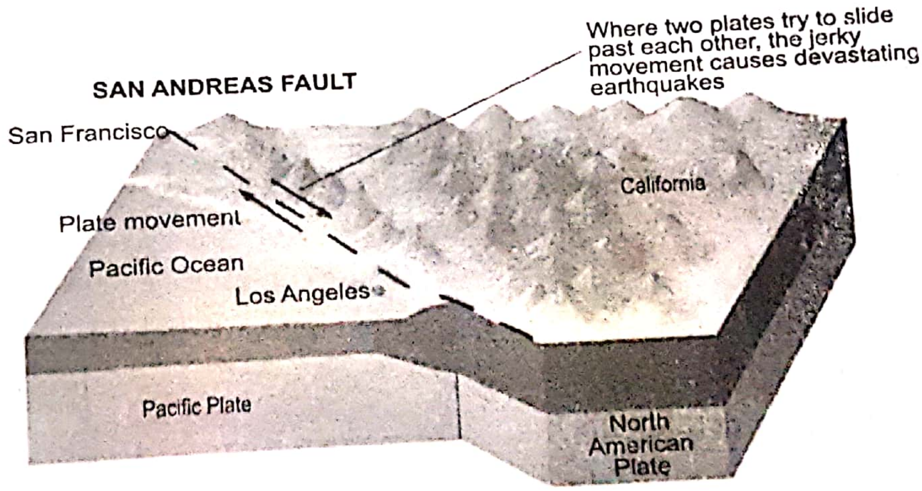
When continental and oceanic plates converge, the oceanic plate (which is denser) subducts below the edge of the continental plate. Volcanoes form as result, but in this setting, the chain of volcanoes forms on the continental crust. This volcanic mountain chain, known as a volcanic arc, is usually several hundred miles inland from the plate margin. The Andes Mountains of South America and the Cascade Mountains of North America are examples of volcanic arcs. No continental-oceanic divergent margins exist today.



Oceanic-Continental Convergence

2. TRANSFORM MOTION

In addition to convergence and divergence, transform motion may occur along plate margins. Transform margins are less spectacular than convergent and divergent ones, and the type of plates involved is really of no significance. As two rock plates slide past one another at a margin, a crack or fault develops. The energy generated by the movement is often released in the form of an earthquake. The best known example of a transform plate margin is the San Andreas Fault in California, where the Pacific and North American plates are in contact.

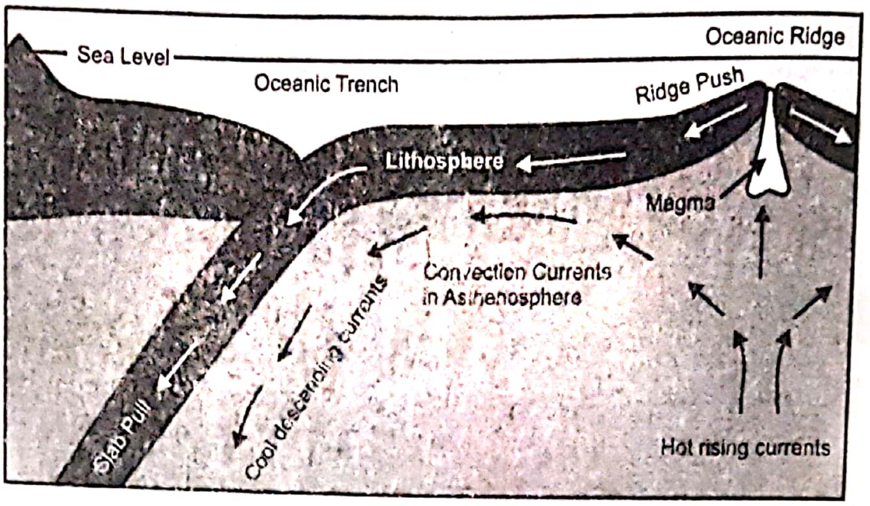


3. DIVERGENT MOTION

Divergent plate boundaries are locations where plates are moving away from one another. This occurs above rising convection currents. The rising current pushes up on the bottom of the lithosphere, lifting it and flowing laterally beneath it. This lateral flow causes the plate material above to be dragged along in the direction of flow. At the crest of the uplift, the overlying plate is stretched thin, breaks and pulls apart.

Divergent Plate Boundary - Oceanic

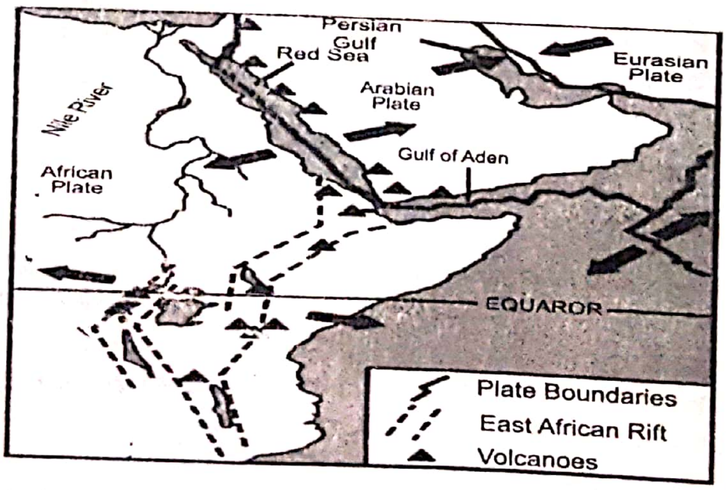
When a divergent boundary occurs beneath oceanic lithosphere, the rising convection current below lifts the lithosphere producing a mid-ocean ridge. Extensional forces stretch the lithosphere and produce a deep fissure. When the fissure opens, pressure is reduced on the super-heated mantle material below. It responds by melting and the new magma flows into the fissure. The magma then solidifies and the process repeats itself.



When oceanic plates diverge, a ridge (mountain chain) develops and seafloor spreading occurs. Molten rock pushes up at the divergent margin, creating mountains and an expanding seafloor. Today, Europe and North America move about 3 inches (7.5 centimetres) farther apart every year as the Atlantic Ocean grows wider. The Mid-Atlantic Ridge is a classic example of this type of plate boundary.

Divergent Plate Boundary - Continental

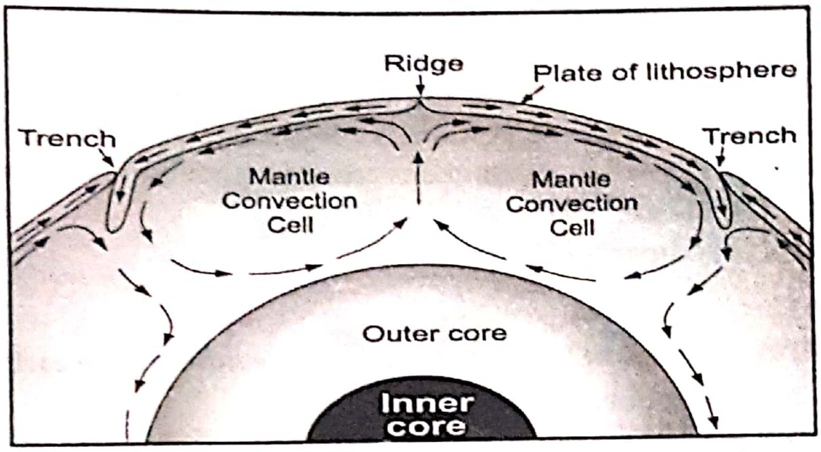
When a divergent boundary occurs beneath a thick continental plate, the pull-apart is not vigorous enough to create a clean, single break through the thick plate material. Here the thick continental plate is arched upwards from the convection current's lift, pulled thin by extensional forces, and fractured into a rift-shaped structure. As the two plates pull apart, normal faults develop on both sides of the rift and the central blocks slide downwards. Earthquakes occur as a result of this fracturing and movement. Early in the rift-forming process, streams and rivers will flow into the sinking rift valley to form a long linear lake. As the rift grows deeper it might drop below sea level allowing ocean waters to flow in. This will produce a narrow, shallow sea within the rift. This rift can then grow deeper and wider. If rifting continues, a new ocean basin could be produced.



The East Africa Rift Valley is a classic example of this type of plate boundary. The East Africa Rift is in a very early stage of development. The plate has not been completely rifted and the rift valley is still above sea level but occupied by lakes at several locations. The Red Sea is an example of a more completely developed rift. There the plates have fully separated and the central rift valley has dropped below sea level.

MODERN THEORY OF PLATE MOVEMENT AND CONTINENTAL DRIFT

Wegener's ideas were not readily accepted during his days because he did not offer a plausible mechanism for the movement of the continents. Wegener suggested it was the spin of the Earth that caused plates to "plough" their way through the mantle beneath, the same was, however, not accepted by other geologists. It wasn't until 1928 that a Scottish geologist Arthur Holmes proposed a mechanism to drive continental drift. Holmes believed a fluid mantle possessed **convection currents** created by heat trapped beneath the Earth's surface. He hypothesized that convection currents welled up toward the surface and then drug continents across the surface.



MOUNTAIN RANGES - THE RESULT OF DEFORMATION OF THE CRUST

One of the most spectacular results of deformation acting within the crust of the Earth is the formation of mountain ranges. **Orogeny** refers to forces and events leading to a large structural deformation of the Earth's lithosphere (crust and solid uppermost mantle) due to the interaction between tectonic plates. The word "orogeny" comes from the Greek (oros for "mountain" plus genesis for "creation") and it is the primary mechanism by which mountains are built on continents. Following are important mountain types:

> **HOW HAVE EARTH'S MOUNTAINS BEEN FORMED**
>
> Mountains are formed in several different ways. For example the Appalachian Mountains on the east coast of the United States are Fold Mountains that were pushed up as ridges on Earth's crust when the Eurasian and American tectonic plates collided. These mountains are perhaps several hundred million years old. The Sierra Nevada Mountains of California were formed through a fault-block process in which large chunks of rock sank leaving other chunks standing. The Black Hills of South Dakota are Dome Mountains that were pushed up by a hot spot in the mantle of that region.

1. Fault Block Mountains

As the name implies, Fault Block Mountains originate by faulting. The Sierra Nevada Mountains of California, and the mountains in the Basin and Range province of the western US, were formed by faulting processes and are thus Fault Block Mountains.

2. Fold & Thrust Mountains

Large compressional stresses can be generated in the crust by tectonic forces that cause continental crustal areas to collide. When this occurs the rocks between the two continental blocks become folded under compressional stresses and are pushed upward to form fold and thrust mountains. The Himalayan Mountains (currently the highest on Earth) are mountains of this type and were formed as a result of the Indian Plate colliding with the Eurasian Plate. Similarly, the Appalachian Mountains of North America and the Alps of Europe were formed by such processes.

3. Volcanic Mountains

The third type of mountains, volcanic mountains, is not formed by deformational processes but instead by the outpouring of magma onto the surface of the Earth. The Cascade Mountains of the western US and, of course the mountains of the Hawaiian Islands and Iceland are volcanic mountains.

4. Residual Mountains

Due to denudation of earth crust, Residual Mountains are formed. Relatively soft portion of earth crust is eroded by agent of denudation like water and winds, which results in formation of depression there. As a result of these depressions, valleys are formed. While hard part of earth is not eroded which forms peak. Residual mountains are not high mountains. Examples are:

- Highlands of Scotland
- Highlands of Scandinavian Countries

Expected Questions

1. Discuss Ocean Floor Spreading? Explain major relief features of the earth?
2. Write a short note on Continental Drift?
3. Explain Tectonic Dislocations? Discuss their chief causes and draw their sketch maps?
4. It is said that the Karakoram and Himalayas are still rising at a certain rate every year? Evaluate this statement with reference with the Theory of Plate Tectonics?
5. What do you understand by the Plate Tectonic Theory? What has it to do with:
   a. The formation of mountains,
   b. Earthquakes,
   c. Volcanoes
6. The theory of plate tectonics is a unifying theory. Discuss.
7. Describe the young fold mountain building process with the help of moving Lithosphere Plate Theory.