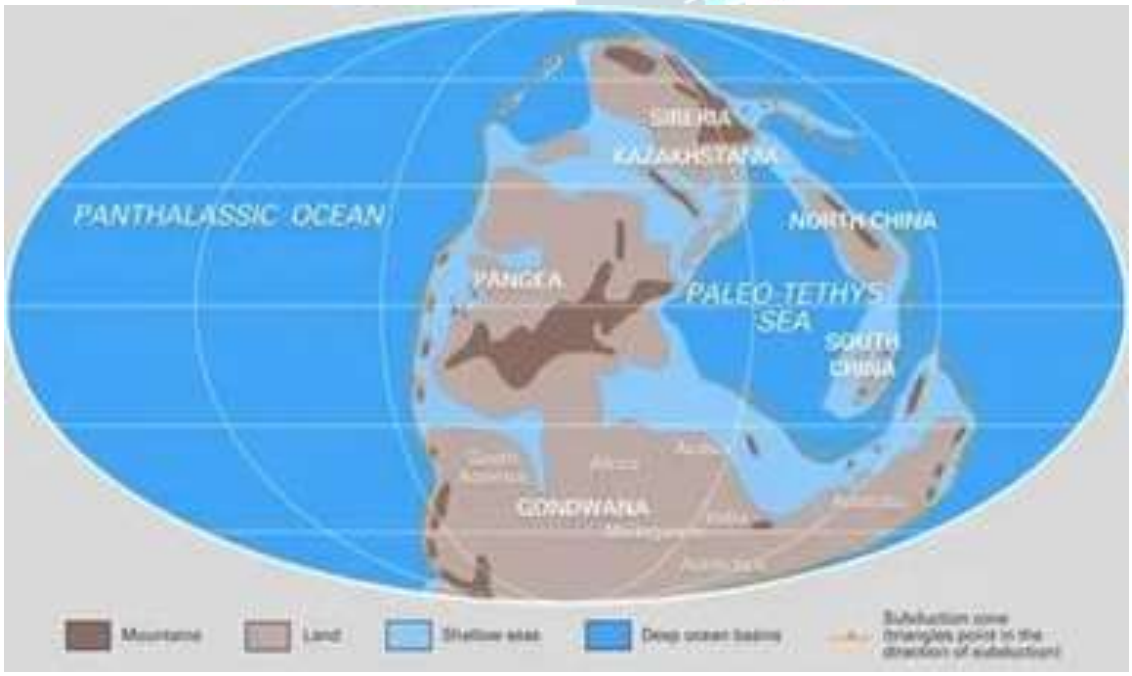
CLASS NOTES
PLATE TECHTONICS

CONTINENTAL DRIFT THEORY

- It is established fact that the Earth crust is made up of different parts, called plates, which move horizontally over the asthenosphere.
- This idea was later fully adopted and developed by Alfred Wegener in 1912 written in a book "The Origin of Continents & Oceans".
- This whole idea of the movements of continent crustal plates was termed as continental drift.
- The continents might have drifted which was first put forwarded by Abraham Ortelius in 1596.
- The 'Continental Drift Theory' of Alfred Wegener suggests that there might have been horizontal displacement of the continental masses on a global scale.
- Wegener assumed that there was only one supercontinent called Pangaea meaning 'all lands'.
- It was surrounded by another super-ocean called Panthalassa.
- The northern part of Pangaea was called Angaraland and the southern part was called Gondwanaland.
- The northern and southern parts were separated by geosyncline, a long narrow shallow sea called Tethys, in which sediments were deposited.



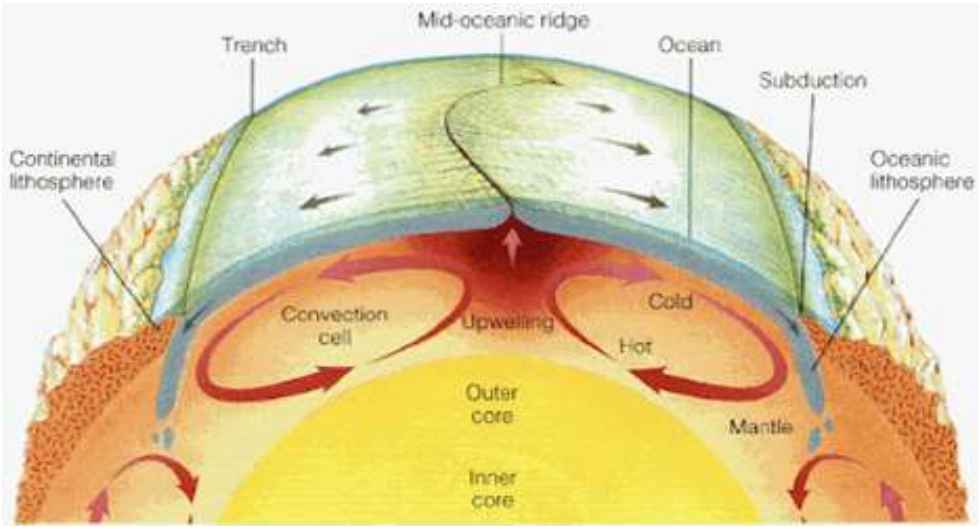
- The minerals constituents silica and aluminum covering continental crust moved over the oceanic crust, which consists of silica and magnesium minerals.
- There are two types of crusts i) continental crust also known as SIAL and ii) oceanic crust called as SIMA.
- The deep sea floor formed as the upper surface of SIMA is largely composed of basalt.
- During the Carboniferous period(approximately 358.9 mya – 298.9 mya) the supercontinent Pangaea got broken & started drifting over SIMA.
- Major events before this time are known with much less certainty whereas the distribution of plants & animals can largely be explained by movements, which have taken place since the Carboniferous period (Steers, 1961).
- The Pangaea was disrupted during subsequent periods & broken landmasses drifted away from each other & thus the present position of the continents & ocean basins became possible.

ENERGY RESPONSIBLE FOR CONTINENTAL DRIFT

- According to Wegener the continents after breaking away from the Pangaea moved in two directions: (i) Equator ward movement; and (ii) Westward movement.
- The equator ward movement of southern part of broken Pangaea was mainly caused by gravitational differential force and force of buoyancy.
- Buoyancy is the upward force exerted by a fluid that opposes the weight of an object immersed in it, causing the object to appear lighter or float.
- The continental blocks are formed of lighter materials (SIAL) and are floating with friction on relatively denser oceanic crust (SIMA).
- Thus the equator ward movement of the continental blocks would depend on the relation of the centre of gravity & the centre of boundary of the floating continental mass.
- Generally, these two types of forces were operating on opposite directions.
- But because of the ellipsoidal form of the Earth, the resultant movements were directed toward the equator.
- The westward movement of the continents was caused by the tidal force of the sun and the moon.
- According to Wegener, the maximum gravitational force of the sun and the moon was there when the moon was nearest to the Earth.
- The force dragged the SIAL over the interior of the Earth, SIMA towards the west.
- This theory lacks the strength for explaining the potential force responsible for the movement of the continents.
- Such forces were extraordinarily small, but it is claimed that even these very small forces may be responsible to cause continental movement.

MECHANISM OF CONTINENTAL DRIFT BY HOLMES

- It was Arthur Holmes, in 1919, who suggested the mechanism of continental drift in more scientific way.
- The theory says- (i) that the continents are drifting away by the horizontal flow of hot magma on which they sit, and (ii) the mantle is flowing because of its convection current.
- Holmes suggested that rocks in the interior of the Earth would buoyantly rise toward the surface from deep within the Earth when heated by radioactivity and then sink back down as they cool and become denser.
- He theorized that convection currents move through the mantle the same way heated air circulates through a room & radically reshape the Earth's surface in the process.



MECHANISM OF CONTINENTAL DRIFT BY HOLMES

- He proposed that upward convection might lift or even rupture the crust, that lateral movement could propel the crust sideways like a conveyor belt, and that is where convection turned downwards, the buoyant continents would crumple up and form mountains.
- Holmes also understood the importance of convection as a mechanism for loss of heat from the Earth and of cooling its deep interior.
- Not until after World War II, could scientists produce the hard evidence to support Holmes's fundamental concept.
- Holmes' theories have continued to be reinforced by new data from seismologists, mineral physicists and geochemists (Earth: Inside and out, 2000).

THEORIES OF MOUNTAIN BUILDING

- Wegener tried to solve the problem of the origin of folded mountains of Tertiary period(66 MYA) on the basis of his Continental Drift Theory.
- The frontal edges of westward drifting continental plates of North & South America were crumpled & folded against the resistance of the rocks of the seafloor & thus the western cordilleras of the North and South America (Rockies, Andes and other mountains) were formed.
- The Alpine ranges of Eurasia were folded due to equatorward movement of Eurasia & Africa together with Peninsular India.
- Here, Wegener postulated contradicting viewpoints.
- According to Wegener, SIAL was floating upon SIMA without any friction & resistance but later he pointed out that mountains were formed at the frontal edge of floating & drifting continental blocks due to friction & résistance offered by SIMA.

GEOSYNCLINAL OROGEN THEORY OF KOBER

- Through Geosynclinal Theory Kober attempted to explain:- the origin of mountains & various aspects of mountain building, e.g. formation of mountains, their geological history and evolution & development.
- His theory is based on the forces of the contraction produced by the cooling of the Earth.
- The force of contraction generated due to cooling of the rigid masses which squeeze buckle & fold the sediments into mountain ranges.

BASE OF THE THEORY

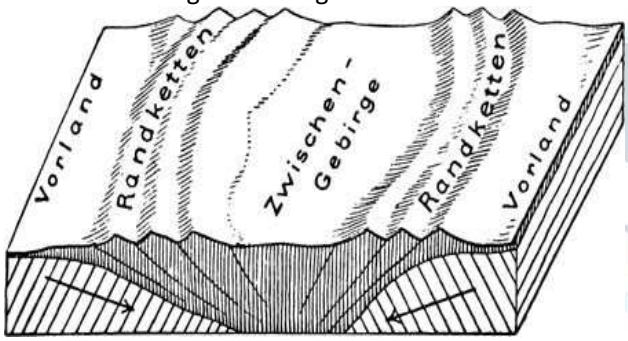
- According to Kober, there were mobile zones of water(geosynclines or Orogen) in the places of present day mountains.
- The mobile zones of geosyncline were surrounded by rigid masses which were termed by Kober as 'Kratogen'.
- Kober identified six major periods of mountain building.
- Three mountain building periods, about which very little is known, occurred during Precambrian period. (4.6 Billion years ago)
- Palaeozoic era (54-252 MYA) saw two major mountain building periods- the Caledonian orogenesis(440-400 MYA) was completed by the end of Silurian period(443–419 MYA) & the Variscan orogeny(Hercynian or Armorican orogeny) was culminated in Permo-Carboniferous period. (300 – 250 MYA)
- The last (6th) orogenic activity known as Alpine orogeny was completed during Tertiary epoch (Cenozoic Era 66 - 2.6 MYA)

MECHANISMS OF THE THEORY

- According to him, the whole process of mountain building passes through three closely linked stages of lithogenesis, orogenesis and gliptogenesis.
- The geosynclines are long & wide mobile zones of water – bordered by rigid masses – named by Kober as forelands or kratogen.
- These forelands are subjected to continuous erosion by fluvial processes & eroded materials are deposited in the geosynclines.
- This process of sediment deposition is called sedimentation.
- The ever-increasing weight of the deposited sediments due to gradual sedimentation put enormous pressure on the beds of geosynclines,

resulting gradual subsidence of the beds of the geosynclines.

- The second stage of mountain formation is called the stage of orogenesis.
- Both the forelands started moving towards each other because of horizontal movement cause by the force of contraction resulting from the cooling of the Earth.
- The compressive force generated by the movement of foreland causes contraction, squeezing & folding of sediments deposited in the geosyncline to form folded mountain ranges.
- If the compressive forces are of the moderate intensity, the marginal sediments of the geosynclines are folded to form two marginal ranges & middle portion of the geosynclines remains unaffected by folding activity.
- This unfolded middle portion is called Zwischen Gebirge or median mass
- According to Kober, the Alpine mountain chain of Europe can be explained on the basis of median masses.
- Third stage — gradual rise of mountains and their denudation by fluvial and other processes.
- Continuous denudation result into gradually lowering of the height of mountains



CONVECTION CURRENT THEORY OF HOLMES

- Arthur Holmes postulated his thermal convection current theory during 1928-29 to explain the intricate problems of the origin of major relief features of the Earth's surface.
- The driving force of mountain building implied by Arthur Holmes is provided by thermal convection current originating from deep within the Earth.

BASE OF THE THEORY

- The origin of convective current within the Earth depends on the presence of radioactive elements in the rocks.
- The disintegration of radioactive elements generates huge heat which melts the rock as magma & thus causes convection current.
- According to Holmes, concentration of radioactive elements in the crust is also there but the generated temperature is not so high because of loss of heat through conduction & radiation from the upper surface at the rate of 60 calories per square centimeter per year – but the gradual accumulation of heat produced by the radioactive elements cause convective currents.
- Ascending convective current originates under the crust near the equator because of greater thickness of crust, whereas descending convective currents are originated under the polar crust because of its shallow depth

MECHANISM OF THE THEORY

- The convective currents are divided into two major groups on the basis of their location i) convective currents of rising columns; & ii) convective currents of falling columns.
- According to Holmes, the equatorial crust was stretched & ruptured due to divergence of rising convective currents which carried the ruptured crustal plates towards the north - south & a syncline was created as Tethys Sea between two blocks.
- This phase is called Opening of Tethys.
- Again two sets of convergent or downward moving currents pull Laurasia & Gondwanaland towards each other and thus Tethys was compressed and folded into Alpine mountains including Himalayas. This phase is called Closing of Tethys.
- Geosynclines are formed due to subsidence of crustal blocks due to compressive force generated by convergent convective current moving laterally together under continental and oceanic crust.
- According to Holmes, the cyclic pattern of convective current and related mountain building pass through three phases or stages.

MECHANISM OF THE THEORY : FIRST STAGE (LITHOGENESIS)

- In the first stage, the rising convective current of two centers converge under the continental slabs & thus form geosynclines due to compression coming from the convergence of two sets of lateral currents.
- As the sediments are pressed downward into geosynclines, these go further downward & are intensely heated and metamorphosed.
- Metamorphism of sediment causes rise in their density which further cause downward movement of the metamorphosed materials. This stage is called Lithogenesis.

MECHANISM OF THE THEORY : SECOND STAGE(OROGENESIS)

- The second stage is marked by – increase in the velocity of convective currents.
- The main cause for this convective current is the downward movement of cold materials in the falling column & upward movement of hot materials in the rising columns of convective currents.
- The high velocity convergent convective current buckle geosyncline sediments and thus initiate the process of mountain building. This stage, thus, is called the stage of Orogenesis.

MECHANISM OF THE THEORY : THIRD STAGE(GLIPTOGENESIS)

- It is characterised by waning phase of thermal convective currents due to incoming hot materials

in the falling column & upward movement of colder materials in the rising columns.

- The termination of the mechanism of convective current yields several results, e.g. (i) the materials of the falling columns start rising because of decrease in the pressure at the top of the falling column due to the end of deposition of materials. This mechanism causes further rise in the mountains.(ii)the metamorphosed rock (Eclogite) with increased density being heavier depressed downward and gets melted due to immense heat and thus it expands.
- This expansion in the volume of molten Eclogite causes further rise in the mountains. This stage is known as the stage of Gliptogenesis.

PLATE TECTONIC THEORY & MOUNTAIN BUILDING

- The theory tells that the result of plate convergence and its involvement in sedimentation, deformation, igneous activities, erosion and isostatic balance leads to formation of mountains.
- There are four different types of plate convergence
  - ➢ Convergence of two oceanic plates,
  - ➢ Convergence of oceanic and continental plates,
  - ➢ Convergence of two continental plates and
  - ➢ Continent- Arc collision

CONVERGENCE OF TWO OCEANIC PLATES

- Two oceanic plates may converge at the destructive plate boundary where one oceanic plate, which is heavier and denser, subducts in the trench beneath the lighter low density plate.
- The resultant compression leads to the formation of island festoons and Island-arcs.
- Island festoons are chain of islands that form an arc shaped structure, found along the edges of continents
- The best examples of this type are the Japanese Islands and Philippines Island.
- The ocean crust, along with its sediments, is thrust beneath and the rocks on the continental side of the trench are metamorphosed under high pressure condition.
- The molten magma rises up and forms a pile of volcanic rocks & exposes them above the sea level to form Island arcs.

CONVERGENCE OF TWO CONTINENTAL PLATES

- When convergence and collision takes place, the continental plate having denser materials is subducted under the continental plate having relatively lighter materials.
- This brings about huge lateral compression in the sediment deposited in the geosyncline situated between two converging continental plates as well as the sediment laying on the margins of the continents.
- This compressional force squeezed the fold and further deforms the sediments. Due to this, the folded mountains are formed.
- The Alpine -Himalayan mountain system provides the best example.
- In the Mesozoic era(252 to 66 MYA) there existed a long geosyncline, known as the Tethys Sea, between Laurasia in the north & Gondwanaland in the south.
- After the Mesozoic era, Gondwanaland started breaking up and Deccan shield started moving northward at the approximate rate of 16 cm per year.
- The result of converge of these two land masses was that the Tethys sea became narrower and ultimately closed.
- The marine sediments & the crust of the Tethys seas suffered from compression led to the folding of the rock strata and the Himalayas were born.

CONVERGENCE OF OCEANIC & CONTINENTAL PLATE

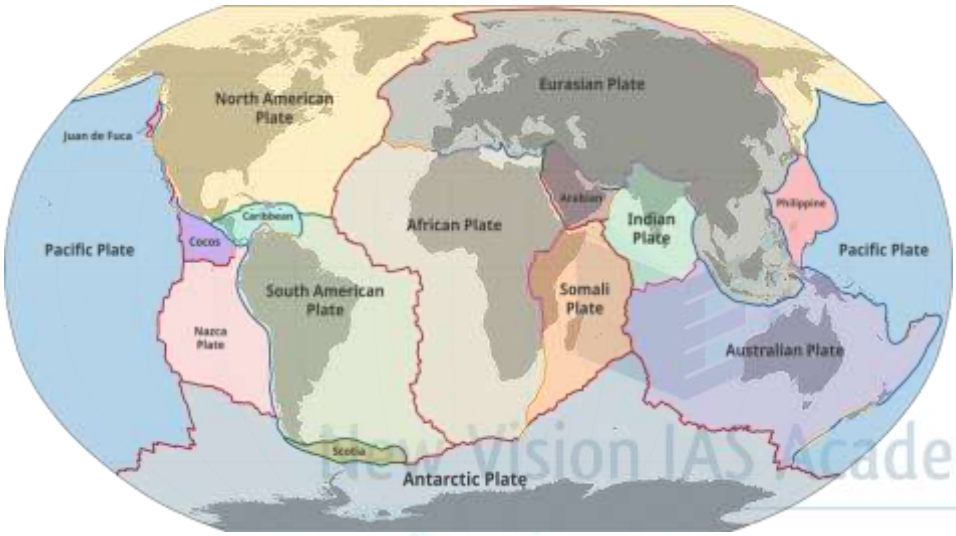
- It is the most prevalent of all the collisions as most of the mountains encircling the American coast of the Pacific Ocean formed by this type of collision.
- Convergence & collision generate intense compression force and the sediment deposited on the continental margin is squeezed and folded.
- The Rocky Mountains of western North America & the Andes of western South America are the best examples of mountain building by continent- ocean plate collision.

CONTINENT- ARC COLLISION

- Continent-Arc collision occurs when a continental plate collides with an arc.
- This kind of situation exists in New Guinea where the mountains were formed about 20 million years ago due to convergence of the Islands arc lying to the north edge of Australia.
- As such, the northern part of the Island is an old Island arc while the southern part of the Island is a part of Australia.

PLATE TECTONIC THEORY

- It is considered as a revival of the Continental Drift Theory.
- It tells that the Earth's outer layer consists of several rigid lithospheric plates consisting of continental (SIAL) & oceanic crust (SIMA) & the upper mantle
- Plates are defined as broad rigid segments of lithosphere consisting of continental & oceanic crust including the rigid upper mantle floating on the underlying hot viscous asthenosphere.
- The rigid continental plates are 100-150 km thick whereas the thickness of the oceanic crust ranges from 6 to 100 km.
- The plates are drifting in the process – huge pressure is generated along the plate boundaries — responsible for all the major geomorphic & tectonic features.
- The present shape & distribution of the continents and oceans can be described with seven major and over twenty minor lithospheric plates.
- The major plates are: African Plate, Pacific Plate, North American Plate, Antarctic Plate, Eurasian Plate, Indo-Australian Plate and South American Plate.
- The important other minor plates are: Cocos Plate, Filipino Plate, Juan de Fuca Plate, Caribbean Plate, Scotia Plate, Nazca Plate, Arabian Plate, etc.



- There are mainly three types of identified plate boundaries and margins: divergent or constructive plate boundaries, convergent or destructive plate boundaries, and transform or lateral plate boundaries.
- The divergent plate boundaries are mostly seen in the deep sea along the mid oceanic ridges and the process is known as "sea floor spreading"

DIVERGENT OR CONSTRUCTIVE PLATE BOUNDARIES

- Two plates moving in opposite direction is called divergence. So, it is a zone of divergence characterized by continuous upwelling of mountain material resulting into the formation of new oceanic crust.

CONVERGENT OR DESTRUCTIVE PLATE BOUNDARIES

- The boundary of two or more crustal plates is known as convergent plate boundary. Here the plates are dragged down through trenches along subduction zones into the mantle.
- The denser crustal plate goes down the lighter one and melts or gets destroyed into the mantle

TRANSFORM OR LATERAL PLATE BOUNDARIES

- These are formed where two crustal plates slide past one another.
- In this case plates are neither created nor destroyed, but severe Earthquake is experienced.

MECHANISM OF PLATE MOVEMENT : CONVECTION CURRENT

- Convection current involves the whole mantle having large amount of radioactivity which causes huge heat concentration in the mantle.
- As the current ascend from below, they diverge and spread laterally along the lower part of the plates.
- Convection current causes the lithosphere to split and the plate may move laterally along the direction of the convection current.
- The high heat flow along the mid-oceanic ridges provides evidence to this process.
- Convectional current is only found in Asthenosphere where the size of convection cells are said to be smaller.

CONVECTION CURRENT

- The other type of mantle convection involves jet like plumes are called mantle plume of low density materials from the core mantle boundary.
- As the plume reaches the lithosphere, it spreads out laterally doming surficial zones of the Earth and moving them along in the direction of radial flow.
- Mantle plumes are thought to be responsible for the initial breaking of the Pangaea.

MECHANISM OF PLATE MOVEMENT: SLAB PULL

- In the convergent boundary, the denser plate slides down the lighter plate causing subduction.
- The subducted portion of the plate causes slab pull.
- This force accounts for most of the overall forces acting on plate tectonics.
- Besides this, the 'ridge push' force adds about 5 to 10 percent of the overall force for plate movement.

MECHANISM OF PLATE MOVEMENT: RIDGE PUSH

- The magma coming out of the mid-oceanic ridges causes the 'Ridge Push'.
- There are two main models of ridge push, namely gravity wedging and gravity sliding.
- The mid-oceanic ridges rise thousands of metres above the ocean floor.
- New seafloor created along the mid-oceanic ridges is very hot, thin & higher in elevation than the abyssal plains and trenches.
- The newly created plate/seafloor will effectively slide down the slope & move towards the subduction zone causing sea floor spreading.
- The oceanic plate gets thicker & denser as it progresses away from the spreading centre, the ridge push force increases towards the subduction zone

CONTINENTAL DRIFT & PLATE TECTONIC : A THEORETICAL ANALYSIS

- With the advancement of the Plate Tectonic Theory, the Continental Drift Theory has got enormous improvement.
- Continental Drift Theory says that the continents are in motion while according to plate tectonics not only the continents but the seafloor are also spreading.
- The generation of new oceanic crust at mid-oceanic ridges seems to be compensated by the consumption of old oceanic crust along subduction zones. So, the crustal plate is to move outward from the mid-oceanic ridges.
- According to Plate Tectonic Theory, it is not SIAL that is in motion, floating over SIMA but the lithospheric Plate over the asthenosphere.
- The Continental Drift Theory talked about the gravitational and tidal forces as the chief mechanism for the movement of the continents which were largely inadequate
- While Plate Tectonic Theory gave five different mechanisms for the movement of the continents.
- The theory explains almost every aspects on the geo-tectonic features of the Earth as well as the continental drift hypothesis.
- Therefore, one can infer that, the Plate Tectonic Theory is the latest and modern concept of Continental Drift Theory

PLATE TECTONIC THEORY: VOLCANISM,EARTHQUAKE & TSUNAMIS

- Volcanic activity will take place when two plates converge as evident with the Pacific & the Eurasian plate; and the Nazca and the South American plates.
- The subduction of the plate is also resulted from the activity of melting & volcanism.
- The molten Pacific and Nazca is thrown by the volcanoes of Mayon and Luzon in Philippines; Misti in Peru; Chimborazo and Cotopaxi in Andes, etc.
- Whereas subducted African plate releases fire in Iran, Caucasus and Italy.
- Divergence leads to quite type of basaltic eruption which is seen along all the mid-oceanic ridges.
- There are two types of associations of volcanic activity with plate tectonics: plate margin volcanism & intraplate volcanism.
- There are two types of plate boundaries where volcanic activities take place. i.e. constructive or divergent plate boundary & destructive margin or convergent plate boundary.
- Volcanism in central parts of plates is not common, but it can be explained as the surface expression of local thermal variation or hot spots in the mantle.
- Frequent Earthquakes take place at the diverging as well as converging plate boundaries.
- The oceanic ridges are offsets by many transform faults.
- Movement along this transform faults generate Earthquakes which have a shallow foci.
- Convergent plate boundaries are characterized by most widespread & intense Earthquake.
- Tensional Earthquake occurs on the oceanic side of the trench, where normal faulting occurs form tensional stresses generated by the initial bending of the plates.
- At intermediate depths, Earthquakes are caused by extension or compression, depending on the pacific characteristics of seduction zone
- The movements of under-sea convergence or destructive plate margins are instigated to the creation of tsunamis.
- Tsunami occurs when there is rapid vertical movement in the oceanic crust that results in a displacement (rise or drop) in the overlying water
- Tsunamis are the result of an Earthquake event which displaces sea water.
- Instead, most tsunamis tend to act like tide, with a rise in sea level that surges onto the coast with very strong currents.

- However, unlike a rising tide, there can be a rapid retreat of sea level prior to the huge surge i.e. tsunami (USGS, 2005).
- A tsunami is a series of ocean waves generated by sudden displacements in the sea floor, landslides, or volcanic activity.

EVIDENCES OF CONTINENTAL DRIFT & UNDERLYING PLATE TECTONIC

- Most of the continents/shapes look like they were separated from a single great continent (Pangaea).
- They exist as pieces of a jigsaw puzzle. For example, the shape of the east coast of North and South America matches with the shape of the west coast of Africa and Europe.
- Geologically, both the coasts of Atlantic are also identical.
- The geological structure of the eastern coast of South America & western coast of Africa are more or less similar.
- Many fossil comparisons along the edges of continents look like they fit together – suggests species' similarities
- There is a large amount of seismic, volcanic, and geothermal activities along the conjectured plate boundaries.
- The concentration is striking, and indeed this plot serves to define the plate boundaries extremely well.
- The upwelling of lava or magma in the mid-oceanic ridge forms a new crustal plate.
- So, it is certain that they are young in geological age. This has been scientifically proven.
- Similar plant and animal fossils are found around different continental shores, suggesting that they are certainly joined together.
- The fossils of Mesosaurus, a freshwater reptile, found both in Brazil and South Africa are one of the important examples.
- Another is the discovery of fossils of the land reptile known as Lystrosaurus from locations in South America, Africa, and Antarctica.
- There are also living evidences, may be the same animals being found on two continents.
- Some Earthworm families are also found in South America and Africa

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