Plate Tectonics

Introduction

After new information on ocean floor, earth's magnetism, distribution of volcanoes and earth-quakes, flow of heat from earth's interior, and worldwide distribution of plant and animal fossils was obtained theory of plate tectonics was formulated in the 1960's and 1970's. It was a unifying theory to explain fundamental processes shaping earth's surface.

Historical Evolution of Concept

- Term plate was first used by J. I Wilson in 1965.
- In 1965, Tuzo explained the plate tectonics as combination of
  - Theory of continental drift by Alfred Wegener in 1912
  - Theory of seafloor spreading by Harry Hess in early 1960's
- Mechanism of plate motion was given by Mckenzie and Parker in 1967 based on Euler's geometric theory. They gave paying stone hypothesis where-by oceanic crust was considered newly formed at mid-oceanic ridges and ruined at ocean trenches.
- Paving stone hypothesis was confirmed by Isacks and Sykes in 1967
- W J. Morgan and Le Pichon gave plate tectonics in 1968. Since then, continental drift and displacement formed basis of plate tectonics.
- Jack Oliver provided seismologic evidence to support plate tectonics theory.

Structural Elements of Plate Tectonics

Theory explains the structure of earth as:

- **Plates:** It is breaking of earth's outermost layer, lithosphere into **seven large,** rigid pieces called African, North American, South American, Eurasian, Australian, Antarctic, and Pacific plates. Other minor plates are Arabian, Nazca, and Philippines plates.
- **Plate Boundaries:** Meeting place of two plates is plate boundary and is discussed in detail in next section.
- **Plate Boundary Zones:** These are broad belts where boundaries of plates and effects of plate interaction are known. Movement of plates de-forms by extension over broad belt called plate-boundary zone. Interactions at plate boundary zone involve minimum two large plates and one or more microplates that occur in between them. These interactions lead to complex geological structures and earthquake patterns. An example of plate boundary zone is Mediterranean-Alpine region between Eurasian and African Plates within which many smaller plate fragments (microplates) are recognized.
- **Crust:** It is earth's top layer lying on top of the plates with thinner crust. It is denser than continental crust. It constantly forms and destroys. Due to continental spreading, oceanic crust is more active than continental crust.
- **Mantle:** It lies under the crust and is made of silicon, oxygen, magnesium, iron, aluminum, and calcium. Mantle has been divided into upper and lower mantle.

- **Upper Mantle:** It is rigid and is part of lithosphere (along with crust). Asthenosphere is part of upper mantle, which has plastic properties (as rocks are under high pressure and temperature). It lies below lithosphere (crust and upper mantle) at depth of 100 to 250 km.
- **Lower Mantle:** It flows slowly, at a rate of a few centimeters per year

Processes in Plate Tectonics

According to the theory

- Plates move in different directions and with different speeds (from 2 to 10 cm per year) with respect to each other These crash together, pull apart, or sideswipe each other
- Edges of these plates, where they move against each another, are locations of high geologic activity like earthquakes, volcanoes, and mountain building.
- Term "continental drift" is not entirely accurate as plates are composed of continental and oceanic crust that drifts over earth's surface. Ocean floors move continually through sea floor spreading and they spread from center and sink at edges.
- Convection currents below plates move them in different directions.
- Radioactive decay is main source of energy driving these convection currents that occur deep in earth.

Plate Boundaries

Tuzo predicted following types of plate boundaries:

- Mid-ocean ridges or divergent boundaries causes formation of ocean crust
- Trenches or convergent boundaries where subduction of plates occur
- Transform faults or large fractures in seafloor or on land, where plates slip by each another

Divergent, Constructive or Accreting Boundaries

Location of movement of plates apart is called divergent boundary. These occur along spreading centers where new crust is made by magma pushing up from the mantle. Mid-Atlantic Ridge is a sub-merged mountains range that extends from Arctic Ocean to southernmost Africa. Following are effects of this boundary.

- Rate of spreading along Mid-Atlantic Ridge is 2.5 cm per year Seafloor spreading over last 100 to 200 million years has led Atlantic Ocean to grow from small water inlet between Europe, Africa, and Americas into the ocean.
- In East Africa, spreading processes broke away Saudi Arabia away from remaining African continent to create Red Sea.
- East Africa could be a possible location for earth's next major ocean. When spreading continues, complete separation of three plates meeting at present-day African continent takes place and permit Indian Ocean to flood the area and make easternmost African corner (Horn of Africa) a huge island.

Convergent, Consuming or Destructive Boundaries

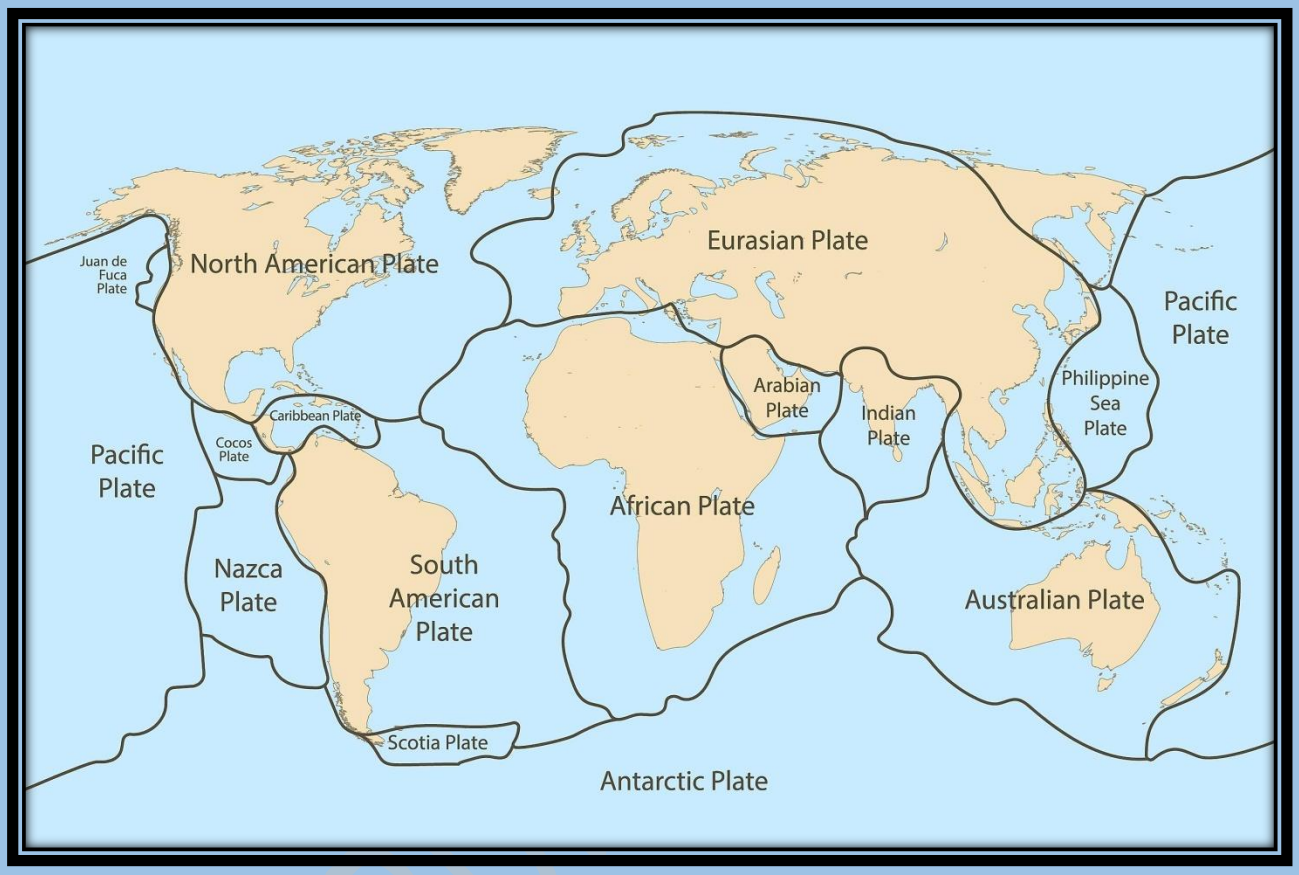
Crustal convergence occurs when plates move towards each other Convergence can generate subduction or buckling based on the type of crust.

- Subduction occurs for heavier plates by destruction of crust when one-plate dives under another Subduction zone is the location of sinking of plates. Recycling or destruction of crust is seen in these regions.
- There is a possibility that neither plate would sink after convergence causing buckling. This happens mainly when two lighter continental plates collide.

Convergence can be classified as.

- **Oceanic-Continental Convergence:** Off the coast of South America along Peru-Chile Trench, oceanic plate pushes continental plane causing subduction under continental part of South American Plate. This lifts South American Plate upwards to create Andes Mountains. This region is home to strong, destructive earthquakes and rapid uplift of mountains.
- **Oceanic-Oceanic Convergence:** Marianas Trench (parallels Mariana Islands) is the region of convergence of fast-moving Pacific Plate against slower moving Philippine Plate. Pacific plate plunges deep into earth's interior (about 11 km). Subduction in oceanic-oceanic plate convergence causes earthquakes and volcanic formation:
  - Over many years, lava erupts and volcanic debris pile on ocean floor until a submarine volcano rises above sea level to create island volcano. These volcanoes are mainly strung out in chains known as island arcs. Magmas creating island arcs are made by partial melting of descending plate and oceanic lithosphere above it.
  - Descending plate produces stress at the interaction of two plates creating frequent moderate to strong earthquakes.
- **Continental-Continental Convergence:** Its main example is Himalayan range. When two continents meet head-on, neither is subducted as continental rocks are comparatively light and they resist downside motion. Rather the crust buckles and is pushed up or sideways. Eurasian plate crumbled by collision of India into Asia 50 million years ago overrides Indian Plate. After this collision, slow continuous convergence of two plates for many years has pushed up Himalayas and Tibetan Plateau to their recent heights. Maximum growth was noticed in last 10 million years.

Major plates of the world



Transform Boundaries

Region or zone where plates do not produce or destroy and just slide horizontally past each other is called transform boundary.

- They are commonly seen in ocean floor characterized by zigzag plate margins and shallow earth-quakes.
- Few of them occur on land, for example, San Andreas Fault zone in California is 1,300 km long and is sometimes tens of km wide. It slices through 2/3rd of Californian coast.

Rate and Direction of Movement of Major Plates

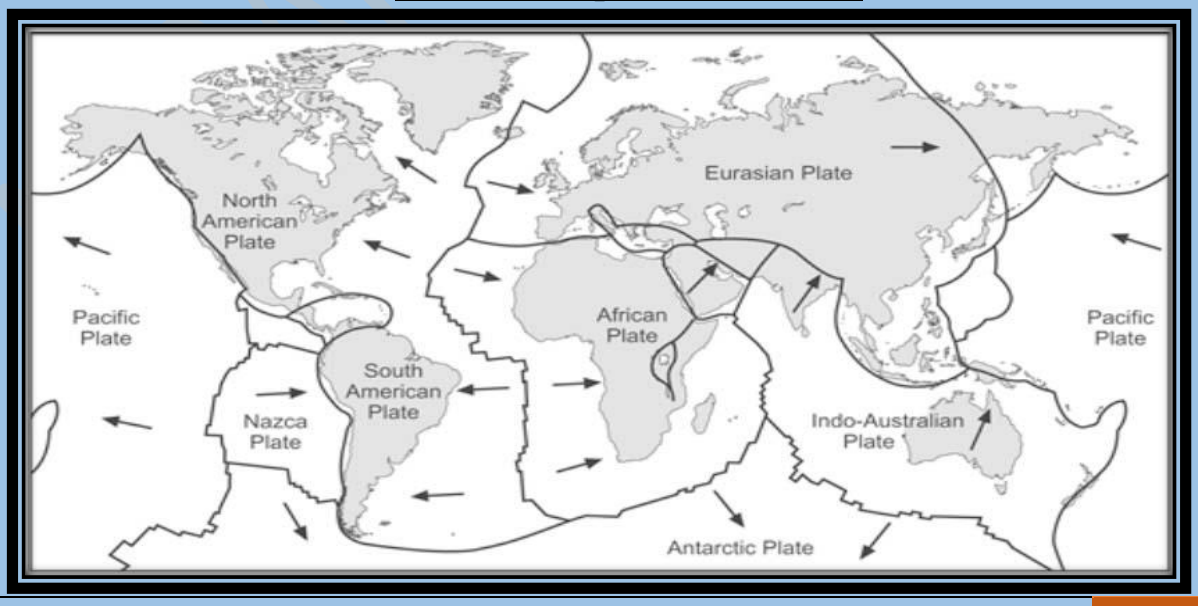
Rate of plate movements is given in the table while direction is indicated in the figure.

Table : Rate of movement of plates

Plate	Absolute Velocity (cm/yr.)
Antarctic	-2.05
African	-2.15
Arabian	-4.65
Caribbean	-2.45
Cocos	-8.55
Eurasian	-0.95
Indian	-6.00
Nazca	-7.55
North American	-1.15
Pacific	-8.10
Philippine	-6.35
South American	-1.45

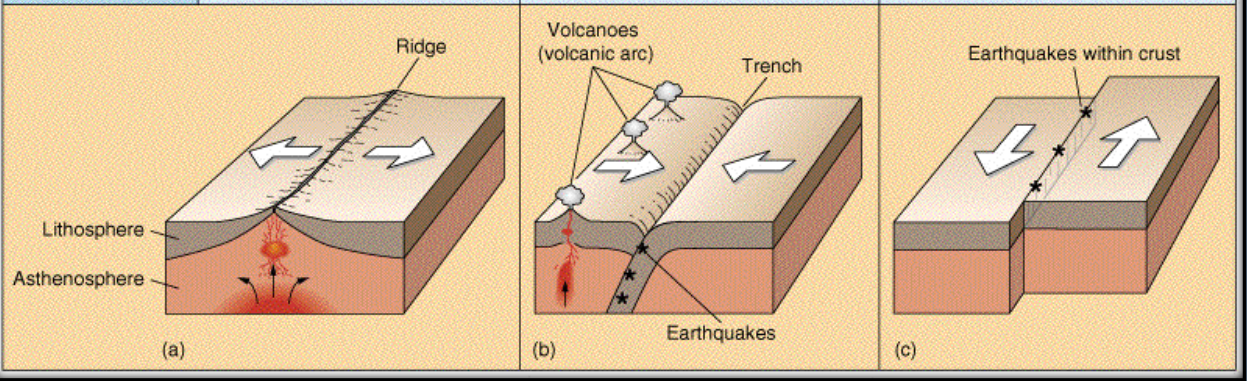
- Pacific Plate is moving northwest.
- North American plate is moving west-southwest.
- Juan De Fuca Plate is moving east-northeast.
- Eurasian Plate is moving away from the North American Plate.
- Antarctic Plate moves downwards but towards the east that is towards the South American Plate.
- Arabian Plate is moving northward and colliding with the Eurasian Plate.
- African plate is moving northeast and is drawing closer to the Eurasian Plate.

Direction of plate movements



Type of Plate boundary

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



Location of plate boundaries