Plate Tectonics

Learning Outcomes:

Students will able to:

1. ***Outline briefly the history of plate tectonics***
2. ***Give a definition for plate tectonics.***
3. ***Label major continental and oceanic plates.***
4. ***Describe the types of plate boundaries.***
5. ***Describe the processes occurring at each plate boundary.***
6. ***Describe the Caribbean plate and the adjacent plates.***

History

History - Continental drift

Francis Bacon (in 1620) was the first to formally draw attention to the fact that the continents could be fitted together like a jigsaw puzzle.In the early twentieth century, both Alfred Wegener (Germany) and F.B. Taylor (USA) came independently to same idea, that continents were not static, but were drifting. However, the concept of continental drift usually attributed to Alfred Wegener.

Alfred Wegener was a German climatologist and arctic explorer who suggested the concept of continental drift. Continental drift is the idea that the continents move around on Earth's surface.

Wegener suggested that there was once one large supercontinent, which he named Pangea. It existed about 250 million years ago. This broke up, first splitting into Laurasia in the north and Gondwanaland in the south, before forming the continental configurations that we know today.

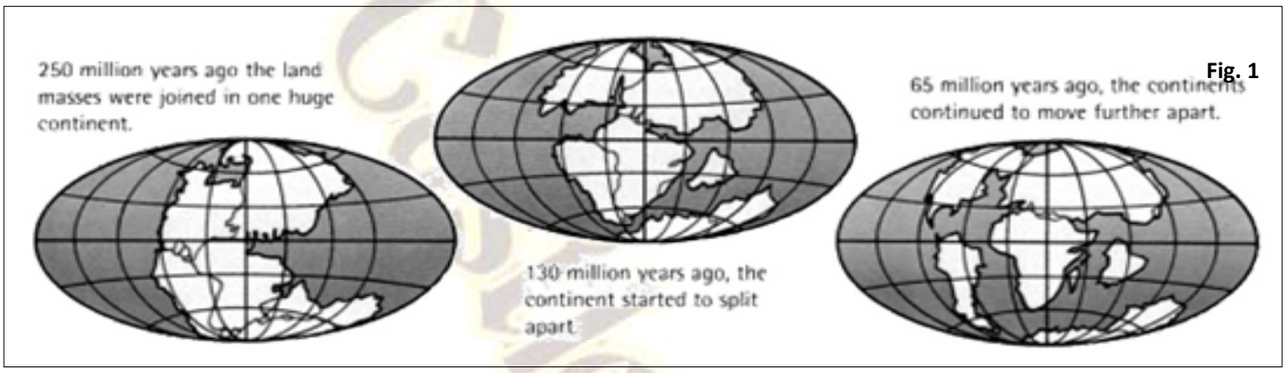


Fig. 1

Wegener's evidences are summarized below.

1. **The apparent fit of the continents.** A look at a world map show the coastlines of the contents appear to fit together.
2. **Fossil correlation.** Identical fossils have been found in the rocks on either side of the Atlantic Ocean. Some of the most common fossils are: mesosaurus, cynognathus, lystrosaurus and glossopteris.
3. **Rock and mountain correlation.** Identical rocks and mountains structure have been found on either side of the Atlantic Ocean.
4. **Paleoclimate Data.** Coal have been found in cold regions and glacial evidence have been found in warm regions.

However, his ideas were not taken seriously by many geologists, who pointed out that there was no apparent mechanism for continental drift. Specifically, they did not see how continental rock could plow through the much denser rock that makes up oceanic crust. Wegener could not explain the force that drove continental drift, and his vindication did not come until after his death in 1930.

Sea-Floor Spreading

Following World War I, echo-sounding devices (primitive sonar systems) began to measure the ocean depth. These investigations revealed that the ocean was more rugged than previously thought.

In the 1950s oceanic explorations greatly expanded. Data gathered by oceanographers from many countries led to the discovery of a great mountain range on the ocean floor virtually encircling the Earth. These mountain ranges are called mid-ocean ridges. Though hidden beneath the ocean surface, the global mid-ocean system is the most prominent topographic feature on the surface of the planet. **See figure 2**.

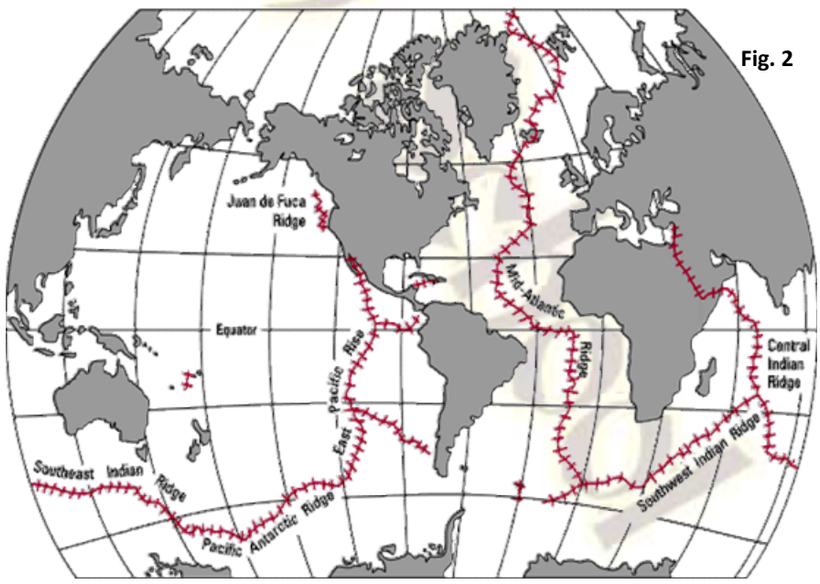


Fig. 2

In 1961, scientists realized that mid-ocean ridges mark weak zones where the ocean floor was being ripped in two along the ridge crest. New magma from deep with the Earth rises easily through these weak zones and eventually erupts along the crest of the ridges to create new oceanic crust. Older rocks will be found farther away from the spreading zone while younger rocks will be found nearer to the spreading zone. This process is known as **<u>seafloor spreading.</u> See figure 3.**

Seafloor spreading is a process that occurs at mid-ocean ridges, where new oceanic crust is formed through volcanic activity and then gradually moves away from the ridge. Seafloor spreading helps explain continental drift in the theory of plate tectonics.

SEA-FLOOR SPREADING

Fig. 3

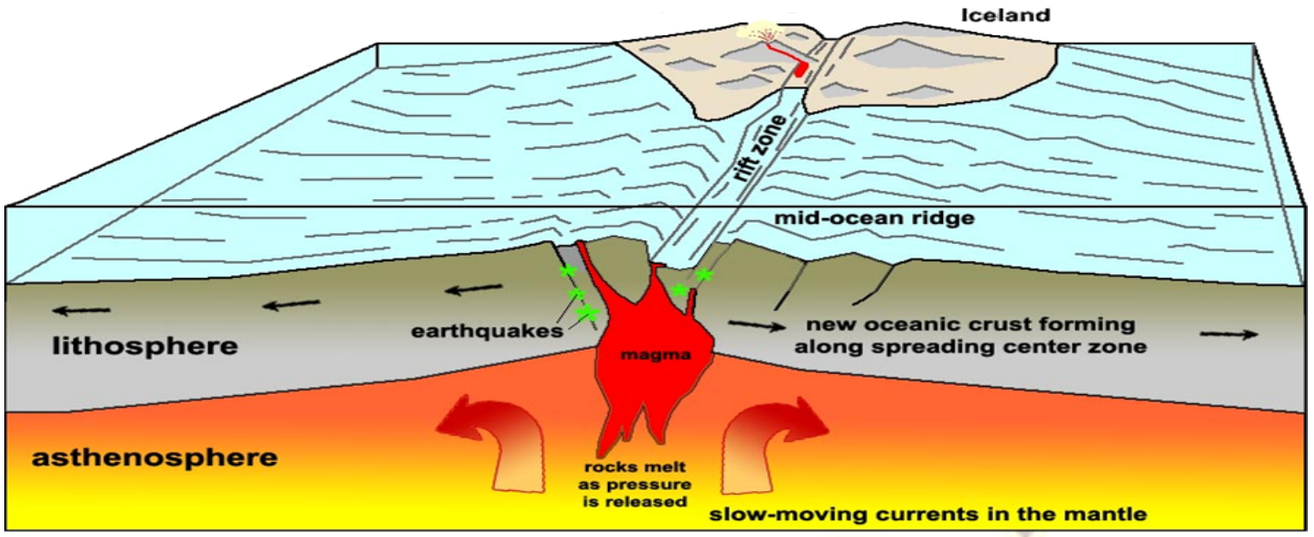


PLATE TECTONICS

In the 1960s, a Canadian geophysicist, J. Tuzo Wilson, combined the continental drift and seafloor spreading hypotheses *(proposed explanation)* to propose the theory of plate tectonics.

Tuzo said that Earth's crust, or lithosphere, was divided into large, rigid pieces called plates. These plates "float" atop an underlying rock layer called the asthenosphere. In the asthenosphere, rocks are under such tremendous heat and pressure that they behave like a viscous liquid (like very thick porridge).

Plates are made up of two layers:

i.the crust
ii.the rigid uppermost part of the mantle.
See figure below

Types of plate boundaries

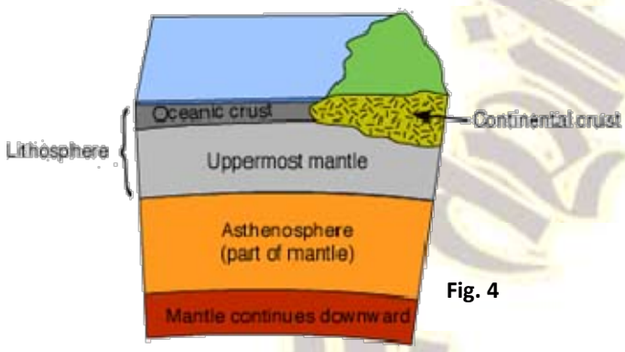
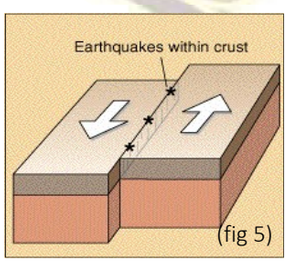


Fig. 4

Three types of plate boundaries exist:

The different types of plate boundaries are:

1. *Transform boundaries*: These occur where plates move pass horizontally past each other along faults. **(fig 5)**
2. *Divergent boundaries*: occur where two plates moves apart from each other. **(fig. 6)**
3. *Convergent boundaries*: occur where two plates moves towards each other. **(fig. 7)**



(fig 5)

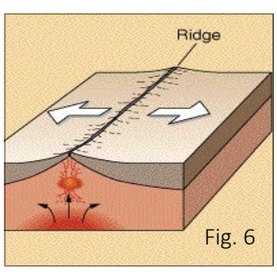


Fig. 6

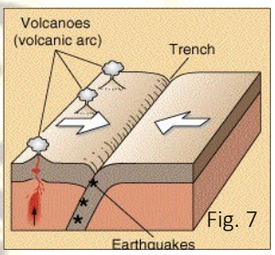


Fig. 7

Transform Boundary	Divergent Boundary	Convergent Boundary
Lateral or horizontal sliding	Spreading margin	Subduction margin or collision margin
Conservative boundary lithosphere neither created or destroyed)	*Constructive boundary* Oceanic lithosphere created	*Destructive margin* - Oceanic lithospheric destroyed
No major feature formed	Creation of ocean ridge and rift valley	Creation of trench, fold mountain
No volcanic activity	Volcanic activity	Volcanic activity

Transform plate boundary

Also known as transform fault boundary, transform plate margin, strike-slip boundary, sliding boundary, conservative plate boundary or neutral plate boundary.

A transform boundary occur when tectonic plates slide and grind against each other along a fault. The plate motion is horizontal. **See figure 8.**

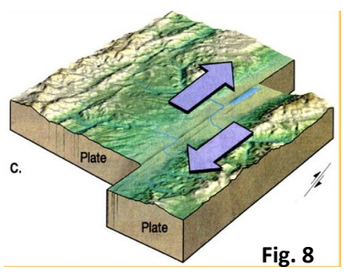


Fig. 8

Since the plates on either side of a transform boundary are merely sliding past each other and not creating or destroying each other, transform boundaries has no spectacular features. However, lots of earthquakes are generated at transform boundaries.

Most transform boundaries are found on the ocean floor. **See figure 9.** However, the most famous transform boundaries are found on land. Many transform boundaries are locked in tension before suddenly releasing, and causing earthquakes.

In a transform boundary, plate is neither created nor destroyed.

Examples of transform boundary/margins include:

1. The *San Andreas Fault* in California, where the Pacific Plate meets the North American Plate and they grind past each other
2. The *Alpine Fault* in New Zealand It forms a transform boundary between the Pacific Plate and the Indo-Australian Plate.
3. the northern of the Caribbean Plate and the Southern edge of the

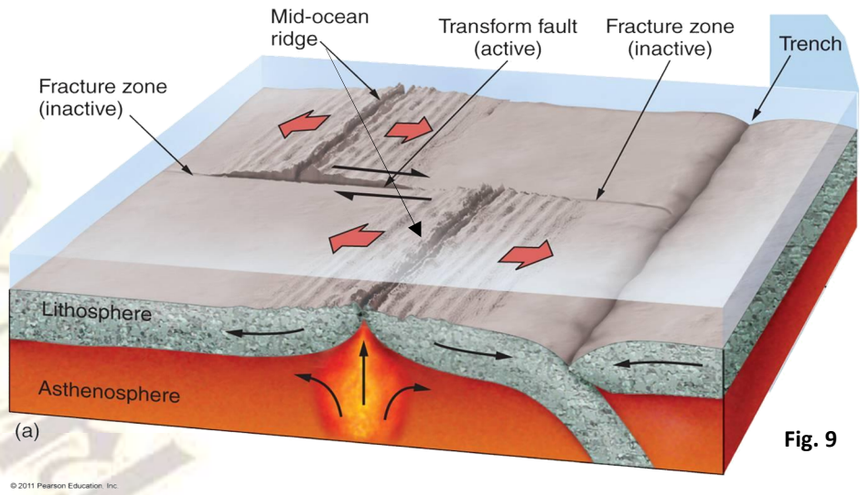


Fig. 9

North American Plate.

Divergent boundaries

Places where plates are coming apart are called divergent boundaries. Divergent boundaries occur where plate move away from each other. Divergent boundary occur in ocean and also on continent. At divergent boundary you find tensional cracks, and faults, shallow earthquakes, high heat flow, and basaltic eruption.

Formation of divergent boundary.

During *rifting* the continental crust is stretched and becomes thin and a *rift valley* forms. **See figure 10.** The continents begins to tear in two along the rift valley. True oceanic crust is created by continuous basaltic erupts from between the two continents. **See figure 11.** The upwelling molten rock pushes up the edge of the two continental margins created a ocean ridge system. **See figure 12. [A *ocean ridge* is an underwater mountain system formed by plate tectonics.]** The upwelling magma also pushes the ocean crust away from the ridge. The process is called *sea-floor spreading.*

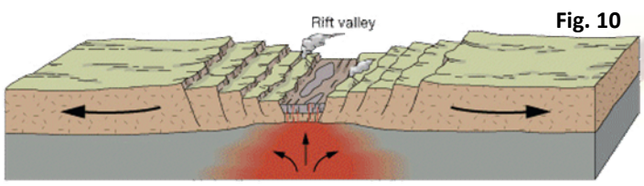


Fig. 10

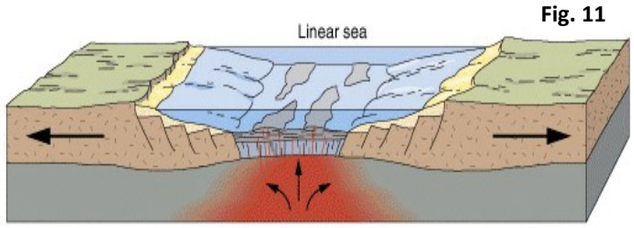


Fig. 11

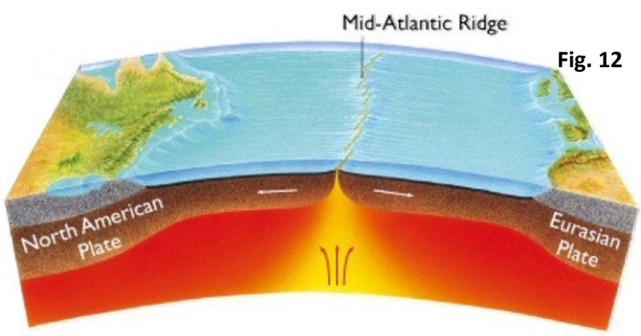


Fig. 12

2. When an oceanic plate converges with a continental plate, the dense oceanic plate will subduct under the continental plate.
3. If the two plates converging towards each other are continental plates, the continents collide and crumple but neither is subducted.

If the spreading is slow the crest/ridge has a rift valley. Fast spreading ridge prevents a rift valley from forming.

Examples include: Where a divergent boundary crosses the ocean floor, the rift valley is much narrower, only a kilometer or less across

(a) *the Mid-Atlantic ridge.* is an underwater mountain range of the Atlantic Ocean and Arctic Ocean. The highest peaks of this mountain range form islands. **See figure 2**

(b) *The East Pacific Rise* **See figure 2**

(c) *Mid Indian Ridge,* **See figure 2**

Examples include: Where a divergent boundary crosses the land, the rift valleys which form are typically 30 to 50 kilometers wide. **Figure 13**

(a) *the East Africa Rift Valley:* is a vast geological feature, approximately, 6000 kilometres (3,700 mi) in length. It extends from Lebanon in the north to Mozambique in the south. The rift valley varies in width from thirty to one hundred kilometers, and in depth from a few hundred to several thousand meters.

(b) The *Rio Grande rift* in New Mexico.

(c) *The boundary between the African Plate and Arabian Plate*

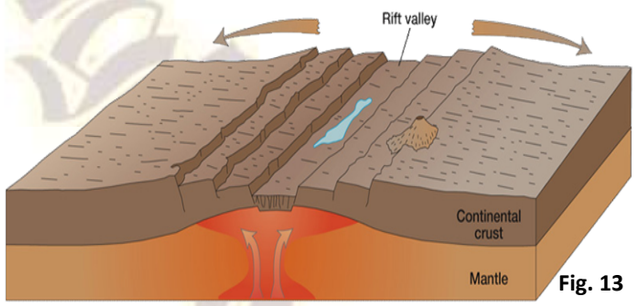


Fig. 13

Convergent Plate Boundaries

At convergent plate boundaries two plate move towards each other. Three types of convergent boundaries are recognized.

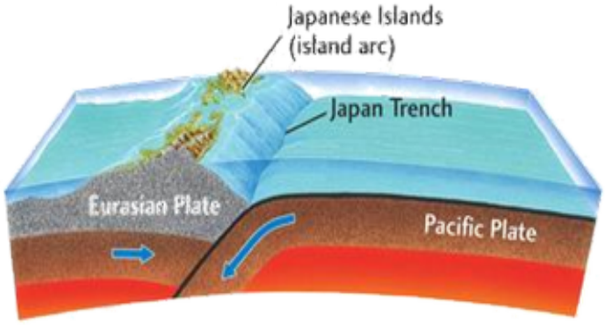
1. A plate made up of oceanic crust can move toward another oceanic plate, in which case one plate will subduct/dive under the other.

Oceanic-oceanic convergence - Subduction zone See figure 14.

When two plates with oceanic crust converge the older heavier one plate subducts under the other. The subducting plate bends downwards forming a trench with a broad curve.

As one plate subduct under the other, a *benioff zone* of earthquake is created.

As the descending plate reaches depths of at least 100 km, magma is generated. The magma then works its way upward to erupt as an *island arc*. The island is parallel to the ocean trench.



Examples of Volcanic Island Arc and Ocean Trench

Island Arcs	Trench	Interacting plates
Japan Islands,	Japan T.	Oceanic section of Eurasian P. and Pacific Plate
Aleutian Islands	Aleutian T.	Oceanic section of N. American P. and Pacific Plate
Lesser Antilles	Tobago Trough	Caribbean plate and N. & S. American Plate
Solomon Islands	Solomon T.	

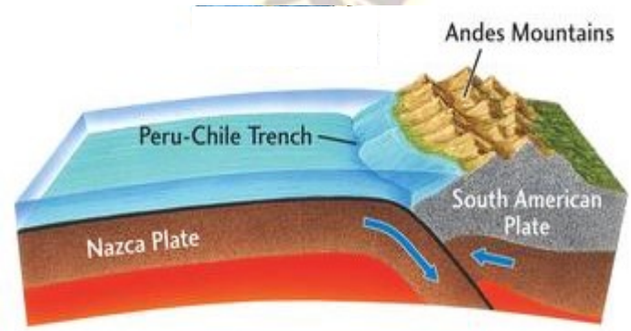
Oceanic-continental - Subduction zone

When one plate is composed of oceanic lithosphere and the other is composed of continental lithosphere, the oceanic plate is subducted. The crust which subducts then melts, gets destroyed and converted back into magma. The newly formed magma will try to rise to the earth's surface. When the magma reach the earth's surface volcanoes will form fairly close to the edge of the over-riding continental plate . These volcanoes will form long chains of fold mountains. About 80% of the world's active volcanoes are found at subduction zones.

An oceanic trench is formed where the denser plate is subducted underneath the other plate. Example **Peru-Chile Trench**

When an oceanic plate pushes into and subducts under a continental plate, the overriding continental plate is lifted up and a mountain range is created. Example the **Andes Mountains** (South America) and the **Rocky Mountains** (North America).

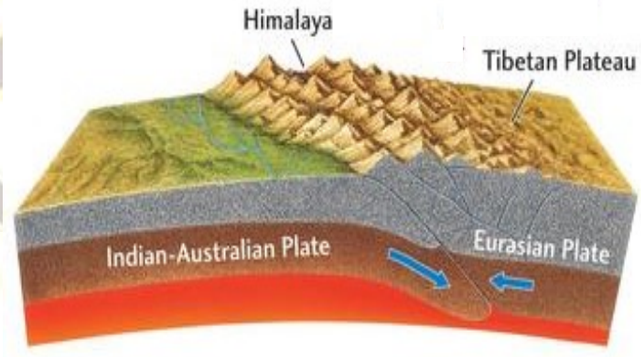
Subduction margins are marked by benioff zone of earth-quakes, volcanic activity and young fold mountain belt.



Continental - Continental - Collision Zone

When two plates containing continental crust collide, both are too light to subduct. When two continents meet head-on, neither is subducted because the continental rocks are relatively light and resist downward motion. Instead, the crust tends to buckle and be pushed upward or sideways. A continent-continent collision creates large mountain ranges. The entire continental-continental *collision zone* is marked by shallow earthquakes.

This best example is where the northern margin of the Indian Plate is being thrust under a portion of the Eurasian plate, lifting it and creating the **Himalayas**.



Convergent Boundary		
	Features	**Activities**
Ocean + Ocean	ocean trench, volcanic island	Earthquake, volcanic
Ocean + Continental	ocean trench, fold mountains, volcanic mtns.	Earthquake, volcanic
Continental+ Continental	fold mountains, earthquakes	earthquake

Plate tectonic in the Caribbean.

The Caribbean Plate is a mostly oceanic tectonic plate underlying Central America and the Caribbean Sea off the north coast of South America.

The Caribbean Plate borders the North American Plate, the South American Plate, the Nazca Plate and the Cocos Plate. These borders are regions of intense seismic activity, including frequent earthquakes, occasional tsunamis, and volcanic eruptions.

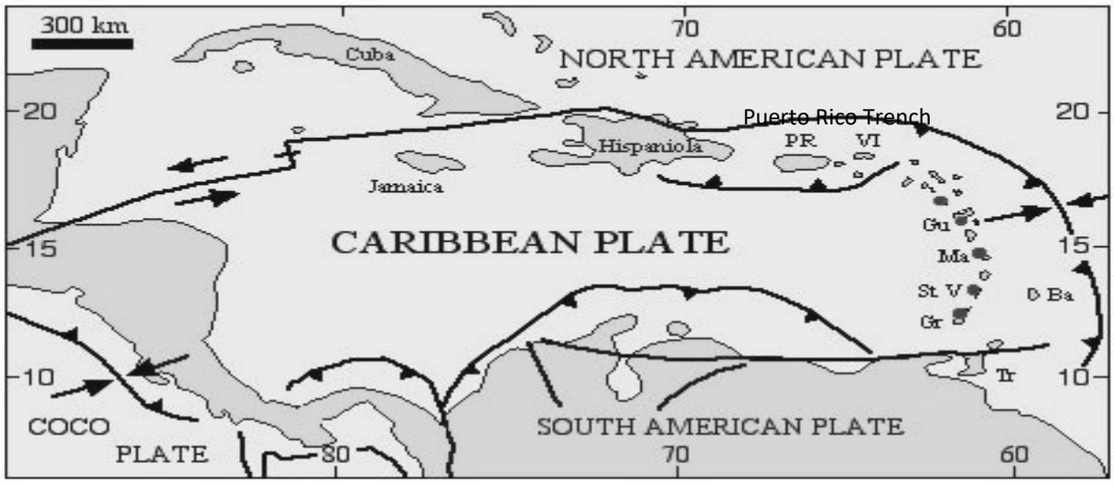
The northern boundary with the North American plate is a trans-form or strike-slip boundary. The Puerto Rico Trench, the deep-est part of the Atlantic Ocean (roughly 8,400 meters), lies along this border.

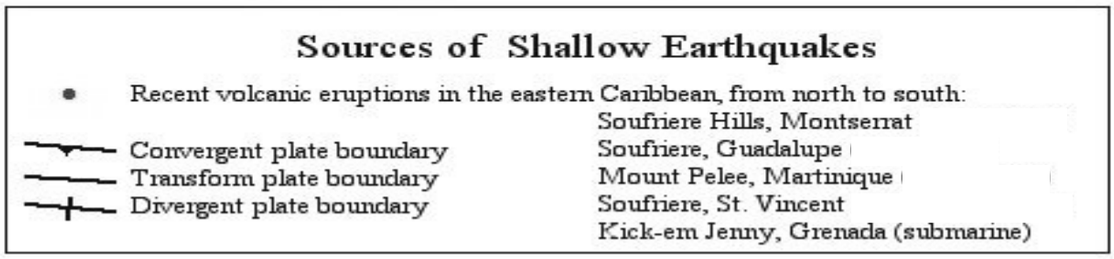
The eastern boundary is a subduction zone, the Lesser Antilles subduction zone, where oceanic crust of the South American Plate is being subducted under the Caribbean Plate. Subduction forms the volcanic islands of the Lesser Antilles. This boundary contains seventeen active volcanoes, most notably Soufriere Hills on Montserrat; Mount Pelée on Martinique; La Grande Soufrière on Guadeloupe; Soufrière Saint Vincent on Saint Vin-cent; and the submarine volcano Kick 'em Jenny which lies about 10 km north of Grenada.

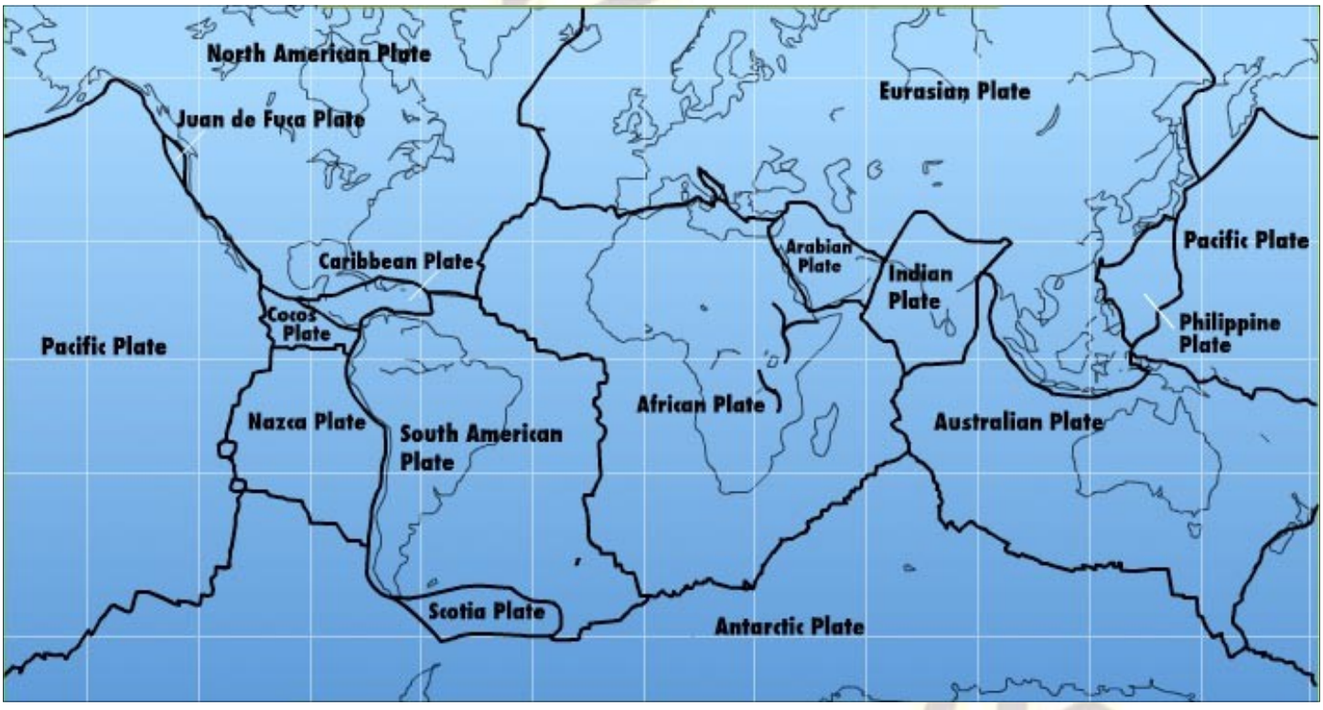
Along southern boundary, the Caribbean Plate interacts with the South American Plate forming Barbados, Trinidad, and Tobago (all on the Caribbean Plate), and islands off the coast of Vene-zuela (including the Leeward Antilles) and Colombia. This bound-ary is in part the result of transform faulting along with thrust faulting and some subduction.

The Caribbean plate is moving eastward about 22 mm per year in relation to the South American plate.

The western portion of the plate is occupied by Central America. The Cocos Plate in the Pacific Ocean is subducted beneath the Caribbean Plate, just off the western coast of Central America. This subduction forms the volcanoes of Guatemala, El Salvador, Nicaragua, and Costa Rica, also known as the Central America Volcanic Arc.







GLOSSARY

Plate (tectonic plate or lithospheric plate) - *a large, mobile slab of rock that is part of the earth's surface.*

Continental drift - *the movement of continents over the earth's surface.*

Sea-floor spreading *- the formation of sea-floor at the crest of ocean ridge and its horizontal movement away from the ridge towards an oceanic trench*

Rifting - *breaking of the earth's crust and lithosphere where they are being pulled apart.*

Rift valley - *a lowland region that forms where tectonic plate are being pulled apart or rift.*

Sea-floor spreading - *the process in which new ocean floor is created as molten material from the earth's mantle rises in margins between plates or ridges and spread out.*

Benioff zone - *a dipping flat zone of earthquakes that is produced by the subduction of oceanic crust beneath a continental crust.*

Island arc - *an arc-shaped group of volcanic islands.*

Collision zone - *a zone where convergent continental crust interact.*