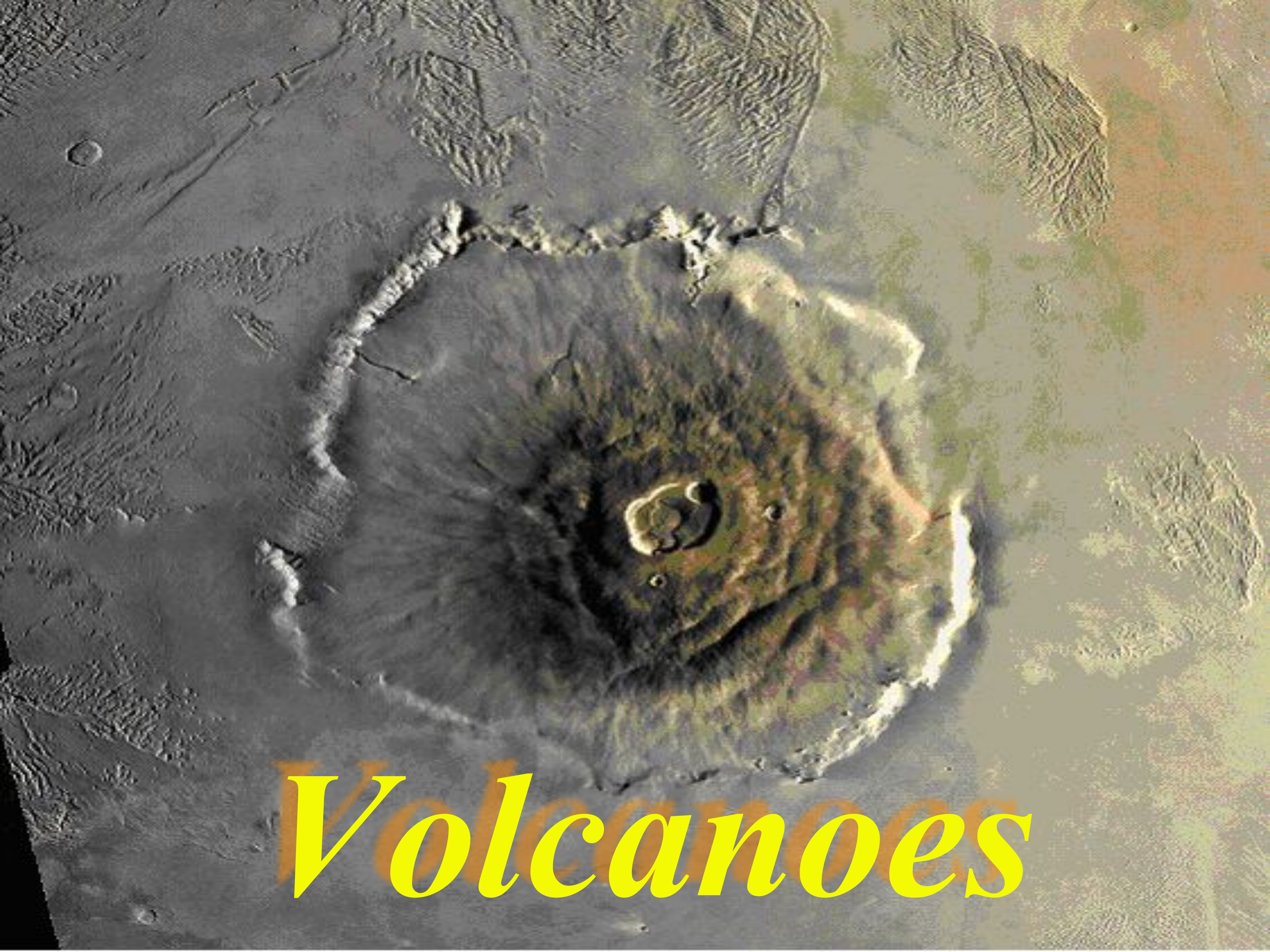
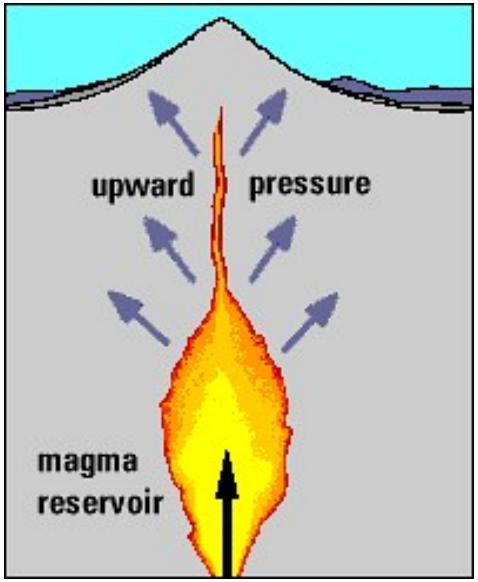
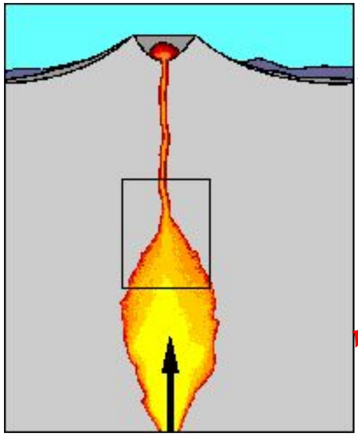

Volcanoes

What is a volcano?

Volcanoes are geologic safety valves that release excess pressure in subsurface magma chambers and mark the vent of a conduit, through which material is expelled from depth. Internal pressure builds up as the solid crystalline earth surface confines it to a smaller volume. As this pressure in the liquid magma exceeds the confines of the rock surface above it, the magma mass works its way upwards migrating from a region of high pressure to that of a low pressure, finally resulting in what is called a volcanic eruption – spewing out the dissolved gasses, water vapour and the silicate liquid (magma or lava).

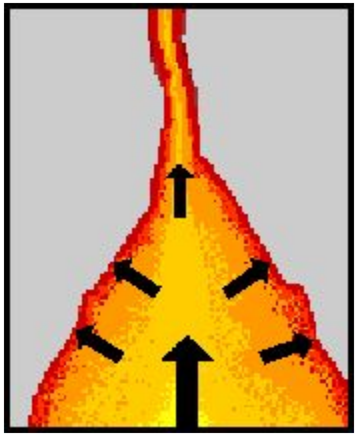


Upward pressure from rising magma deforming the surface into a volcano

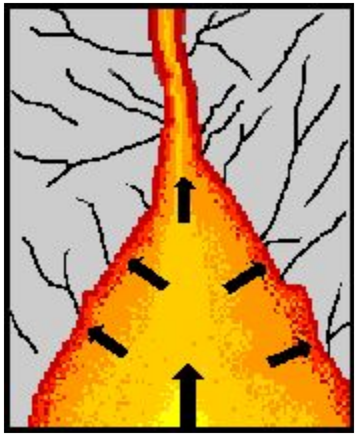


Magma rises in reservoir beneath volcano

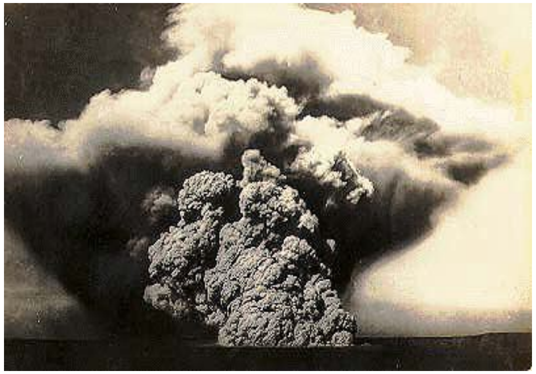
Rising magma & volcanic gasses exerting pressure



High pressure causing rocks to break, triggering earthquakes



What is a volcano?



Volcanic eruptions are one of Earth's most dramatic and violent agents of change. Not only can powerful explosive eruptions drastically alter land and water for tens of kilometers around a volcano, but tiny droplets of sulfuric acid erupted into the stratosphere can change our planet's climate temporarily.

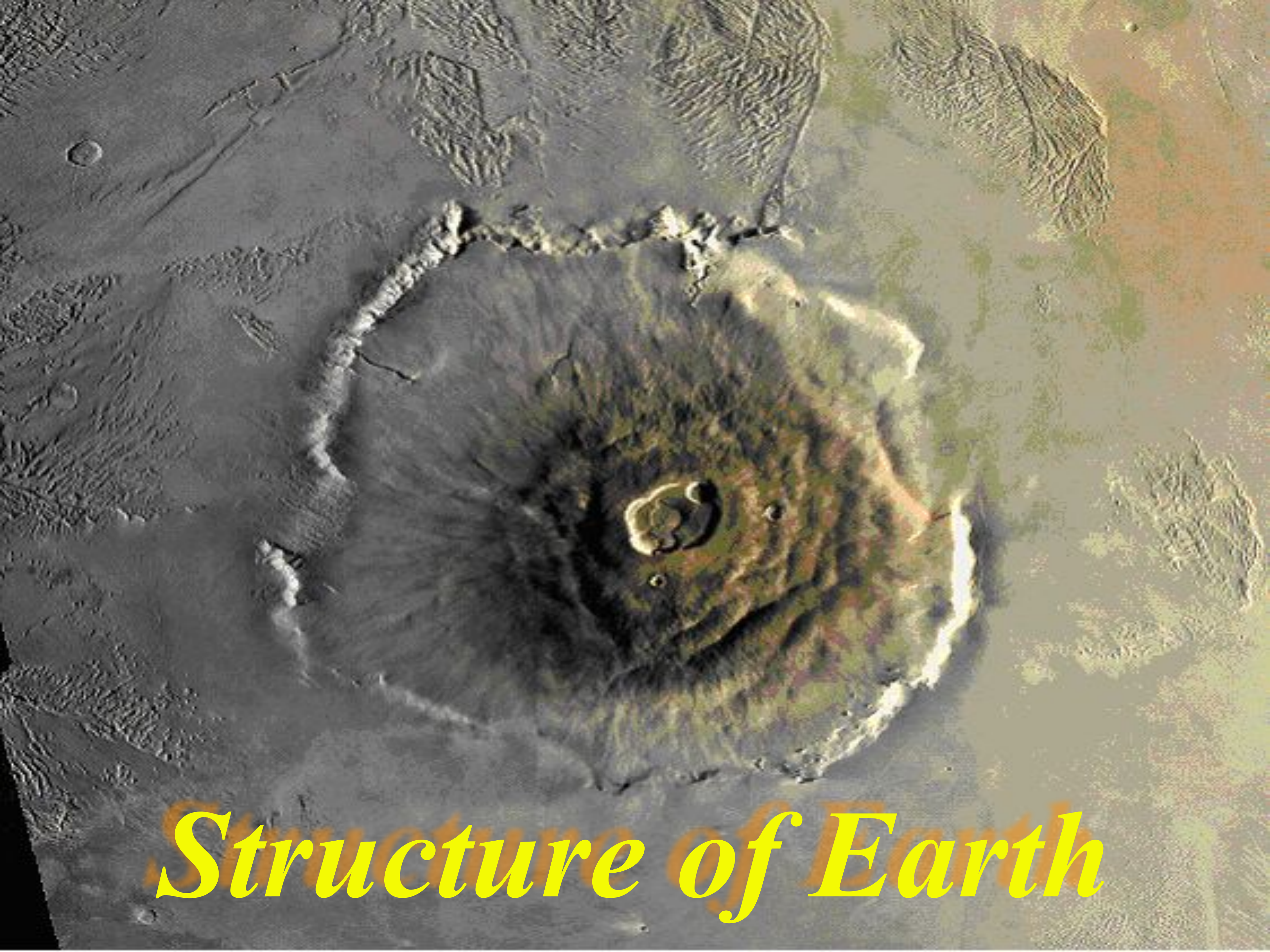
Most of the activity involves the explosive ejection or flowage of rock fragments and molten rock in various combinations of hot or cold, wet or dry, and fast or slow. Some hazards are more severe than others depending on the size and extent of the event taking place and whether people or property are in the way. And although most volcano hazards are triggered directly by an eruption, some occur when a volcano is quiet.

Eruptions often force people living near volcanoes to abandon their land and homes, sometimes forever. Volcanic activity since 1700 A.D. has killed more than 2,60,000 people, destroyed entire cities and forests, and severely disrupted local economies for months to years.

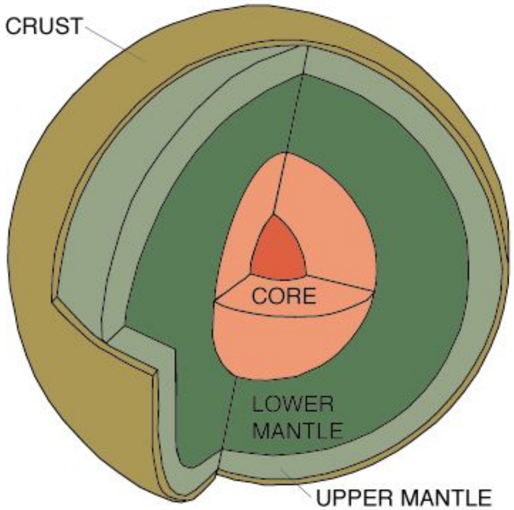
What causes a volcano?

To understand the reasons behind the formation of a volcano it is very essential to understand the structure of the Earth & the concept of plate tectonics. In fact, plate tectonics is the very base of all Earth activities.

The concept of the formation & motion of plates on the Earth's surface will be discussed in the consequent slides. Before that we will briefly look into the structure of the Earth.


Structure of Earth

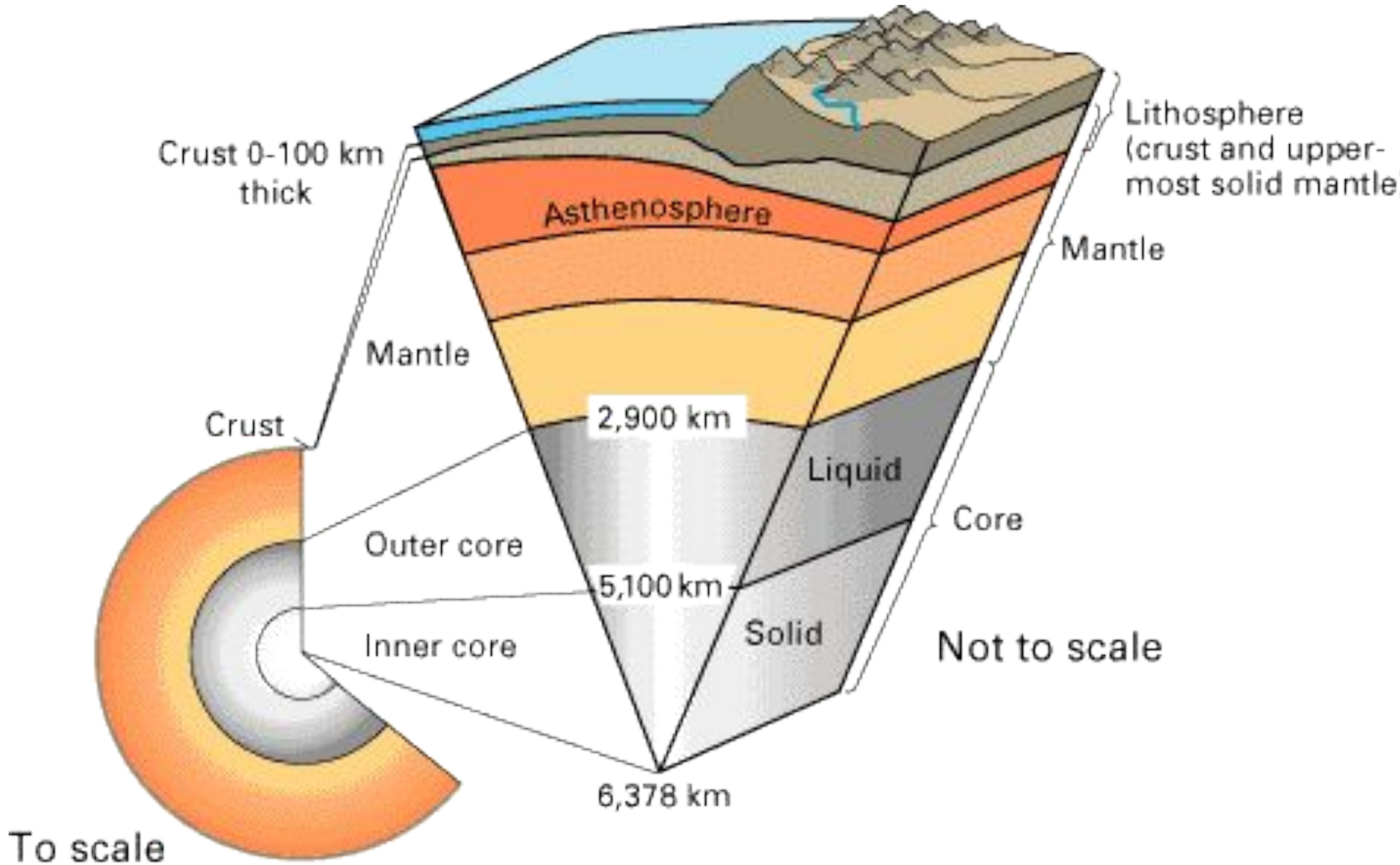
Structure of the Earth



The Earth is divided into three chemical layers: the core, the mantle and the crust.
Crust, the outermost layer, is rigid and very thin. Below the crust is the mantle, a dense, hot layer of semi-solid rock approximately 2,900 km thick. The mantle, which contains more iron, magnesium, and calcium than the crust, is hotter and denser because temperature and pressure inside the Earth increases with depth. At the center of the Earth lies the core, which is nearly twice as dense as the mantle because its composition is metallic (iron-nickel alloy). The Earth's core is actually made up of two distinct parts: a 2,200 km-thick liquid outer core and a 1,250 km-thick solid inner core.

The upper part of the mantle is cooler & more rigid than the deep mantle. In many ways, it behaves like the overlying crust. Together they form a rigid layer of rocks called the lithosphere. Below the lithosphere is a relatively narrow, mobile zone in the mantle called the asthenosphere which is composed of hot, semi-solid material, which can soften and flow after being subjected to high temperature and pressure over geologic time.

Detailed layers of the Earth



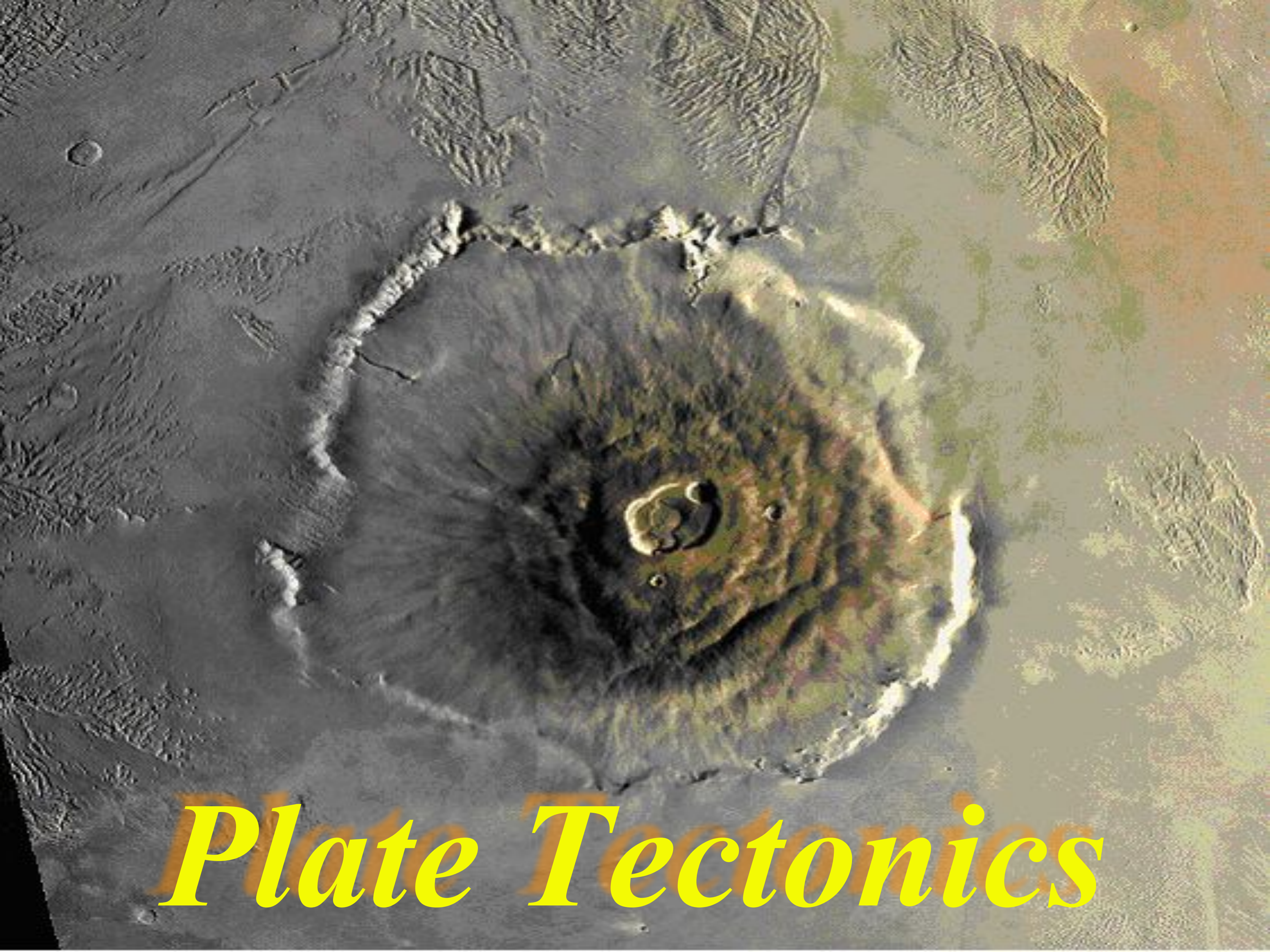


Plate Tectonics

The theory of Plate Tectonics

Plate tectonics is a relatively new theory that has revolutionized the way geologists think about the Earth. According to the theory, the surface of the Earth is broken into large plates. The size and position of these plates change over time. The edges of these plates, where they move against each other, are sites of intense geologic activity, such as earthquakes, volcanoes, and mountain building.

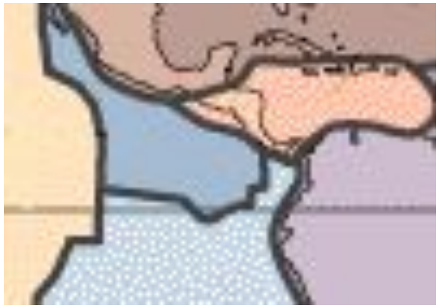
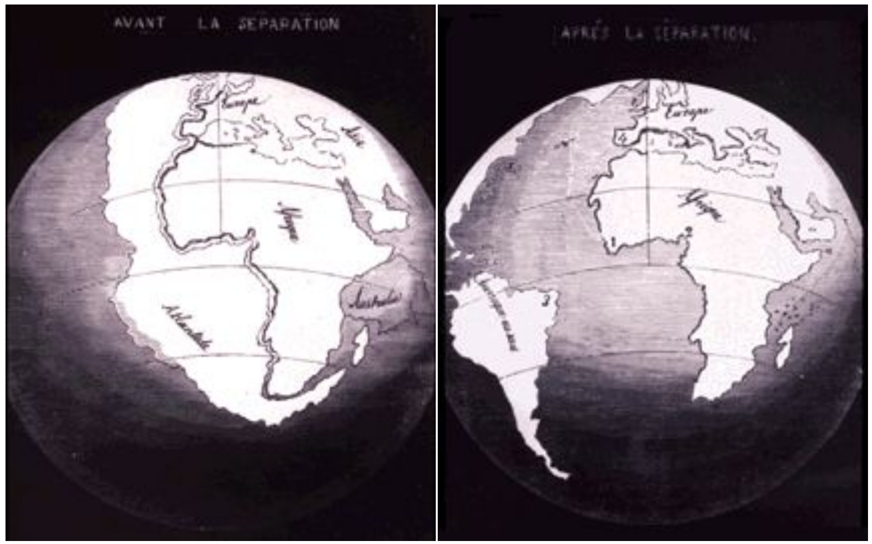


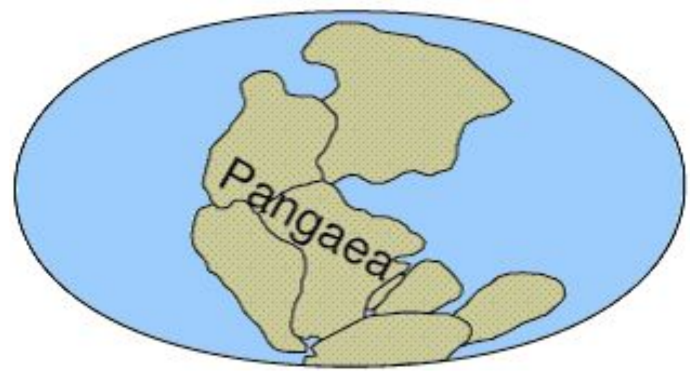
Plate tectonics is a combination of two earlier ideas, continental drift and sea-floor spreading. Continental drift is the movement of continents over the Earth's surface and in their change in position relative to each other. Sea-floor spreading is the creation of new oceanic crust at mid-ocean ridges and movement of the crust away from the mid-ocean ridges.

The concept of Continental Drift

The remarkable observance and discovery of the way continents, particularly the coastlines of South America and Africa, fit together like pieces of a jigsaw puzzle, gave rise to the idea of continental drift.



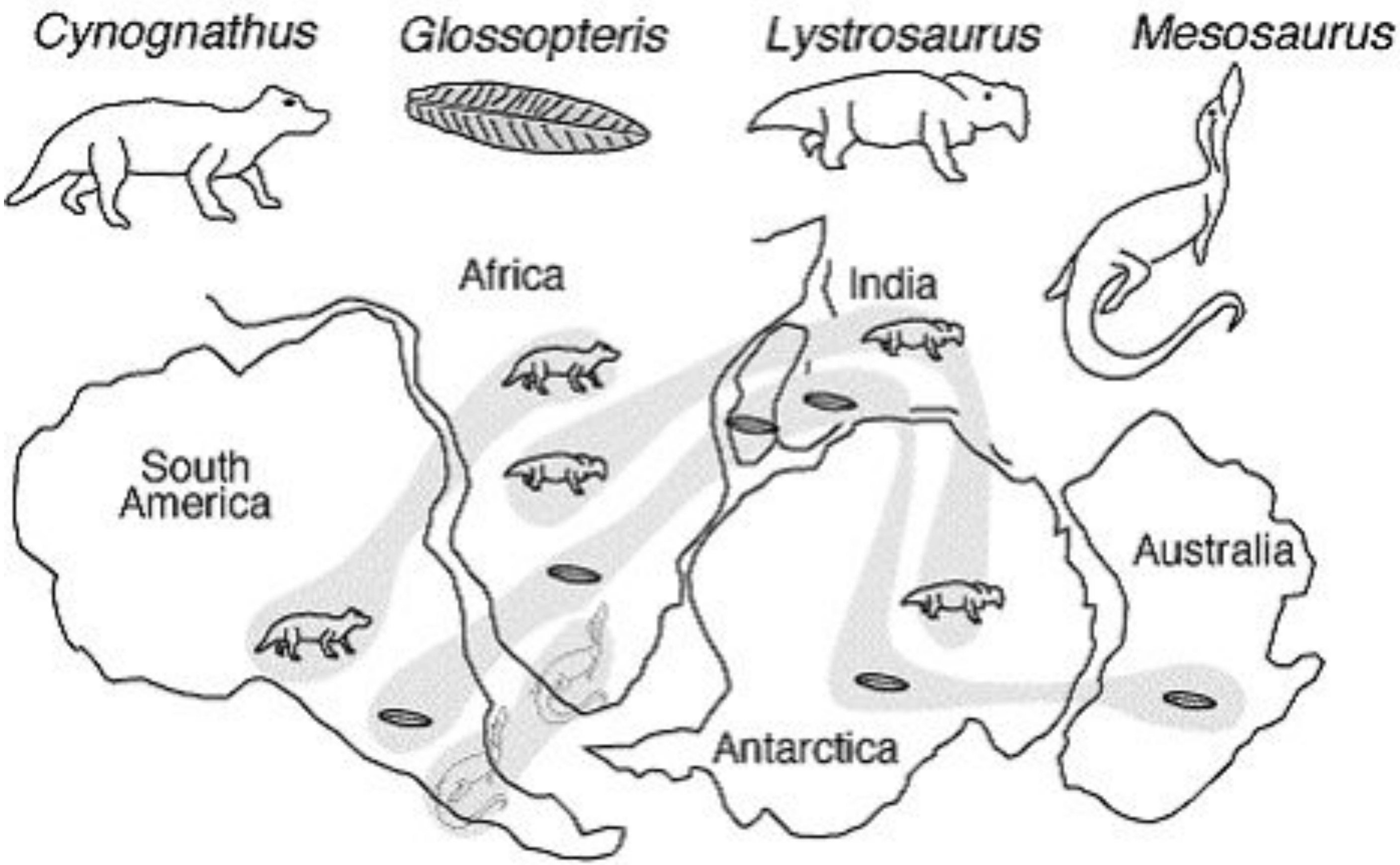
Alfred Wegner, a German meteorologist and geophysicist, from this observation and many other evidences proposed the theory of continental drift. He suggested that a supercontinent, Pangaea, once existed, that about 200 million years ago began breaking into smaller continents. These continents then drifted to their present positions.



The supercontinent 'Pangaea', meaning 'all land'

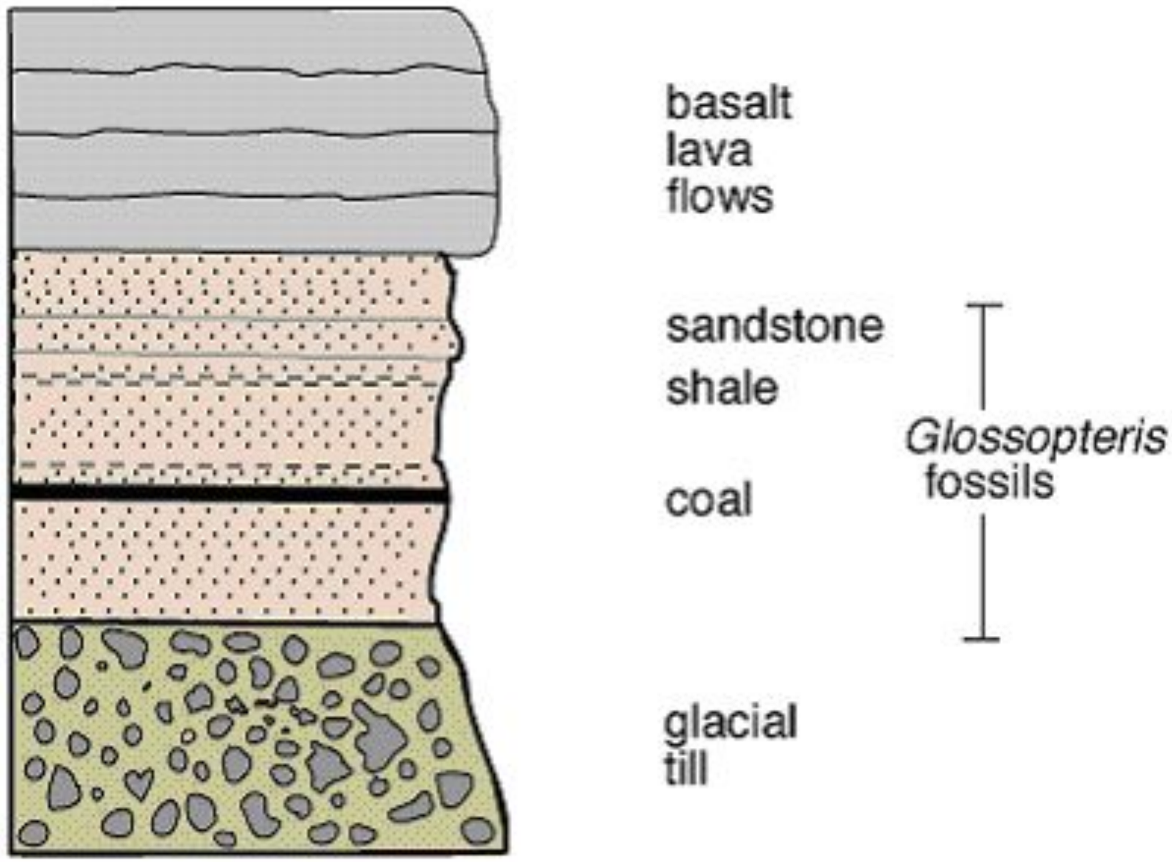
Evidences given by Wegner

to support his theory



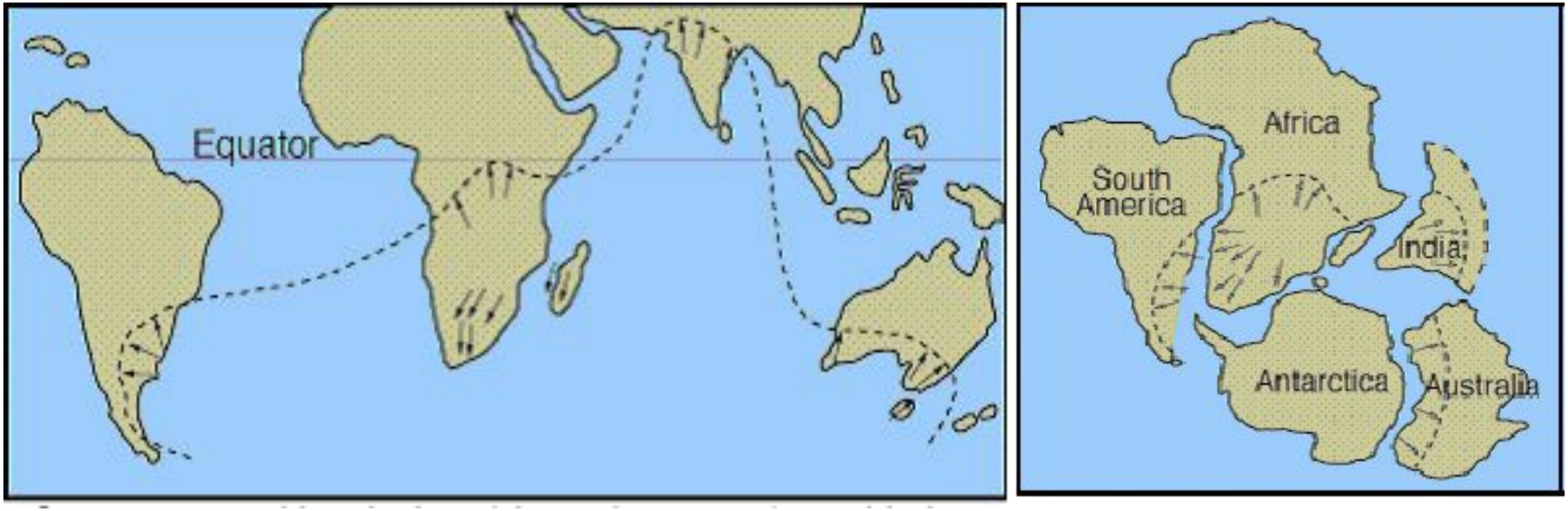
The distribution of the fossils of these species could be accounted for by initially spreading across Pangaea, followed by the breakup of the supercontinent

Evidences given by Wegner
to support his theory



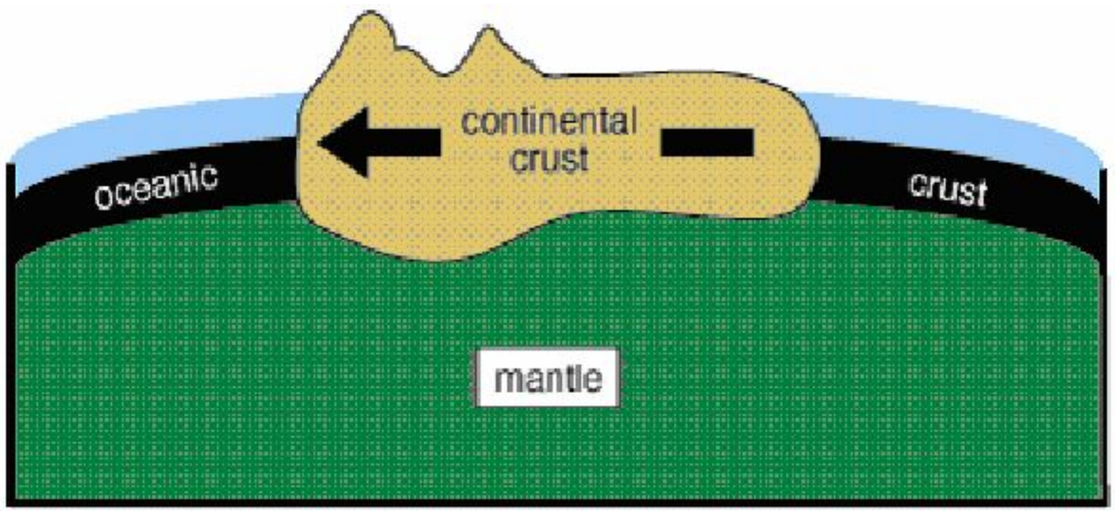
Similar layers of rocks were formed in Antarctica, Australia, South America, Africa and India before Pangaea broke apart. Glossopteris fossils were found in the rocks of each continent.

Evidences given by Wegner
to support his theory



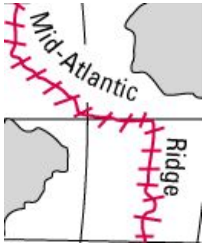
Glaciation in South America, Africa, India, and Australia is best explained if these continents were once connected. Glaciers covered all or part of each of these continents during the same time period in the geologic past.

Wegner's theory fails



The greatest shortcoming with Wegner's theory was the lack of an adequate mechanism for moving the continents. Wegner proposed that the Earth's spin caused the continents to move, plowing through the oceanic plate and producing mountains on their leading edges. Geologists at that time understood enough about the strength of rocks to know that this was highly unlikely & physically impossible for a large mass of solid rock to plow through the ocean floor without breaking up.

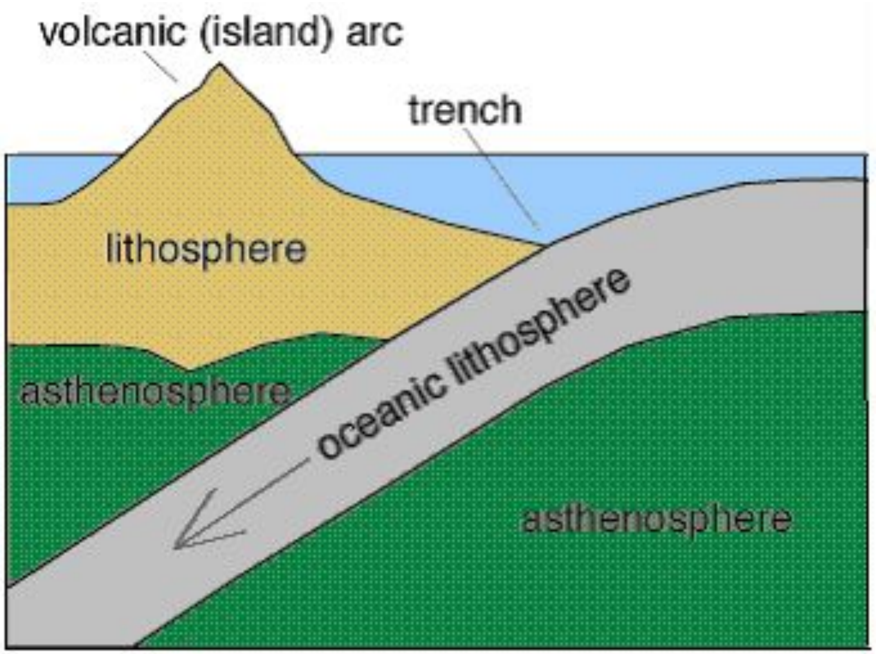
The concept of Sea-floor Spreading



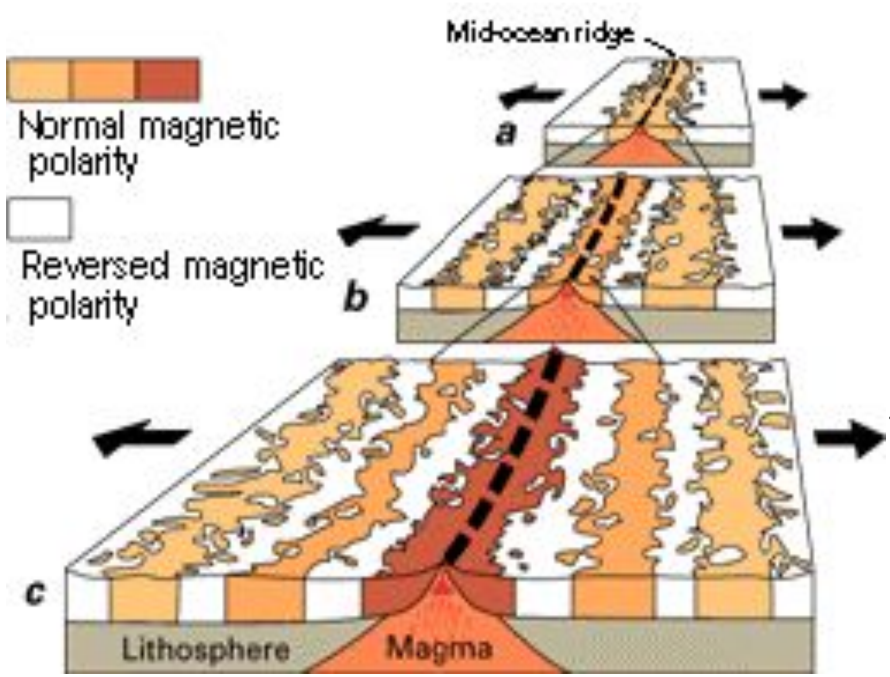
With advances in our knowledge of the sea floor and the magnetic properties of the rocks, new evidences were found, to again, further support the continental drift theory.

The ridge in the Atlantic Ocean helped us study & understand that mid-ocean ridges was a global system, virtually encircling the entire Earth. A region of active seismic belt, this global mid-ocean ridge extending for more than 60,000 km, through all the world's oceans, is perhaps the most prominent topographic feature on the surface of the planet.

Explaining the global rift system, Harry Hess & Robert Dietz, independently proposed, that new ocean floor is formed at the rift of mid-ocean ridges. The ocean floor, and the rock beneath it, are produced by magma that rises from deeper levels, moving the ocean floor laterally away from the ridge & plunging in oceanic trenches along the continental margin.



Evidence supporting the Sea-floor Spreading hypothesis



The Earth's magnetic field is known to periodically reverse polarity changing the north magnetic pole to the south magnetic pole and vice-versa. The iron rich minerals which are abundant in basaltic composition, when in fluid state, tend to align themselves to the Earth's magnetic field. And as these minerals crystallize into solid rock form they freeze their magnetic polarity, which, under normal circumstances, even if their positions are changed, do not change their 'preserved' polarity.

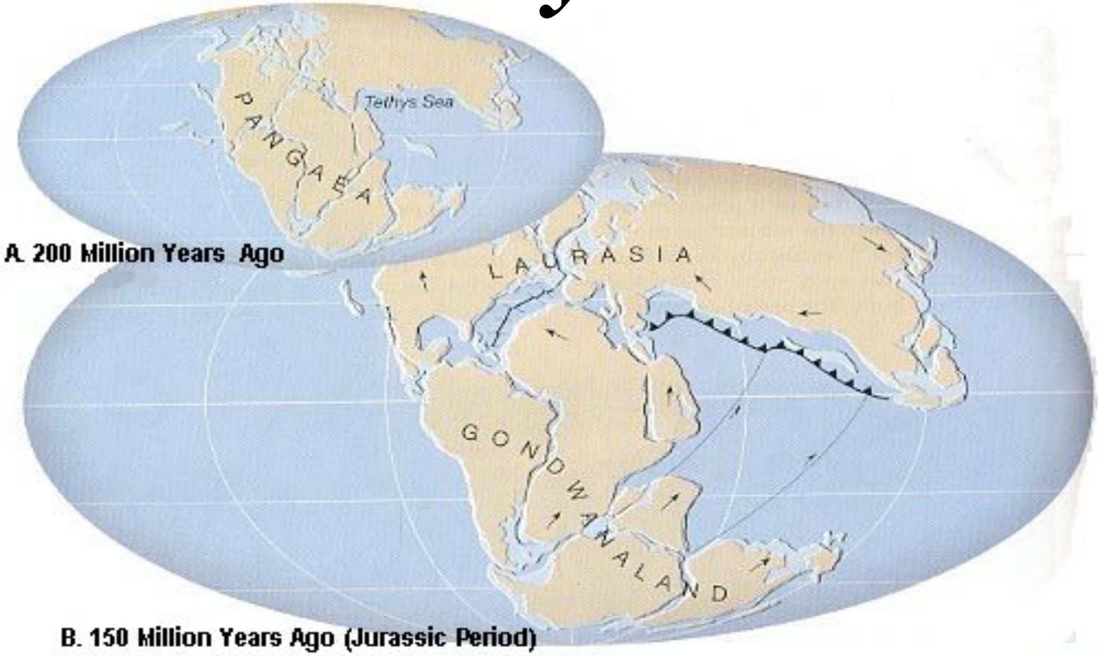
This phenomenon known as paleomagnetism, shown in rocks formed thousands & millions of years ago provide us with ample information about the Earth's magnetic history exhibited at that time. Regions of the Earth at ridges, where volcanic activity has been going on for thousands of years at a stretch forming new deposits of sediments on the crust have been found to show normal & reverse polarity in alternate stretches with increasing distance from the ridge. This proved to be the most profound evidence of sea-floor spreading.

Birth of the Plate Tectonics

Combining the concepts of the continental drift & sea-floor spreading, along with newer evidences provided by improved technologies, lead us to the theory of plate tectonics, only about 50 years back. Wegner's concept of 'all land' Pangaea was accepted along with its breaking up into the present continents, but unlike his proposal, the continents did not travel through the oceans, but parts of continents along with oceanic crust travelled together as plates, where these plates would be 'formed' at the ridges and 'lost' back to the mantle at trenches.

On the basis of this theory, the history of the formation and evolution of the Earth, as is seen today, was formed.

History & evolution of Earth

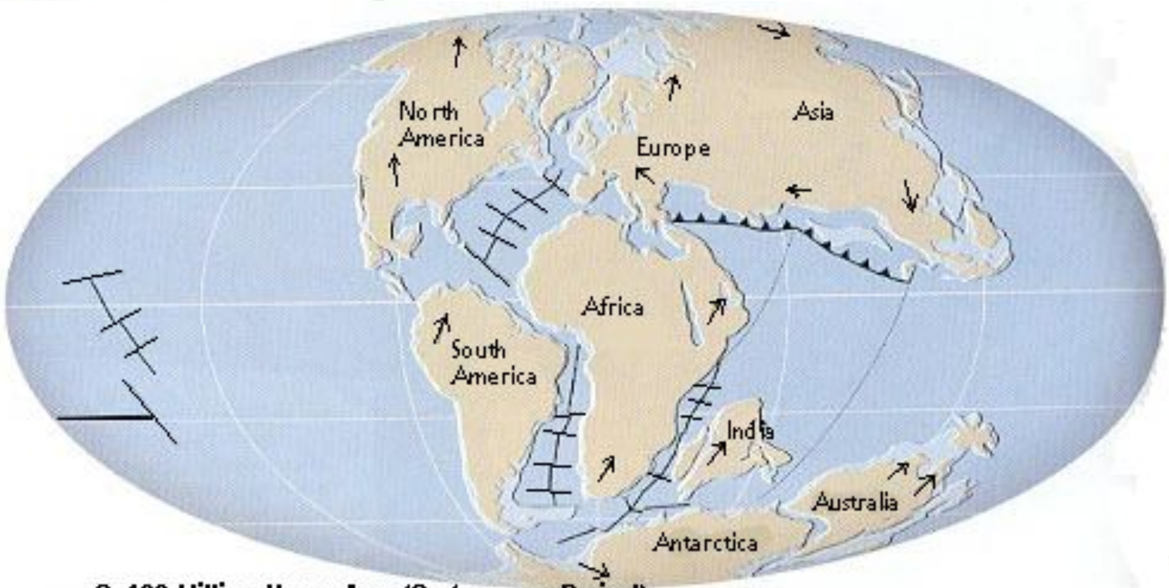


A. 200 Million Years Ago

B. 150 Million Years Ago (Jurassic Period)

From the 'all land' Pangaea, 200m years ago, the supercontinent broke into large continents in northern hemisphere & southern hemisphere, known as Laurasia and Gondwanaland respectively.

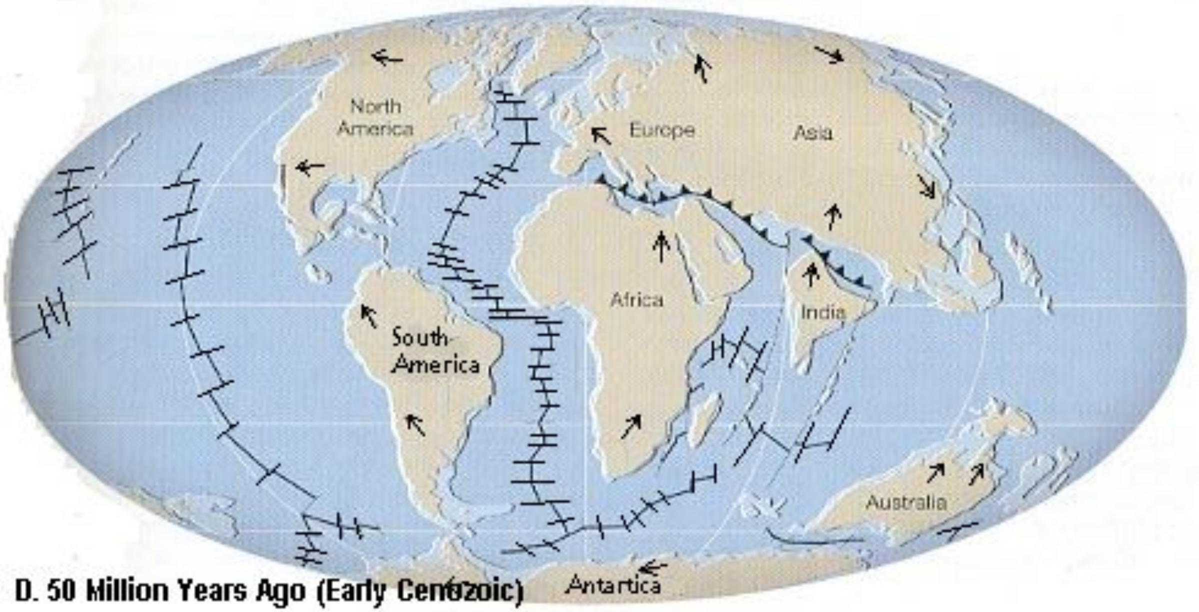
About a 100m years ago, as India broke away from Antarctica, the seven other known continents started separating from each other.



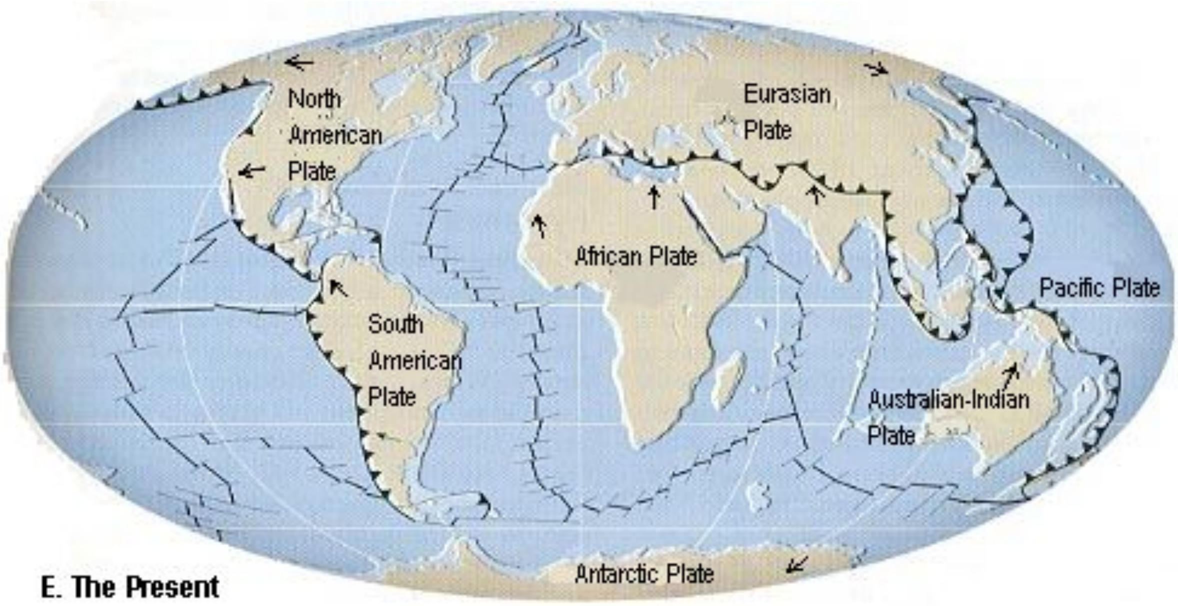
C. 100 Million Years Ago (Cretaceous Period)

History & evolution of Earth

By early Cenozoic Period, as India approached Asia, the Antarctic ocean between Africa & Americas also started becoming wider. All the other presently known plates were formed by this period.



D. 50 Million Years Ago (Early Cenozoic)

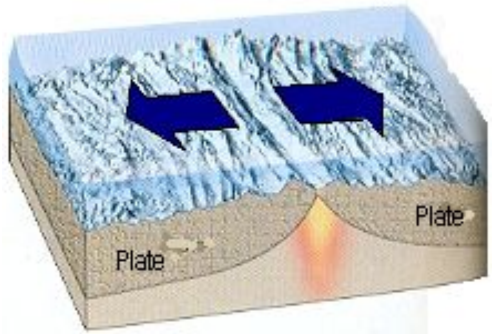


E. The Present

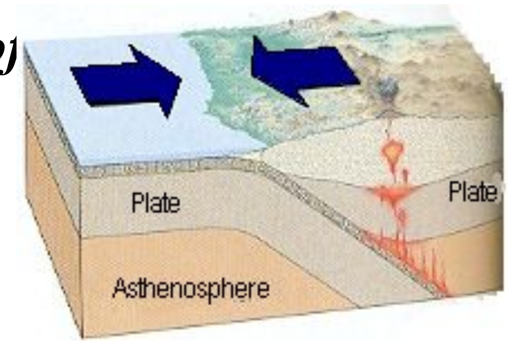
By now India hit Asia and became a part of it and all other continents had taken their present positions with their plate boudaries marked with 'ridges' & 'trenches'

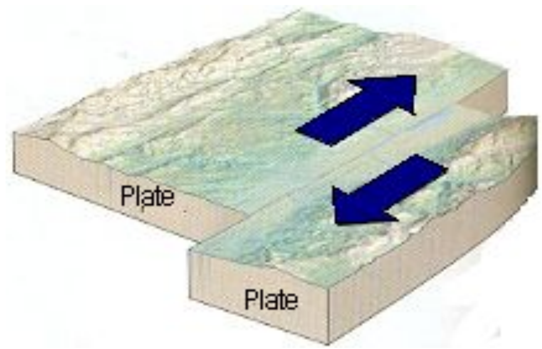

Plate Motions

How plates behave at boundaries



The way plates interact at their boundaries depends on their relative motion and whether the edges consist of oceanic crust or continental crust. Broadly there are three types of plate motions or boundaries identified:



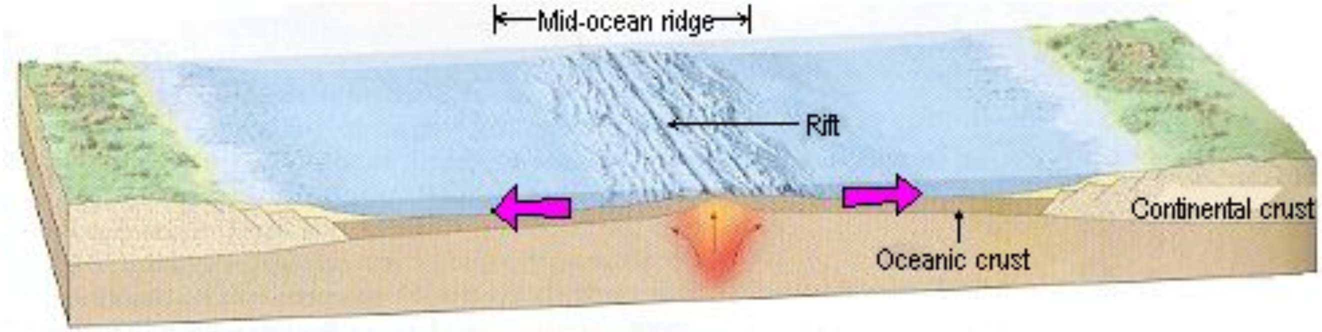


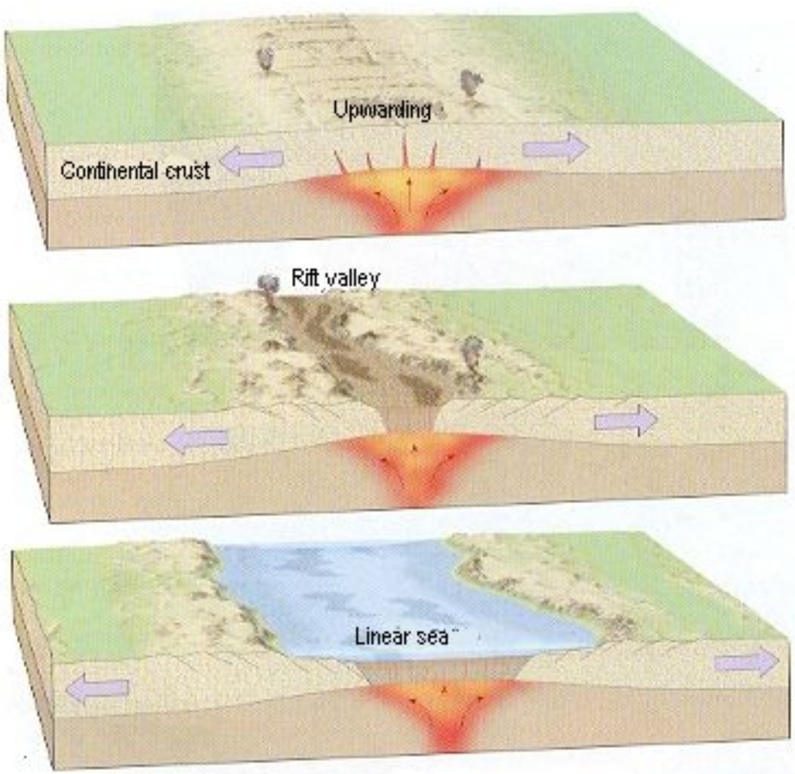
A. ***Divergent boundaries** – plates moving away from each other*

B. ***Convergent boundaries** – plates moving towards each other*

C. ***Transform boundaries** – plates sliding past each other*

Divergent Boundaries





The sea-floor spreading at ridge axes give rise to the fractures between two plates. These fractures are filled up by the upwelling of magma, adding new oceanic crust. Such plate boundaries exhibit what is called divergent motion. Most of these divergent plate boundaries are hidden deep beneath the oceans, characterized by the ridges formed. Much earlier, the breaking up of the continental crust of Pangaea was facilitated by this phenomenon only.

Formation of the huge Atlantic ocean as seen today, was formed by the divergent motions of the African & South American plates over millions of years.

Convergent Boundaries

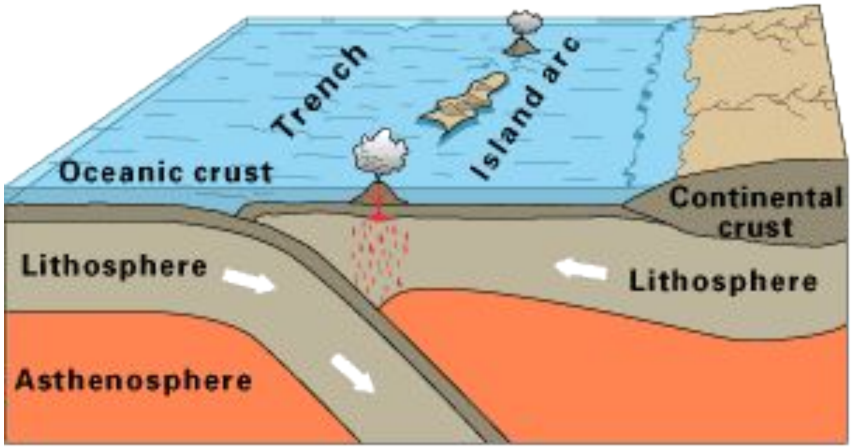
Considering the volume & surface area of Earth as constant, if new crusts are being formed at divergent boundaries, existing crusts have to be consumed somewhere. This takes place at 'subduction zones' present between plates converging into each other.

At convergent boundaries, where plates move towards each other, one plate (denser that the other) subducts under the other. As the oceanic plates, generally being the denser one, subducts beneath the overriding plate, they produce a deep trench at the bend.

These boundaries are major zones of volcanic activity.

The characteristics around such boundaries are greatly influenced by the type of crust present there - continental or oceanic.

Convergent Boundaries



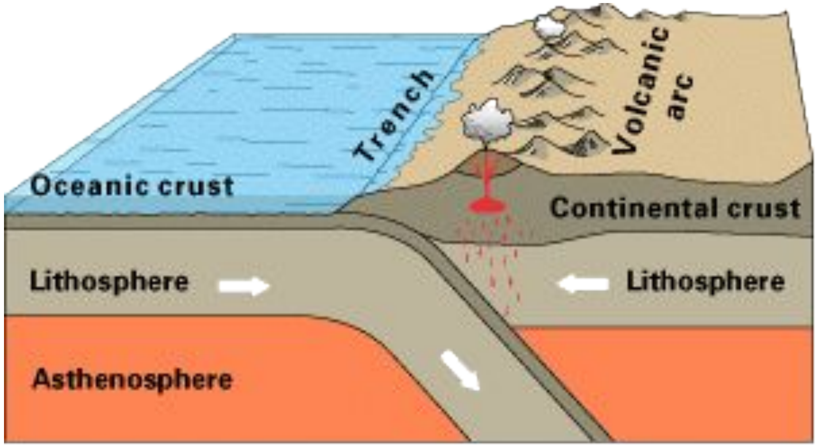
Oceanic-oceanic convergence

Oceanic-Oceanic Convergence

When two lithospheric plates consisting of oceanic crust converge, one of them bends beneath the other. When this descending plate reaches a depth of about 100-150 km, heat drives water & other volatile components from the subducted sediments into the overlying mantle. This results in the partial melting of the mantle rocks forming magma. Since this newly generated magma is less denser that the mantle rocks, they rise & migrate to the surface, eventually erupting into explosive volcanoes.

These volcanoes erupt on the overriding oceanic crust & as this activity continues, it gives rise to a chain of small volcanic islands known as 'volcanic island arc'. Sandwich Islands in the South Atlantic are an example of such an arc.

Convergent Boundaries



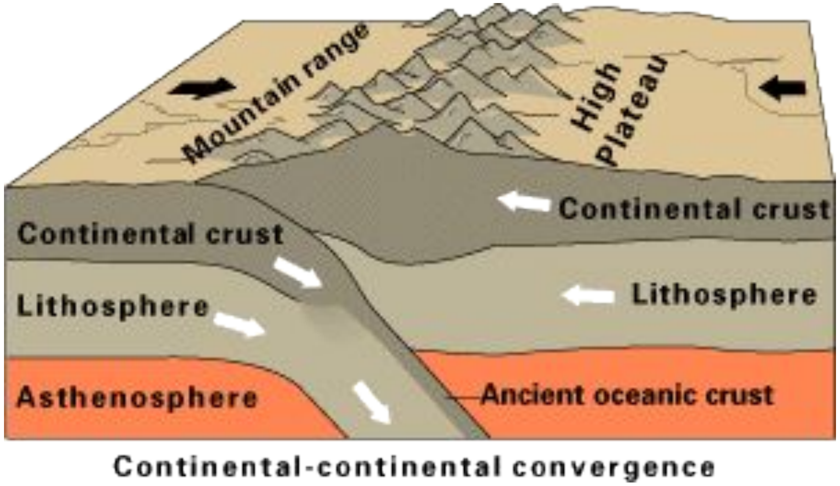
Oceanic-continental convergence

Oceanic-Continental Convergence

Whenever the leading edge of a plate capped with continental crust converges with one with oceanic crust, the less dense continental plate remains floating while the denser oceanic plate sinks into the asthenosphere. Volcanic activity is initiated, in a similar way as seen in oceanic-oceanic convergence, forming 'continental volcanic arc' in this case.

Andes Mountain range flanking the west coast of South America is a product of convergence of the Nazca Plate beneath the South American Plate.

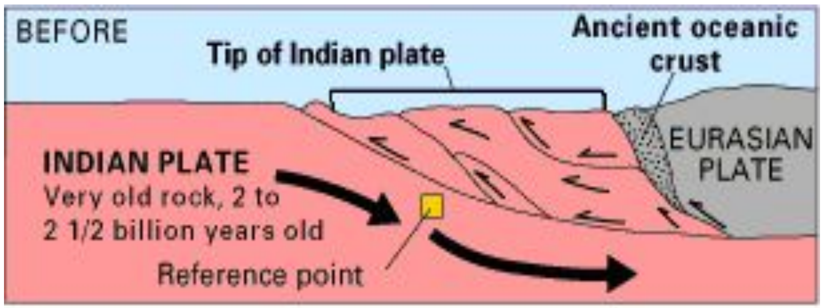
Convergent Boundaries

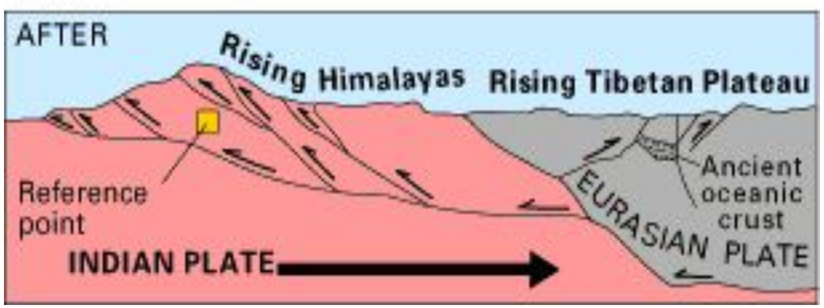


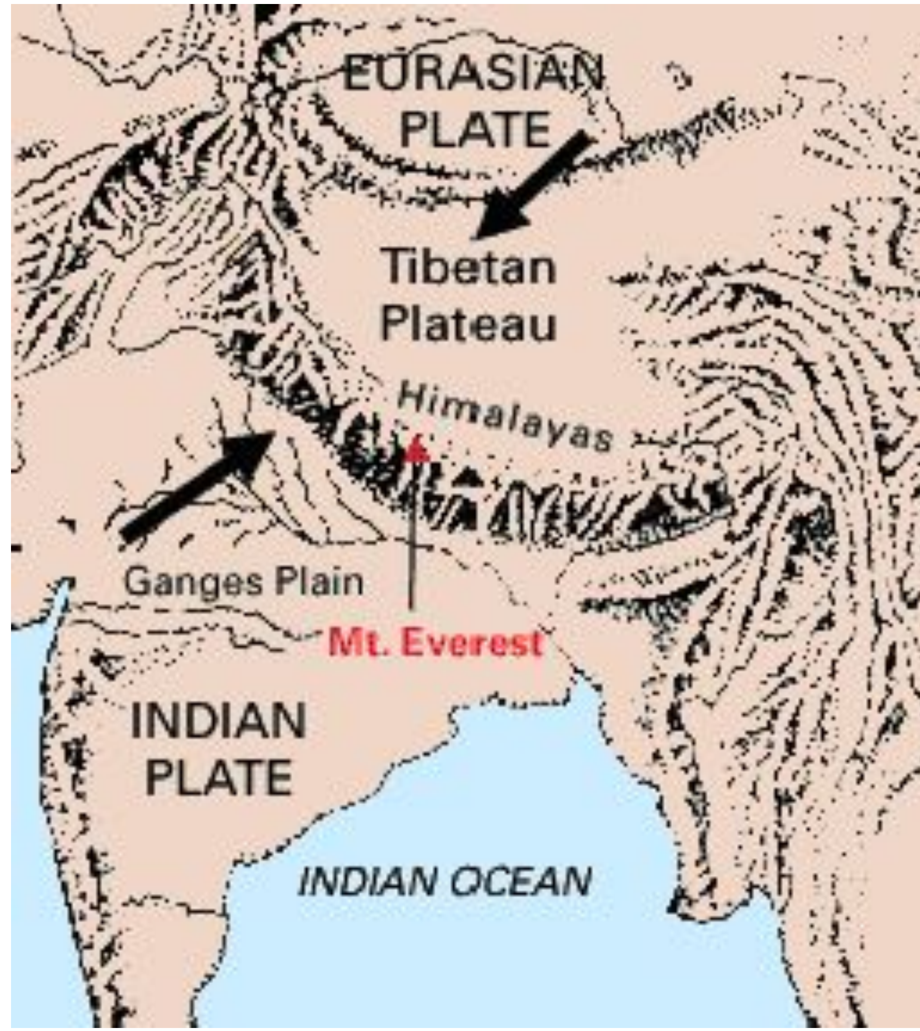
Continental-Continental Convergence

When two plates carrying continental crusts converge, neither plate will subduct beneath the other because of the low density of the continental rocks. This sort of a 'head on' collision between two continental plates gives rise to the formation of mountains, where the continental crust of both the plates ride over each other. The best example of this are the spectacular Himalyan Range formed by the convergence of the Australian-Indian Plate into the Eurasian Plate.

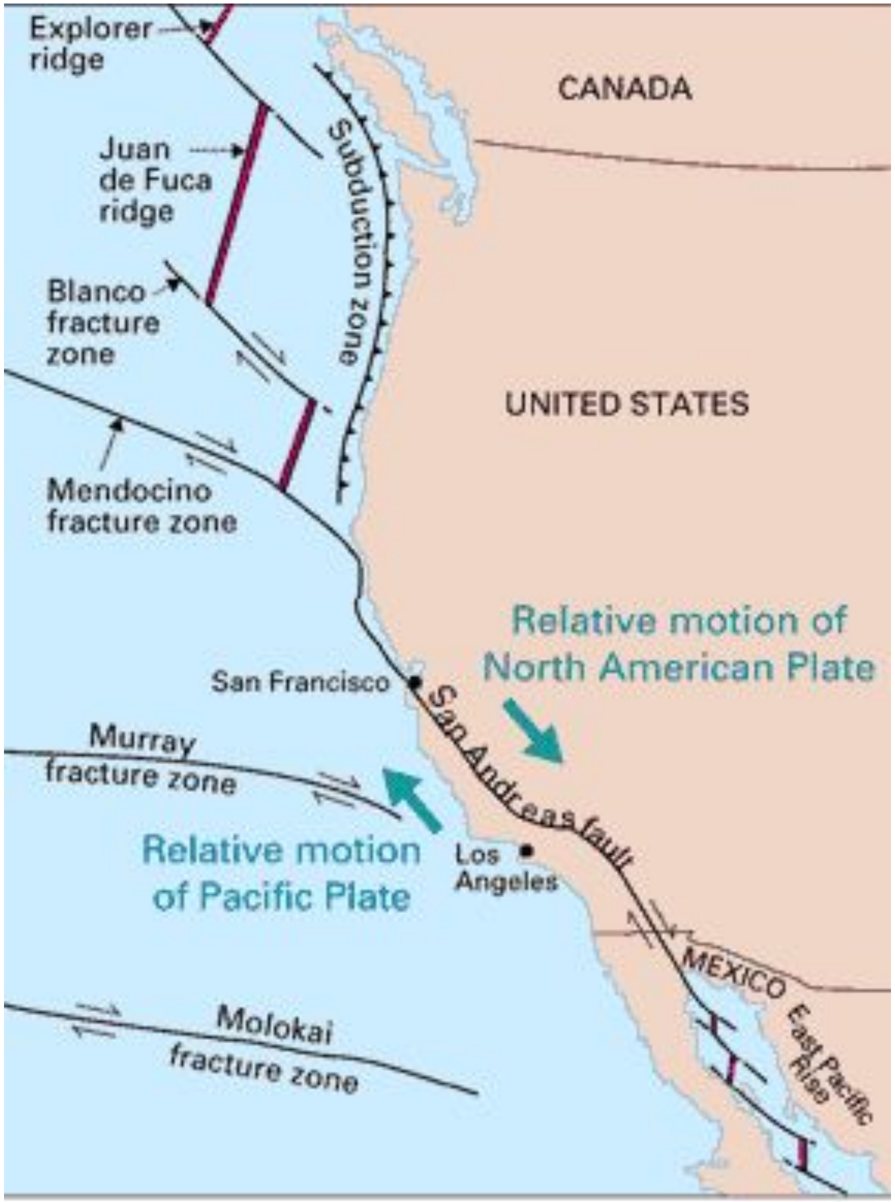
Convergent Boundaries







Transform Boundaries

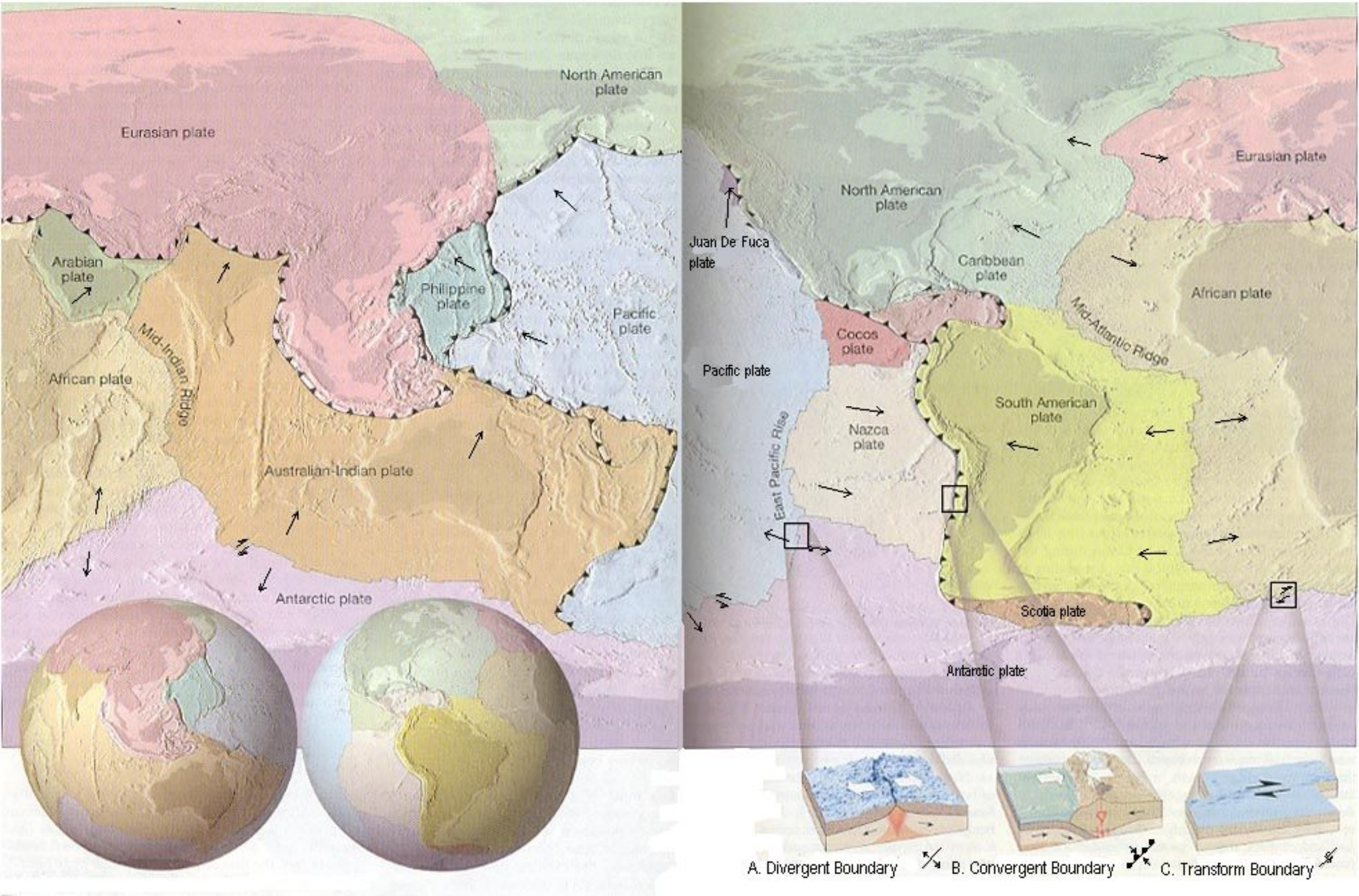


This type of plate boundary is one where plates grind past each other without the production or destruction of lithosphere. Also known as transform faults or fracture zones, they provide the means by which the oceanic crust created at ridge crests are transported to the site of destruction at the deep-ocean trenches.

The relatively small Juan de Fuca plate moving southeast is subducting under the North American plate. This movement is being facilitated by Blanco fracture zone & the Mendocino fault, connecting with the San-Andreas fault.

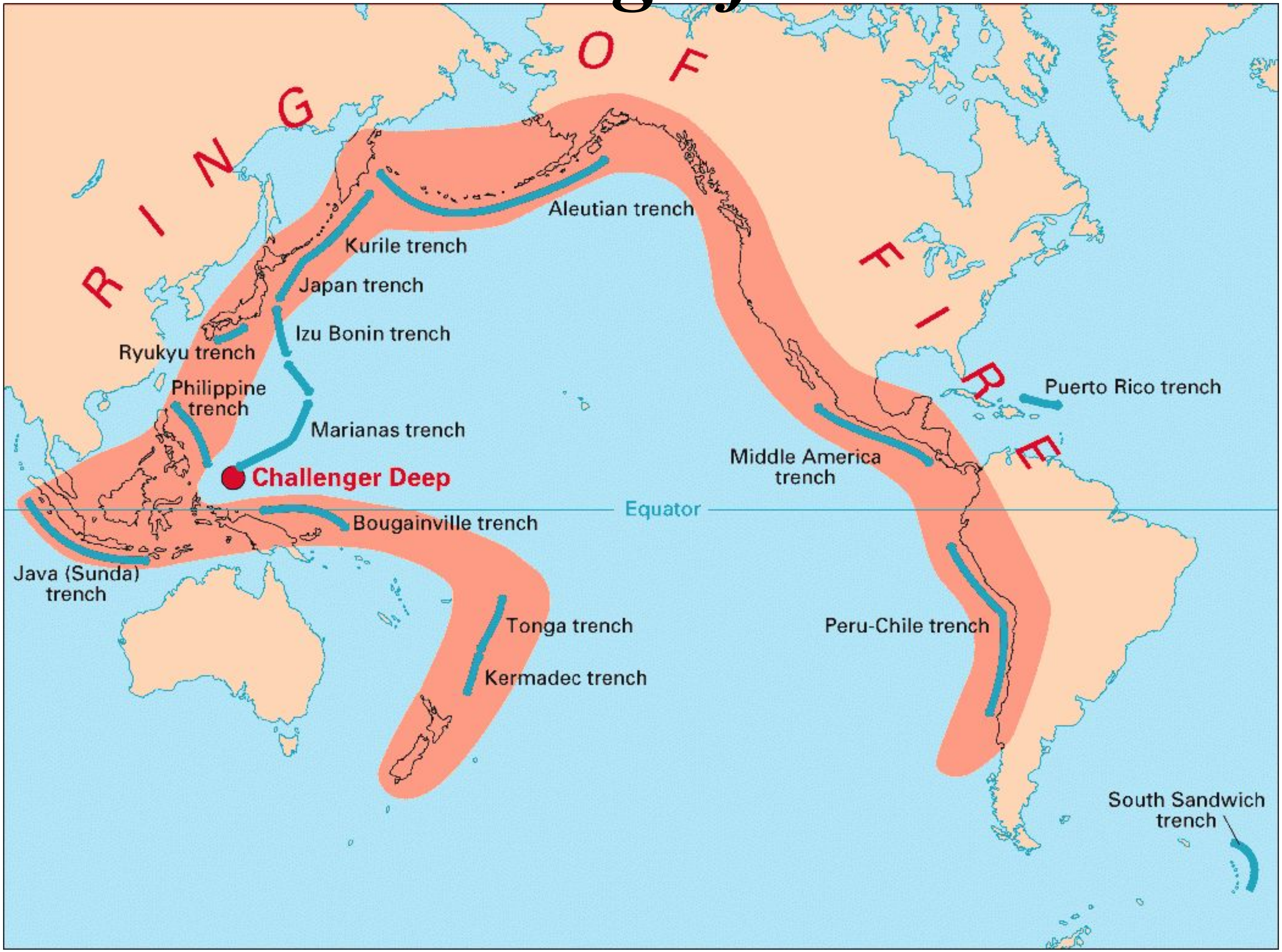
Though mostly these faults fall under oceans, but few are seen even on continental crusts, for example the San-Andreas fault in California. These faults are defined by shallow earthquakes.

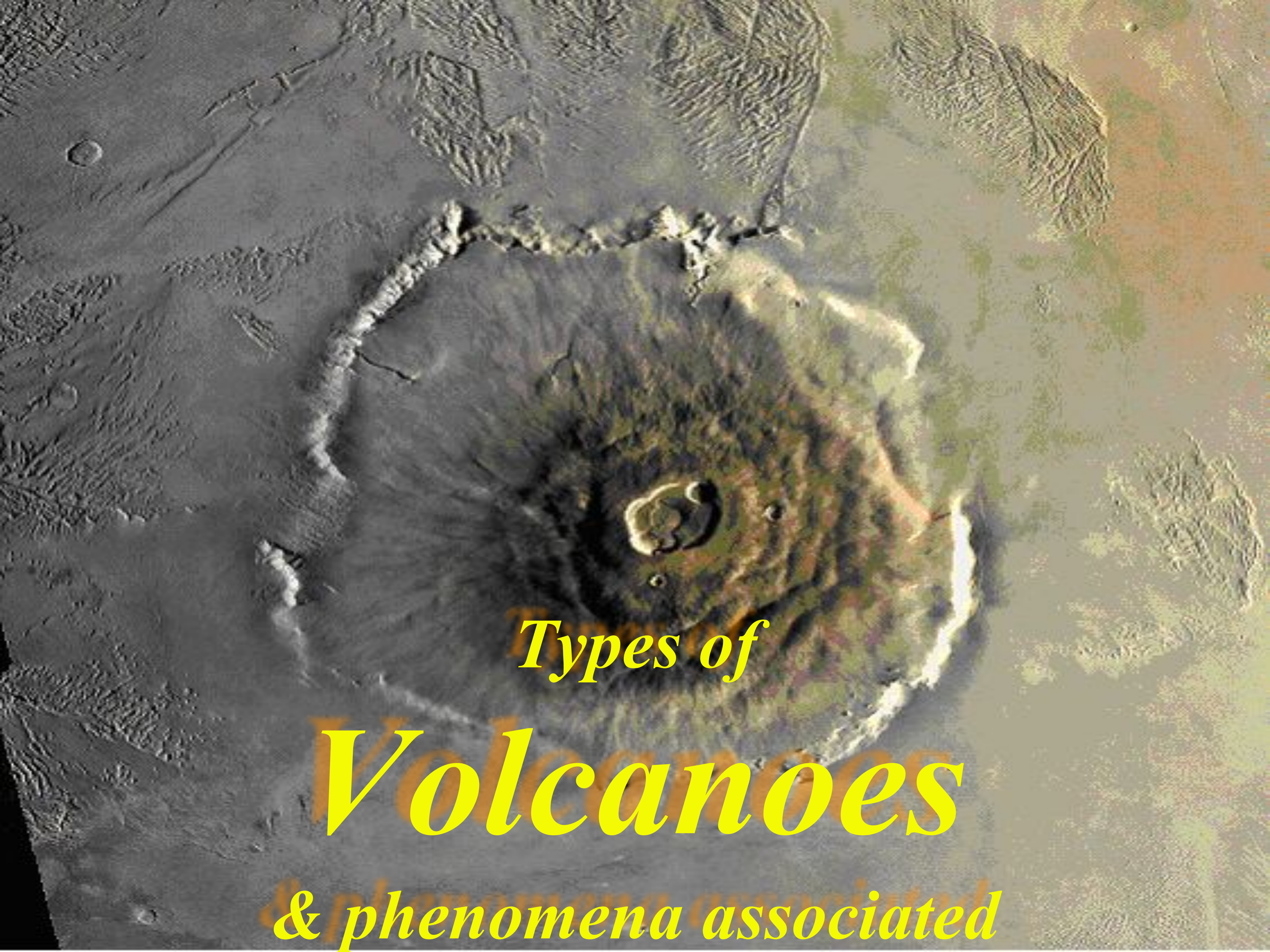
Plates of the World



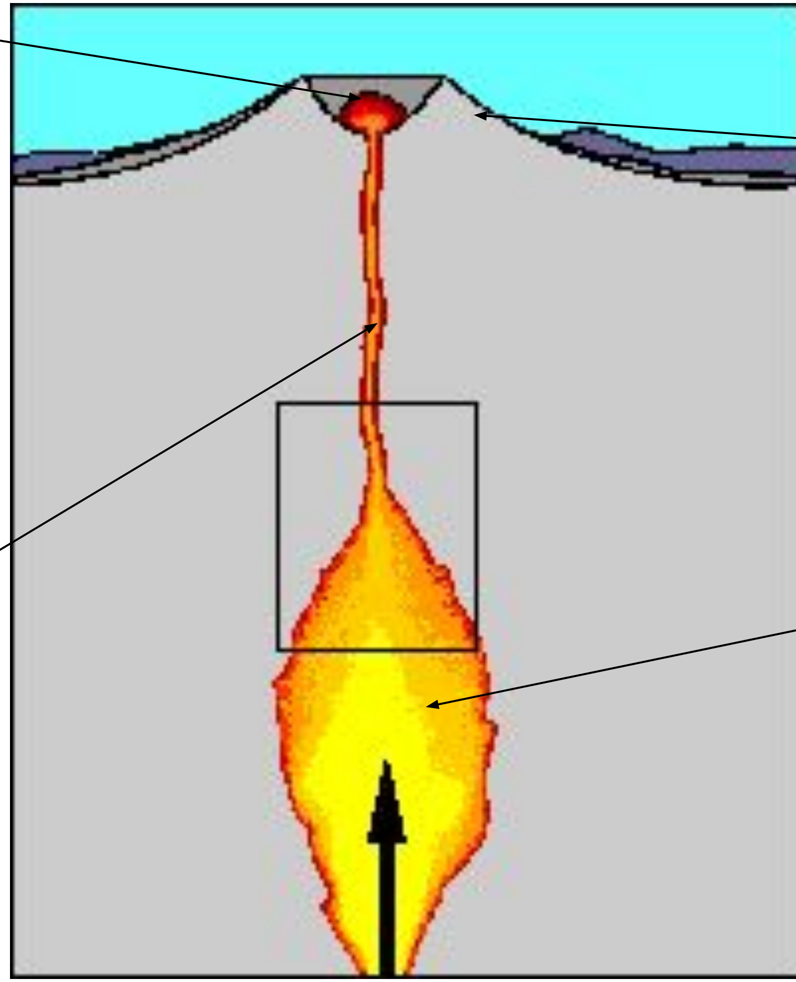

The Ring of Fire

The Ring of Fire




Types of
Volcanoes
& phenomena associated

The basic components of a Volcano



Crater
Located at the summit it is a steep walled depression from where the eruption happens

Dome
As lava flows out, with time it takes the shape of a mountain like structure called dome

Vent or Conduit
Magma rises through this opening fighting the confines of the solid rock.

Magma Chamber
Zone of magma formation stored within the mantle beneath the volcano

Volcano Types

After understanding the basic phenomenon of earth activities & the main reasons as well as regions of volcanic activities, we will study the three main kinds of volcanoes identified.

Shield volcanoes
Composite cones
Cinder cones

Before discussing the above mentioned types of volcanoes, we need to know about the kinds of materials extruded during eruptions and the phenomena associated with them.

1. Volcanic Gases

Gases dissolved in magma are released during eruptions. These gases, consisting mainly of water vapour & carbon dioxide, along with SO_2, CO, H_2, H_2S, HCl, HF play a key role in building up the pressure inside for the eruption. The increasing pressure exerted by these gases due to high temperature & low near-surface pressure decides whether the volcano would erupt as an explosive lava fountain or as viscous lava flows.

Volcano Types

2. Tephra

Tephra is a general term for fragments of volcanic rock and lava regardless of size that are blasted into the air by explosions or carried upward by hot gases in eruption columns or lava fountains. The lightest of the form, volcanic ashes are amongst the most havoc wrecking.

←Volcanic ash

Lava Flow →

3. Lava Flows

Lava flows are streams of molten rock that pour or ooze from an erupting vent. Lava is erupted during either nonexplosive activity or explosive lava fountains. Lava flows destroy everything in their path, but most move slowly enough that people can move out of the way. The speed at which lava moves across the ground depends on several factors, including type of lava erupted and its viscosity . Fluid basalt flows(50% silica content) can extend tens of kilometers from an erupting vent. Viscous andesite flows(70% silica content) move only a few kilometers per hour

Volcano Types

4. Pyroclastic flow

Pyroclastic flows are high-density mixtures of hot, dry rock fragments and hot gases that move away from the vent that erupted them at high speeds. They may result from the explosive eruption of molten or solid rock fragments, or both. They may also result from the nonexplosive eruption of lava when parts of dome or a thick lava flow collapses down a steep slope.

←Pyroclastic Flow

Lahar →

5. Lahars & Volcanic landslides

Lahar is a hot or cold mixture of water and rock fragments flowing down the slopes of a volcano and (or) river valleys. Eruptions may trigger one or more lahars directly by quickly melting snow and ice on a volcano or ejecting water from a crater lake.

Landslides are large masses of rock and soil that fall, slide, or flow very rapidly under the force of gravity. Landslides are common on volcanoes because their massive cones typically rise hundreds to thousands of meters above the surrounding terrain; and are often weakened by the very process that created them--the rise and eruption of molten rock.

Volcano Types

Shield Volcanoes

When fluid lava is extruded, the volcano takes the shape of a broad, slightly domed structure, called a shield volcano. Shield volcanoes are built primarily of basaltic lava flows and contain only a smal percentage of pyroclastic materials. These are generally the biggest volcanoes in magnitude, extending upto 9km in height and 100km in diameter. The Mauna Loa volcano in Hawaii Islands as an example of a shield volcano.

These volcanoes have unusually large summit depressions that exceed 1km in diameter and are known as calderas (the crater area of shiled volcanoes).

←Mauna Loa Volcano in Hawaii

Composite Volcanoes

These are the most picturesque volcanoes also known as Stratovolcano. A composite cone is a large, nearly symmetrical structure composed of interbedded lava flows and pyroclastic deposits. A composite cone extrudes viscous lava for long periods, then suddenly, the volcano violently starts ejecting pyroclastic materilas. Both these activities occur simultaneoulsy resluting in the alternate layers of lava & pyroclasts in their structure. Mt. St. Helens in Washington is a perfect exapmle of a composite volcano.

Volcano Types

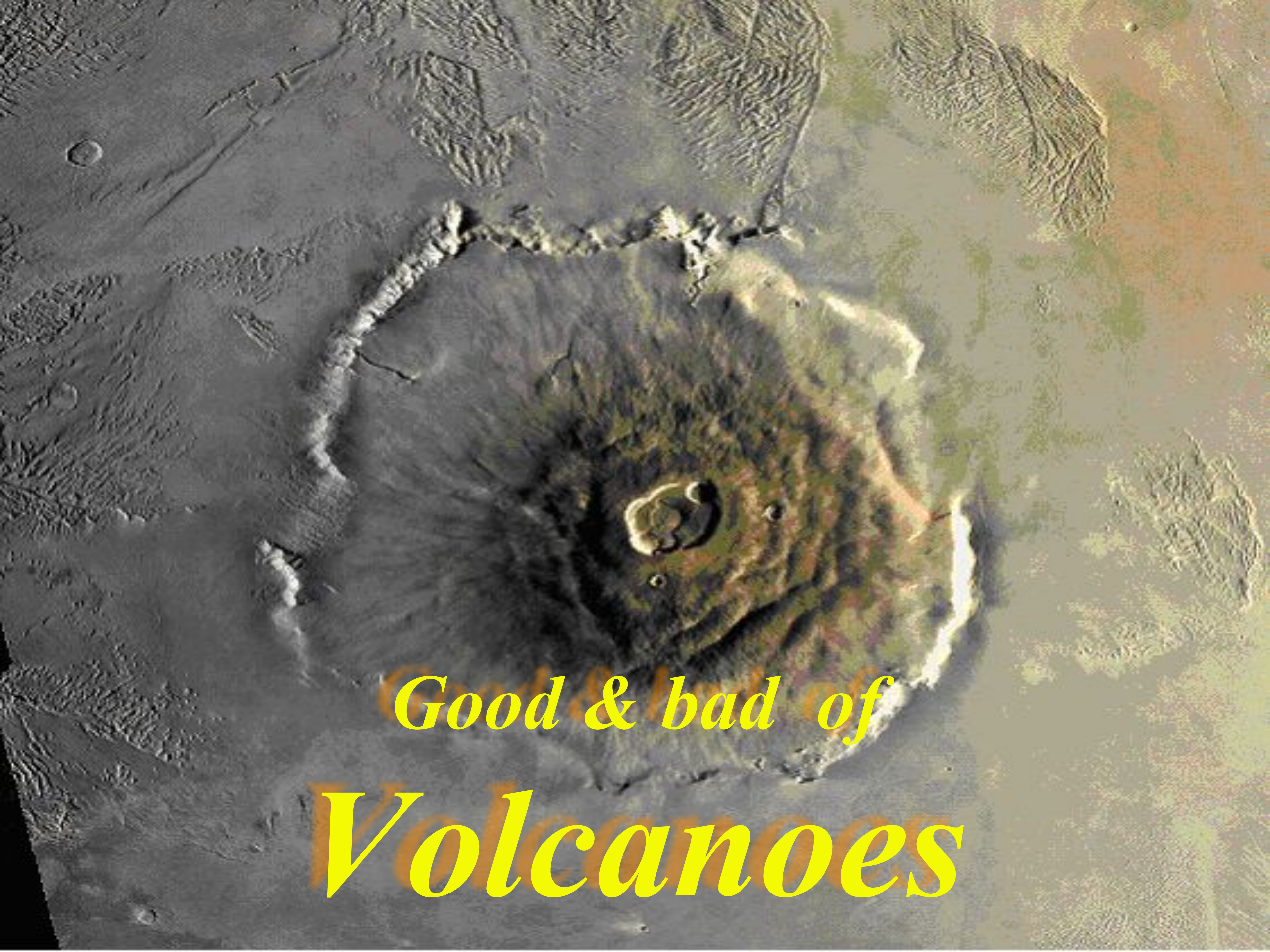
Cinder Cones

Cinder cones are the smallest type of volcanoes, usually less than 300m high and about only 1km in diameter, having very steep slopes. These are generally formed as parasitic cones on or near larger volcanoes. Also they frequently occur in groups. Volcano Paricutin, in Mexico City is the most studied cinder cone by geologists.

Mount St. Helens, in Washington. A composite cone before May 18, 1980

On May 18, 1980

After May 18, 1980



Good & bad of Volcanoes

Hazards of volcano

Although the direct hazards of volcanoes are known to all of us, one relief is that most of the disastrous and violent volcanoes are present under the sea or present in areas where human civilizations are not present. However, other related hazards which spread away from the region of volcanic activity is what makes them a cause for concern.

The most widely known are earthquakes. Generally the built up pressure near volcanoes are released in low magnitude earthquakes. Many a times, after eruption earthquake aftershocks are seen. Near oceans, these shocks also result in tsunamis.

Associated with eruptions are the spread of volcanic ash, the smallest and lightest form of tephra, which can cover large distances, clogging pipelines, covering houses and turning the area into a deserted remain.

Acid rains following eruptions is another common phenomenon.

Among other disastrous after affects are lahars and landslides which can reduce cities and habitations around the volcanoes to mere rubbles.

Lava flows blasting or flowing into living areas burn down every and anything coming in their way also makes places inhabitable.

Benefits of volcano

Many of the Earth's natural resources of energy, minerals, and soil are concentrated near past or present plate boundaries. The utilization of these readily available resources have sustained human civilizations.

Volcanoes can clearly cause much damage and destruction, but in the long term they also have benefited people.

1. Fertile soils

Over thousands to millions of years, the physical breakdown and chemical weathering of volcanic rocks have formed some of the most fertile soils on Earth. In tropical, rainy regions, such as the windward (northeastern) side of the Island of Hawaii, the formation of fertile soil and growth of lush vegetation following an eruption can be as fast as a few hundred years. Some of the earliest civilizations (for example, Greek, Etruscan, and Roman) settled on the rich, fertile volcanic soils in the Mediterranean-Aegean region. Some of the best rice-growing regions of Indonesia are in the shadow of active volcanoes. Similarly, many prime agricultural regions in the western United States have fertile soils wholly or largely of volcanic origin.

Benefits of volcano

2. Ore Deposits

Most of the metallic minerals mined in the world, such as copper, gold, silver, lead, and zinc, are associated with magmas found deep within the roots of extinct volcanoes located above subduction zones. Rising magma does not always reach the surface to erupt; instead it may of crystalline rocks (generally called plutonic or granitic rocks). Some of the best examples of such deep-seated granitic rocks, later exposed by erosion, are magnificently displayed in California's Yosemite National Park.

3. Fossil Fuels

Oil and natural gas are the products of the deep burial and decomposition of accumulated organic material in geologic basins that flank mountain ranges formed by plate-tectonic processes. Heat and pressure at depth transform the decomposed organic material into tiny pockets of gas and liquid petroleum, which then migrate through the pore spaces and larger openings in the surrounding rocks and collect in reservoirs, generally within 5 km of the Earth's surface. Coal is also a product of accumulated decomposed plant debris, later buried and compacted beneath overlying sediments. Most coal originated as peat in ancient swamps created many millions of years ago, associated with the draining and flooding of landmasses caused by changes in sea level related to plate tectonics and other geologic processes. For example, the Appalachian coal deposits formed about 300 million years ago in a low-lying basin that was alternately flooded and drained .

Benefits of volcano

Geothermal Energy .4

Geothermal energy can be harnessed from the Earth's natural heat associated with active volcanoes or geologically young inactive volcanoes still giving off heat at depth. Steam from high-temperature geothermal fluids can be used to drive turbines and generate electrical power, while lower temperature fluids provide hot water for space-heating purposes, heat for greenhouses and industrial uses, and hot or warm springs at resort spas. For example, geothermal heat warms more than 70 percent of the homes in Iceland, and The Geysers geothermal field in Northern California produces enough electricity to meet the power demands of San Francisco. In addition to being an energy resource, some geo-thermal waters also contain sulfur, gold, silver, and mercury that can be recovered as a byproduct .of energy production


Thank You
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