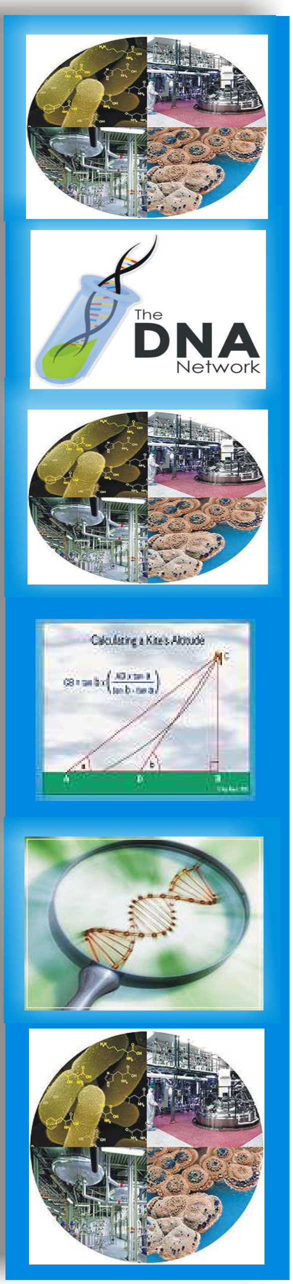

BHU - GEOLOGY

SAMPLE THEORY

- FORMATION OF CONTINENTS OCEANS
- PLATE TECTONICS
- DIVERGENT PLAGE BOUNDARIES
- CONVERGENT PLATE BOUNDARIES
- WILSON CYCLE

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FORMATION OF CONTINENTS AND OCEANS

- **Continents and Ocean Basins**
  - 29 % of the Earth's surface is land and 71 % of its surface is water
- **Relief Features of the Continents**
  - The continental masses consist of two basic subdivisions
  - Active mountain-belts
  - Inactive stable regions
  - The mountain-belts grow through geological processes like **volcanism** (accumulations of volcanic rock through the extrusion of magma) and **tectonic activity** (breaking and bending of the Earth's crust where lithospheric plates come together)
- **Alpine Chains**
  - Active mountain-belts are usually narrow zones along continental margins (examples: circum-Pacific–belt around the Pacific basin, Eurasian-Indonesian belt)
  - Mountain-belts that lie offshore from continents are called **Island Arcs**
- **Continental Shields**
  - **The majority of the crust is composed of comparatively inactive regions under which lie much older rock**
  - The most common structural type of crust in these inactive regions are know as continental shields which are low-lying continental surfaces beneath which lie igneous and metamorphic rocks
  - Continental shields are either exposed Precambrian age rocks (greater then 570 million years old) consisting of low hills and plateaus

- Large areas of continental shields are covered by younger sedimentary rocks (covered shields) that accumulate on the continental shields when sea levels were higher during the past 570 million years

- **Mountain Roots**
  - Remains of old mountain belts lie within the shields in many places
  - They are mostly composed of Paleozoic rocks (range in age between 570 and 245 million years old) and Mesozoic rocks (range in age between 245 and 66 million years old) that have been intensely bent and folded (and metamorphosed)
  - Examples: The Caledonian Highlands across the northern British Isles and Scandinavian (formed during the early Paleozoic; 400 million years ago), Maritime Provinces of Canada and New England (formed during the late Paleozoic; 250 million years ago)
- **The Ocean Basins**
  - Ocean crust consists almost entirely of basalt (thinly covered by sediments)
  - Compared to the continental crust (on average over a billion years old) the ocean crust is much younger (less than 200 million years old, on average less than 60 million years old)
- **The Midoceanic Ridge**
  - A typical ocean basin is characterized by a central structure that divides the basin more or less in half (a midocean ridge)
  - Midocean ridges consist of submarine hills that rise gradually to a rugged central zone (the highest point along the ridge; the axial rift)
- **The Ocean Basin Floor**
  - Abyssal plains on either side of midoceanic ridges are deep (average depth of 5000 m below sea level) plains coated with fine sediment

- **Continental Margins**

• Continental margins are of two types

• Active continental margin found where either a subduction zone or a transform fault coincides with continent-ocean interface, e g. Andean and Japan continental margin are systems.

• Passive continental margin occur along the edges of opening ocean basin like the Atlantic basin. Such margins are characterized by minimal tectonic and igneous activity.

Active Margin Continental Margins Rifts

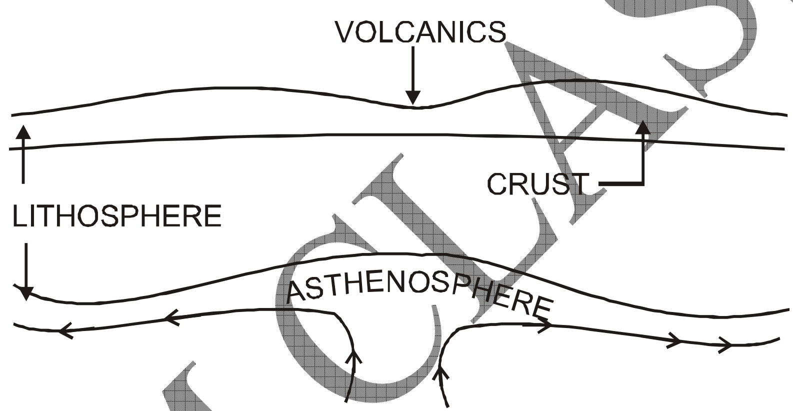


Fig. 1

Passive Continential Margins Rifts

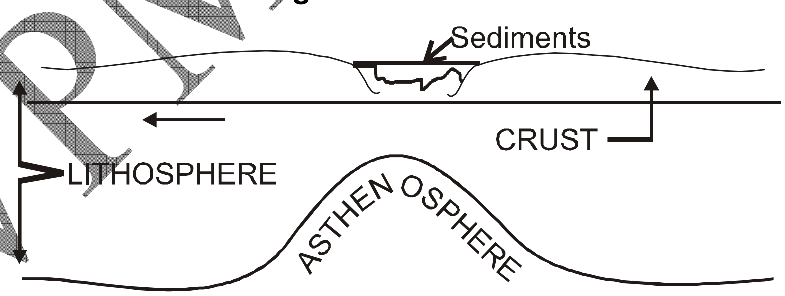


Fig. 2

- Continental margins are narrow zones in which oceanic lithosphere is in contact with continental lithosphere
- The **continental rise** is the region where the ocean floor begins to rise as it approaches the continental margin
- The **continental slope** is the region where the ocean floor steepens greatly
- The **continental shelf**, at the top of the continental slope, is a gently sloping region some 120 to 160 km wide with an average water depth of 150 m
- There are two types of continental margins 1) **passive** and 2) **active**
- Passive continental margins are not subject to tectonic and volcanic activity (North and South Atlantic Ocean basins, Indian and Antarctic Ocean basins)
- The Pacific ocean basin continental margins are characterized by mountain belts or island arcs with offshore **deep ocean trenches** (depths between 7,000 to 11,000 m)
- Deep ocean trenches mark the boundary between two lithospheric plates being force together

• Oceanic Crust and Continental Crust

Earth’s relatively thin solid crust is the portion of the lithosphere that interfaces with the ocean, atmosphere, cryosphere, and biosphere. The crust beneath the ocean differs from the crust of the continents in composition, density, and thickness. In this section, we compare the characteristics of oceanic and continental crust beginning with the basic distinction among rock types.

EARTH MATERIALS

- Rocks composing the crust are classified as igneous, sedimentary, or metamorphic based on the general environmental conditions in which the rock formed.
- Cooling and crystallization of hot molten magma produces igneous rock.

• Magma may remain within the crust and cool slowly forming coarse-grained igneous rock such as granite or

• It may spew onto Earth's surface as lava through vents or fractures in bedrock and solidify rapidly forming fine-grained igneous rock such as basalt or glassy material such as obsidian.

• Sedimentary rock may be composed of any one or a combination of compacted and cemented fragments of rock and mineral grains, partially decomposed remains of dead plants and animals (e.g. shells, skeletons), and minerals precipitated from solution.

• A rock is metamorphosed (changed in form) when exposed to high pressure, intense heat, and chemically active fluids—conditions that exist in geologically active mountain belts.

• Marble is a common metamorphic rock formed by the metamorphism of limestone ($CaCO^3$) and quartzite is a very durable metamorphic rock formed b metamorphism of sandstone (mostly SiO_2).

• Continental crust is mostly granite, a coarse-grained rock rich in minerals containing silica and aluminum.

• Oceanic crust, is mostly basalt, a fine-grained rock rich in minerals containing iron and magnesium.

• Continental crust is thicker (20 to 90 km or 12 to 56 mi) and less dense than oceanic crust (only 5 to 10 km or 3 to 6 mi thick).

• Oceanic lithosphere has a maximum thickness of about 100 km (62 mi) whereas continental lithosphere ranges in thickness from 100 to 150 km (62 to 93 mi).

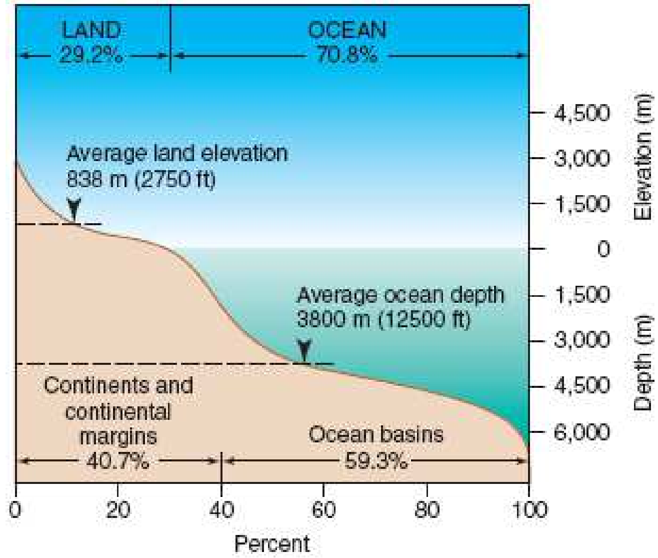


Fig.3 Hypsographic curve of Earth's surface, showing the relative distribution of ocean and land.

ROCK CYCLE

• Surface and internal geological processes transform rock from one type to another in the rock cycle .

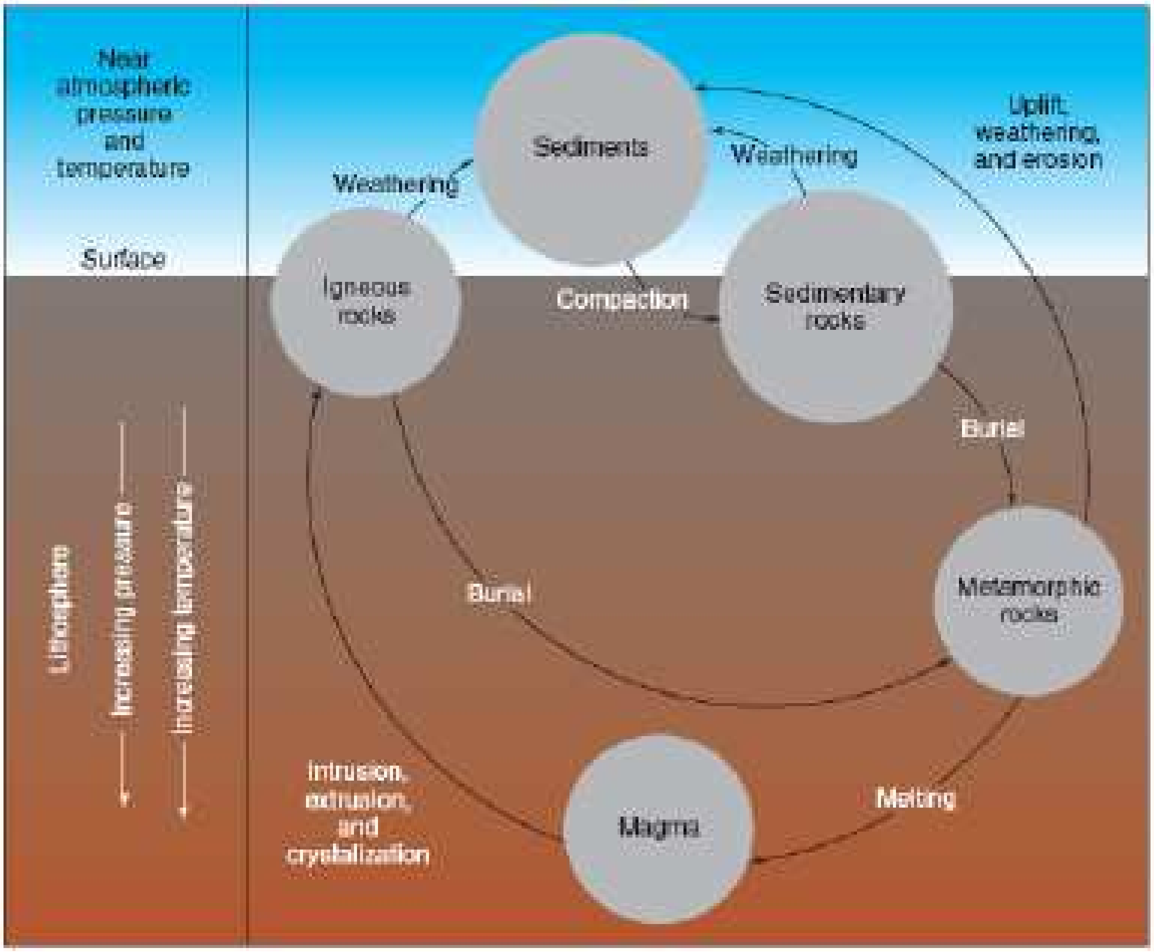


Fig.4 Rock Cycle

- Through the rock cycle, rocks and their component minerals are continually regenerated.
- Consider an example. Physical and chemical weathering processes fragment an igneous rock mass that is exposed to the atmosphere into sediments which are subsequently transported by running water and deposited in a lowlying basin.
- In time, the accumulated sediments compact and are cemented together as they gradually convert to sedimentary rock.

• The mounting weight of the continually accumulating sediments forces the sedimentary rock to greater depths within the crust.

• Temperature and confining pressure increase with depth so that the rock is eventually metamorphosed, that is, recrystallized into metamorphic rock.

• At some depth in the subsurface, the temperature is so high that the metamorphic rock melts into magma.

• The magma may subsequently migrate upward along fractures within the crust, and then cool and crystallize into igneous rock, thereby completing the rock cycle.

- **Ocean Bottom Profile**

• Ocean depth varies markedly from one place to another.

• Over large areas water depth is less than 200 m (650 ft); in other areas the water is as deep as 11,000 m (36,000 ft).

• Average ocean depth is about 3800 m (12,500 ft).

• The vertical cross-sectional profile of the ocean bottom, includes the continental margin and ocean basin.

• In places the ocean bottom is nearly flat and essentially featureless whereas in other places the ocean floor exhibits considerable topographic relief.

• Parts of the ocean bottom are volcanically active with lava interacting chemically with seawater.

- **CONTINENTAL MARGINS**

• The ocean scientists delineate three distinct zones seaward from the coastline.

• The zone closest to the beach features a very gentle slope extending out to a water depth that averages about 130 m (430 ft).

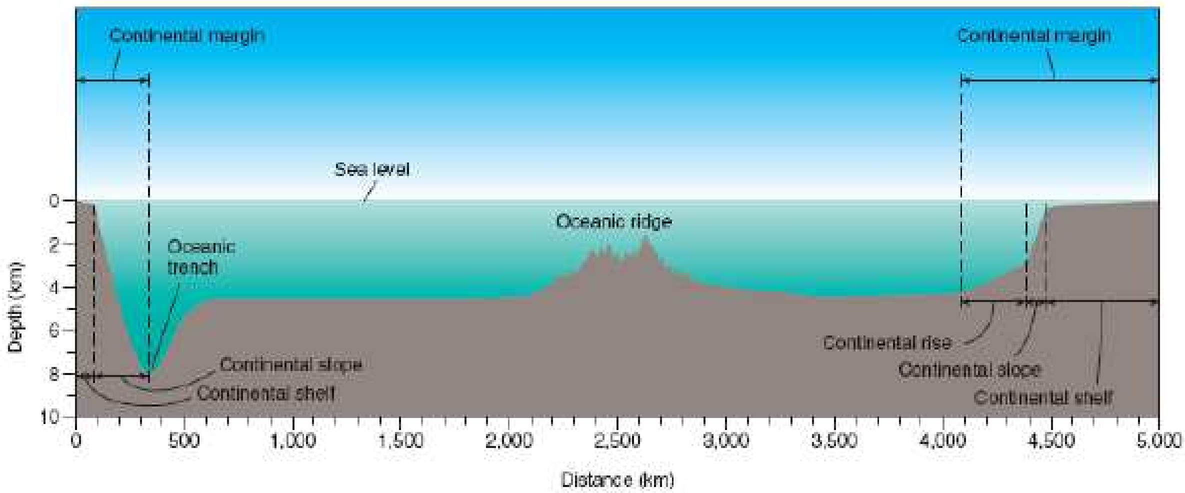


FIG : 5 Cross-sectional profile of the continental margin and ocean bottom with the vertical scale greatly exaggerated.

• Seaward from there to a depth of about 3000 m (9800 ft) the water depth increases much more rapidly with distance offshore.

• Then a relatively narrow zone is transitional from the steep slope of the previous zone to the more-or-less flat ocean basin.

• The initial, gently sloping zone is the continental shelf;

• The second, more steeply sloping zone is the continental slope; and

• The third transitional region is the continental rise.

• The continental shelf, slope, and rise together comprise the continental margin.

- **OCEAN BASINS**

• Ocean basins have a varied topography featuring deep trenches, sea mounts, and submarine mountain ranges.

• Much of the ocean bottom (about 42%) is comprised of plains and low hills, most rising no more than about 100 m (330 ft) above the plain.

• Blanketed with sediments that tend to smooth out any irregularities in the bedrock below, abyssal plains and abyssal hills are typical of ocean basin topography—apart from the 23% of the ocean bottom that is covered by ridge systems.

- **Plate Tectonics and Ocean Basin Features**

• The most prominent features of the ocean basins, including trenches and mid-ocean ridge systems, are products of tectonic stresses.

• All plates, except the Pacific, include parts of continents as well as ocean basins.

• Mountain building and most volcanic activity and earthquakes take place at boundaries between plates, many of which occur either within the ocean basins or along their margins.

PLATE TECTONICS

• Oceanic plates (5 to 10 km thick) are comparatively thin compared to continental plates (40 km thick)

- **Plate Motions and Interactions**

• Oceanic plates spread apart along midoceanic ridges

• As the plates pull apart creating a gap, magma from the mantle rise to fill it

• The upwelling magma (which produces new ocean floor) forces the oceanic plates other either side of the midoceanic ridge apart in opposite directions and is therefore know as a spreading or **divergent plate boundary**

• Spreading oceanic plates inevitably collide with continental crust or other portions of oceanic crust

• This usually results in subduction of one plate beneath another that forms a **convergent plate boundary**

• Oceanic trenches mark to location of one plate subducting beneath another plate

- The subducting plate (oceanic crust) sinks under its own weight into the asthenosphere where it becomes heated and is eventually melted
- Melting of the subducted oceanic crust produces magma which progressively rises through the overlying crust to form plutonic magma chambers beneath the surface of the crust or volcanoes if the reach the surface of the crust
- Where two plates come in contact with one another and simply side past one anther in different directions, the boundary between the plates is known as a **transform boundary**

Earthquakes occur along rather narrow belts on the earth today, and these belts mark boundaries between Lithosphere plates. There are four types of seismic boundaries, distinguished by their epicenter distribution and geological characteristics

(A) Ocean ridges. (B) Subductions Zones (C) transform faults (D) Collisional Zones.

- **The Global System of Lithospheric Plates**
    - The lithosphere is broken into six large plates crustal plates and nine smaller crustal plates
- **Subduction Tectonics**
    - Subduction along converging plate boundaries produces zones of intense tectonic and volcanic activity
    - High standing mountain belts are elevated along subduction zones through the process of compression
    - Compression along subduction zones folds and thrusts up rocks (once deposited along passive continental margins) into mountain belts
    - This process is known as **orogenesis** (mountain build through tectonic compression)

- Impacts of volcanic arcs with continents causes the sedimentary strata deposited along the former passive continental margin to be folded and thrusted up into mountain belts
- Volcanic terrain, originally associated with the island arc, eventually gets thrusted up onto the larger continental mass

- **Accreted Terrains of Western North America**
  - Western North America consists of a number of terrains derived from other locations in the Pacific Ocean basin
  - The collision of each of these terrains with the North American continent during the last 100 million years resulted in the folding and thrusting up of the western Cordillera (Rocky Mountains)
- **Continent-Continent Collisions**
  - Mountain belts are also folded and thrust up when two large continental bodies collide (example: Himalayan Mountains as a result of the collision of the Indian continent with the Eurasian continent)
- **Continental Rupture and New Ocean Basins**
  - As heat from the mantle below large continental masses forces its way upward, the crust is both lifted and stretched apart causing the crust to fracture which allows crustal blocks to drop(settle into the mantle) eventually forming a long, narrow **rift valley**
  - Magma from the mantle fills the widening rift valley forcing the plates apart (this is the beginning of a divergent or spreading plate boundary)

• The widening rift valley eventually fills with water and a new ocean basin, with a mid oceanic ridge is born (resulting in the breakup of a continent) example: the Rift Valley in East Africa is breaking East Africa away from the main African continent)

- **Continents of the Past**

• In 1915, Alfred Wegener (a Swiss Climatologist) after observing the global distribution and shape of the continents on maps suggested that all the major continents of the present day Earth were once joined together as one super continent he called **Pangaea** (all the land)

• This has been shown to be true and since the time of Pangaea, 245 million years ago, the process of continental rupture, similar to the present day scenario in East Africa, has divided the continents and moved them to their present locations

- **DIVERGENT PLATE BOUNDARIES.**

• **Ocean ridges**

• Ocean ridges are characterized by shallow earthquakes limited to axial rift zones.

• These earthquakes are generally small in magnitude, commonly occur in swarms and appear to be associated with intrusion and extrusion of basaltic magmas.

• The ocean basins have magnetic reversal natural.

• **Subduction zones** (CONVERGENT PLATE BOUNDARIES)

• Convergent plate boundaries are defined by earth hypocenter that lie in an approximate plane and dip beneath are system.

• This plane known as the seismic zone or Benioff zones, dips at moderate to steep angle and extends in some instances to the 670 Km. seismic discontinuity.

• **Transform faults**

• Transform faults produce large structural discontinuities, and in some cases structural and topographic breaks known as fracture zones are left on the ocean floor.

• Fracture zones include ridge-ridge transform faults and their aseismic extensions and the transforms faults may or may not be active.

• **Collisional zones**

• Deformational zones associated with collisional boundaries are widespread, as exemplified by the India-Asia boundary which extend for at least 3000 Km. north east of the Himalayas.

• Thrust fault mechanisms generally dominate near the suture zone, such as the indus culture in the Himalayas. Strike-slip faulting is common in the overriding plate.

- **Characteristics of continental rift**
  - Rifts may narrow, and long
  - Associated with domal uplifts,
  - Crustal thinning under the rift system
  - High heat flow in rift system

CONVERGENT PLATE BOUNDARIES

• When adjacent plates move toward one another, they create a convergent plate boundary. There are three possibilities:

• Two oceanic plates collide (e.g., the Pacific and Philippine plates),

• An oceanic plate and continental plate collide (e.g., the Nazca and South American plates), and

• Two continental plates collide (e.g., the Indian and Eurasian plates).

• In a subduction zone, the denser oceanic plate slips under the other plate and descends into the mantle.

• With downward transport of rock and sediment, a deep elongated depression (trench) forms on the ocean floor.

• Temperature and confining pressure increase with depth within Earth's interior so that a plate is heated and compressed as it descends into the mantle. • • Also, the friction of plates grinding past one another generates heat and earthquakes. (This is the origin of almost all sunami-generating earthquakes.) • • At depths approaching 80 km (50 mi), the subducting plate begins to melt into magma, which migrates upward toward Earth's surface and contributes to mountain building and explosive volcanic eruptions. (The eruptions of Mount St. Helens and Mount Pinatubo are recent examples.)

• Whereas new lithosphere forms at divergent plate boundaries, lithosphere is destroyed by being incorporated into the mantle in subduction zones at convergent plate boundaries.

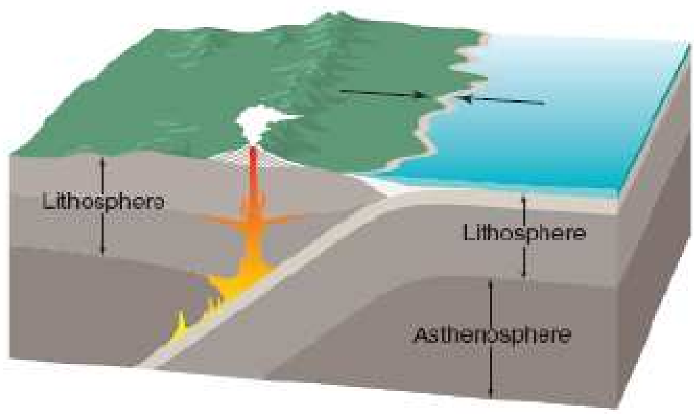


FIG: 6 A convergent plate boundary where an oceanic plate subducts under a continental plate.

• In oceanic-to-oceanic plate collisions, volcanic activity associated with subduction forms island arcs, curved chains of volcanic islands.

• Trenches usually lie on the seaward sides of island arcs with relatively shallow seas near continents.

• For example, the islands of Japan are part of a volcanic island arc with the Sea of Japan on the continental side and a trench on the Pacific Ocean side. • At the convergent plate boundary just off the west coast of South America, the Nazca plate subducts under the South American plate, producing the offshore Peru-Chile Trench, which is 5900 km (3660 mi) long, 100 km (62 mi) wide, and more than 8000 m (26,300 ft) deep.

• Associated with subduction of the Nazca plate is the Andes, a prominent mountain range including many volcanoes forming the backbone of South America.

• TRANSFORM PLATE BOUNDARIES

• Adjacent plates that slide laterally past one another produce a transform plate boundary.

• Although crust is neither created nor destroyed and these boundaries are generally free of volcanic activity, slippage can deform rock and trigger earthquakes.

• The San Andreas Fault of California, site of frequent earthquakes, occurs along a transform plate boundary where the Pacific plate (carrying a piece of California) slides toward the northwest, past the North American plate.

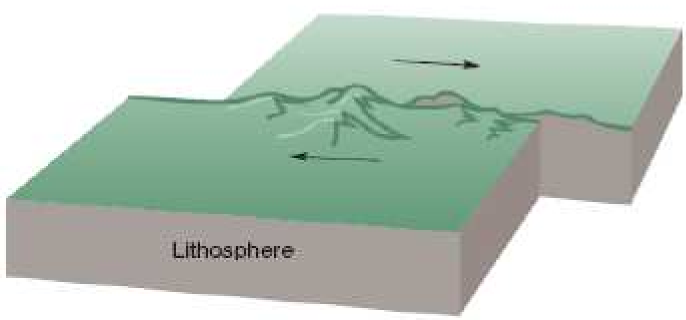


FIG :7 A transform plate boundary is often the site of shallow earthquakes

• MANTLE CONVECTION AND SEA LEVEL

• Mantle convection causes vertical (up and down) movements of the continents accompanied by apparent changes in sea level.

• For example, in southern Africa, an expansive plateau about 1600 km (1000 mi) across and almost 1600 m (5200 ft) high has been slowly rising over the past 100 million years.

• Geologists do not attribute this vertical motion to tectonic activity—the region has been tectonically inactive for 400 million years or so.

• Rather, a hot mushroom-shaped mass (a superplume) several kilometers across ascending within the underlying mantle is pushing the plateau upward and as the plateau rises, sea level falls.

HYDROTHERMAL VENTS

• The hydrothermal vents are more common and associated with all three categories of divergent plate boundaries (fastspreading, slow-spreading, and ultraslow spreading).

• Evidence of hydrothermal venting has been reported along most of the mid-ocean ridge system at intervals of less than 200 km (125 mi).

• Hydrothermal activity on the ocean bottom is a source of some dissolved constituents of seawater although the principal source is suspended and dissolved substances delivered to the ocean by rivers and streams

• Hydrothermal vents are home to diverse communities of exotic marine organisms, including bacteria, crabs, shrimp, mussels, starfish, and tubeworms.

• One type of tubeworm found in the Galápagos area of the Pacific Ocean floor may grow to a length of 2.4 m (8 ft).

WILSON CYCLE

• Cycles of ocean basin spreading and closing are called Wilson cycles after the Canadian geologist J. Tuzo Wilson (1908-1993) who first recognized and described the stages in the life span of an ocean basin.

• A Wilson cycle consists of six stages: embryonic, juvenile, mature, declining, terminal, and suturing.

• The cycle begins because thick continental crust does not conduct heat as readily as thinner oceanic crust.

• A supercontinent that remains in one location for hundreds of millions of years acts like a blanket, retarding heat flow from Earth's interior.

• This causes the mantle beneath the supercontinent to warm.

• As the underlying mantle warms, it expands, elevating the overlying continent and stretching the continental crust.

• Convection currents in the mantle also contribute to this stretching and eventually the crust fractures, forming a rift valley.

• With rifting of the continental crust, the broken sides rise about a kilometer enclosing a valley that often fills with fresh water.

• In East Africa, long, deep lakes now occupy narrow rift valleys.

• Rift valleys gradually widen and eventually connect to the ocean and the freshwater lakes become narrow saline gulfs.

• The divergent plate boundary widens and additional oceanic crust is generated signaling the mature stage of the Wilson cycle.

• Today, the Atlantic is a mature ocean with geologically passive margins.

• Subduction becomes more widespread around the border of the ocean basin during the declining stage of the Wilson cycle.

• In time, cooling and the loss of volatiles increase the density of oceanic plates. • Under the influence of gravity, these plates slide down and away from the topographic high of the mid-oceanic ridge and sink into the as thenosphere at subduction zones.

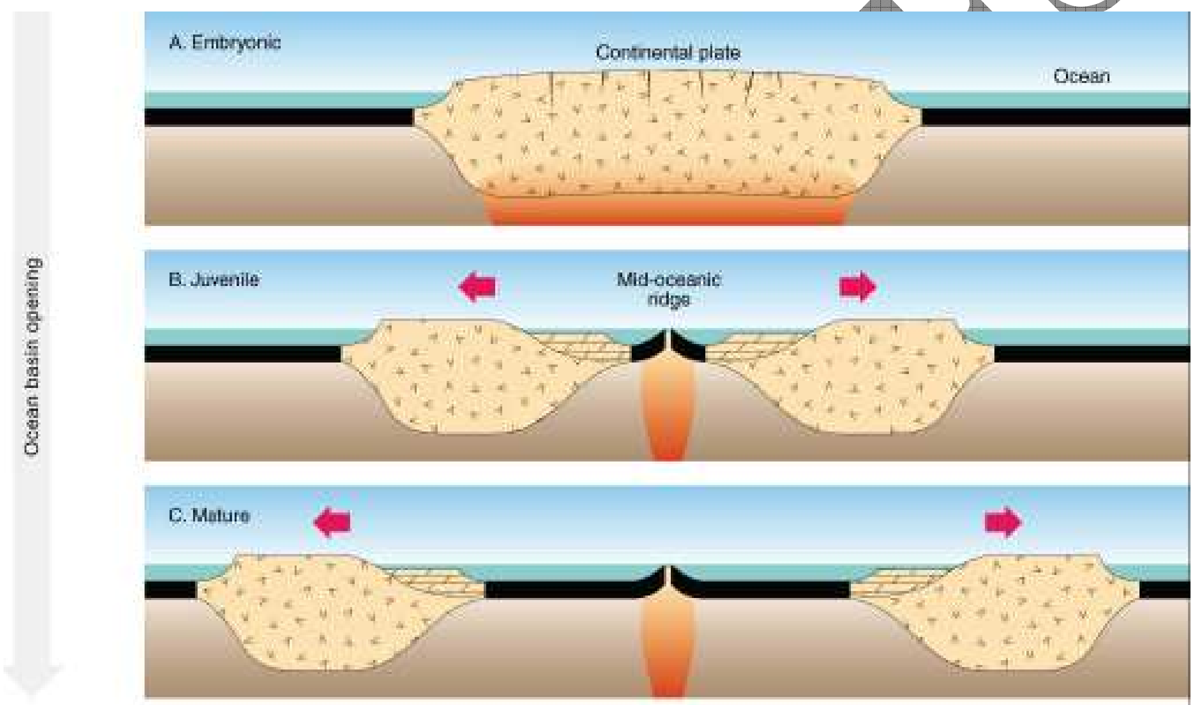
• Following the declining stage of the Wilson cycle, the ocean basin closes through subduction as continents from opposite sides of the ocean basin bear down on one another and eventually collide.

• These events signal the final two stages of the Wilson cycle: the terminal and suturing stages.

• In the terminal stage, the continents are not yet touching but subduction of the intervening oceanic crust causes a narrowing of the sea separating the continents.

• The two colliding continental crusts, being less dense than the oceanic crust, do not subduct but rather override one another causing uplift and mountain building.

• Collision of the continents squeezes out the intervening ocean and causes subduction of oceanic crust.



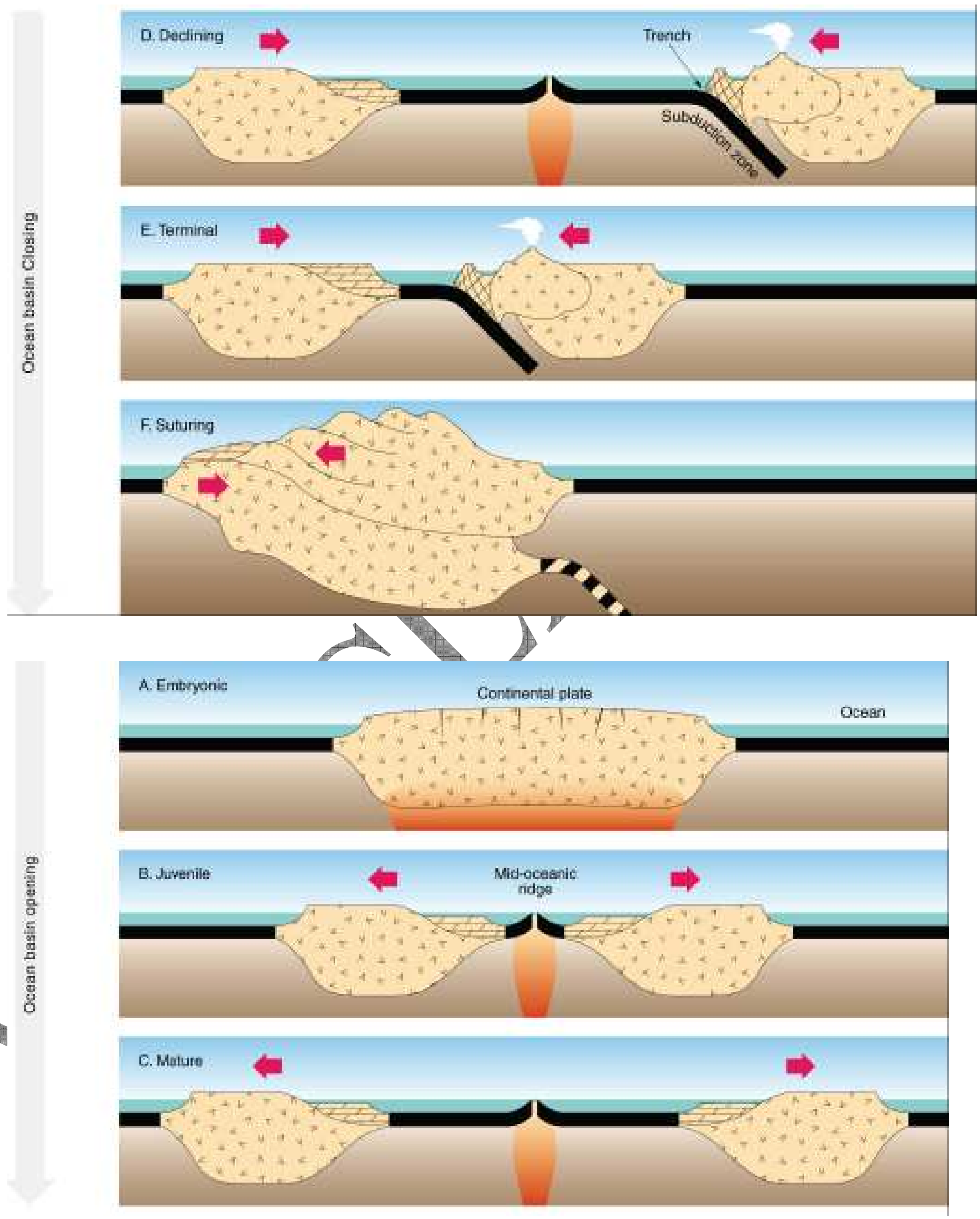

Ocean basin Closing
D. Declining
Trench
Subduction zone
E. Terminal
F. Suturing
Ocean basin opening
A. Embryonic
Continental plate
Ocean
B. Juvenile
Mid-oceanic
ridge
C. Mature

FIGURE : 8 A simplified model of the Wilson cycle, showing the formation and closing of an ocean basin.