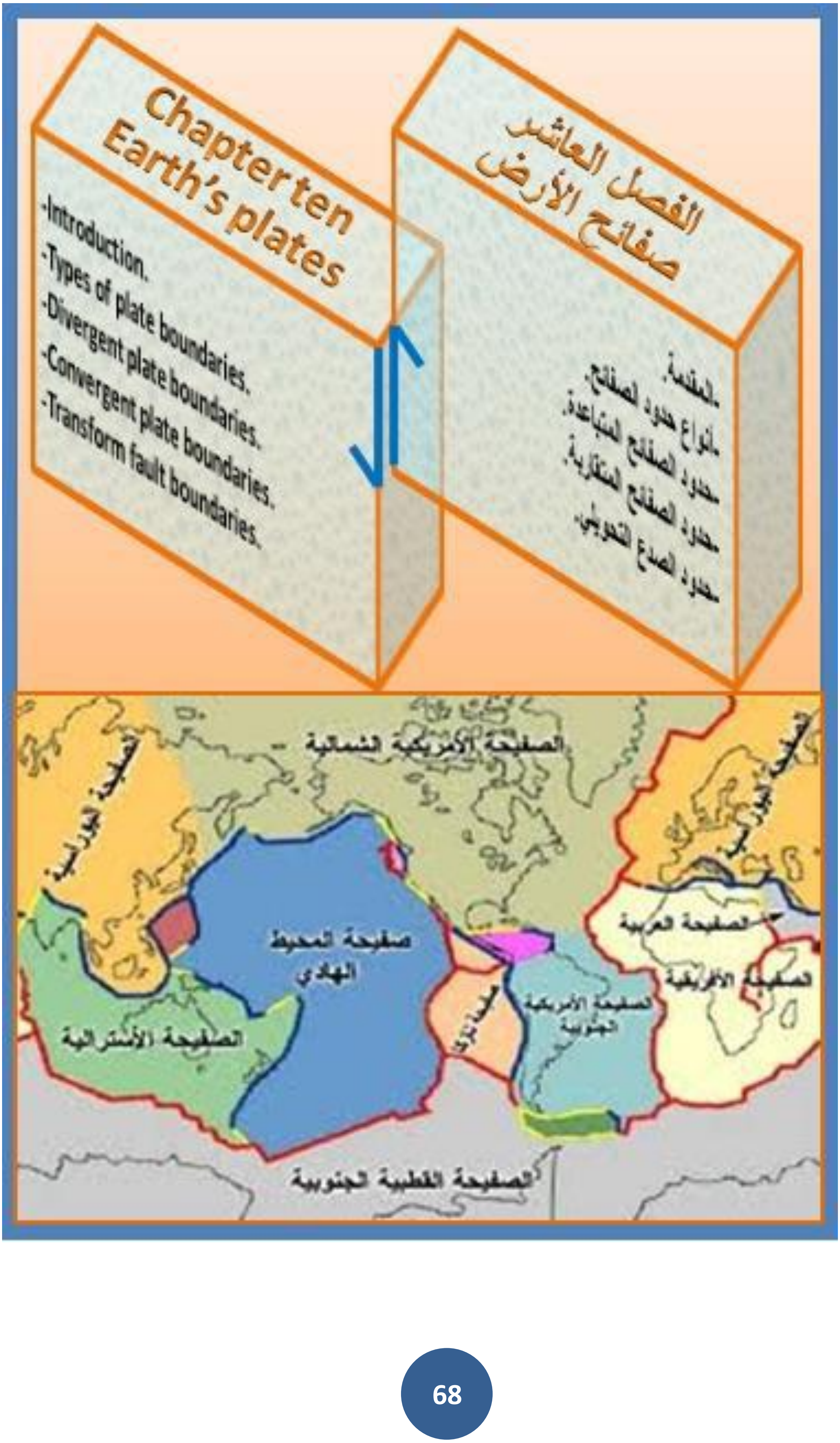

Chapter ten
Earth's plates
-Introduction.
-Types of plate boundaries.
-Divergent plate boundaries.
-Convergent plate boundaries.
-Transform fault boundaries.
الفصل العاشر
صفائح الأرض
-المقدمة.
-أنواع حدود الصفائح.
-حدود الصفائح المتباعدة.
-حدود الصفائح المتقاربة.
-حدود الصدع التحويلي.
الصفيحة الأمريكية الشمالية
الصفيحة الأوراسية
صفيحة المحيط الهادي
الصفيحة العربية
الصفيحة الأفريقية
الصفيحة الأمريكية الجنوبية
الصفيحة الأسترالية
الصفيحة القطبية الجنوبية

10.1- Introduction:

Earth is a dynamic, ever changing planet!

If we could go back in time 200 million years, there would be no rocky mountains and valleys. Moreover, we would find landmasses with unfamiliar shapes and located in different positions from today's continents.

Earth scientists have shown that the landmass are not fixed, but slowly migrate across the globe. (Fig.10.1).

(Pangaea is meaning all the land).

Fig.10.1

Large landmass has split apart resulting in the formation of oceans, while the floor of the ocean has been recycled back into earth's interior.

Further, landmass that was separated by vast oceans have since collided and formed larger continents.

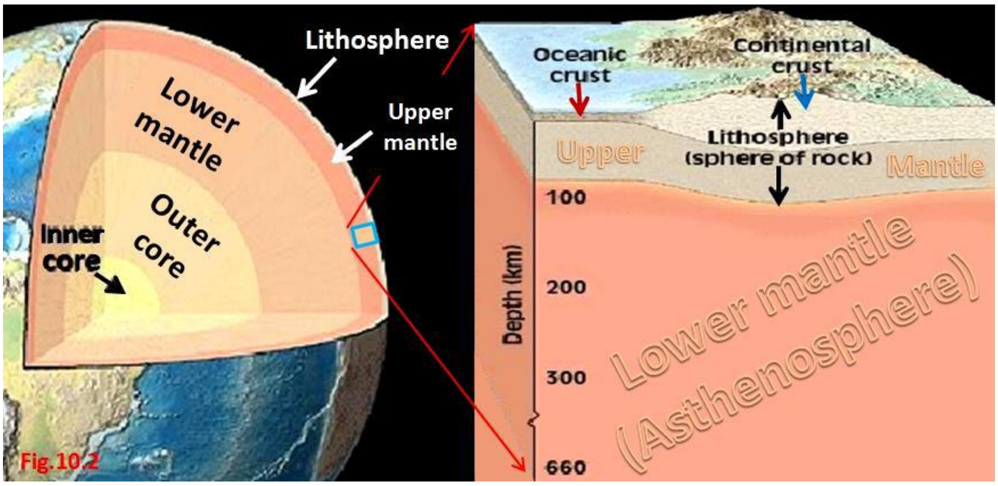
The movement of earth's outer layer continues today. Result of this movement includes earthquakes, volcanoes and building of earth's mountains.

The modern scientific theory which describes the movement of earth' outer layers is called **plate tectonics**.

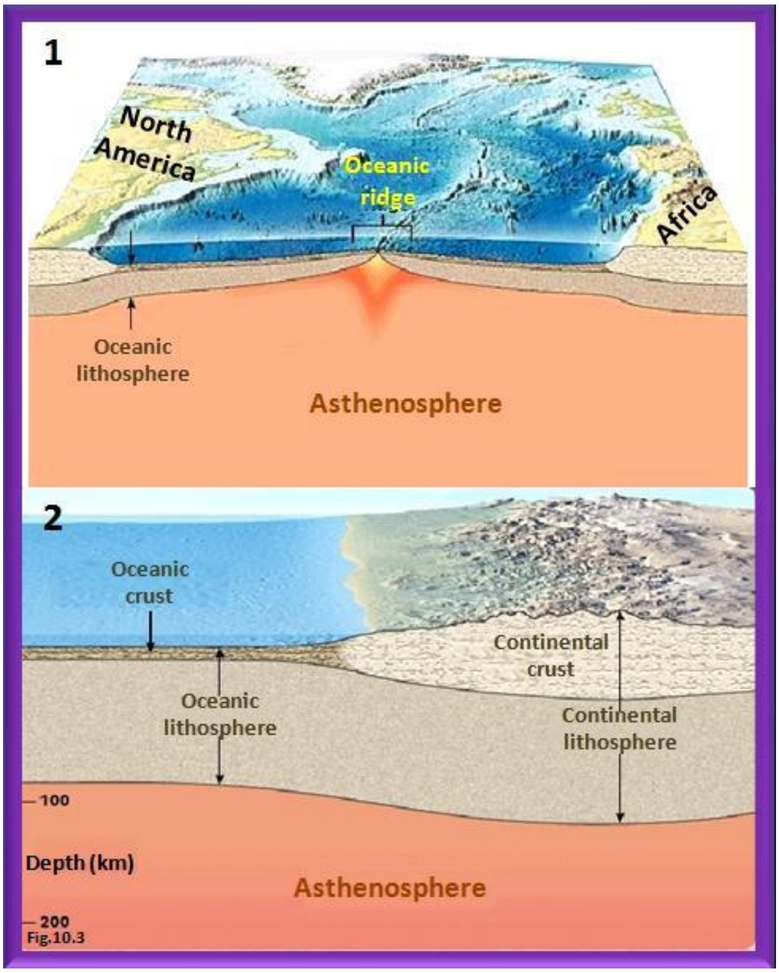
According to the plate tectonics theory, the **uppermost mantle**, along with the overlying crust, behave as a strong, rigid layer known as the **lithosphere**. So

Lithosphere = Upper mantle + earth crust

(Fig.10.2).

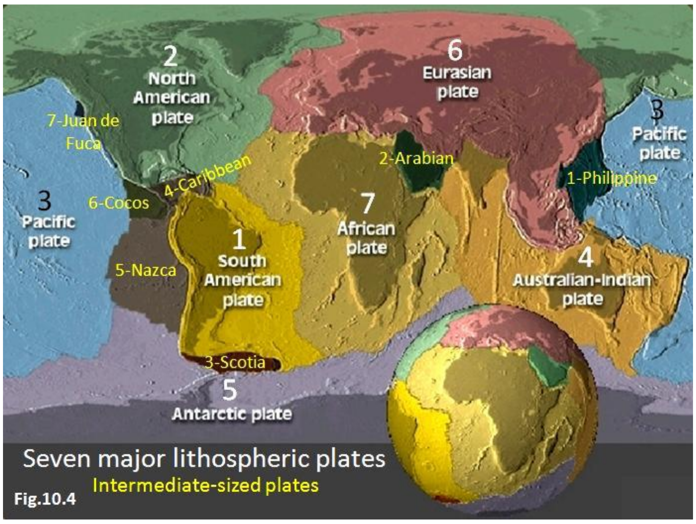


The **lithosphere** is **thinnest** in the oceans where its thickness may vary from as little as a few kilometers at the **oceanic ridge** to 100 kilometers in the deep-ocean basins. (Fig.10.3). 1.
By contrast, **continental lithosphere** is generally 100-150 kilometers thick but may be more than 250 kilometers thick below older portions of the continents. 2.
This rigid outer shell (lithosphere) overlies a hotter, weaker layer in the upper mantle known as the **asthenosphere.** 1 and 2.



Scientists think that the weak rock within the asthenosphere allows earth's rigid outer shell to move. Further, the lithosphere is broken into numerous segments, called lithospheres plates, or simply **plates** into:

A-Seven major lithospheric plates are recognized. They are:
1-South American plate. 2-North American.
3-Pacific plate. 4-Austtralian-Indian.
5-Antaractic. 6-Eurasian
7-African plate. (Fig.10.4).
The largest is the **pacific plate**, which encompasses a significant portion of the pacific ocean basin.
Notice that most of the largest plates include an entire continent plus a large area of ocean floor.
B- Intermediate-size plates include:
1-Philippine plate. 2-Arabian.
3-Scotia. 4-Caribbian
5-Nazca. 6-Cocos
7-Juan de Fuca plate. (Fig.10.4).



f planets. For example, most of our planet's earthquakes, volcanoes and mountain buildingEach plate is in constant motion relative to all other plates.
As the plates move, the distance between two locations on the same plate remains constant whereas the distance between sites on different planets gradually changes.
Most interactions occur at the margins (edges) o occur **along boundaries**.
Notice how the distribution of moderate to strong earthquakes is related to plate boundaries. (Fig.10.5). 1.
Volcanoes are also associated with **plate boundaries**. 2.

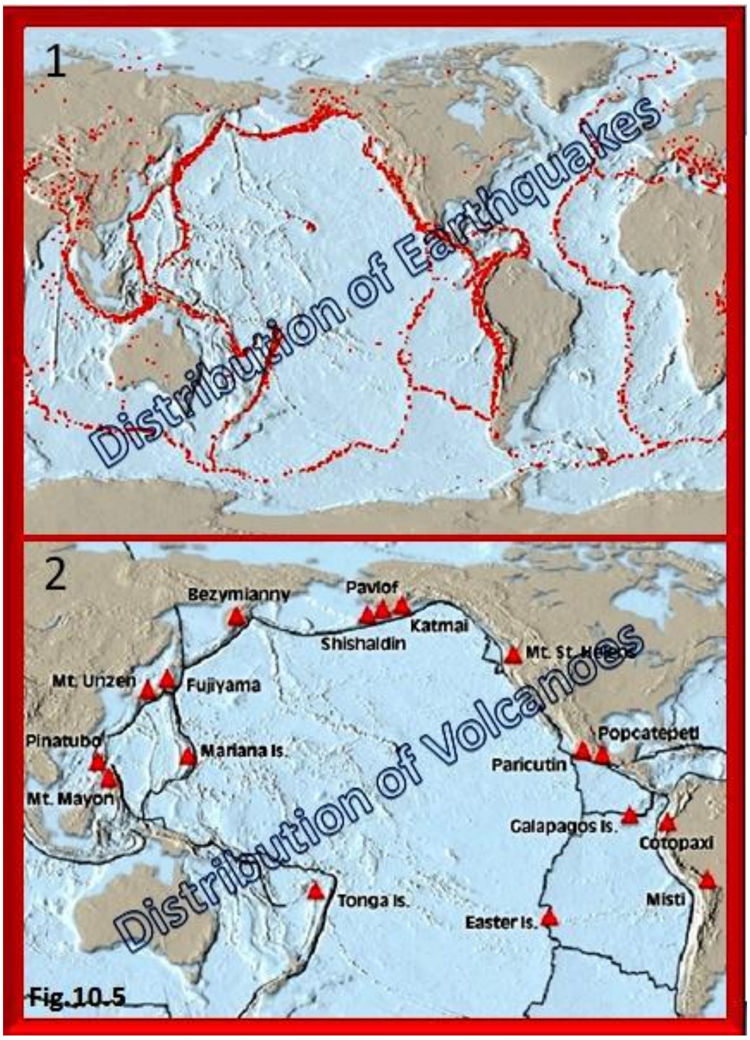


Fig.10.5

10.2- types of plate boundaries:

1- Divergent plate boundaries: Occur where two plates move apart from each other.
2- Convergent plate boundaries: Two plates move together toward each other.
3- Transform fault boundaries: Occur where two plates grind to each other.
Typically, all three types of boundaries can be found surrounding a plate.

1- Divergent boundaries:

At divergent plate boundaries, plates move apart. (Fig.10.6). 1.
Most divergent plate boundaries are located along crests of **oceanic ridges**. 2.
Let's examine the **Mid-Atlantic ridge** which extends along a north-south path down the center of the Atlantic ocean. 3.
Here as a plates move apart, the gap is filled with molten rock that oozes up from the hot mantle below. 4.

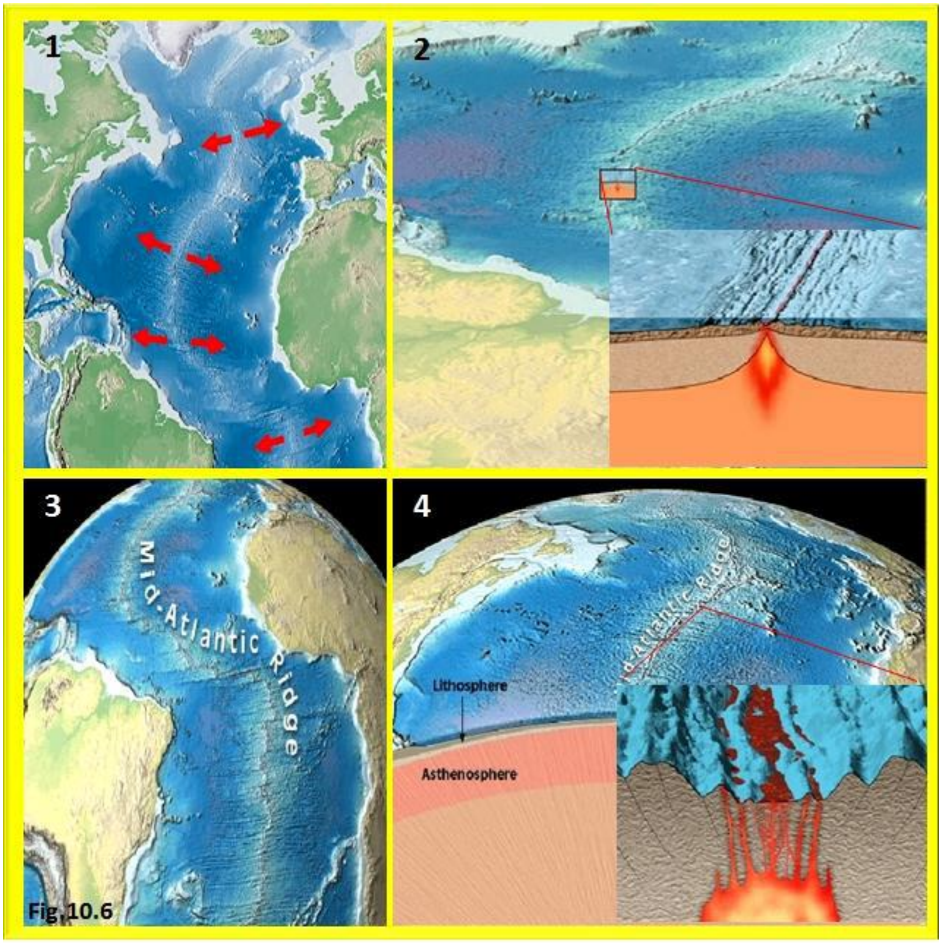


Fig.10.6

Gradually, this molten rock, called **magma**, Cools to make new slivers of sea floor. (Fig.10.7).

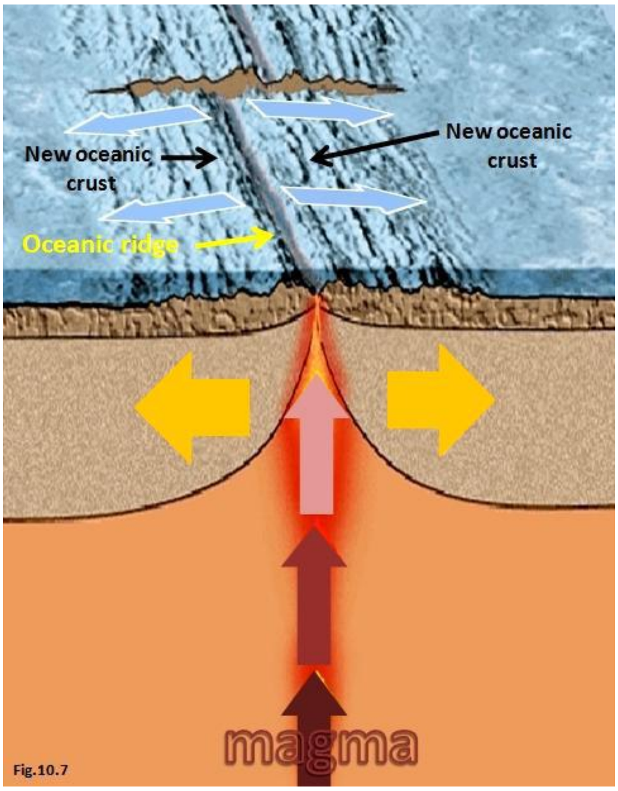


Fig.10.7

In a continuous manner, spreading and upwelling of magma add oceanic lithosphere to the edges of the diverging plates.
This mechanism has created the floor of the Atlantic ocean during the past 160 million years and is called **seafloor spreading**.
(Fig.10.8). 1 .. 6.
Average rates of seafloor spreading are about **5** centimeters per year.

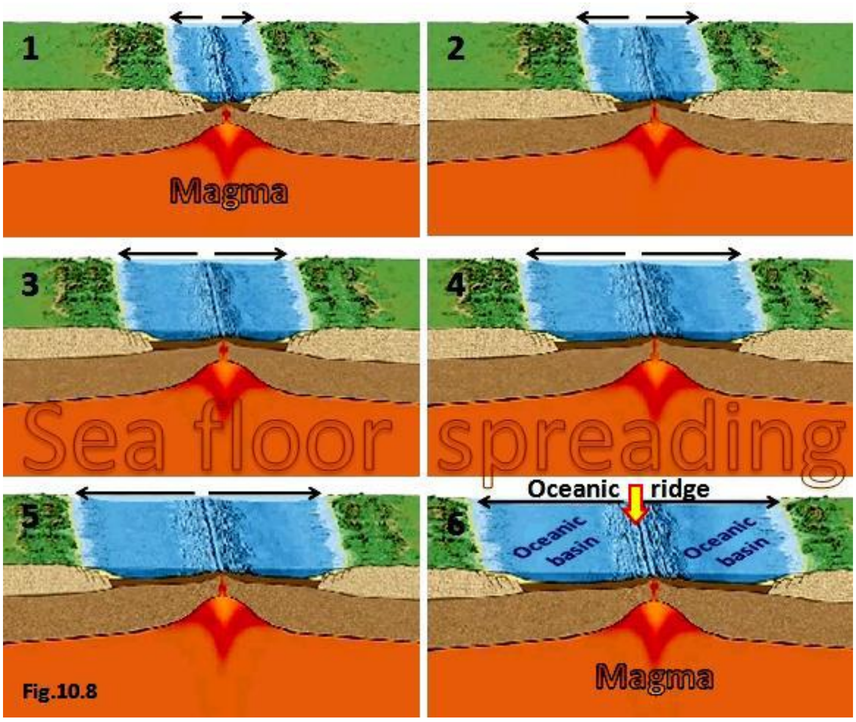


Fig.10.8

Some of the slowest spreading rates (2 centimeters per year) occur along the Mid-Atlantic Ridge; whereas rates exceeding 15 centimeters per year have been recorded along the East Pacific Ridge. (Fig.10.9).

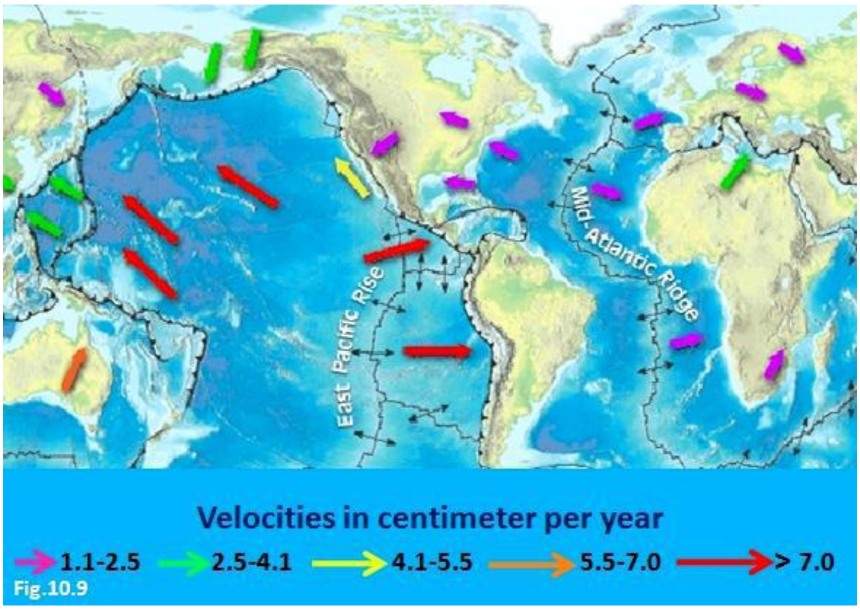


Fig.10.9

Although these rates of seafloor spreading seem slow on human time scale, they are rapid enough to have generated all Earth's ocean basins in the last 200 million years.
Spreading centers can also develop within a continent, in which case the landmass may split into two or more smaller continents.
This is known as **continental rifting**. F .10.10). 1 … 4.

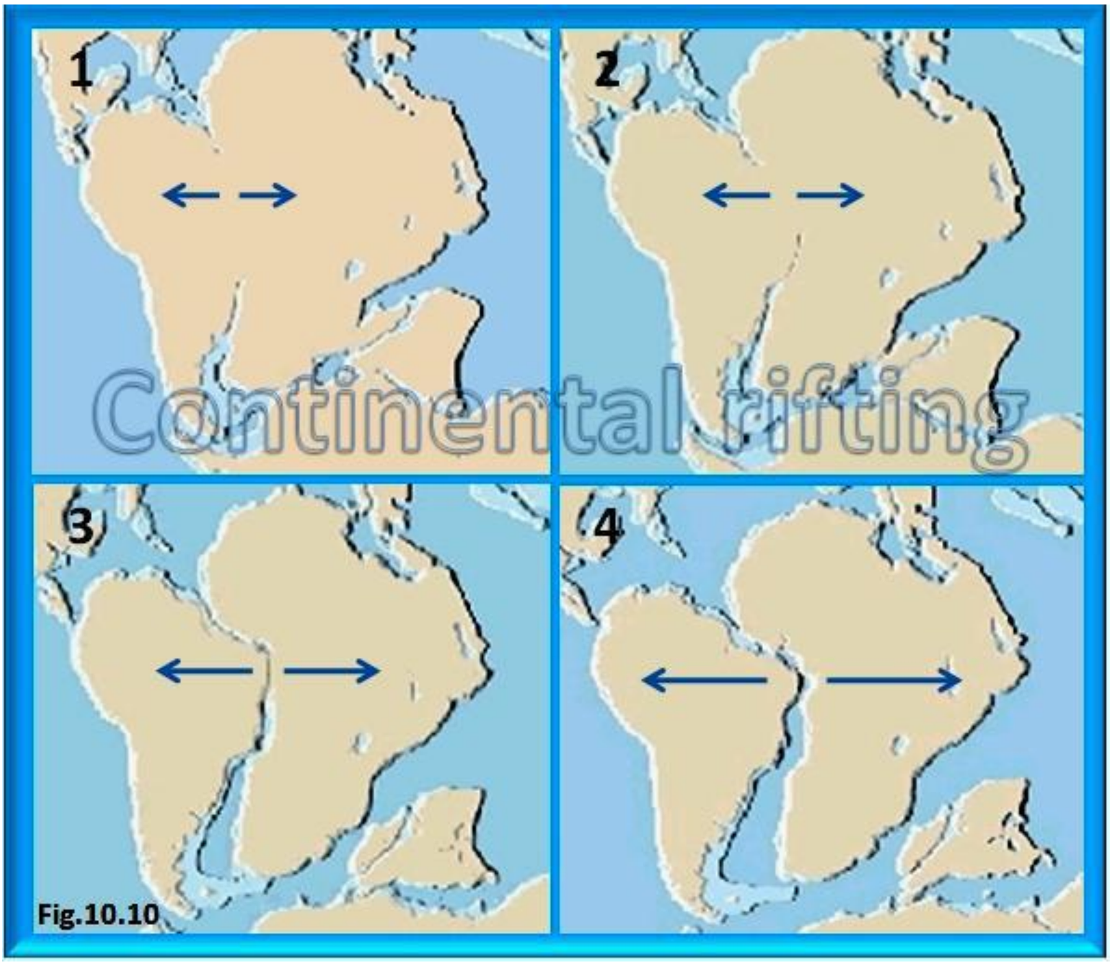


Fig.10.10

Continental rifting takes place where forces pull two plates in opposite directions. (Fig.10.11). 1. As the lithosphere stretches, molten rock rises from below to up warp the crust. 2.

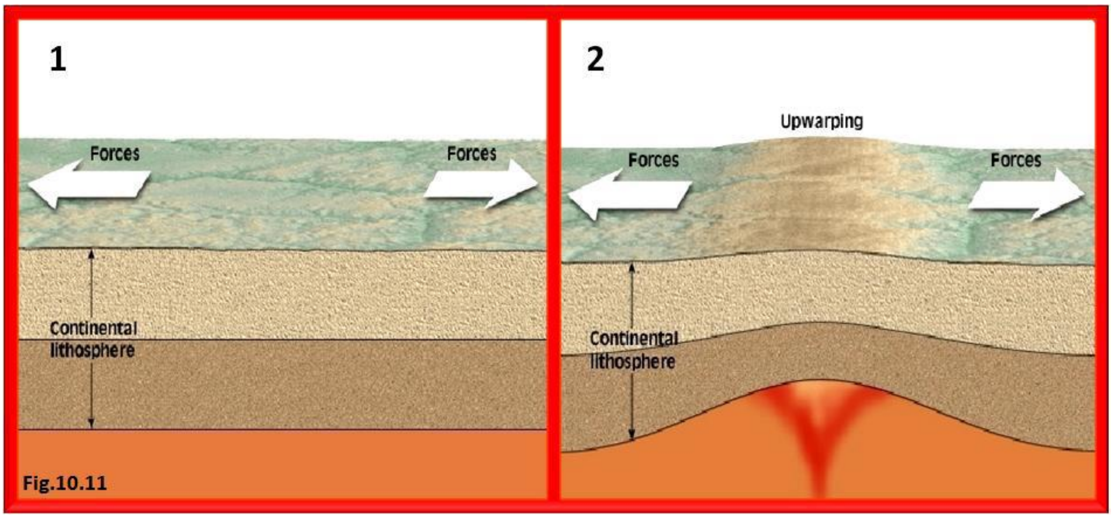


Fig.10.11

Eventually, the crust fractures to form a long trough called a **rift valley**. (Recall that rift valley is also found along the crests of some oceanic ridge). (Fig.10.12). 1.
Slowly, the rift valley lengthens and deepens. 2.

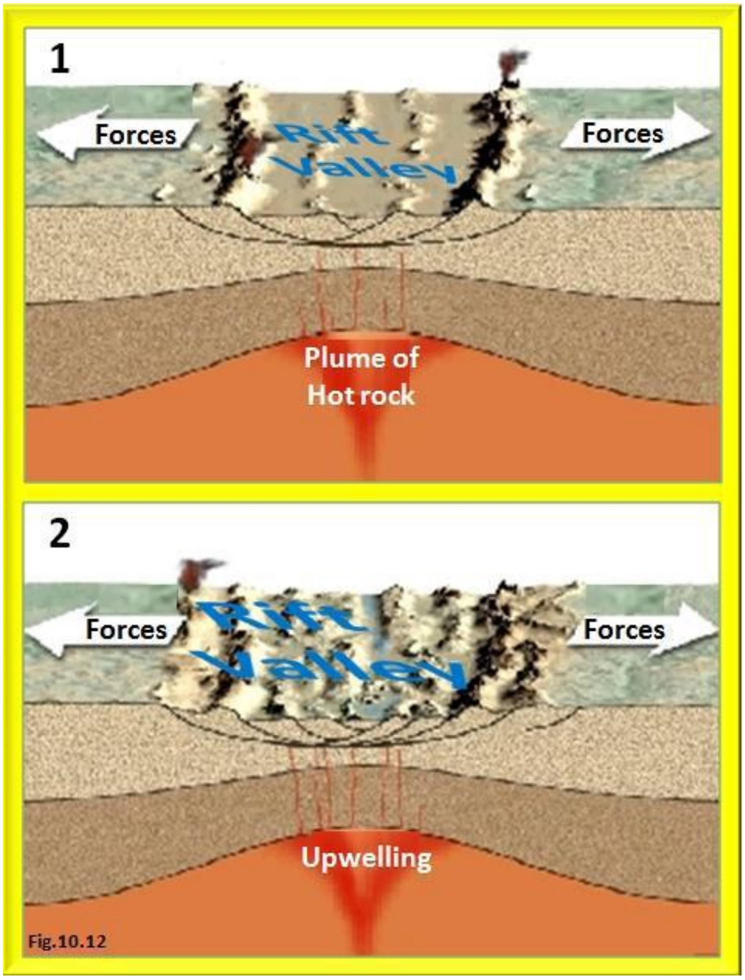


Fig.10.12

The East African **rift valleys** are Examples of such features. (Fig.10.13).

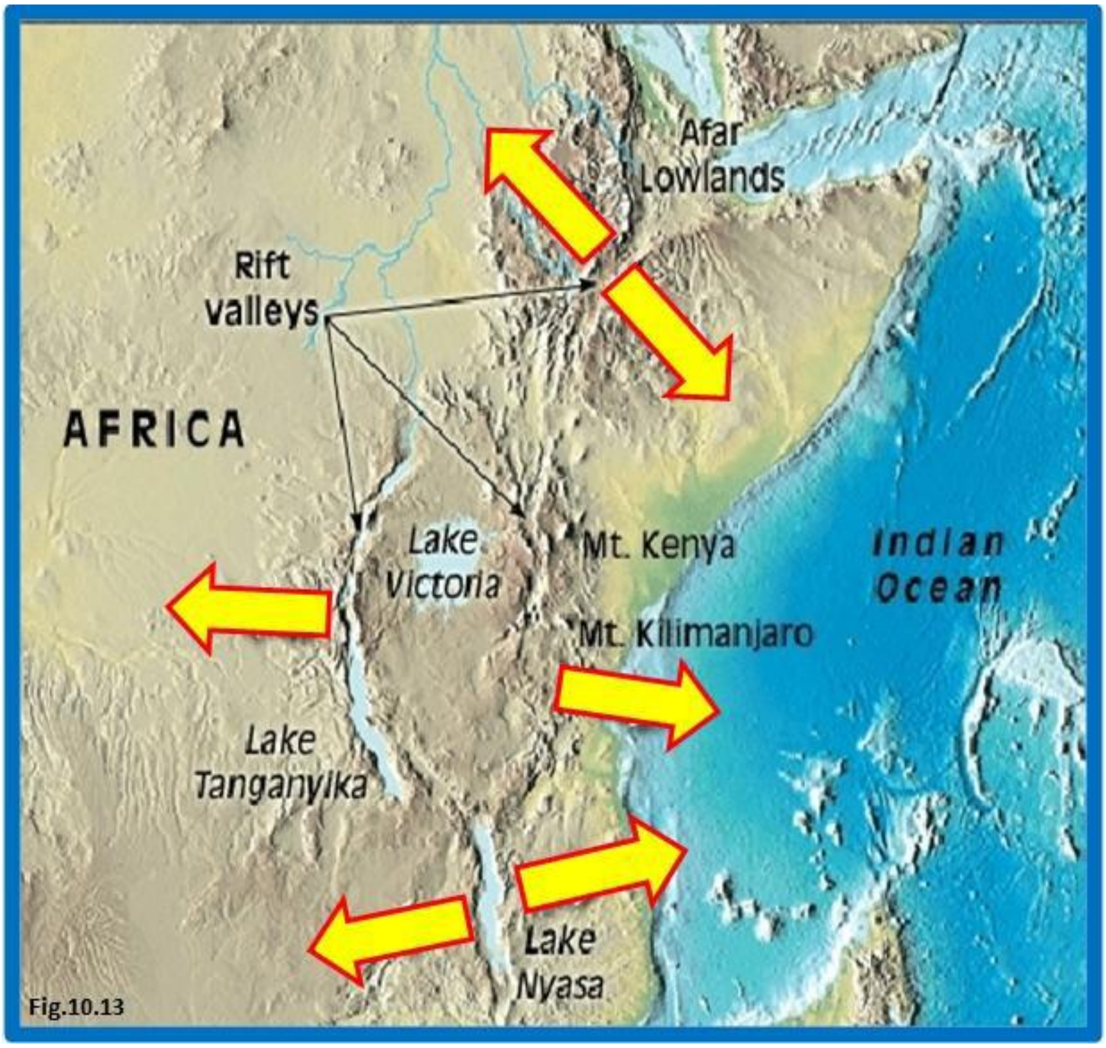


Fig.10.13

If spreading continues, it will extend to the plate margin and split the landmass into two, like South America and Africa did over 100 million years ago. (Fig.10.14).

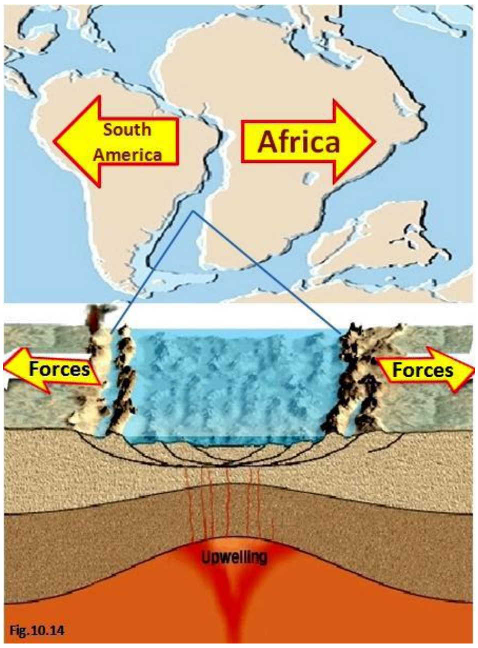


Fig.10.14

At this point the **rift valley** becomes a long, narrow sea with an outlet to the ocean, similar to the red sea. (Fig.10.15).

Fig.10.15

The red sea formed as the Arabian peninsula separated from North Africa.
Consequently, the Red sea provides Earth scientists with a view of how the Atlantic ocean may have looked in its infancy. (Fig.10.16).
Continued divergence brings us back "full-circle" to the development of a spreading center such as the present-day Mid-Atlantic Ridge.

Fig.10.16

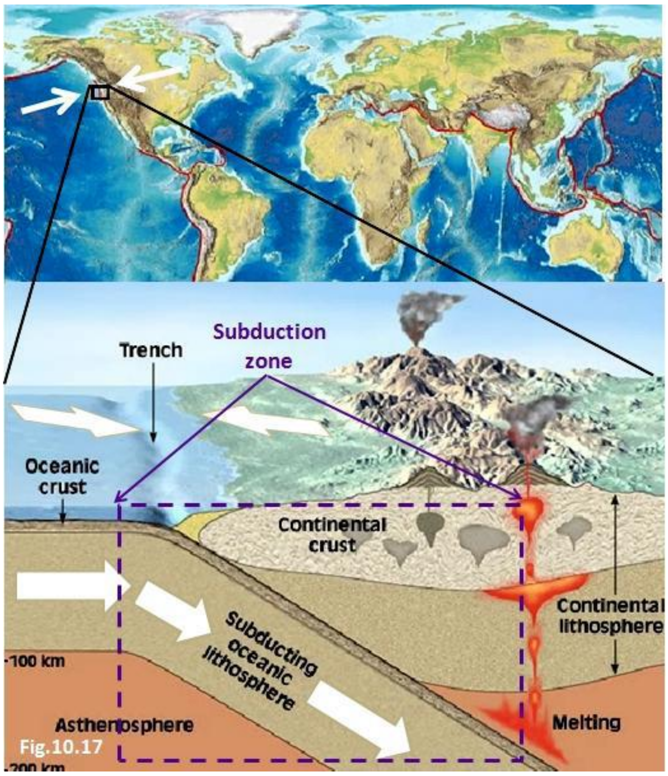
2- Convergent boundaries:

Although **new lithosphere** is continually being produced at divergent plate boundaries, the surface of our planet is not growing larger.

To balance the amount of newly created lithosphere, older portions of oceanic lithosphere descend into the mantle along convergent plate boundaries.

Convergent plate margins occur where two plates are moving toward each other and the motion is accommodated by one plate sliding beneath the other. (Fig.10.17).

Convergent plate boundaries are also called **subduction zones**, because they are sites where lithosphere is descending (Being subducted) into the asthenosphere. (Fig.10.17).



-Deep-oceanic trenches:

develop between two converging plates and indicate where the subducting plate begins its descent beneath the overriding plate.

Subduction occurs because the density of the subduction lithospheric plate is greater than that of the underlying asthenosphere.

Older oceanic lithosphere is cooler and denser than the underlying asthenosphere.

By contrast continental lithosphere is less dense and therefore more buoyant, which prevents it from being subducted to any great depth.

As a consequence, the subducted plate is almost always **oceanic**. (Fig.10.18).

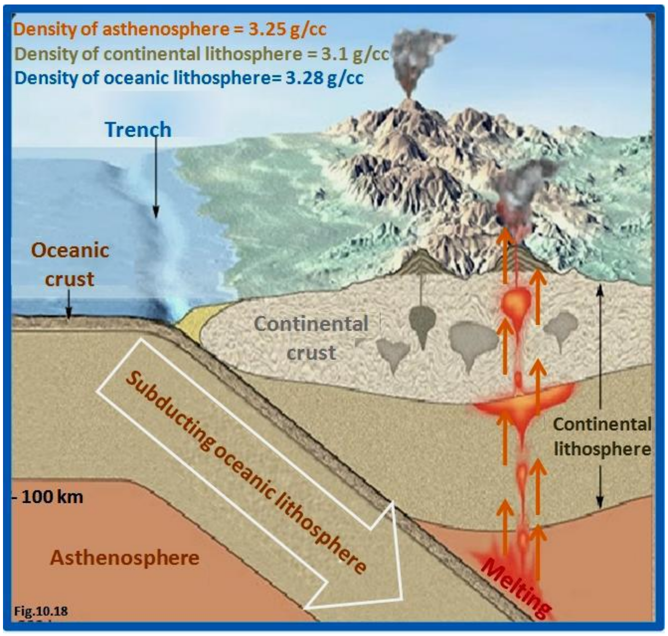


Fig.10.18

Some plates of oceanic lithosphere descend into the asthenosphere at angles of only a few degrees, whereas others plunge nearly vertically (90 degrees). (Fig.19.19). 1 and 2.
The angle at which oceanic lithosphere descends into the asthenosphere, depends on its density. When a plate of lithosphere is **less** than 10 million years old it is typically less dense than the underlying asthenosphere and subduction is nearly horizontal. 3.
As oceanic lithosphere ages (gets further from the spreading center), it cools. This causes it to thicken and increase in density. Once the age of oceanic lithosphere **exceeds** 10 million years, it is denser than the asthenosphere and will sink given the opportunity. 4.

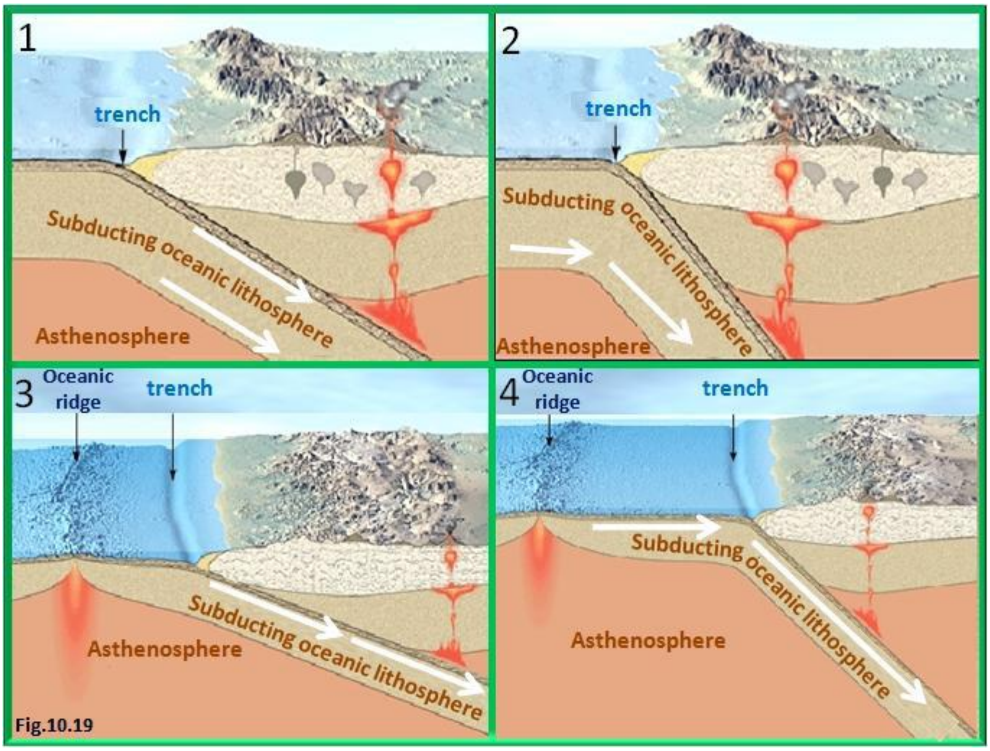
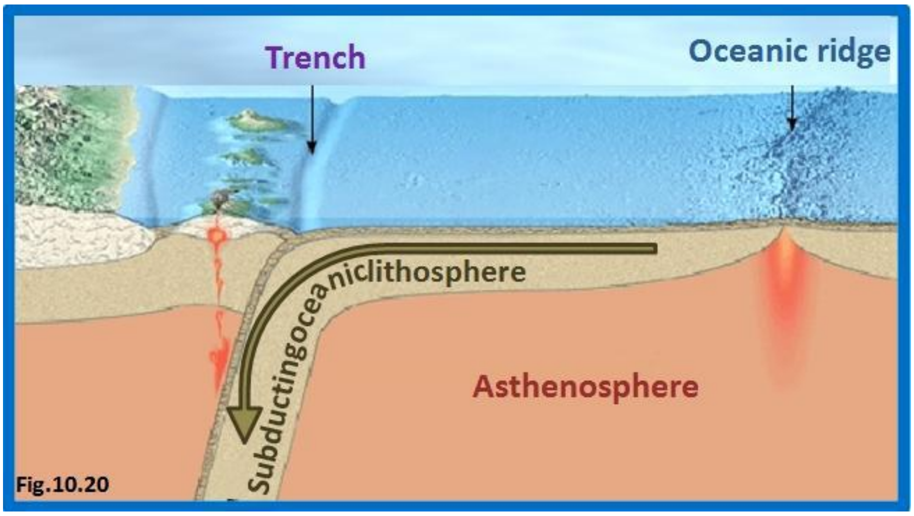


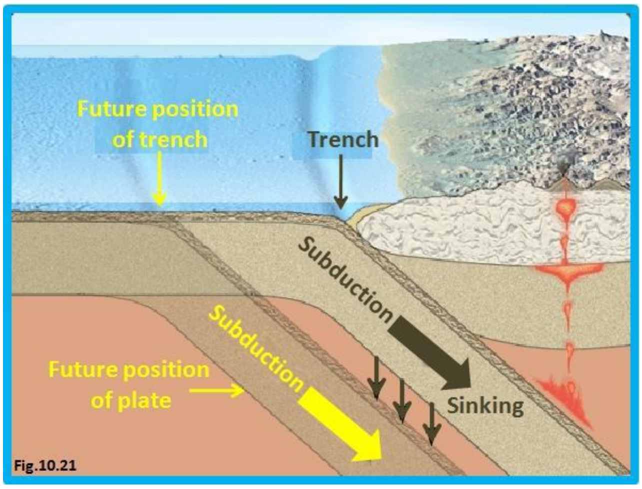
Fig.10.19

In parts of the Western Pacific some oceanic lithosphere is older than 160 million years. This is the thickest and densest in today's oceans.

The subduction plates in this region typically descend into the mantle at angles approaching 90 degrees. (Fig.10.20).



It is important to realize that a subducting plate does not follow a fixed path into the mantle. Rather, it sinks vertically as it descends, causing the **trench**. (Fig.10.21).



When the subduction plate sinks, it creates a flow in the asthenosphere that "pulls" the overriding plate toward the **retreating trench**. (Imagine what would happen if you were sitting in a lifeboat near the titanic as it is sank!) (Fig.10.22) 1.

Although all convergent plate boundaries have many similar characteristics, they are highly variable features.

Nevertheless, they can be placed into one of three broad groups based on the type of crustal material involved.

Convergent plate boundaries form:

A-Continental lithosphere overrides oceanic. 2.

B-Plate of oceanic lithosphere is subducted beneath another. 3.

C-Two plate of continental lithosphere converge and eventually collide.

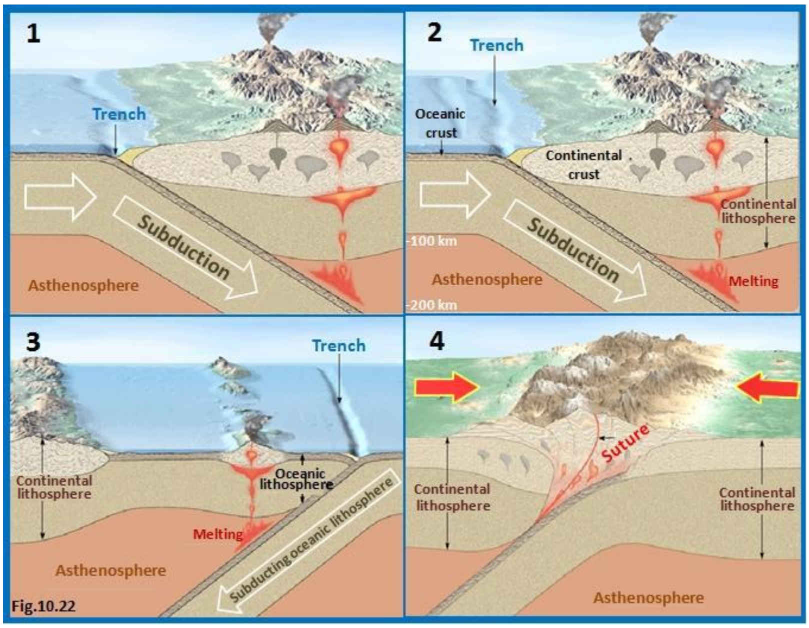


Fig.10.22

The spreading, Collision, Subduction zone and trench of Tectonic plates is showing below: (Fig.10.23).

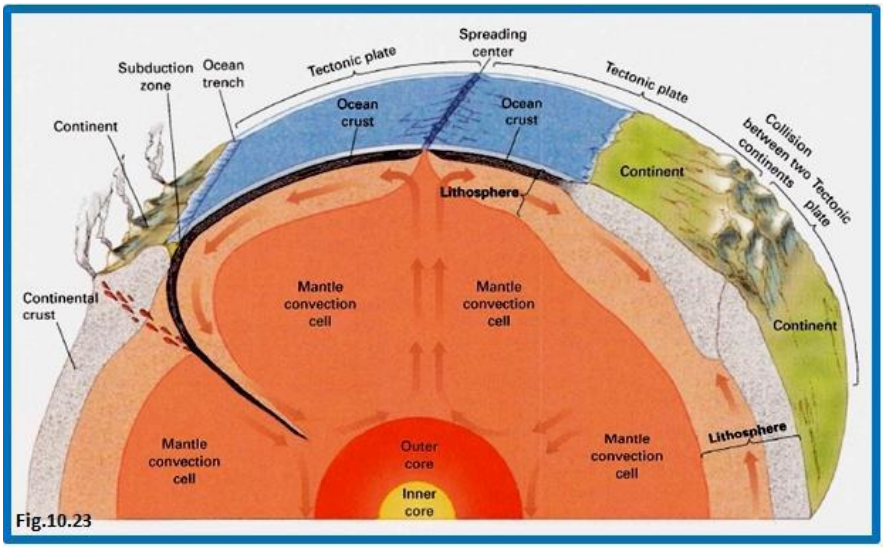
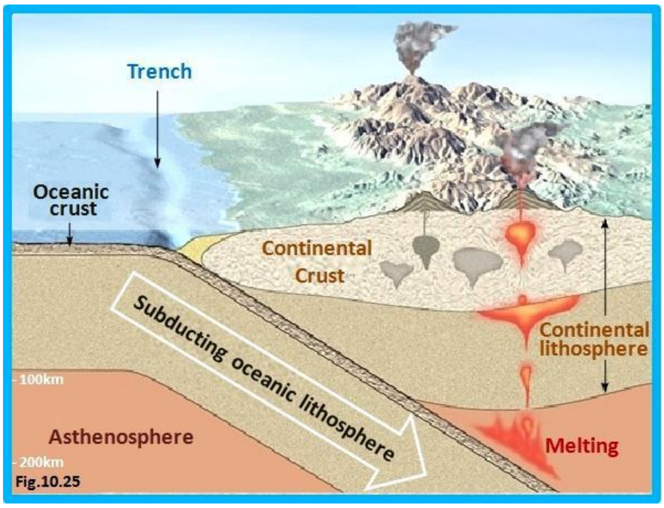


Fig.10.23

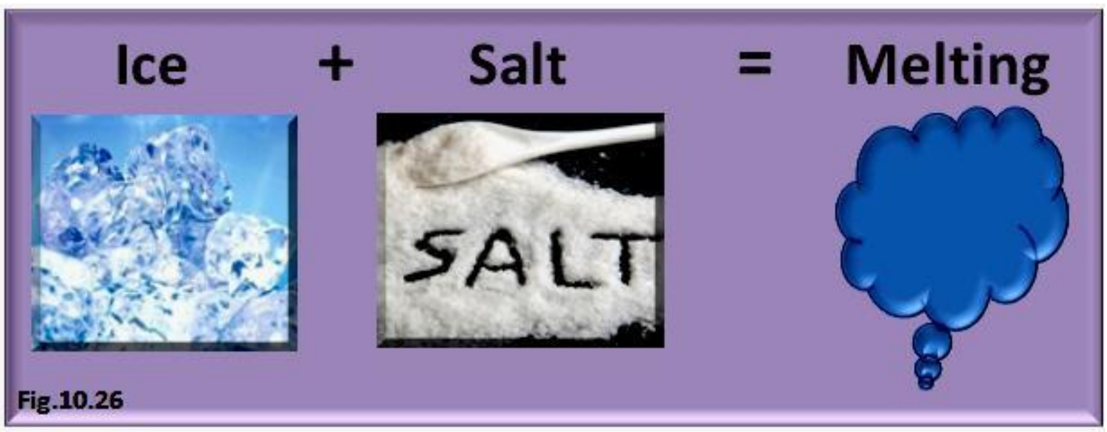
A- Continental lithosphere overrides Oceanic:

Let's take a look at what happens when an oceanic plate converges with continental lithosphere. (Fig.10.24).

Whenever a plate capped with continental crust converges with a plate of oceanic lithosphere, the buoyant continental plate remains "floating" while the denser oceanic plats descends into the mantle.
When the descending oceanic plate reaches a depth of roughly 100 killiometers, melting is triggered within the hot asthenosphere that lies above it. (Fig.10.25).



But how the subduction of cool plate of oceanic lithosphere causes mantle rock to melt?
The answer lies in the fact that water acts like salt does to melt ice. That is, "wet" rock, in a high temperature environment, melts at a lower temperature than "dry" rock. (Fig.10.26).



Sediments and oceanic crust contain a large amount of water which is carried to great depths by a subduction plate.

When the plate plunges downward, water is "squeezed" from pore spaces as **confining pressure** increases. At greater depths, heat and pressure drive water from hydrated (water-rich) minerals such as amphiboles. (Fig.10.27). 1.

At a depth of roughly 100 kilometers, the asthenosphere is sufficiently hot that introduction of water typically leads to **partial melting**. 2.

The semi-molten rock generated by this process contains as little as **10 percent melt**, which is mixed with unmelted mantle rock. Being less dense than the surrounding mantle, this hot mobile mixture gradually rises toward the surface as tear-drop shaped structures. 3.

When this partially molten material reaches the base of the crust, it is thought to "pond" beneath the somewhat less dense continental rocks. Here fluid **basaltic magma** separates from the unmelted components and continues its ascent. 4.

Depending on the environment, Mantle-derived, basaltic magma may rise through the crust to feed volcanic eruption at the surface.

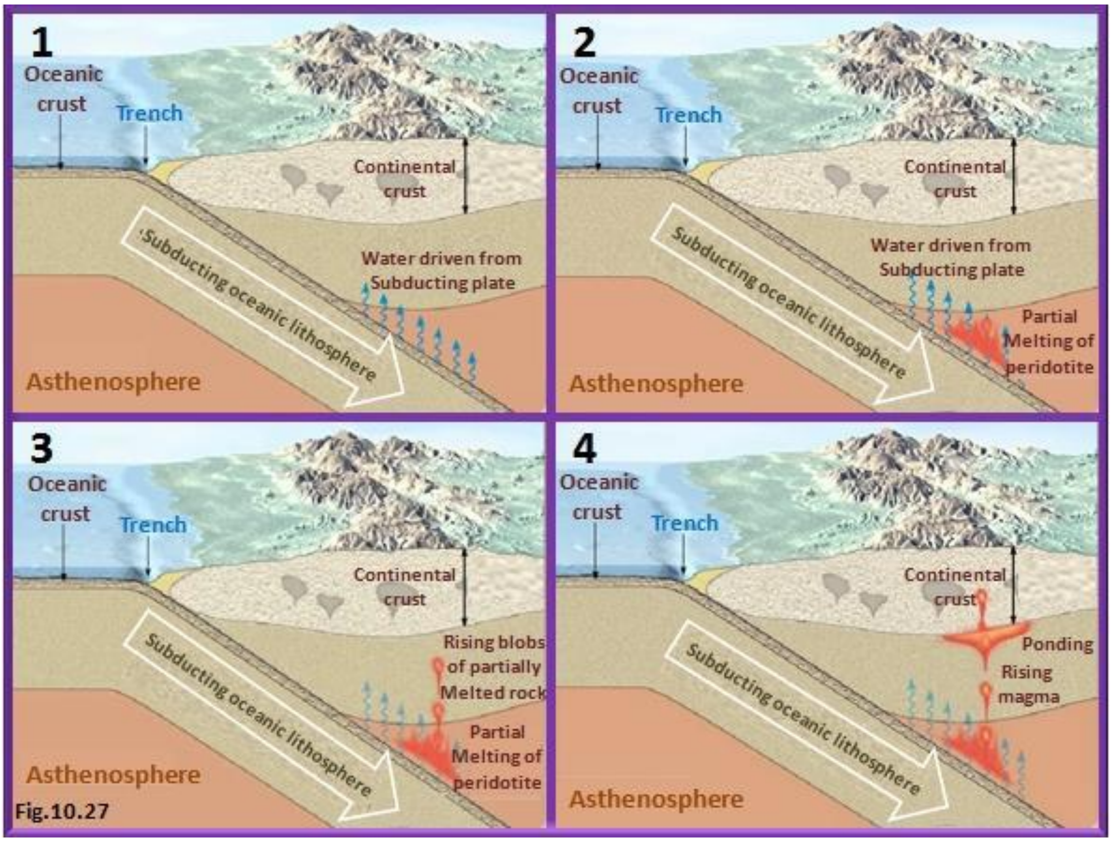


Fig.10.27

In a continental setting, basaltic magma typically melts and assimilates some of the crustal rocks through which it ascends.

The result is the formation of the **silica-rich magmas** having an **andesitic** composition, or less often, a **rhyolitic** composition. (Fig.10.28). 1

On occasions when andesitic magmas reach the surface, they often erupt explosively, generating large columns of volcanic ash, pumice and gases

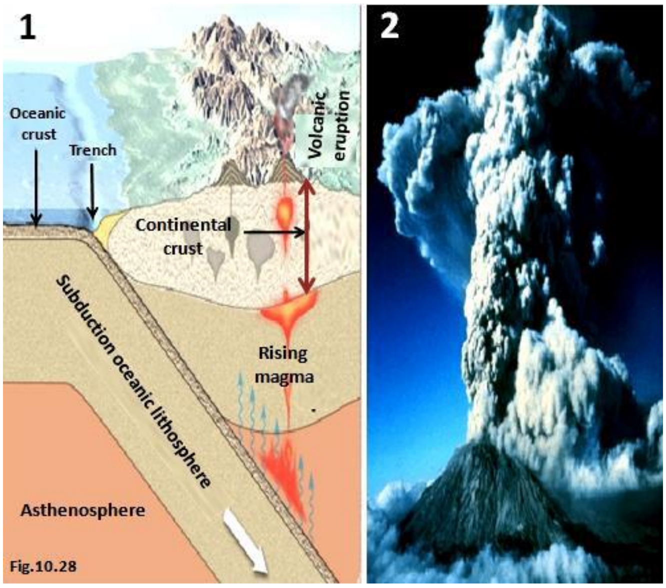


Fig.10.28

The volcanoes of the towering Andes are the products of magma generated by the subduction of the oceanic Nazca plate beneath the South American continent.

This chain of volcanic peaks, termed a **continental volcanic arc**, identifies the region of intrusive and extrusive igneous activity associated with an oceanic-continental convergent boundary. (Fig.10.29).

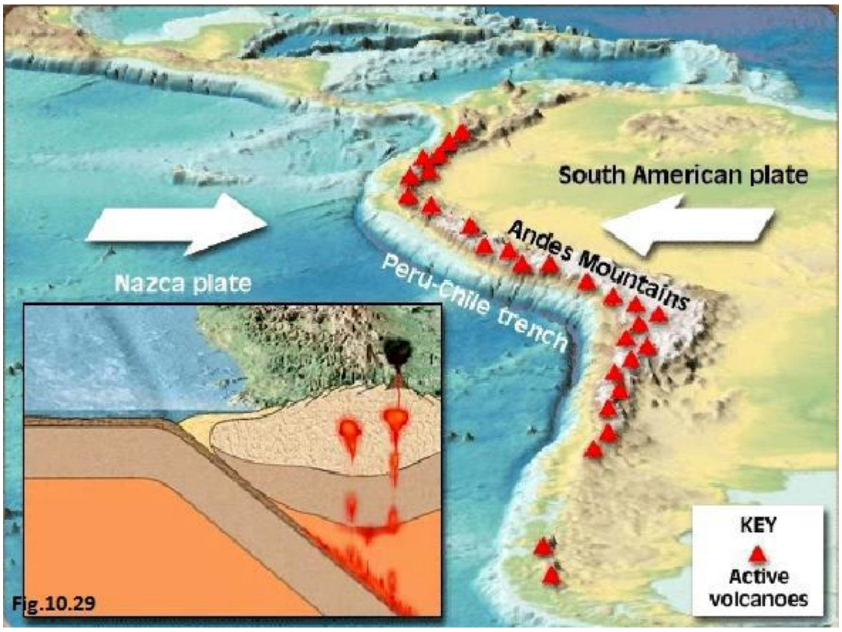


Fig.10.29

B- Plate of oceanic lithosphere is subducted beneath another:

Now let's look at what happens when two plates composed of oceanic lithosphere converge. In this setting, one oceanic plate descends beneath the other, often initiating volcanic activity at the surface.

Here, volcanoes grow up from the ocean floor, rather than on a continent. Should the volcanoes continue to grow, they will eventually reach the surface to form a **volcanic island arc**, or simply, an **island arc**. (Fig.10.30).

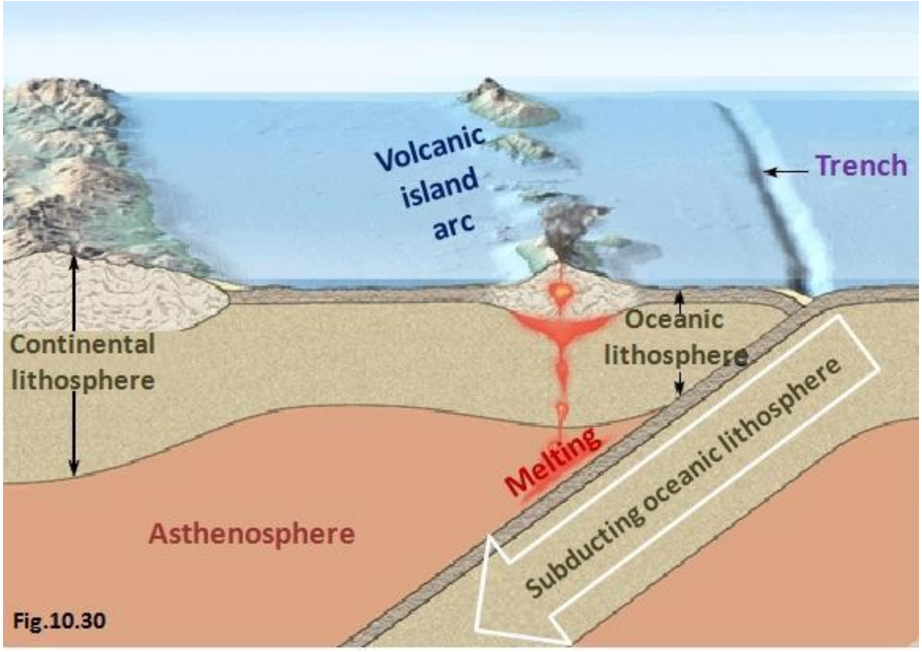


Fig.10.30

The image below shows a volcanic island arc that is part of Indonesia. (Fig.10.31). 1.
Most volcanic island arcs located in the Western Pacific, where they form parallel to a deep-oceanic trench. 2.

Fig.10.31

C- Two plate of continental lithosphere converge and eventually collide:

The third type of convergent plate boundary exists where two lithospheric plates, each carrying continental crust, collide.

If the subduction plate also contains continental lithosphere, continued subduction eventually brings the two continents together.

F .10.32). 1 … 4.

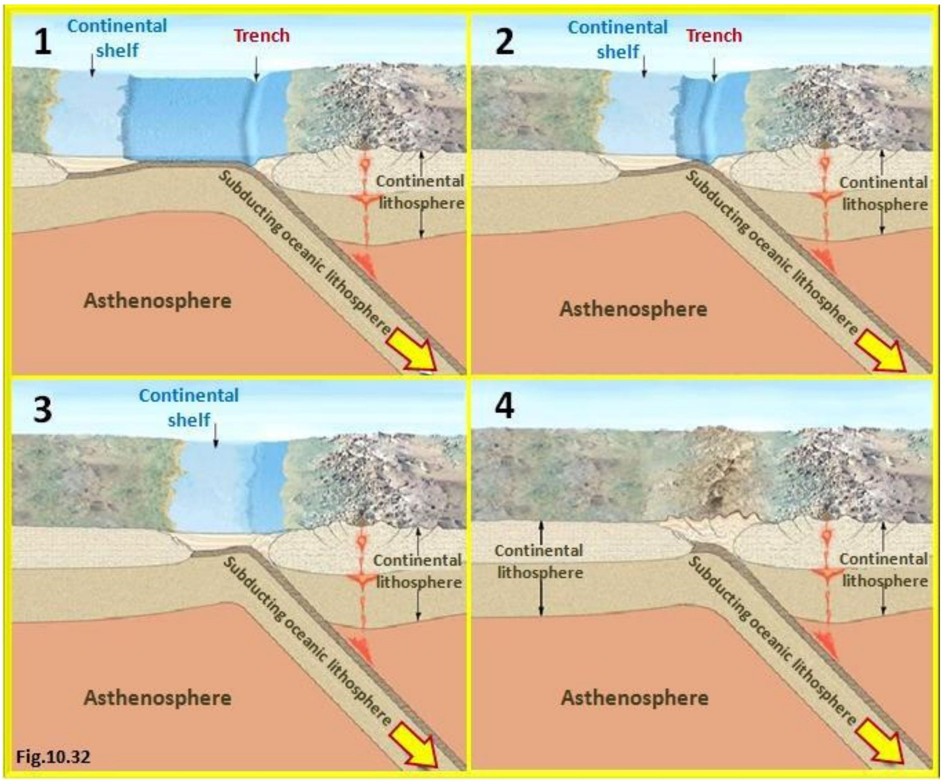


Fig.10.32

Because continental crust is too buoyant to undergo appreciable subduction, a collision between the continental plates results. (Fig.10.33).

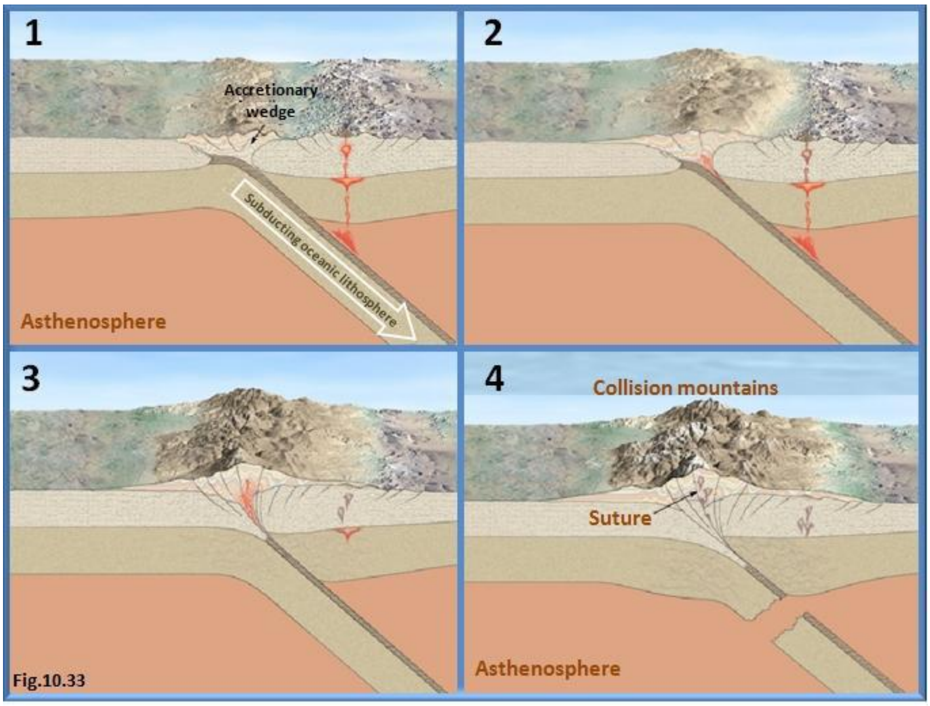


Fig.10.33

Such a collision occurred when India "rammed" into Asia and produce the Himalayas-the most spectacular mountain range on Earth and the Tibetan Plateau. (Fig.10.34). 1 and 2.
Other examples are the Urals, Caucasus, Pyrenees, Caledonians, Appalachians and Alps

Fig.10.34

3- Transform fault boundaries:

The third type of plate boundary is called a **transform fault**. It found where plates slide horizontally past one another without generating new lithosphere as occurs along divergent plate boundaries and without the destruction of lithosphere as occurs along convergent zones. (Fig.10.35). 1.

Most transform faults join two segments of the oceanic ridge system. 2.

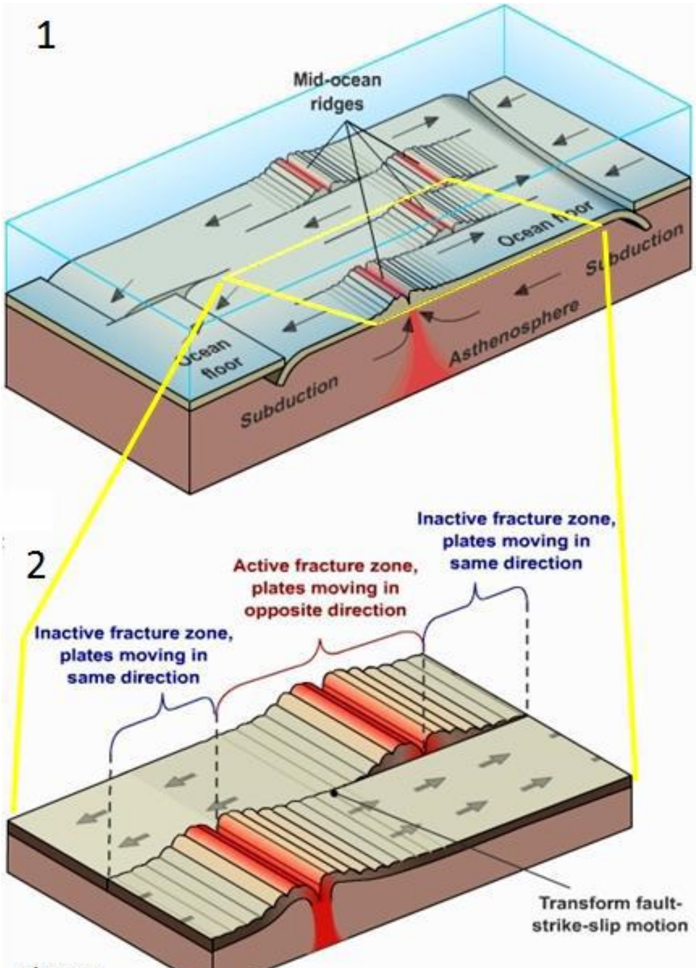


Fig.10.35

Transform faults join the globe's active belts (convergent and spreading centers) into a continuous network. (Fig.10.36).

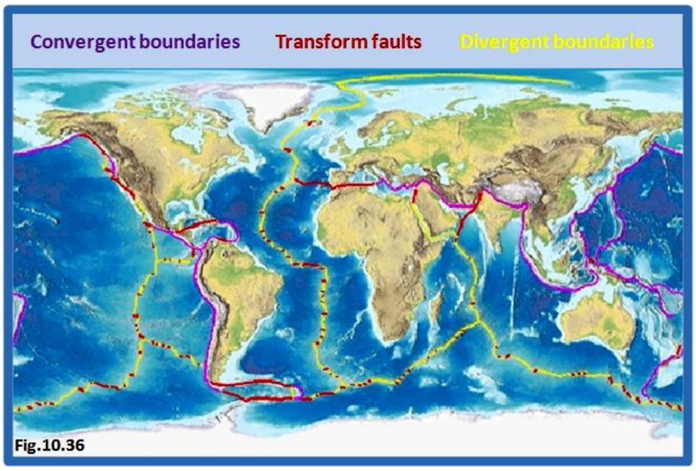


Fig.10.36

The adjacent plates of oceanic crust grind past one another, sporadically generating earthquakes. (Fig.10.37).

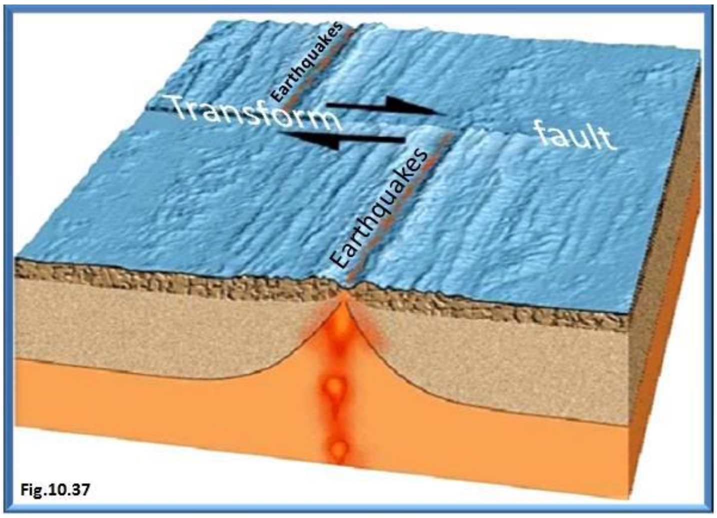


Fig.10.37

Although most transform faults are associated with oceanic ridge, some like the Andreas Fault in California, cut through continental crust. (Fig.10.38). 1.
Such situations provide geologists an opportunity to study transform faults first hand. 2.
Along the San Andreas Fault, the Pacific plate is moving toward the northwest, past the North American plate.

Fig.10.38

1- Earth's rigid outer layer overlies a zone of weaker and hotter material known as the : a- cry sphere. b- lithosphere. c- asthenosphere. d- mesosphere.

2- Great earthquakes can be generated at transform fault boundaries. a- true. b- false. 3- Most volcanic island arcs located in the ------------------. a- western pacific. b- Gulf of Mexico. c- Caribbean Sea. d- South Atlantic.

4- At divergent plate boundaries, two plates ------------------------.

a- move together. b- grind each other. c- join to produce a large plate. d- move a part. 5- Whenever a plate of oceanic lithosphere convergence with a plate of continental lithosphere -----------------------------.

a- the continental lithosphere descends into the asthenosphere. b- the continental lithosphere gets pushed toward the ridge. c- the oceanic lithosphere descends into the asthenosphere. d- the oceanic lithosphere gets pushed toward the ridge.

6- Transform faults occur where plates slide past one another and generate new lithosphere. a- true. b- false.

7- At transform faults boundaries, two plates ------------------------. a- move together. b- grind each other. c- join to produce a large plate. d- move a part.

8- The theory of plate tectonics holds that the outer rigid layer of Earth is broken into about a dozen major segments called shields. a- true. b- false.

9- According to the theory of plate tectonic, plates interact mainly --------------. a- along plate boundaries. b- near the center of each plate where stress is greatest. c- on the underside of each plate.

10- As plates move apart, the gap between them is filled with molten rock called ----------. a- granite. b- silica. c- magma. d- amphibolites.

11- At convergent plate boundaries -----------. a- new lithosphere is forming. b- old lithosphere is being destroyed. c- neither a or b. d- both a and b.

12- Volcano associated with continental volcanic arcs generally -------------. a- are located on island like Hawaii. b- emit mainly lava flow. c- erupt explosively. d- erupt on the average of every 1000 years.

13- Subduction occurs because: a- forces created at spreading centers are causing plates to move together. b- the sediments that cap the oceanic crust act as a lubricant to aid subduction. c- the subduction lithosphere has a greater density than the underlying asthenosphere. d- the lithosphere is warm and weak.

14- Most of the largest plates --------------. a- consist primary of oceanic crust. b- are dominated by continental crust. c- contain large amounts of both oceanic and continental crust.

15- The region where oceanic lithosphere descends into the asthenosphere is called --------------. a- an accretionary wedge. b- a hot spot. c- a mantle plume. d- a subduction zone.

16- Older oceanic lithosphere is cooler, thicker and denser than young oceanic lithosphere. a- true. b- false.

17- Along the San Andreas Fault, the Pacific plate is moving toward the northwest, relative to the North American plate. a- true. b- false.

18- What is the main factor that triggers the formation of magma when a cold plate of oceanic lithosphere is subducted? a- the subducted plate supplies water to the hot mantle rock thereby lowering its melting temperature. b- friction between the subducting plate and the mantle rock generates enough heat to trigger melting. c- the subducting plate carries sediments deep into Earth where it melts. d- the subducting plate displaces hot mantle rock which rises to form magma.

19- The mechanism that has generated the floors of the world's ocean is called ---------. a- ocean floor convergence. b- ocean floor construction. c- seafloor construction. d- seafloor spreading

20- Which one of these mountain belts was NOT formed by a continental collision? a- Himalayas. b- Andes. c- Appalachians. d- Urals.

21- Earth's rigid outer layer is called: a- cry sphere. b- lithosphere. c- asthenosphere. d- mesosphere.

22- Collision mountain belts form because continental crust is too buoyant to undergo subduction, and results in collision between continental fragments. a- true. b- false.

23- New oceanic crust is created at divergent boundaries at rate of about: a- 5 centimeters per century. b- 5 centimeters per year. c- 5 meters per year. d- 5 kilometers per year.

24- The lithosphere is thickest under the oceans and thinner beneath the continents. a- true. b- false.

25- When an oceanic plate and a continental plate converge, a -------------- is formed along a subduction zone. a- asthenospheric rise. b- oceanic trench. c- oceanic ridge. d- transform fault. e- rift.

26- Convergent plate margins occur where two plates are moving toward one another and the movement is accommodated by: a- earth getting larger. b- one plate sliding horizontally the other. c- new material being added at transform fault boundaries. d- one plate descending beneath the other.

27- Most divergent boundaries are located: a- in mountain regions such as the Alps and Himalayas. b- in deep-ocean trenches. c- along oceanic ridge. d- in the center of large continents.

28- Which of these plates is the larger? a- Nazca. b- Pacific. c- Australian-Indian. d- Africa.

29- At convergent plate boundaries, two plates -------------. a- move together. b- grind each other. c- reverse direction. d- move apart.

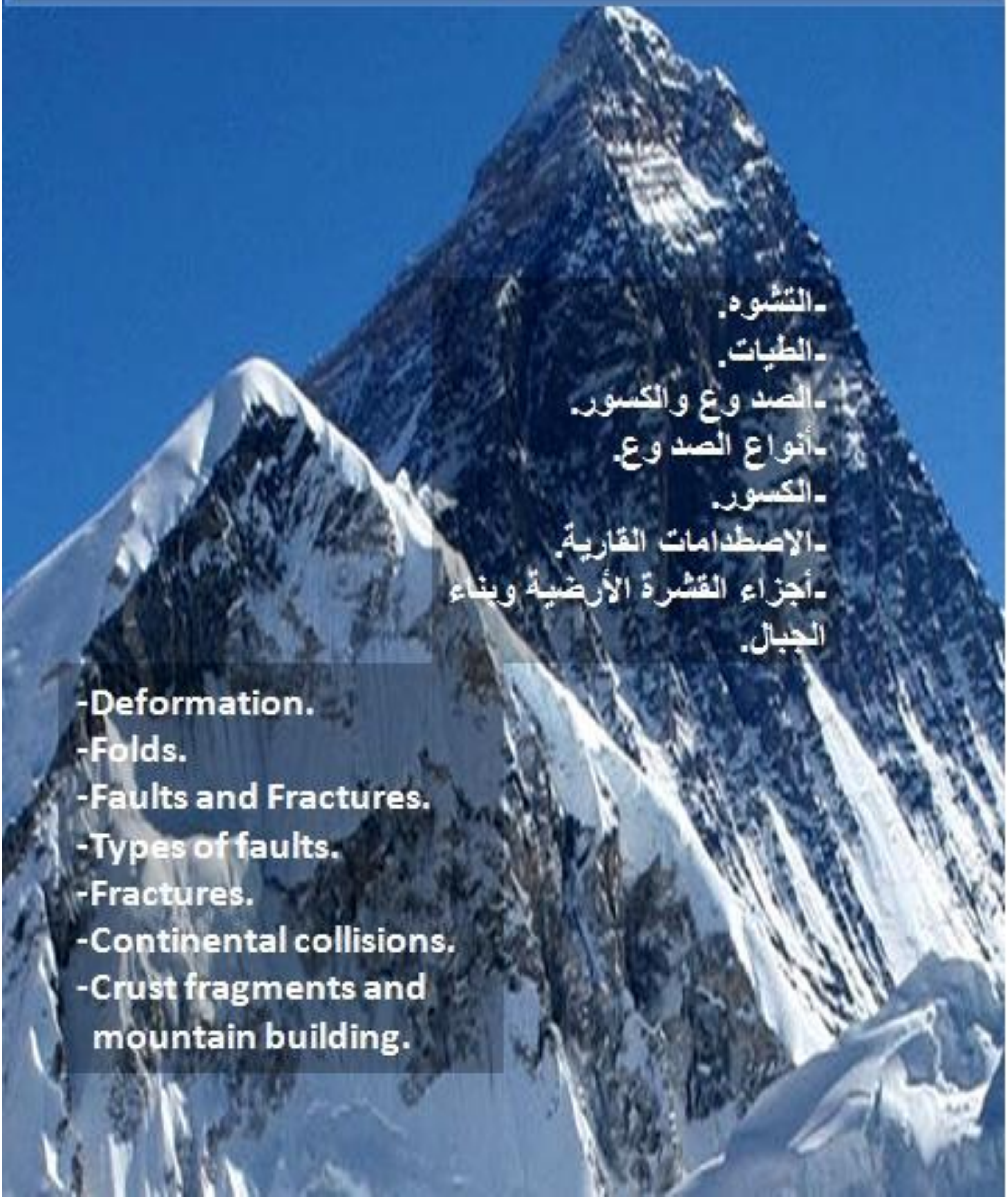
30- When two oceanic plates converge, and one plate descends to form a trench, material from the melting plate often forms a -------- at the surface. a- continental rift. b- volcanic island arc. c- oceanic ridge. d- mountain range.

31- Which of these water bodies was once a rift valley? a- Lake Michigan. b- Red Sea. c- Caspian Sea. d- Black Sea.

32- What layer of earth allows the plates to move? a- cry sphere. b- lithosphere. c- asthenosphere. d- mesosphere.

Chapter eleven — الفصل الحادي عشر

Mountain building — بناء الجبال



-التشوه.
-الطيات.
-الصدوع والكسور.
-أنواع الصدوع.
-الكسور.
-الاصطدامات القارية.
-أجزاء القشرة الأرضية وبناء الجبال.

-Deformation.
-Folds.
-Faults and Fractures.
-Types of faults.
-Fractures.
-Continental collisions.
-Crust fragments and mountain building.

11.1- Deformation:

Earth is a dynamic planet. Tectonic forces deformed rock to produce our planet's spectacular mountain belts.

When rocks are subjected to forces (stresses) greater than their own strength, they begin to deform usually by **folding** and **faulting**. (Fig.11.1).

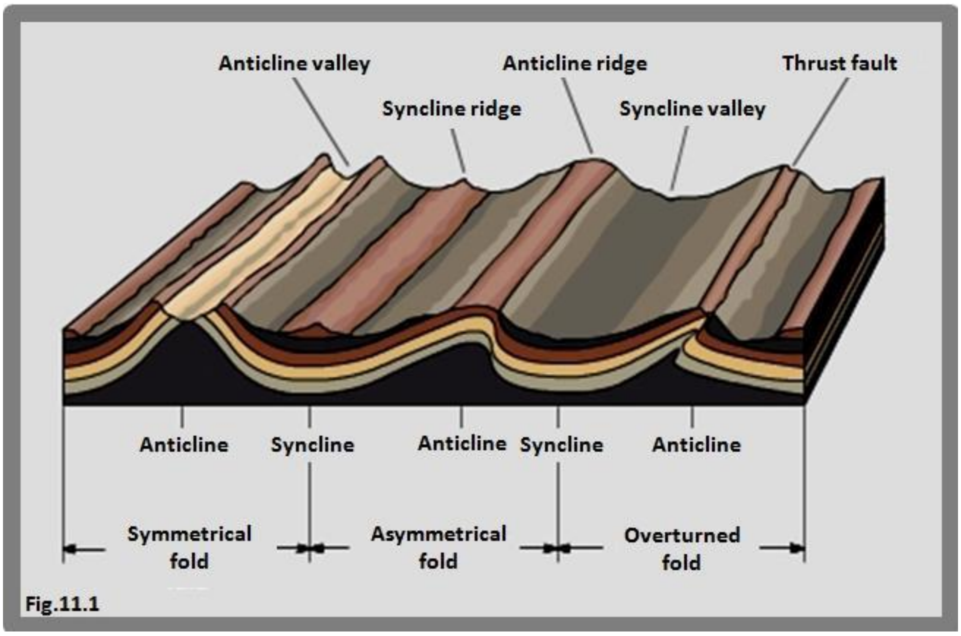


Fig.11.1

Some of the geologic structures associated with crustal deformation include folds, faults and joints or fractures. (Fig.11.2).

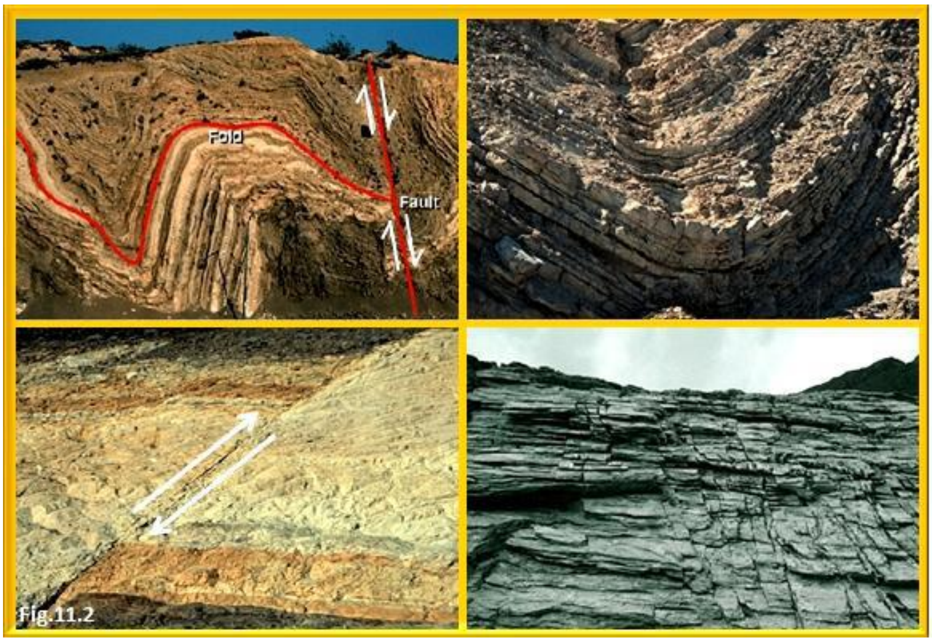
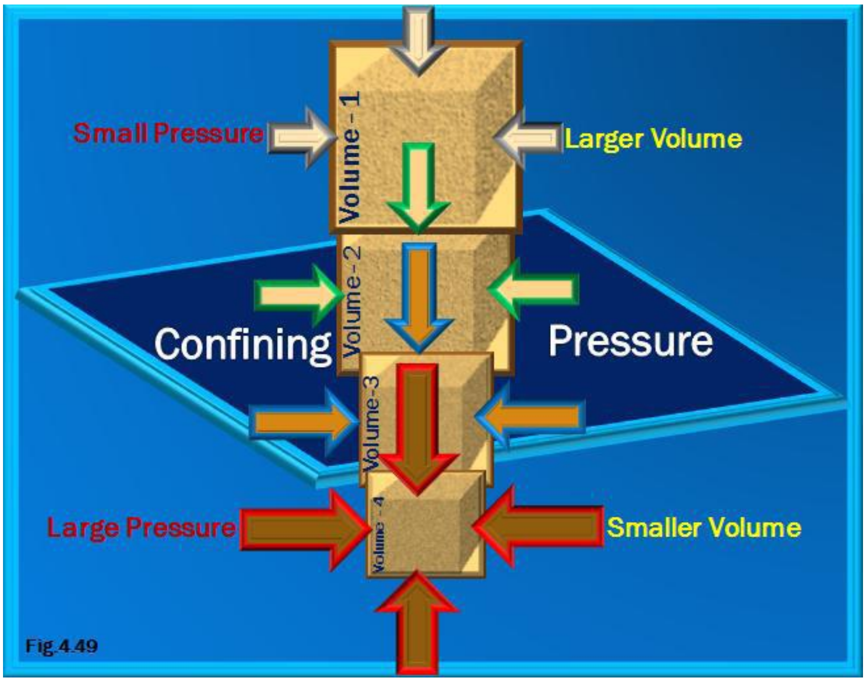


Fig.11.2

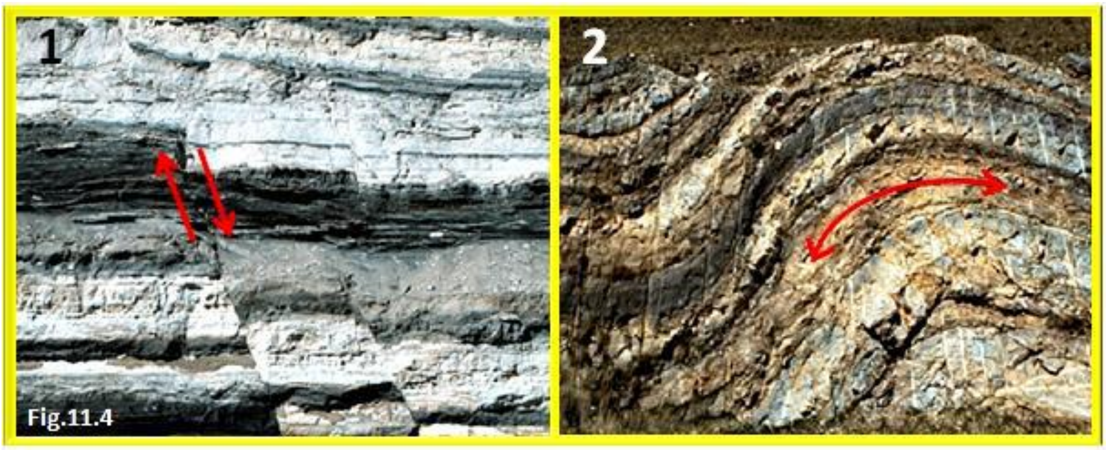
-Confining pressure:

Among the stresses that deform rock is confining pressure, which, like air pressure, is uniform in all direction.

Confining pressure is often the result of the load of overlying rocks and causes a reduction in the volume. (Fig.11.3).



In the upper crust where the confining pressure and temperature are relatively low, rocks are **brittle** and will usually fracture when deformed. (Fig.11.4). 1.
At great depth where confining pressure and temperature are high, rocks become **ductile** and deformed by folding. This deformation occurs at considerable depth. 2.



-Differential stresses:
Like those produced along plate margins, produces most crustal deformations.
F .11.5). 1 … 4.

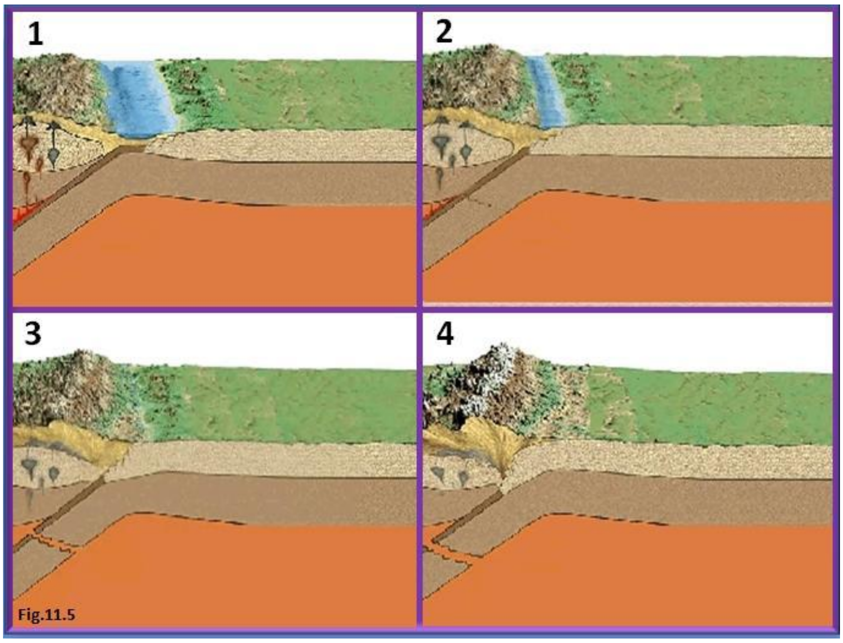


Fig.11.5

When differential stresses act to shorten a rock body, they are known as **compression stresses**. (Fig.11.6). 1.
Conversely, when stresses act in opposing direction, they tend to elongate, or pull apart, a rock unit and are known as **tensional stresses**. 2.
In addition, differential stresses can cause rock to **shear**. 3.
The features of deformation generate features at many different scales.
At one extreme are Earth's major mountain belts and at the other are localized stresses that create small features in bedrock. 4.
These features, which include folds, faults, and fractures or joints, are called **rock structures**

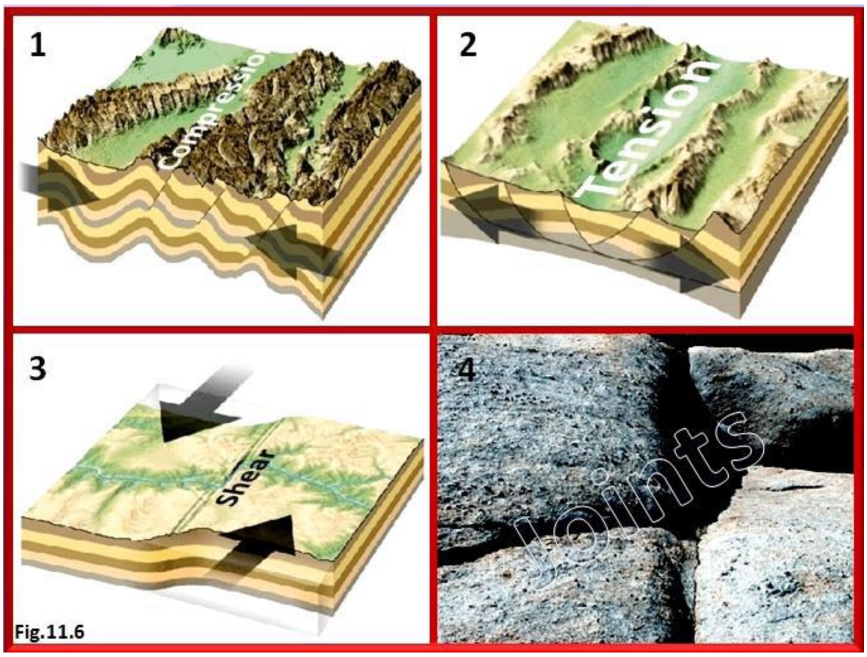


Fig.11.6

11.2- Folds:

During mountain building, flat-laying sedimentary rocks are often bent into a series of wavelike undulation called **folds**.
The two sides of a fold are called **limbs**.

A line drawn along the points of maximum curvature is termed the **axis** (**hinge line**) of the fold, and the **axial plane** is an imaginary surface that divides a fold as symmetrically as possible. (Fig.11.7).

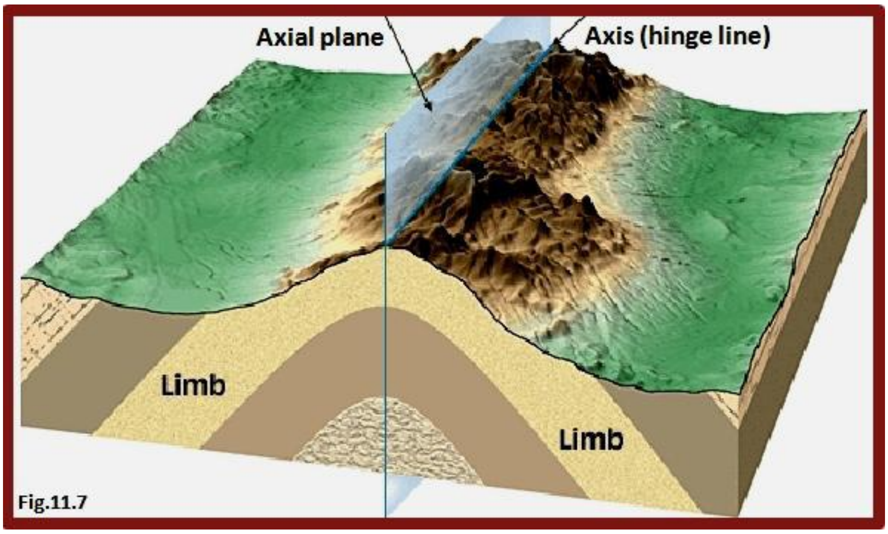


Fig.11.7

The two most common types of folds are called anticline and syncline.

Anticline, which is commonly formed by up folding, or arching, of rock layers and often in associated with syncline. (Fig.11.8).

Depending on their orientation, these basic folds are described :

A-Symmetrical: when the limbs on either side of the axial plane diverge at the same angle. 1.

B-Asymmetrical when the limbs on either side of the axial plane diverge not at the same angle. 2.

An asymmetrical fold is said to be **overturned** if one limb is tilted beyond the vertical. 3.

If an overturned fold "lies on its side" so that the axial plane is horizontal, it is called a **recumbent** fold. 4.

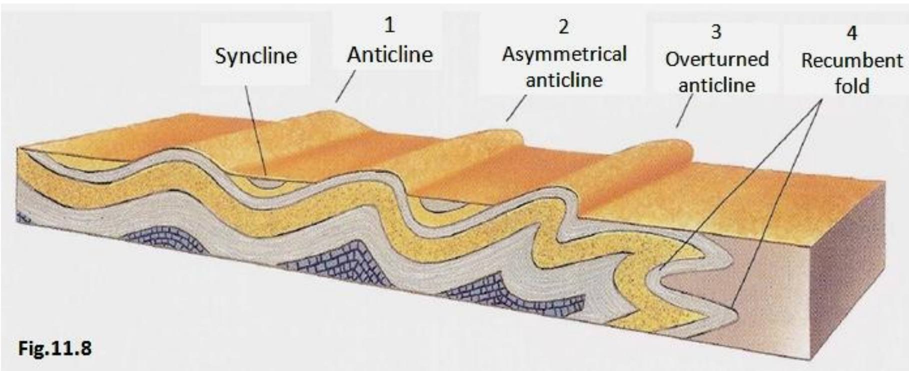


Fig.11.8

Folds do not continue forever, rather ends die out much like wrinkles in a table cloth.

These ends are said **plunge** because their axis penetrates into the ground. (Fig.11.9). 1.

View of plunging folds as they may appear after extensive erosion. 2.

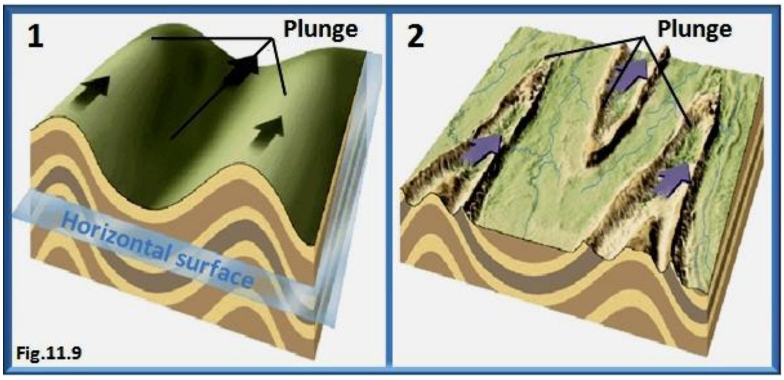


Fig.11.9

Although most folds are caused by compression stresses, some are the consequence of vertical displacements along faults.

Monocline is such structures.

(Fig.11.10).

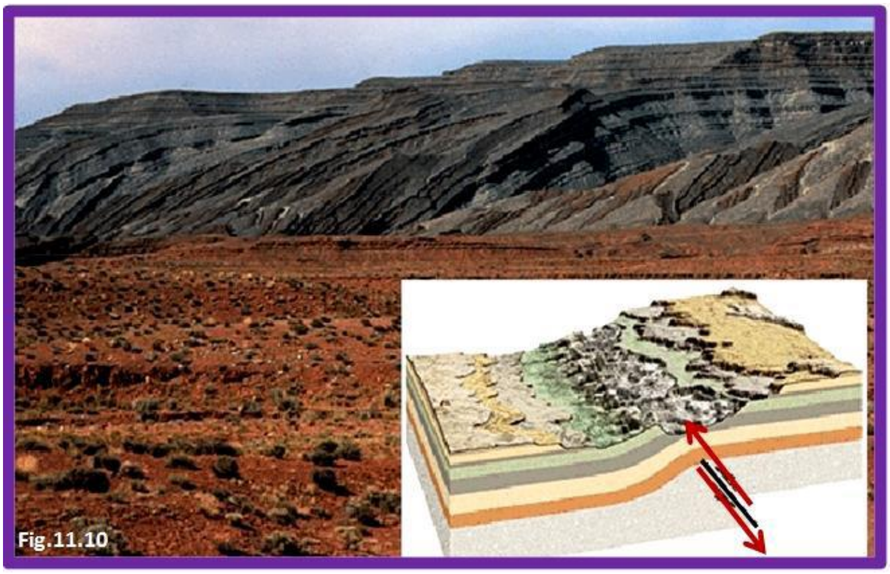


Fig.11.10

Broad **up** warps can also generate nearly circular structures called **domes**. (Fig.11.11). 1.

Nearly circular **down** warped structures are called **basins**. 2.

-

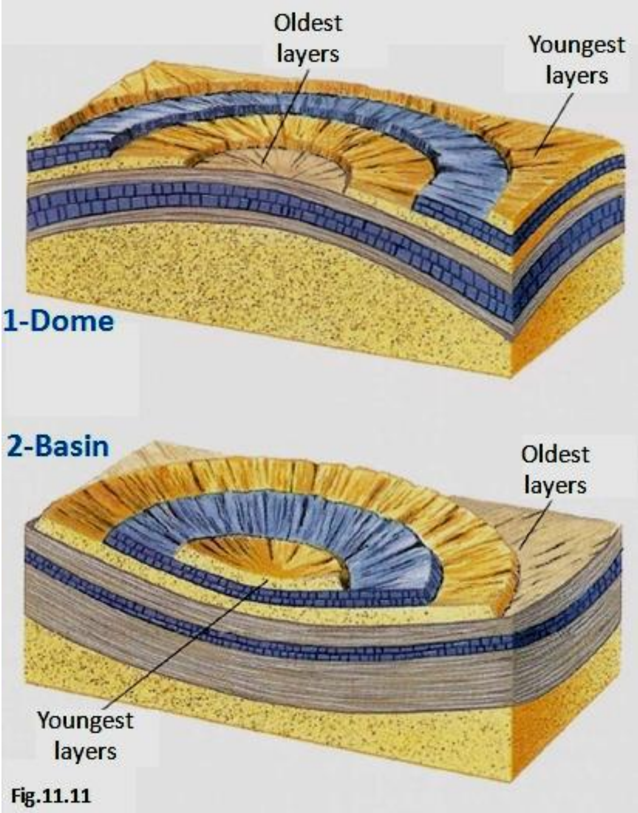


Fig.11.11

11.3- Faults and Fractures:

Faults are fractures along which displacement has taken place. (Fig.11.12). 1.
Faults in which the movement is primarily parallel to the dip of the fault surface are called **dip-slip fault**. 2.

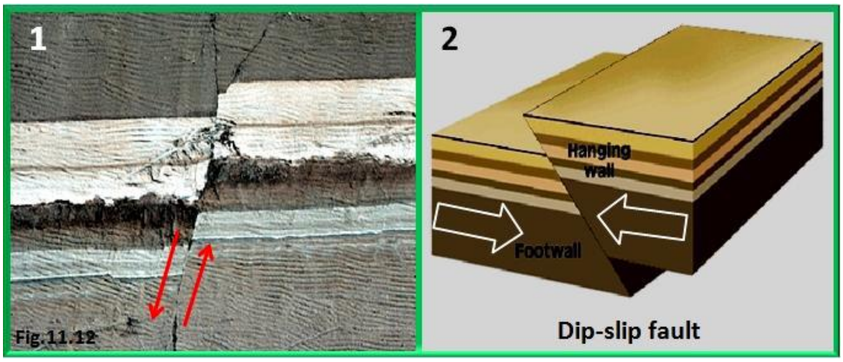
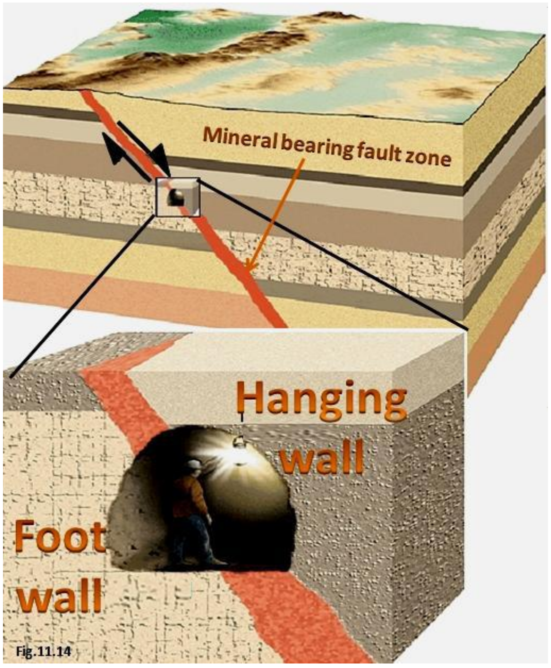


Fig.11.12

Vertical displacements along dip-slip faults may produce long, low cliffs called **fault scarps**. (Fig.11.13).

To describe the displacement along a dip-slip fault, we use nomenclature that arose from miners who excavated shafts along fault zones. (Fig.11.14).
The rock surface above the mineralized fault zone is called the **hanging wall** and the rock surface below the mineralized fault zone is called the **footwall**

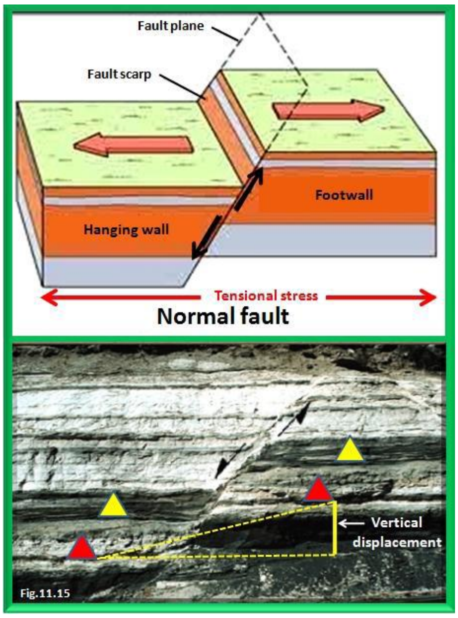


11.4- Types of faults:

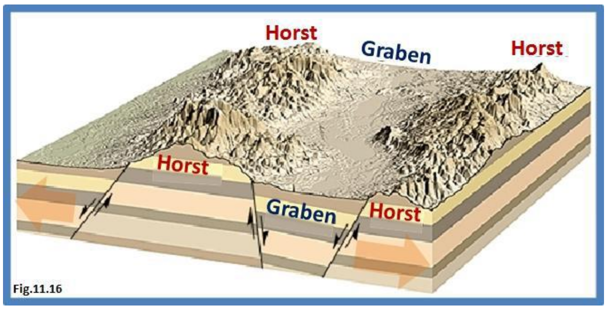
Faults are classified into:

A- Normal faults:

Normal faults indicate the existence of tensional stresses that tend to pull the crust apart.
When the hanging wall block moves down relative to the footwall block, called normal fault. (Fig.11.15). Most normal faults are small, having displacements of only a meter or so.



Normal faulting may also result in a central block called a **graben** which is bounded by uplifted structures called **horsts**.
(Fig.11.16).



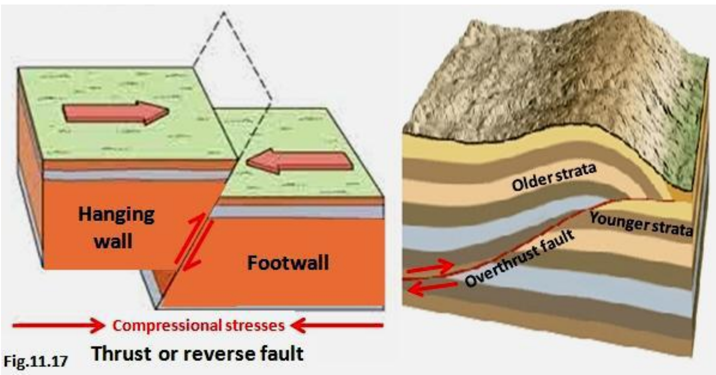
B- Thrust and reverse faults:

When the hanging wall block moves up relative to the footwall block called thrust fault. It occurs in compression environment. The result of this large-scale movement is that older strata overlying younger rock.

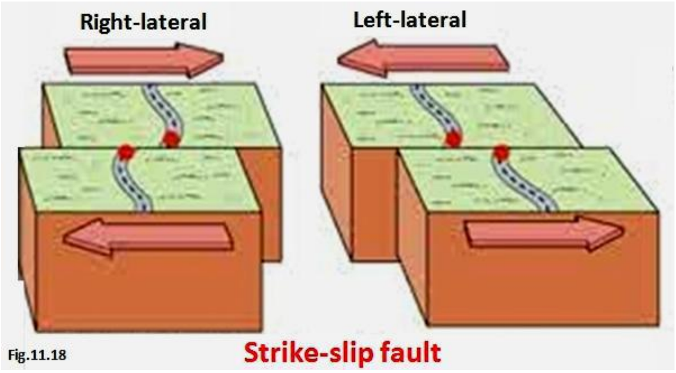
Thrust fault ……. Dip < 45°

Reverse fault ….. Dip > 45°

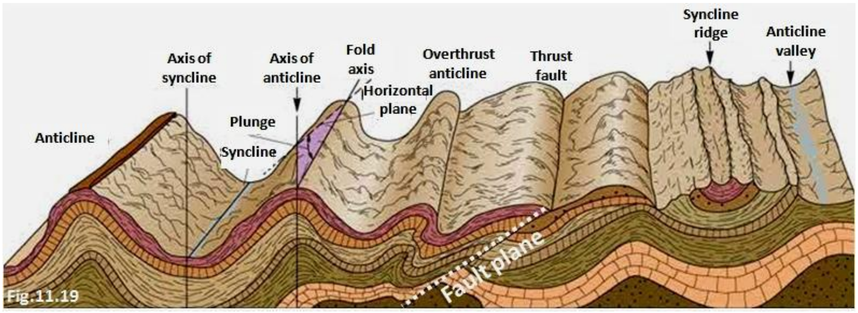
(Fig.11.17).



C- Strike-slip fault:
fault extends parallel to the extending of faulting layers. (Fig.11.18).



Commonly, the mountain belts contains anticline, syncline, overturned anticline, thrust fault, moreover syncline ridge and anticline valley. (Fig.11.19).



11.5- Fractures:
Fractures along which no appreciable displacement has occurred are called **joints**.
(Fig.11.20). 1.
Columnar joints form when igneous rocks cool and develop shrinkage fractures that produced elongated joints column. 2.

Most joints are the result of brittle failure of rocks, when rocks in the outermost crust are deformed. (Fig.11.21).

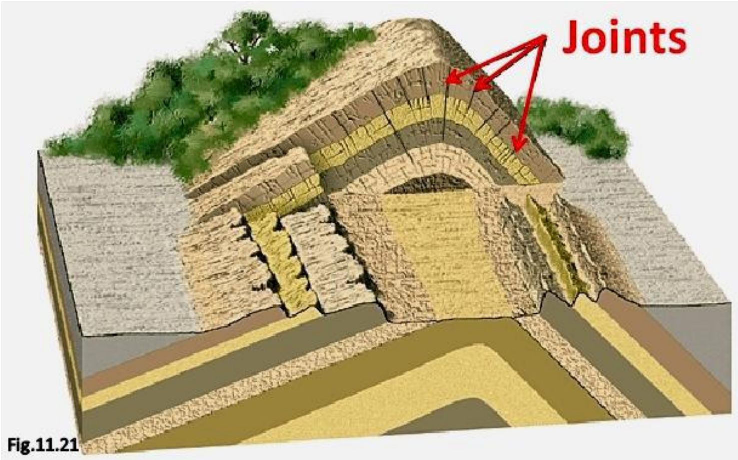


Fig.11.21

11.6- Continental collisions:

Mountains are often spectacular features that rise several hundred meters or more above their surroundings.

Mountain ranges form where two plates of oceanic lithosphere converge and one is subjected beneath the other.

The result is a chain of volcanic strutures called **volcanic island arc**. (Fig.11.22).

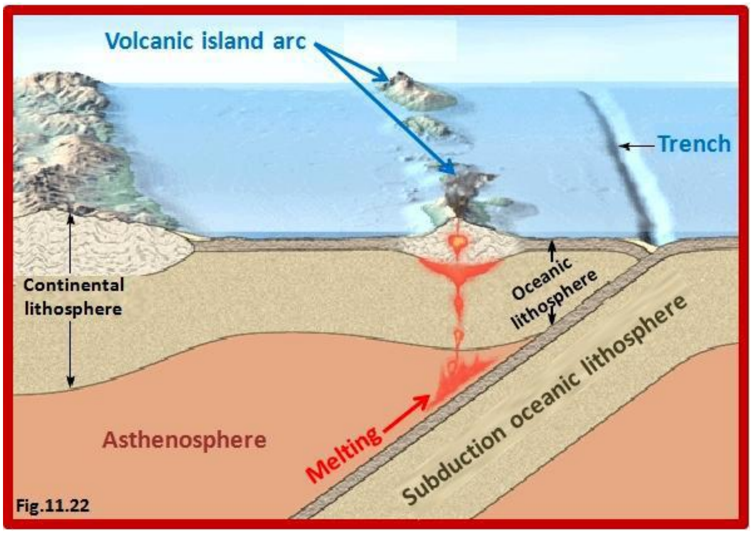


Fig.11.22

However, most major mountain belts show evidence of enormous compressional forces that have folded, faulted and generally deformed large sections of earth's crust.

Most prominent of this group are the relatively young mountain belts of the American Cordillera, which runs along the western margin of the Americas and the Alpine-Himallia chain that extends from the mediterranean through Iran to northen India and into Indochina. Also included the older more deeply eroded mountain belts such as the Appalachians, Caledonians and Urals. (Fig.11.23).

Fig.11.23

Most of these major mountain belts were formed during the collision of two or more buoyant crustal blocks.

Collision mountain ranges develop when continued subduction beneath a continental margin carries another continental block to the trench. (Fig.11.24). 1 … 4.

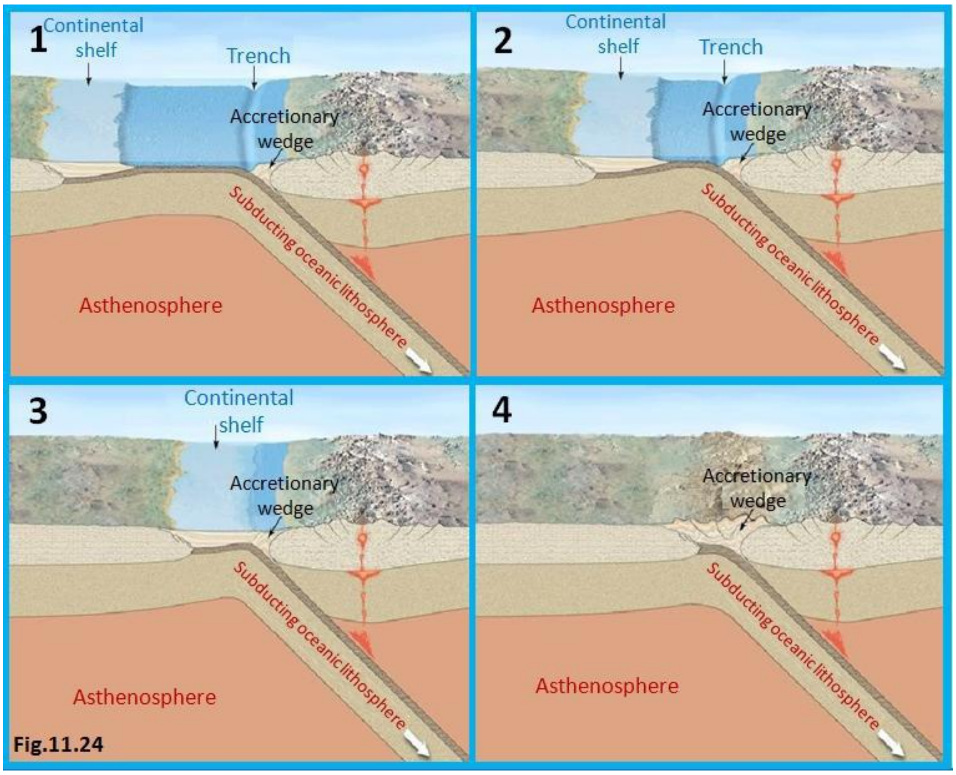


Fig.11.24

Because continental crust is too buoyant to undergo appreciable subduction, a collision between the continental fragments results. (Fig.11.25).

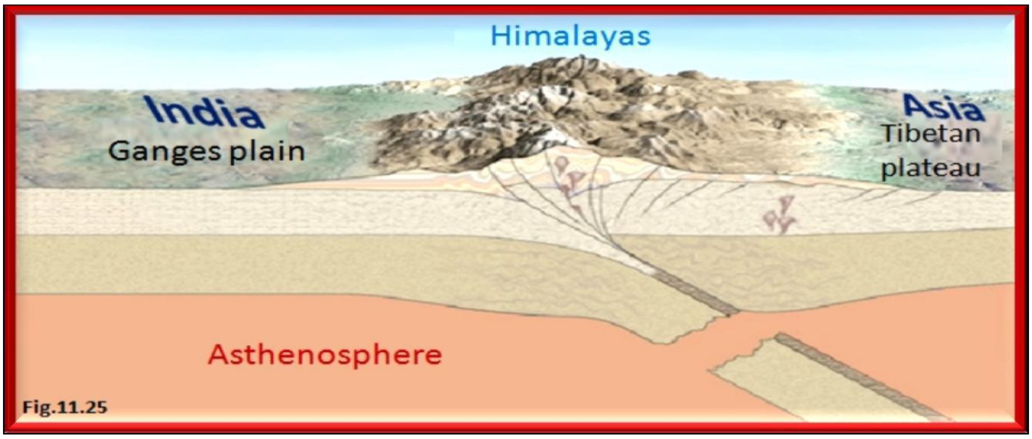


Fig.11.25

Such a collision occurred when the sub continental of India "rammed" into Asia and produced the Himalaya-the most spectacular mountain range on Earth.

The formation of the Himalayas began about 150 million years ago when India separated from the supercontinent of **Pangaea** and began to slowly drift northward. (Fig.11.26).

About 45 million years ago, India reached the trench that was located along the southern margin of Asia.

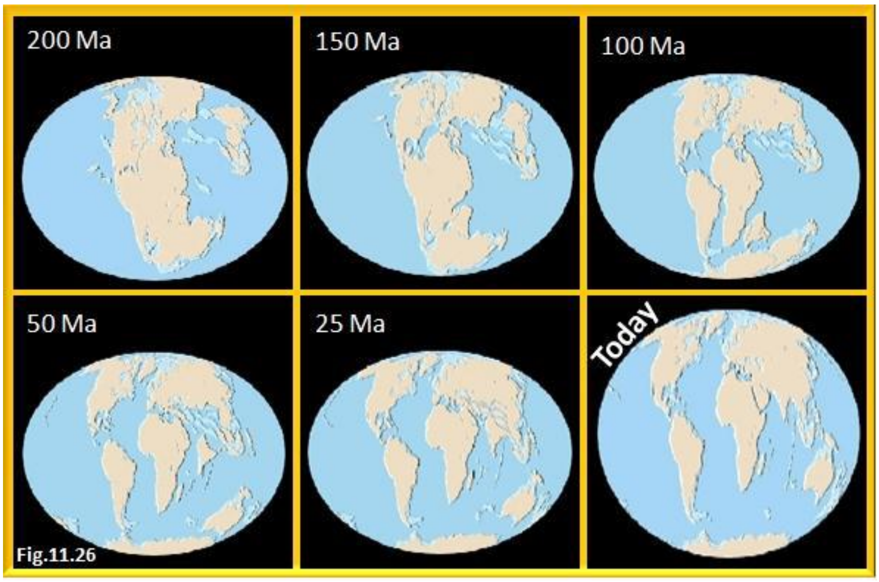


Fig.11.26

The continued northward migration of India deformed and elevated the margins of these continental blocks.
Gradually, these lithospheric plates were shortened and thickened producing the spectacular Himalaya Mountains and the Tibetan Plateau. (Fig.11.27).
It is estimated that India has penetrated at least 2000 kilometers into Asia and is still Moving northward at a rate of few centimeters per year

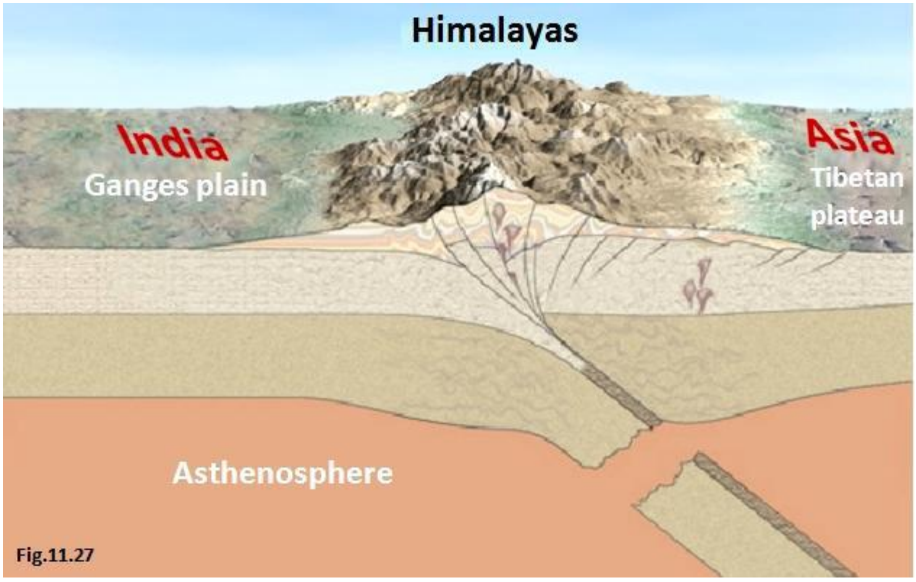


Fig.11.27

11.7- Crustal fragments and mountain building:

Small crustal fragments have also collided with one another, or with continental margin to generate mountainous topography.
Modern day examples of such crustal fragments include the island of **Madagascar**, (Fig.11.28) 1.
And island arcs like **Japan**, the Marianas, and the Aleutian islands. 2.

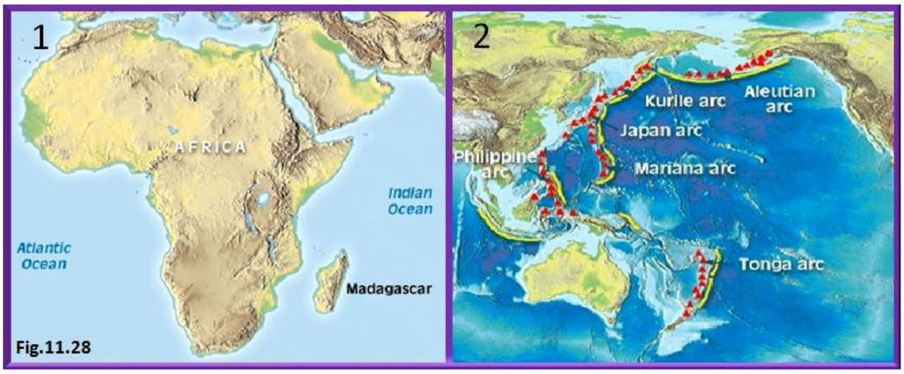


Fig.11.28

Numerous submerged crustal fragments having various origins. (Fig11.29).

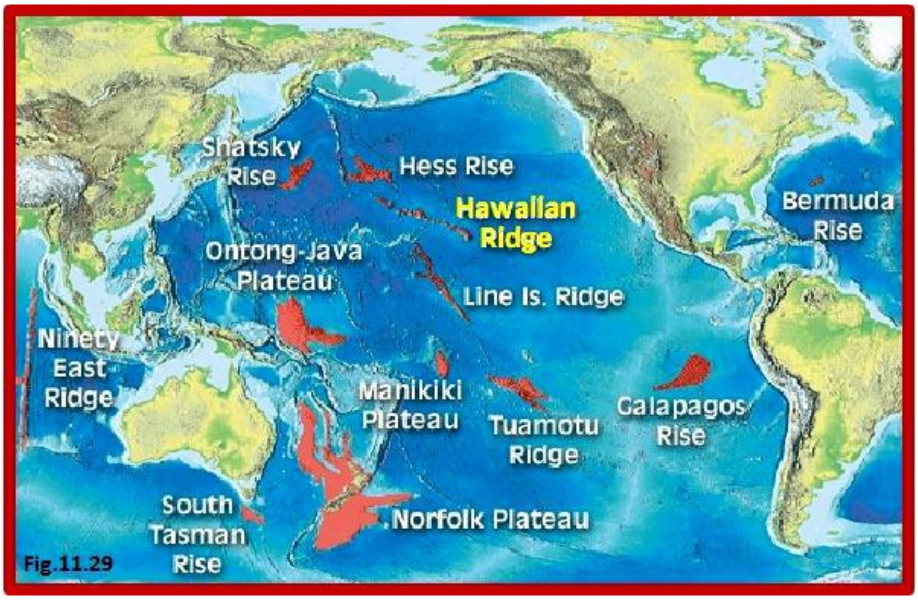


Fig.11.29

For example, an islands arc may be carried to a trench where it is "peeled" from the subducting plate and thrust upon the adjacent continental block, thereby generating a mountainous terrain. This newly accreted material may later be displaced farther inland by the addition of other crustal fragments. (Fig.11.30). 1 and 2.

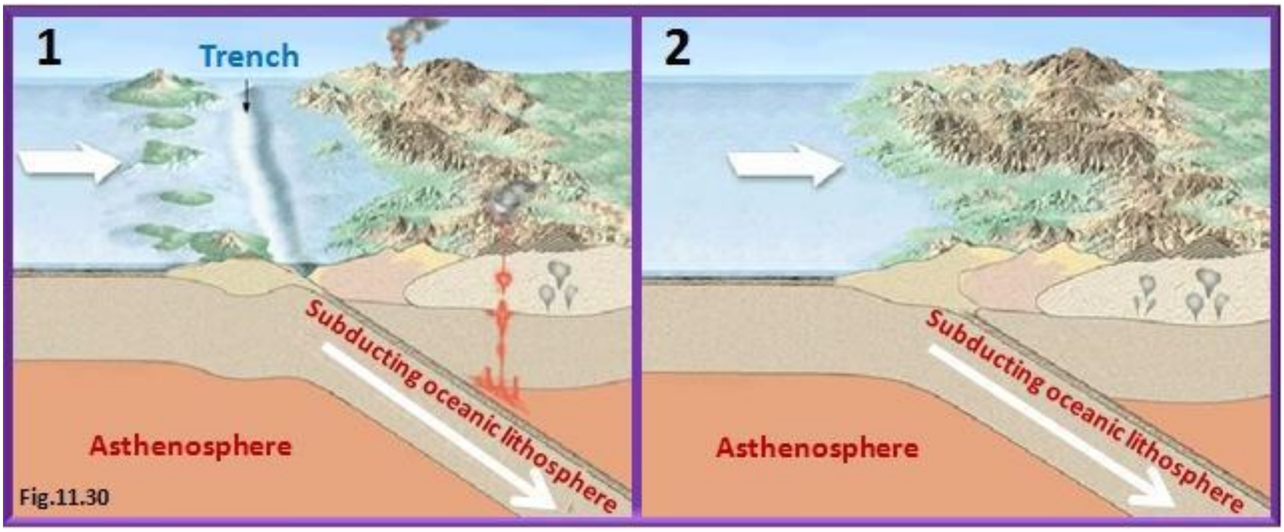


Fig.11.30

The mountain belts of Alaska and British Columbia appear to have formed principally from the accretion of small crustal fragments upon the North American continent. (Fig.11.31). 1 … 4.

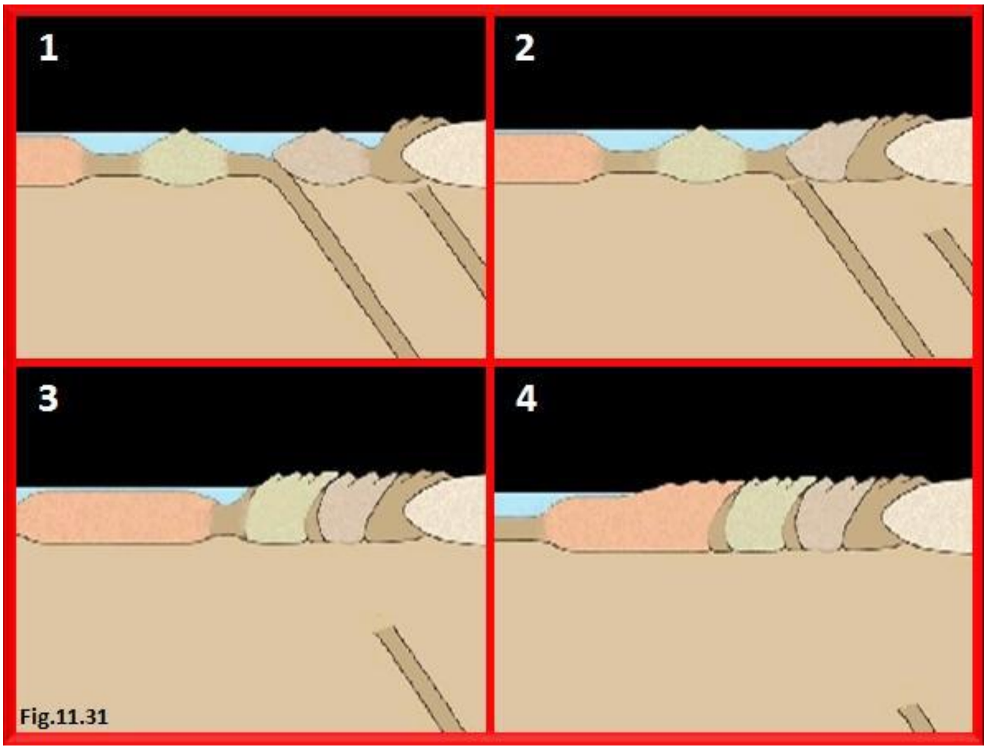


Fig.11.31

Geologists refer to these accreted crustal blocks as **terrains**. Simply, the term terrene designates any crustal fragment that has a geologic history distinct from that of adjoining terrenes. (Fig.11.32).

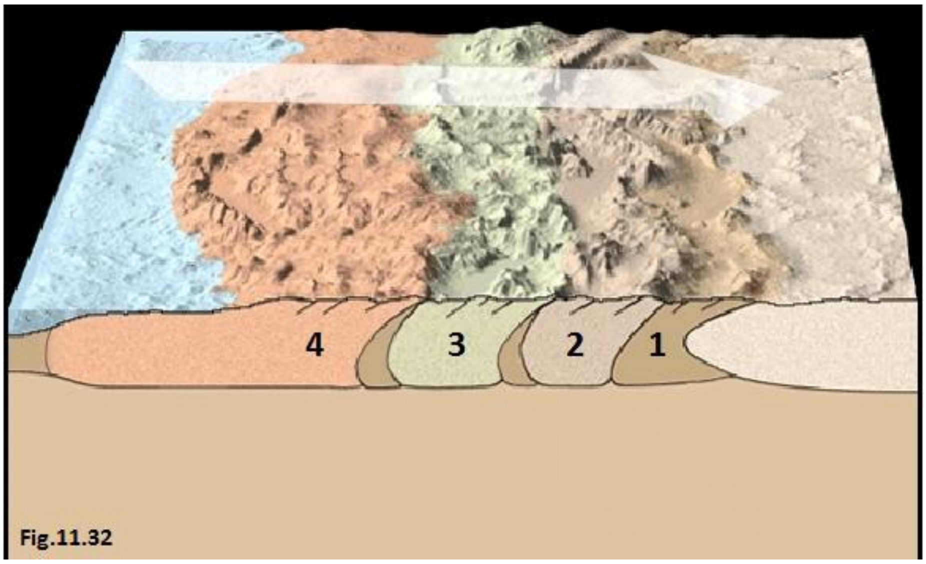


Fig.11.32

1- Nearly circular down warped structures are called -------------. a- basins. b- troughs. c- syncline. d- valley folds.
2- Normal faulting may produce a down-faulted central block called a -------------. a- horst. b- trough. c- graben. d- syncline.
3- An overturned fold that "lies on its side" so that the axial plane is horizontal is called a ------------- fold. a- horizontal. b- disturbed. c- recumbent. d- deformed.
4- Displacement along dip-slip faults may produce long, low cliff, called ---------------. a- escarpments. b- ridges. c- embankments. d- fault scarps.
5- Near Earth's surface crustal rocks tend to deform by ---------------- deformation. a- ductile. b- seismic. c- shear. d- brittle.
6- Compressional stress ---------------- a rock body. a- elongated. b- shorten.
7- Which of these faults may displace older strata over younger strata? a- strike-slip faults. b- normal faults. c- reverse faults. d- thrust faults.
8- Fractures along which no appreciable displacement has occurred are called -------. a- thrust fault. b- joints. c- rifts. d- shear zone.
9- Transform faults are example of ------------. a- strike-slip faults. b- normal faults. c- reverse faults. d- thrust faults.
10- Tensional stresses ----------------- a rock body. a- elongated. b- shorten.
11- This fold commonly formed by uplifting or arching of rock layers. a- syncline. b- up cline. c- anticline. d- recline.
12- At great depths, crustal rock tends to deform by -------------- deformation. a- ductile. b- seismic. c- shear. d- brittle.
13- At dip-slip fault, in which the hanging wall block moves down relative to the footwall block, is called a -------------- fault. a- transform. b- strike-slip. c- normal. d- reverse. e- none of the above.

14- Faults are fractures along which displacement has taken place. a- true. b- false.