Sedimentary Basins

For third year Geology, petroleum branch
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Definition: It is a depression (subsided region) on the earth crust in which (where) thick pile of sediments are accumulating. It has different types, origins, accommodations (depths) and volumes

Hierarchy (پلەی) of sedimentary basin

Sedimentary (means depositional) while basin, in ordinary language it means container),so it called sedimentary basin because there are other types of basin,1- like home steel or plastic basin طشتfor keeping liquids, 2- drainage basin for surface water, 3-ground water basin and 4- petroleum basin or oil basin.

Characteristics of the sedimentary basin

1-All oils of the world are produced in the past sedimentary basins
2-All basin has boundary (shoreline) and source areas
3- All basins contain more than one rock (sediments or facies)
4- All sedimentary basins formed and ended by tectonic force and isostasy processes
5- Nearly all mountain ranges are formed by deformation and uplift of previous sedimentary basin
6- Study of sedimentary basin is necessary for studying of tectonics, paleoclimate and paleoenvironments of an area in the geologic history.
7-The type of basin is indicated according to nature of the 1- underlying crusts, 2- the type of past plates movement involved during basin formation, i.e., divergence or convergence.
8-Nearly all sedimentary basins go through Wilson Cycle.
9- Geologists can study the previous sedimentary basins by: 1- fieldworks or 2- by seismic study and 3- remote sensing and GIS

1. Global Classification of the Sedimentary basin

We can classify (distinguish) the sedimentary basins in different ways on Global scale,

1-Descriptive classification of the sedimentary basins, which depends of nongenetic characteristics of the basin without referring to history, processes, causes and results of its generations,

2. Genetic classification sedimentary basins that depends of genetic characteristics of the basins such as causes, process, results of its development and it relation to the plate tectonics.

1.1. Description classification

1.1.1. According to present activity of the basin

a. Active basins are those basin which now active in accumulating sediments,
b. Inactive basins but little deformed sedimentary basins showing more or less their original shape

1.1.2. According to age

a. Historic basins are those formed and filled with sediment during geologic ages such as Jurassic, Cretaceous, Tertiary basins and others
b. Recent or present day's basins are those which existing and receive sediments now

1.1.3. According to deformation
a-Strongly deformed: b- slightly deformed, c-non-deformed sedimentary basins
1.1.4. According to sedimentary fill, a. totally filled basin, b. partially filled basin, empty or starved basin from sediments

1.1.5. According to size: a- large basin, b- small basin, c- intermediated basin, d- Narrow basin, e-wide basin
1.1.6. According to the present days size, a. small basin is called lake which is tens of km wide, b. intermediated basin is called seas which is hundreds of km wide, c. large basin is called oceans which is thousands of km wide

1.1.7. According to shape: a- elongate, b.circular (rounded). c. oval, d. arcuate, e. irregular and f. equi-dimensional basin.

1.1.8. According to types of sediments: a- siliciclastic dominated basin, b-carbonate dominated basin, c- mixed carbonate-siliciclastic basin

1.1.9. According to types of water: a. normal marine basin, b. salty water basin, c. freshwater basin, d. brackish water basin

1.2. Genetic classification of the basins

New and old tectonic classification of the sedimentary basin

1.2.1. Geosyncline classification (Old classification) of basins

The geosyncline classification concept depends on the vertical crustal movement that has been replaced by plate tectonics (horizontal movement) to explain crustal deformation and basin generation.

Definition of Geosyncline

A geosyncline is subsiding linear trough that was subsided by the accumulation of sedimentary rock strata deposited in a basin and subsequently (Later) compressed, deformed, and uplifted into a mountain range, with possible presence of volcanism and plutonism.

The geologist divided Geosynclines into miogeosynclines and eugeosynclines, depending on the types of rock of the mountain belt resulted from its deformation.

a. Miogeosyncline sedimentary basin

It is assumed to be developed along a passive margin of a continents and is composed of sediments with limestones, sandstones and shales. The occurrences of limestones and well-sorted quartz sandstones indicate a shallow-water origin. Normally contain no volcanism

b. Eugeosyncline sedimentary basin

It is a narrow rapidly subsiding basin usually with volcanic materials mixed with clastic sediments. It is supposed to be developed in the more active basin than miogeosyncline and contain rocks from deep marine environments. Eugeosynclinal rocks include thick sequences of greywackes, cherts, slates, tuffs and submarine lavas (Fig.1). The eugeosynclinal deposits are typically more deformed, metamorphosed, and intruded by small to large igneous plutons. Eugeosynclines often contain flysch typical of a continental-continental convergent boundary.

c. Orthogeosynclines

They are elongated basins, which became filled with very great thick thickness of sediments. They are subsequently deformed to form a fold mountain chain It is it is divided in to Eugeosyncline and miogeosyncline

d. Zeugeosyncline

It is a geosyncline in a craton or stable area which is also an uplifted area, receiving clastic sediments, also known as yoked basin (closed basin) (Fig.1.1) .

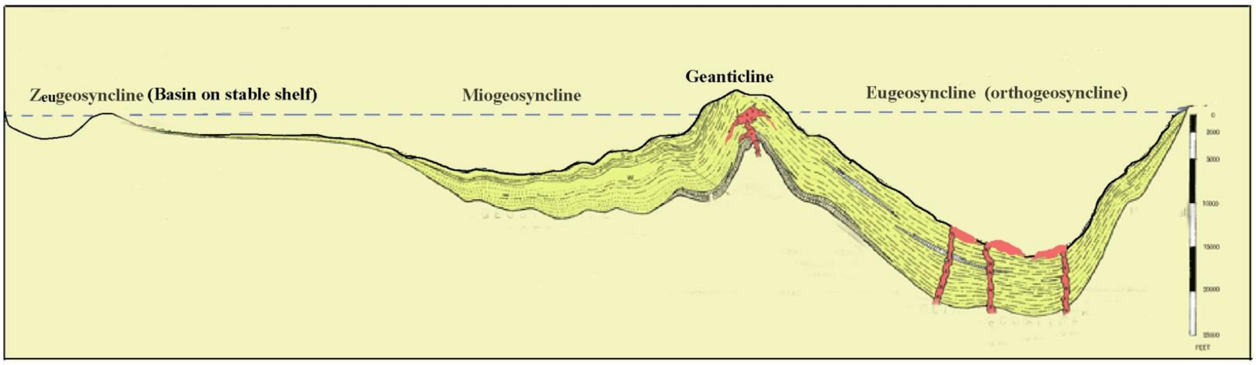

Fig.(1.1) type of main sedimentary basins (geosynclines) according to old classification

1.2.2. Tectonic (new) classification of Sedimentary basin

Fortunately, the sedimentary basins can be accurately classified according to the theory of the plate tectonics. By this theory, genetic classification of the present days and historic (past) basins are possible which show all stage of development of the basins. Plate tectonic tells causes, processes, results, and topography and rocks types of the generated basins. In this classification genetic words (terms) of the basin are used that are related to by global plate tectonics such oceanic basin, forearc basin, backarc basin, trench basin, continental margin basin, rift basin and Piggyback Basin.

Mechanisms of basin development (forming)

a. Isostatic uplift and subsidence due to balancing of crustal or lithospheric by changes in thickness
b. Thrust sheets loading of volcanic piles, sediments and metamorphic rocks by plate tectonics activities
c. Earth internal dynamic activities by asthenospheric flow, mantle convection and plumes

Definition of plate tectonics theory

Plate tectonics proved that the outer rigid layer of the earth (the lithosphere) is divided into a more than 12 plates that move around across the earth's surface relative to each other, like slabs of ice on a lake. All the present days and past sedimentary basins are located either on the boundaries of the plates or on their surfaces.

1.2.3. Types of plate boundaries

Three types of plate boundaries can be identified between the plates and characterized by the way the plates move relative to each other's. They are associated with different type of sedimentary basins, structural and geomorphological features. The different types of plate boundaries are:

a. **Transform boundaries (conservative plate boundaries)**

They are existing where plates slide or perhaps more accurately grind, past each other along transform-faults. The relative motion of the two plates is therefore either sinistral or dextral (Fig.1.2a and b). It is called "transform fault" because it transforms (convert) movement from a segment of oceanic ridges (spreading ridges) to another one or convert mid oceanic ridges to trenches. Transform is conservative plate boundary because the crust neither created nor destroyed.

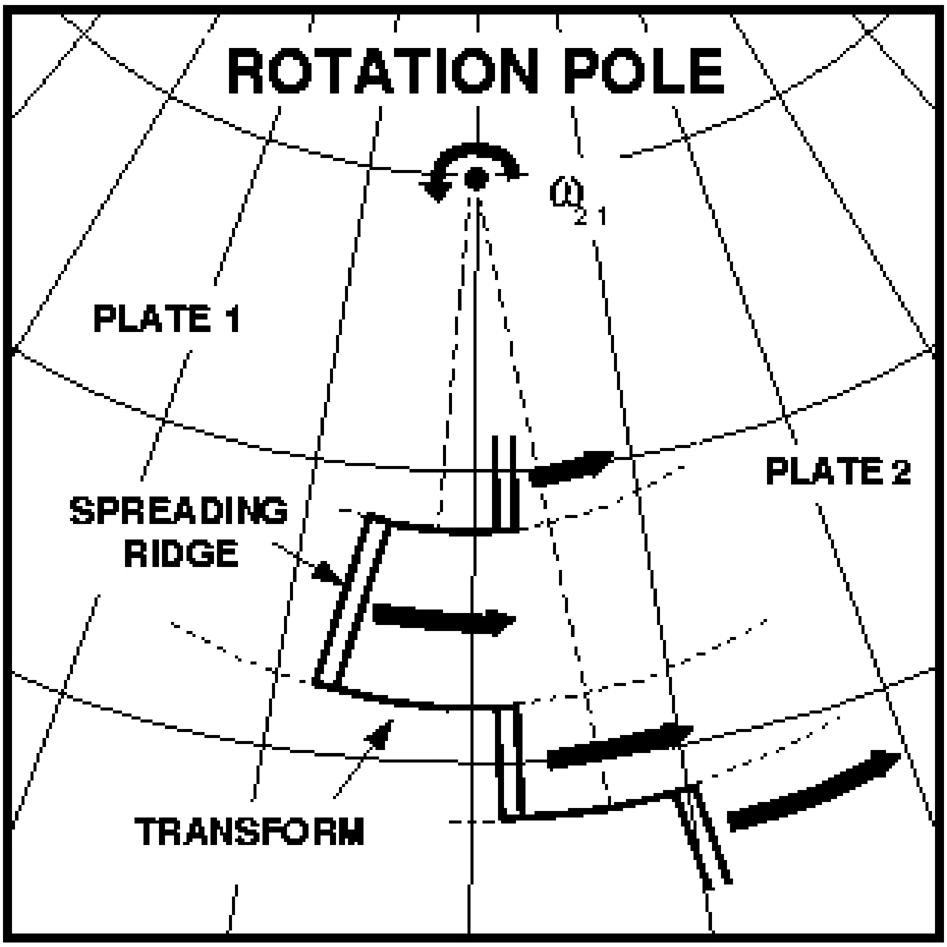

Fig. (1. 2a) transform fault across the mid oceanic ridge-spreading spreading ridge) it is clear from the sketch that length of the faults increase away from the poles while their width decrease

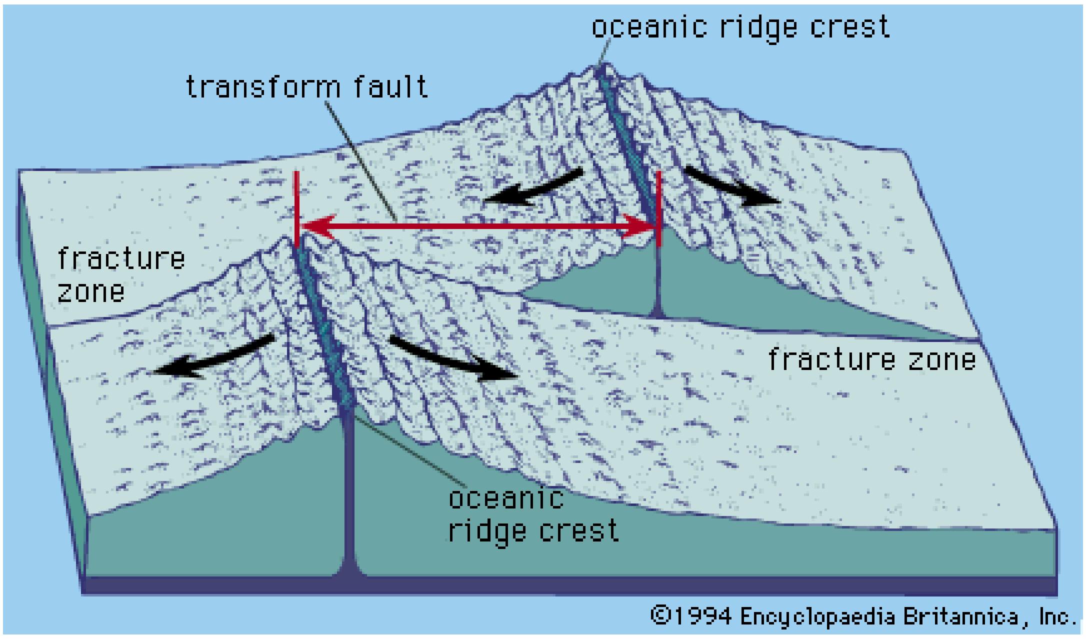

Fig. (1.2b) close up sketch of the transform fault across the mid oceanic ridge

b. Divergent boundaries (constructive boundary)

They are boundaries where two plates move away from each other like Atlantic Ocean and Red sea (Fig.3)

c. Convergent boundaries (or active margins)

They are boundaries where two plates move towards each other commonly forming either a subduction zone (if one plate moves underneath the other) such as East Japan trench. On the other hand, an orogenic belt may be formed if the two collide and compress each other's, such as Zagros at past and Andes at present days (Fig.1.3).

1.2.3.1. Basins related to divergent boundary

a. Rift basin (rift valley)

Rift basin is elongate and narrow basins bounded by normal faults (half grabens or lythtric faults) and developed from widening of the rift valley. The mechanic of its forming is by, 1- thermal uplift of the continental crust, 2- After uplift, the cooling begins which causes subsidence of continental crust with continuous widening (Fig.1.3). Rift sediments commonly consist of continental deposits (Fluvial, lacustrine, alluvial fans sandstone, shale and conglomerate). E.g. East Africa Rift.

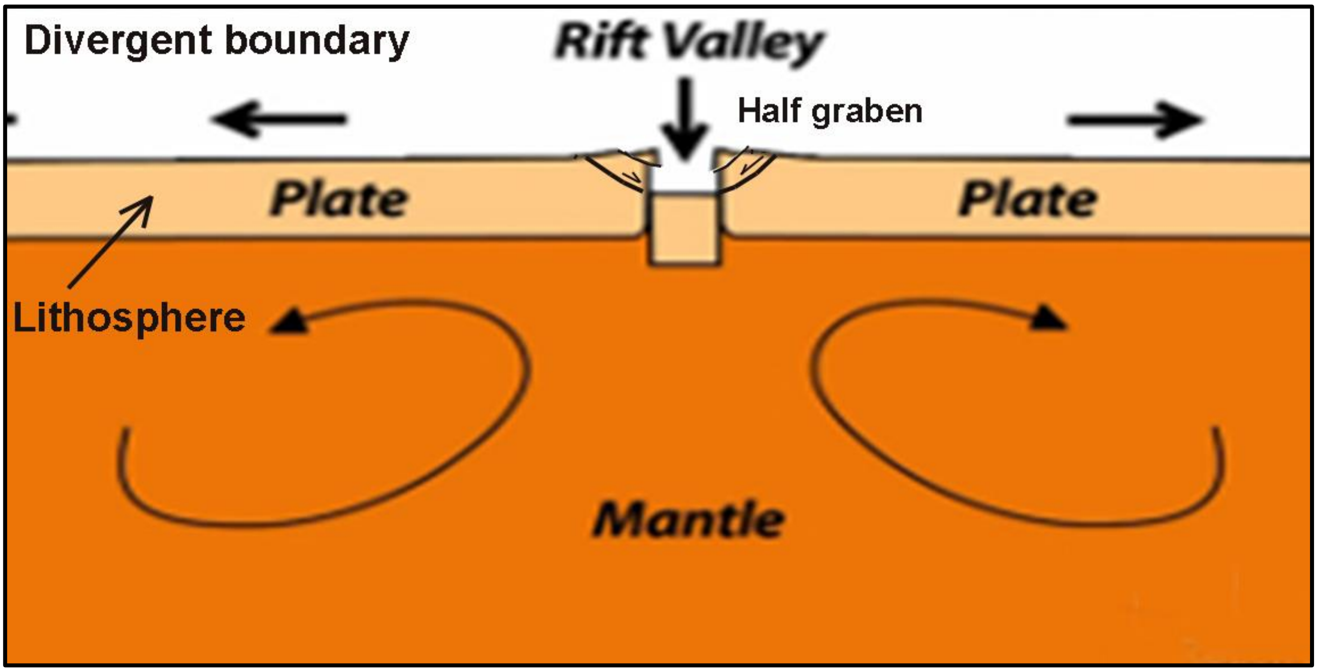

Fig. (1.3) Rift basin or rift valley

b. Failed rifts and aulacogens

Aulacogens is a narrow continental basin which failed to develop to spreading ridge and oceanic basins. This failure is due to cease of diverging of the two blocks (plates) and the oceanic basin not formed. A certain type of such failed rifts is an aulacogen (Fig.1.4).

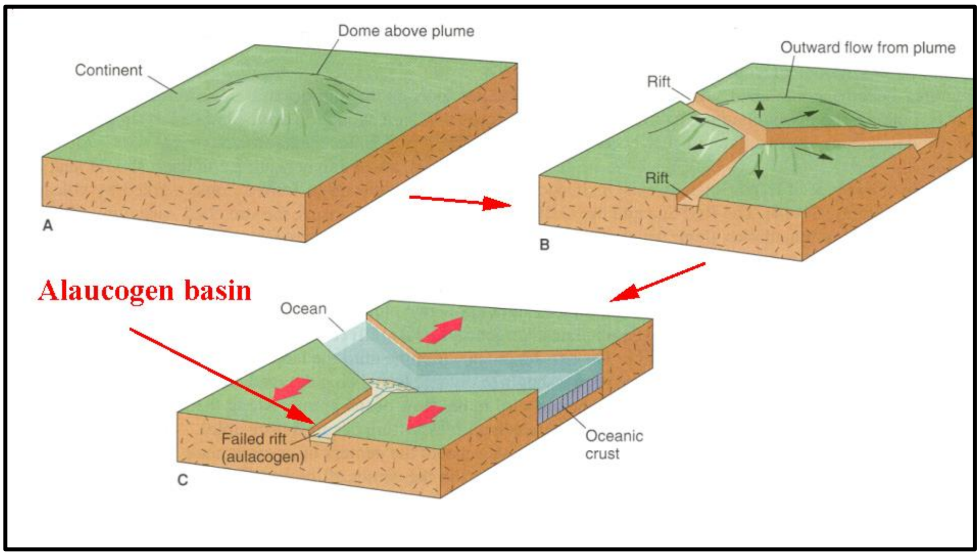

Fig. (1.4) three stages shows how three rifts can be formed and one of them may become inactive which called aulaucogen (failed rift basin). It formed when one limb of the ripple junction of rifting is failed to further expand (divert).

Aulacogens represent the failed arm of a triple junction of a rift zone, where two arms continue their development to form an oceanic. Aulacogen floors consist of oceanic or transitional crust and allow the deposition of thick sedimentary sequences over relatively long times. Basins similar to aulacogens may also be initiated during the closure of an ocean and during orogenies. The dominated sediments are alluvial fan, fluvial, lake facies (sandstone, shale and conglomerate); up to 4 km thick.

b. Initial oceanic basin (proto –oceanic basin)

It is formed from the spreading (enlargements) of rift valley. It is narrow and elongate marine basin originated from continental rift valley and may be expanded into oceanic basin such as Red Sea. Sediments: shelf Carbonate, evaporate, hemi pelagic facies (Fig.1.5a).

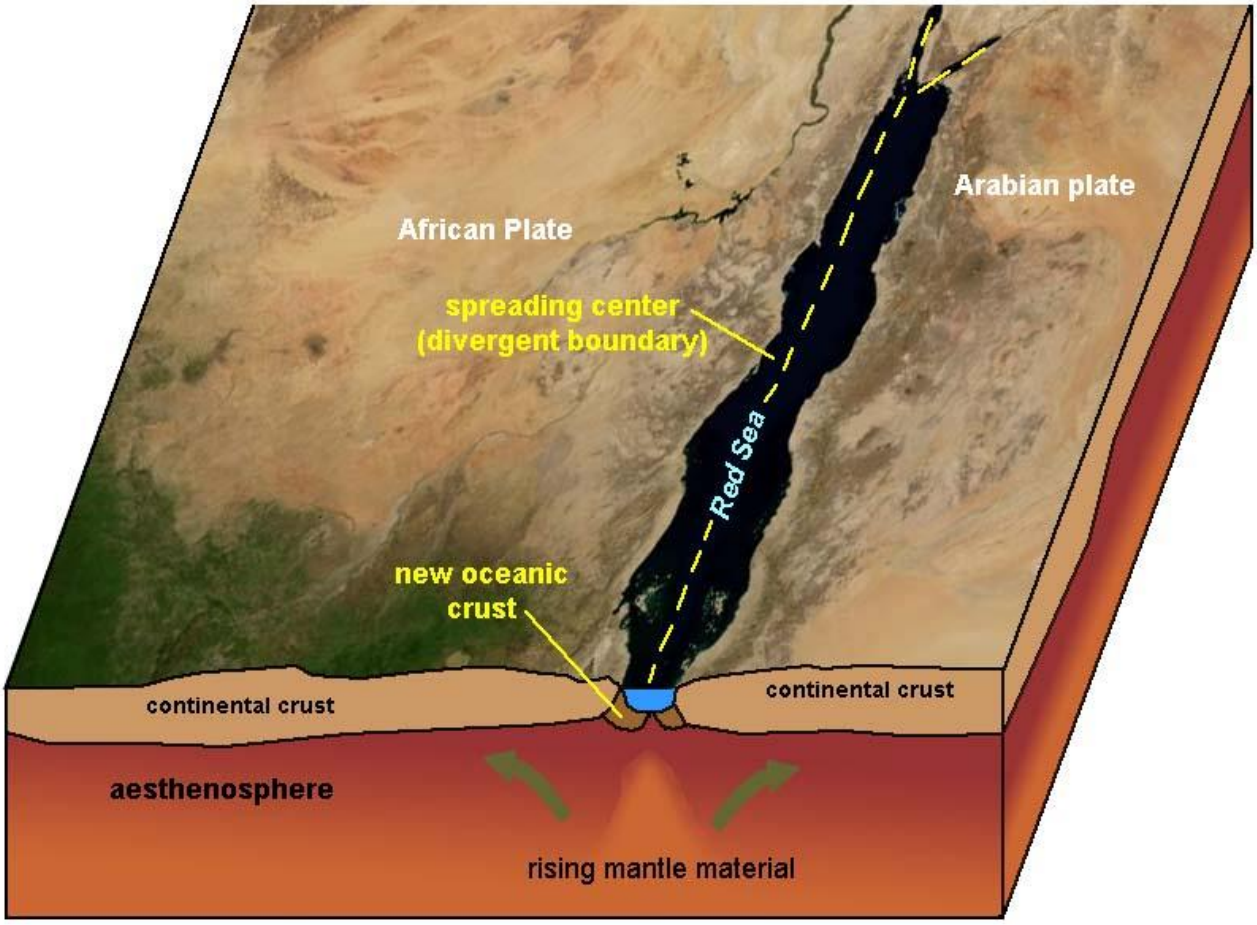

Fig.(1.5a) Block diagram of Initial oceanic basin (proto –oceanic basin) which is represented in this lecture by Red Sea. We can see on plate is separated into two plates by the convection current in the mantel. This current is the main force for plate movement and orogenic belt uplift.

b. Oceanic basin (or Oceanic sag basins)

It is formed from the spreading (enlargements) of rift valley and initial oceanic basin then expand to large oceanic basin by generation new basaltic crust during tens of million years (Fig.1.5b) such as Atlantic and Pacific oceans. In these basins, hemiplegic and pelagic carbonate are bdeposited with marl and oceanic red clay stone.

This basin is occupying the oceanic floor that is located between the mid-oceanic ridge and passive continental margins or trenches (Fig.5b and 1.6a). Deep-sea turbidite (distal fan) or basin plain sediments such as pelagic sediment are main deposits of this basin. Due to the advanced cooling of the old oceanic crust, subsidence is usually low, unless it is activated by thick sedimentary loading near the continental margin.

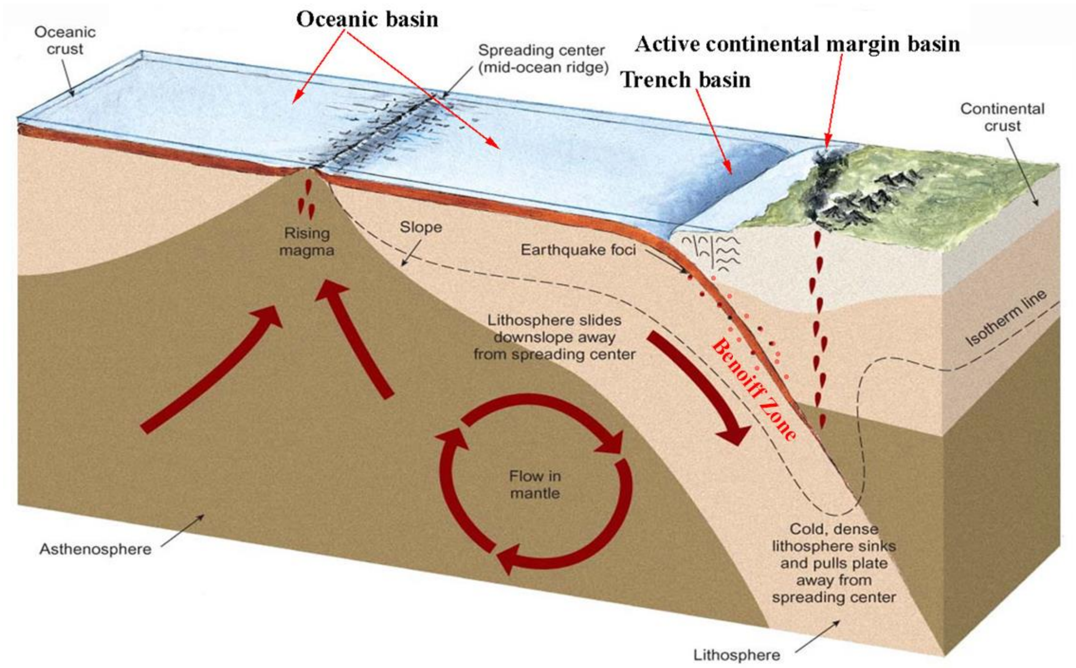

Fig.(1.5b) convection current in the mantel is the main force for plate movement and orogenic belt uplift

Mid oceanic ridge

It is a constructive plate boundary located in the middle of oceans and called mid Oceanic ridge or Oceanic spreading center. It is zone of, 1- volcanic flow and construction of new oceanic crust, 2- it is zone of fracturing and transform faulting, 3-it is the area where moho is in the near the floor of the ocean.

d. Passive continental margin basins

It is the most important basin in all ages and in the present days; it is formed on the inactive continental margin (oceanic margin) of the oceans. It is formed due to rifting persist for long time during which undergoes subsidence due to long-term sediments accumulation. It is developing on top of thinned continental crust and not bordered by morphological highs and represent asymmetric depositional areas (Fig.6a and b). Their underlying crust increasingly thins seaward; hence, subsidence tends to become greater and faster in this direction. When such a basin widens due to continue divergent plate motions and accretion of oceanic crust (drifting stage), it's infilling with sediments lags more and more behind ocean spreading. The morphologically consist of shelf, slope and continental rise in which in most places, depositional features such as fan delta, feeder channels and submarine fans are common. These features associated with extensive turbidites deposition on the slope and in the basin (Fig.6b and 6c)

Iraqi Kurdistan near border with Iran was consisted of this type of basin during Jurassic and Lower Cretaceous in which Balambo, Qamchuqa and Kometan are deposited. The sediments commonly build up in the form of a prism. All types of sediment are deposited such as shelf carbonate, calciturbidite, siliciclastics and siliciclastic turbidites, example in present: Eastern coast of North America.

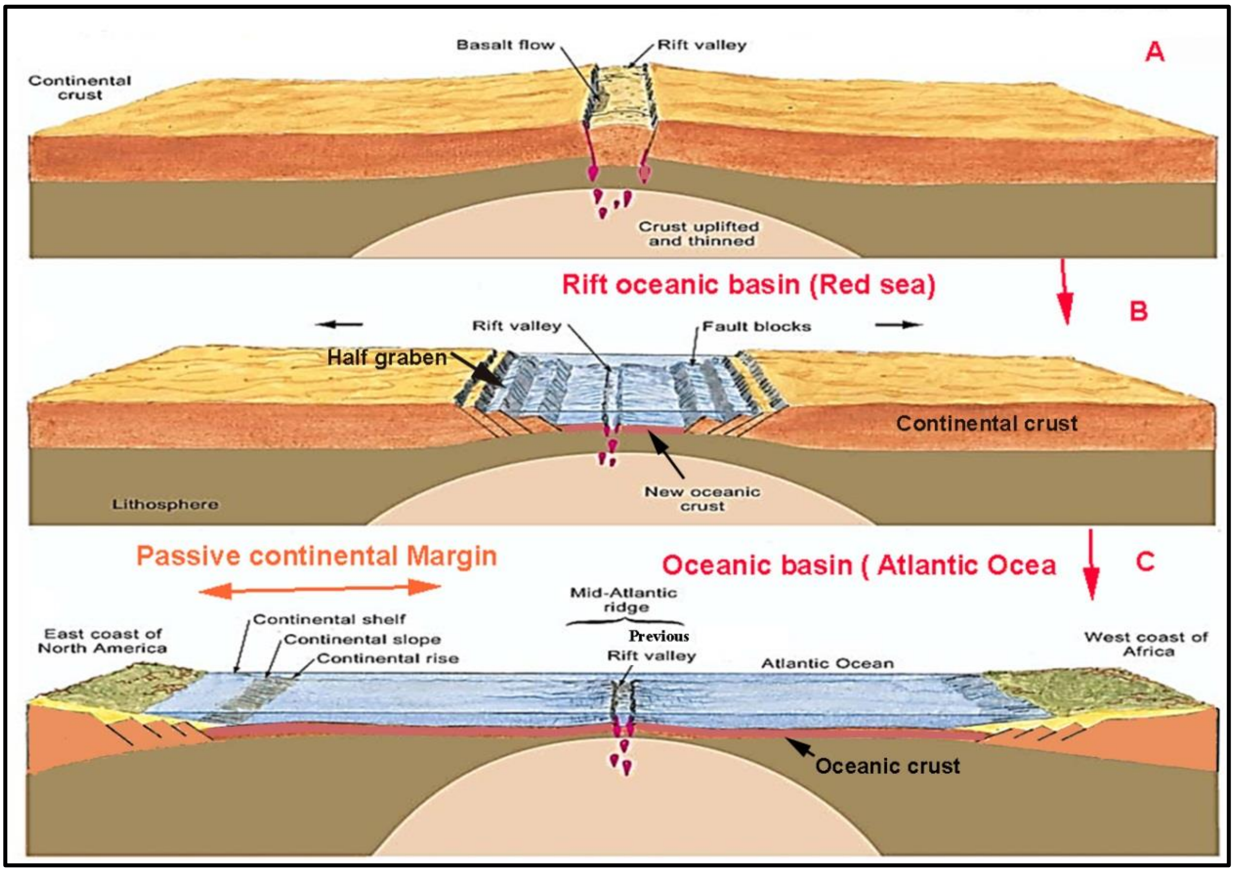

Fig. (1.6a) different stages of development of the divergent boundary, starting from rift valley then initial oceanic basin ending with wide and large oceanic basin

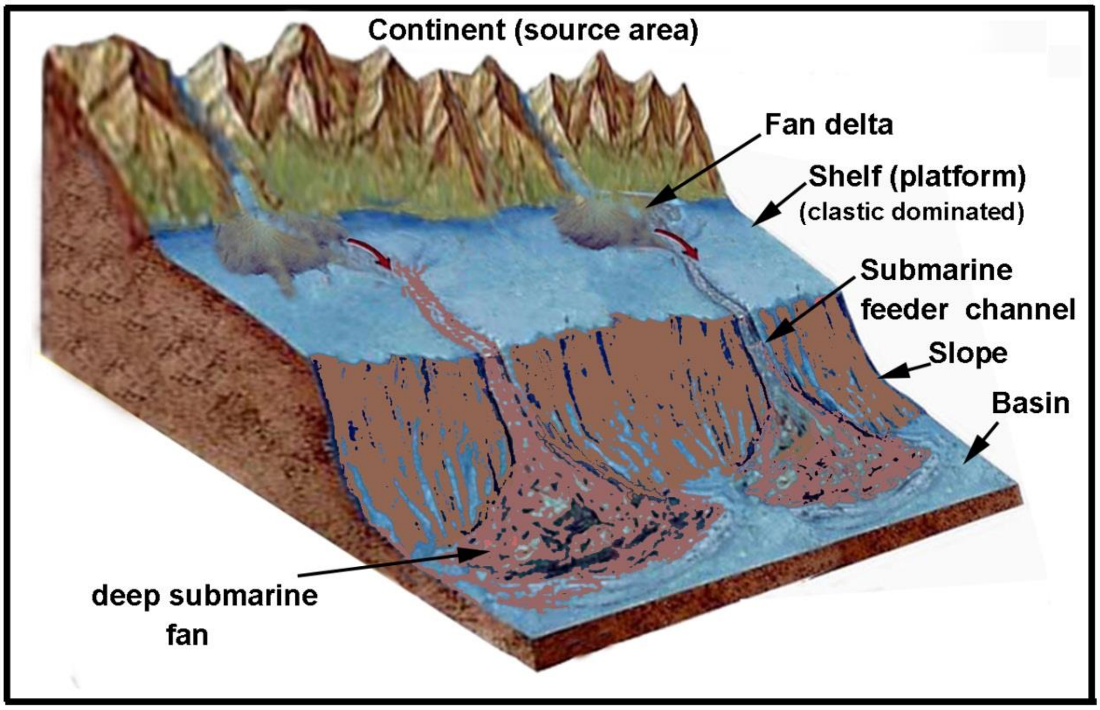

Fig. (1.6 b) The main processes of the continental margin are extensive deep marine turbidites deposition, which associated with fan delta, feeder channels and submarine fan

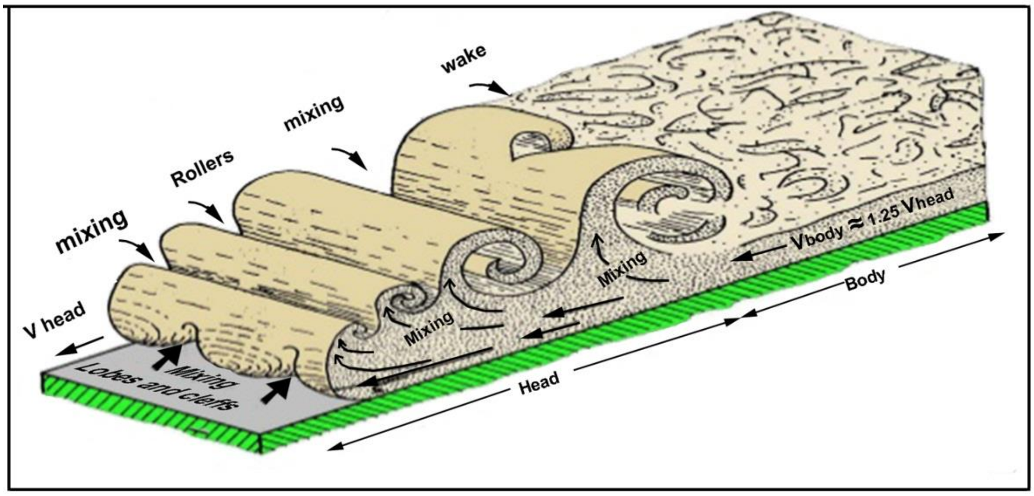

Fig.(1.6c) High density turbidity current on the slope of continental margin

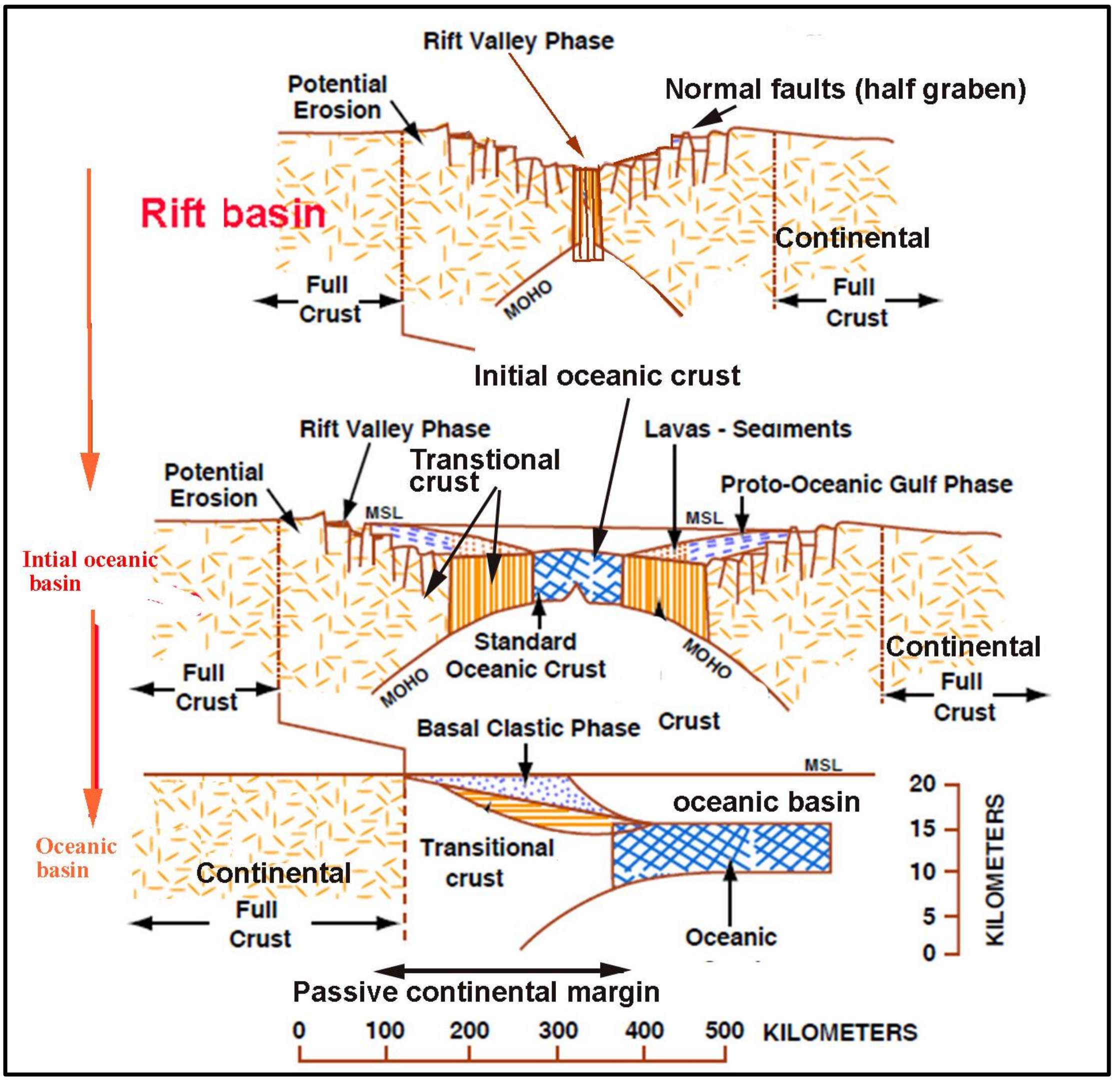

Fig. (1.6b) different stages of development of the divergent boundary, starting from rift valley ending with wide oceanic basin

e. Active continental margin basins

This type of this margin is more active than the passive one as in include subduction zone, trench, volcanic arc and seismic activity Zone (**Benioff zone**) (Fig.1.5b). The sediments of this basin are immature, consist angular, and badly sorted sandstone and conglomerate with clasts of volcanic rocks. We will discuss this basin more in converging boundary.

1.2.3.2. Basins related to Convergent platen boundaries (margins)

This group of basins are formed by convergent plate motions (face to face moving of plates). These basins are formed between two plated or their margins during converging. These basin are: deep-sea trenches, forearc basins, backarc basins, smaller slope basins and intra-arc basins.

a. Trench

A Trench basin is the deepest and more active part of ocean, which is located in front of active continental margin. It is elongate oceanic depression, located between diverging and overriding plates (Fig.7). Its type of the sediments depends on its location of 1-intra-oceanic, 2-proximal to a continent. The sediments of the first are pelagic and hemipelagic sediments while those of the second are siliciclastic and calci-turbidites, bedded chert, hemipelagic and metasedimentary debris eroded off accretionary prism. Example of these sediments is Qulqula Radiolarian Formation in Kurdistan. The sediments form accretionary prism is wedge-shaped, faulted and folded. The prism includes materials carried to trench on down going slab (plate). Example of this basin is western margin of south and North America.

b. Trench-slope (intra-slope) basins

This basin is located between the trench and forearc, its sediments are hemipelagic sediments, turbidites, slumps deposits (Fig.7). Some part of Qulqula Radiolarian Formation and Balambo Formation in Kurdistan.

c. Forearc Basin

This basin is located between the top of accretionary prism and volcanic arc (Fig.1.7); the sediments of this basin include both shallow and deep facies such as marine turbidites and non-marine sediments. The sediments are immature both texturally and mineralogically. They are derived from eroding arc. Volcanic materials increase with proximity to the land. Until now sediment of this basin is not found in Kurdistan

d. Backarc Basins

They are submarine features (basin) that is located between volcanic arc and continent. It is associated with island arcs and subduction zones. They are found at some convergent plate boundaries, presently concentrated in the western Pacific Ocean and they are formed due to accumulation of heat near the subduction zone in side mantel. Therefore, for dissipation of this heat, a local spreading ridge is formed. Back arc basin is extensional (divergent) basin but associate with convergent boundary (Fig.1.7).

Backarc basins form by rifling and ocean spreading landward either of an island arc, or between two island arcs, which originate from the splitting apart of an older arc system (Fig. 1.7). Their sedimentary fill frequently reflects magmatic activity in the arc region. The example of this basin is China Sea between China and Japan. It thought that Walash Naoperdan was deposited in back arc basin during Eocene.

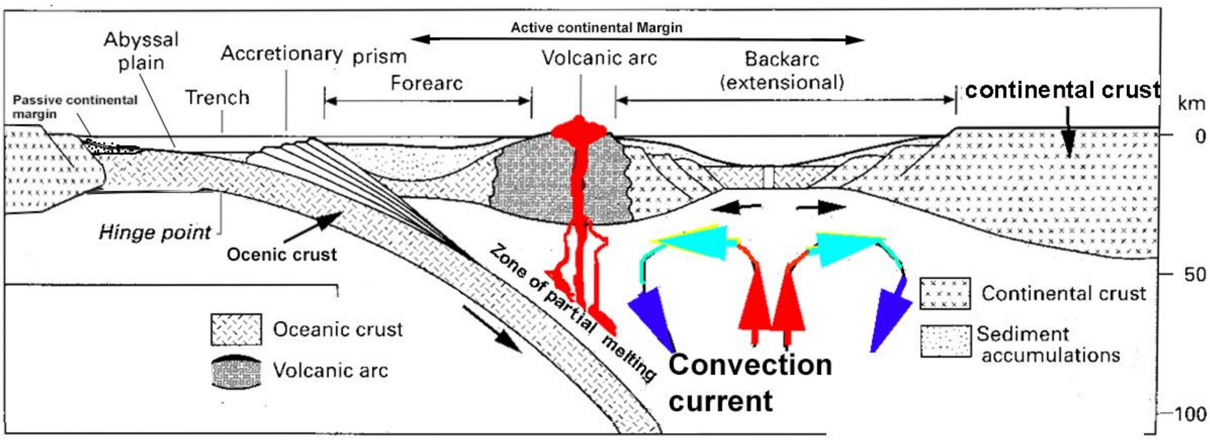

Fig. (1.7) Different basins of the convergent boundary

Table (1) Difference between passive and active continental (oceanic) margin basins

Passive continental margin basin	Active continental margin basin
1-Contains subduction zone	1- It has not subduction zone
2-Contains trench	2-It has not trench
3-Contains Benoiff Zone with active earthquake zone or belt	3-It has not earthquake and benoiff zone
4-Volcanically active so it contains oceanic or continental volcanic arcs	4-Volcanically inactive it has no oceanic or continental volcanic arcs
5-It contain more vocanogenic clastic sediments	5-It contain more carbonate clastics and silicicastic sediments
6-Generally bordered by high mountains	6-Generally bordered by low mountain or deserts
7-It clastic sediments are more mature mineralogically and texturally (well sorted, rounded and contain no unstable minerals	7-It clastic sediments are generally immature mineralogically and texturally (badly sorted, angular and contains unstable minerals
8- It has long age	8- it has relatively short age
9- It is important for oil accumulation due to minor deformation and stability	9-It is not important oil accumulation due to high deformation and tectonic instability

f. Foreland basins

They are elongate regions of potential sediment accumulation that form on continental crust between contractional orogenic (fold and thrust) belt and craton (this means that the foreland basin is formed by thrust loading and then flexturing). Foreland basins are formed by ocean-continent or continent-continent collision. An arc or a bulge separates foreland basin from craton. Thrust belt typically propagates into foreland basin, moving depocenter in the direction of thrust motion (Fig.1.8, 1.9 and 1.10). The sediment of this basin is thick and different which include cycles clastic and carbonate sediments.

1-Peripheral foreland basin

It formed in front of a fold-thrust belt, by depressing and flexuring the continental crust under the load of the overthrust mountain belt (Fig.1.8, 1.9 and 1.10). The extend of these asymmetric basins tends to increase with time, but a resulting large influx of clastic sediments from the rising mountain range often keeps pace with subsidence. The sediment of this basin is both shallow and deep sediments include calciturbidite and siliciturbidites, shelf carbonate and clastics in addition to evaporate. Because cyclic uplift and subsidence it includes several unconformities

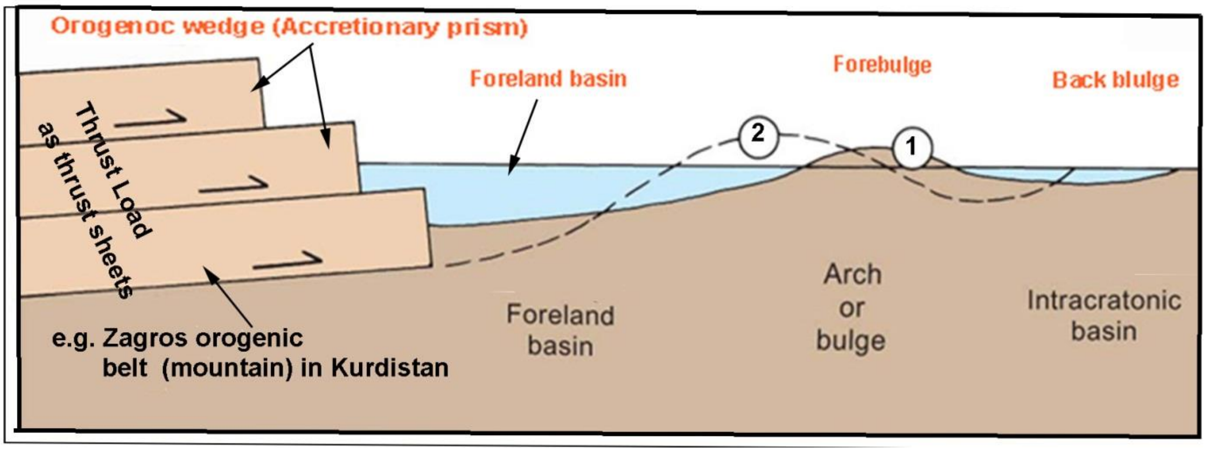

Fig. (1.8) Foreland basin system formed by load of orogenic wedge

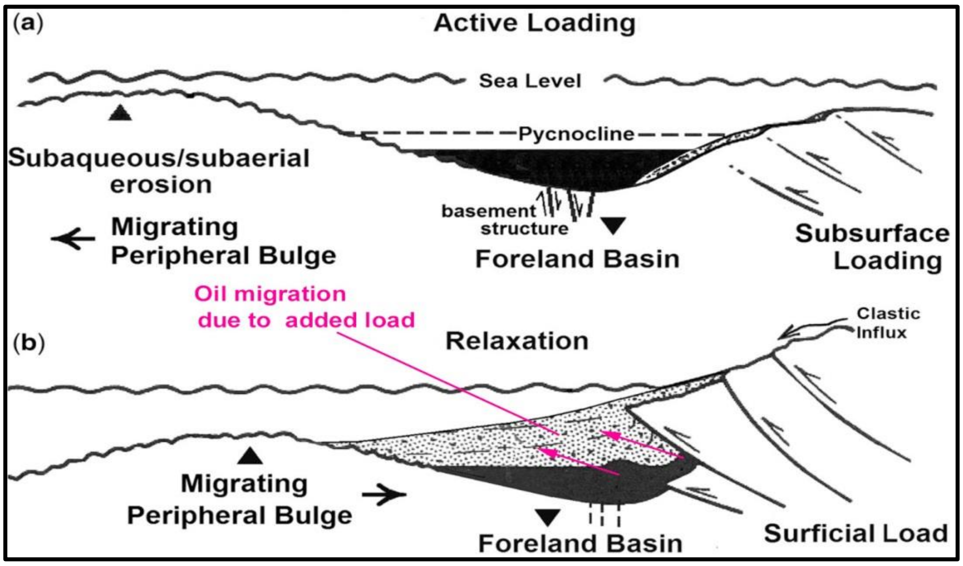

Fig.(1.9) foreland, Foreland basin and other feature of Zagros foreland basin system during Mastrichrian (late Cretaceous)

2. Retro-arc foreland basin

This Foreland basin is developed during ocean-continent collision associated with the growth of a magmatic arc. In this case, the Retroarc foreland basin evolves on the continental side of the mountain belt as seen to the east of the Andes and the Rockies (Fig.1.10a). While pro- (or normal) foreland basin formed on oceanic side of mountain belt (or orogenic belt).

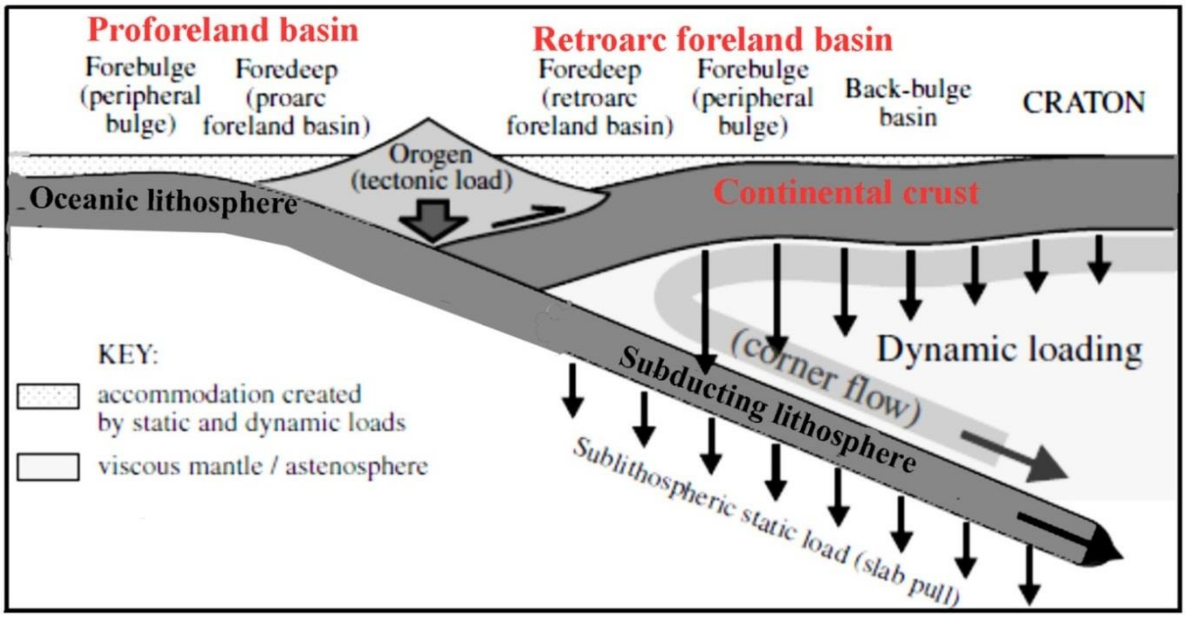

Fig.(1.10a) Retro-arc Foreland basin and pro (normal) foreland basin

i. Intracontinental basin (Intracratonic basins)

These basins developed in the interiors of continents, initially because of subsidence over a rift. They may continue to subside in pulses for hundreds of millions of years after they formed. Their Sediments fill are terrestrial or marine Carbonates, clastics and evaporates (Fig.10b)

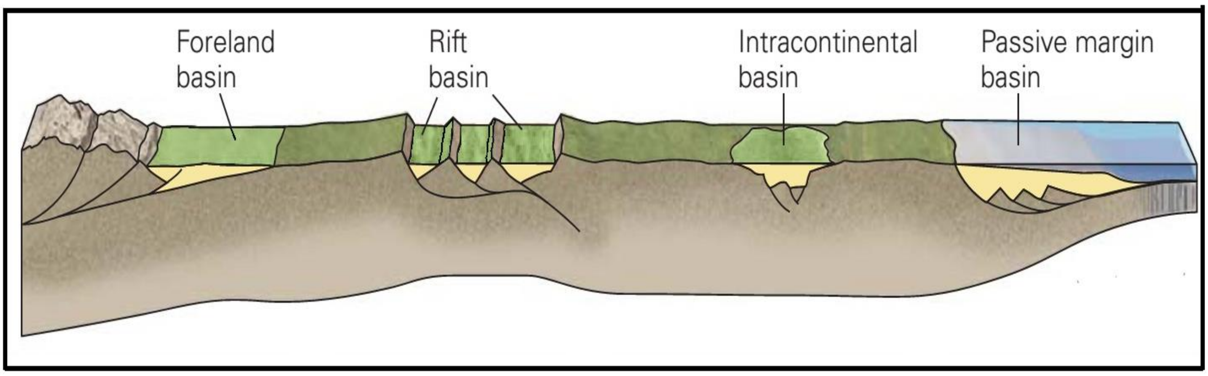

Fig. (1.10b) a diagram shows intracontinental (basin on craton), foreland basin, rift basin and passive margin basins

1.2.3.3. Basins associated with Transform-fault (Strike-slip basin)

a. Pull apart basin (basin associated with transform fault (strike-slip and wrench fault)

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Definition of transform fault

A transform fault or transform boundary, is a type of fault whose relative motion is predominantly horizontal, in either a sinistral or dextral direction. Furthermore, transform faults end abruptly and are connected on both ends to other faults. It connects to either mid oceanic ridges, or subduction zones. While most transform faults are hidden in the deep oceans where they form a series of short zigzags accommodating seafloor spreading, the best known are those on land at the margins of tectonic plates. Transform faults are the only type of strike-slip fault that can classified as a plate boundary. It is called transform fault because it transforms (changes) plate movement along a line (mid oceanic ridge) to another line (ridge) (Fig.1.10c).

Pull apart basin

Pull apart basin (fig.1.12) formed by transform motions (slip) of two plate past each other. The pull apart basin is formed due to present of discontinuity normal to transform fault during slipping the two sides of the disconformity separate and form an elongate pull-apart basins during long time as seen in the figure 1.1.2

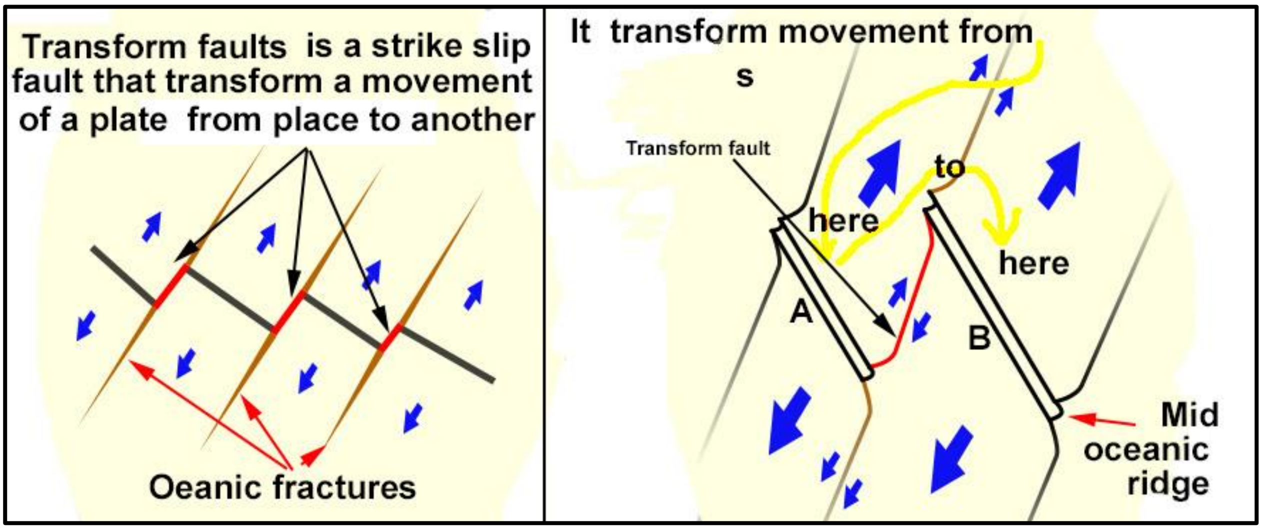

Fig.(1.10c) transform fault across the mid oceanic ridge that transforms movement of a plate from place to another,

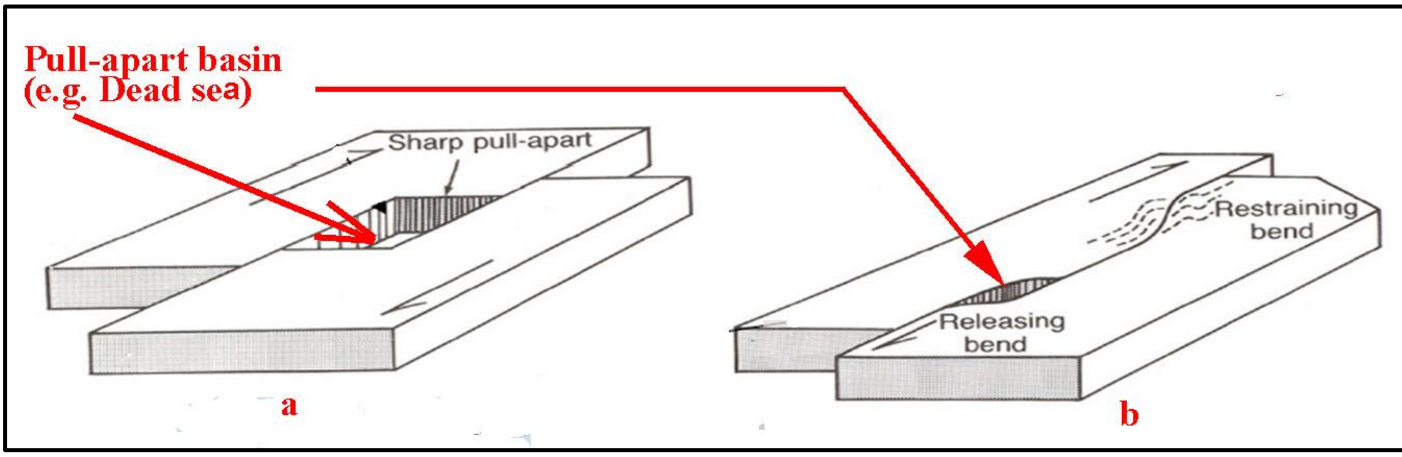

Fig.(1.12) basins and structures that are associated with strike slip (transform fault) straight pull-apart, b) bending pull-apart with restraining bend (preventive bend) may form high topography

2. Local Zonation (subdivision) of the sedimentary basin

In the previous sections, we have discussed and classified sedimentary basin on Global scale but in the coming sections we divide and classify them on the local scale.

1. According to light penetration and depth of water column

The water column is subdivided according depth and amount of light penetration in to photic zone (0 to 200 m deep) and aphotic Zone (more than 200 m deep) as shown (fig. 2.1)

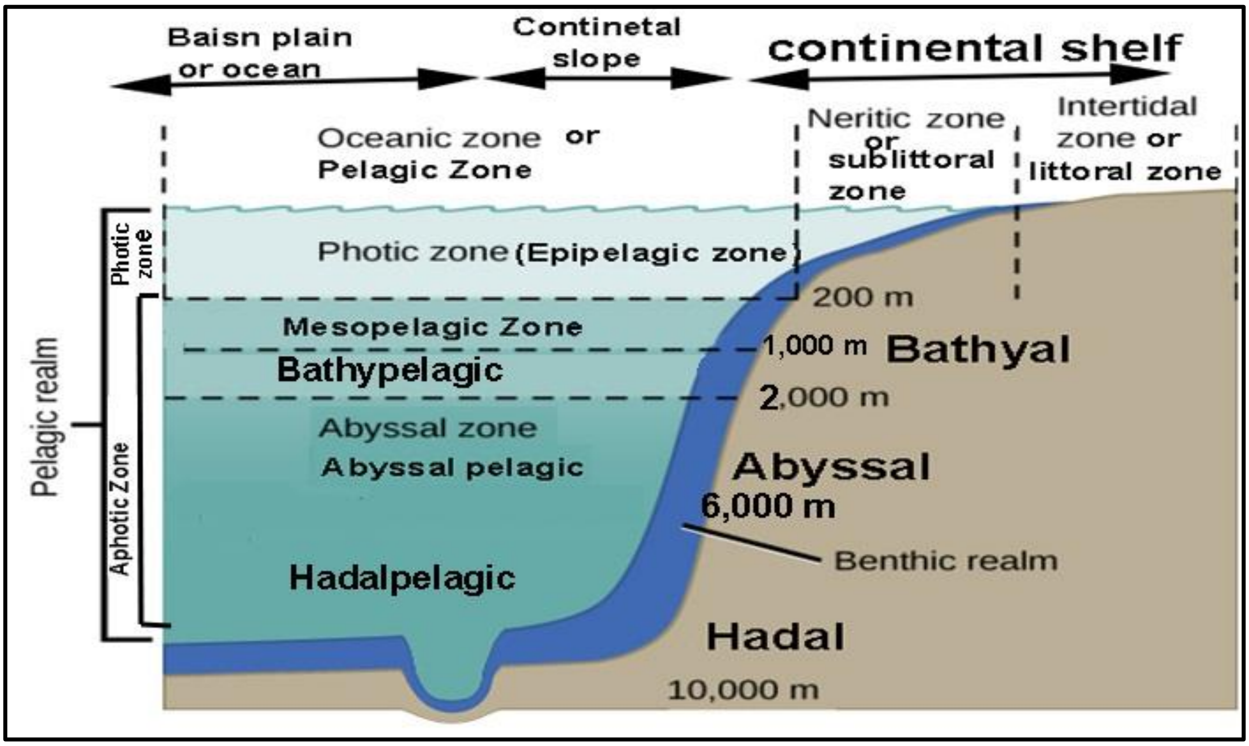

Fig. (2.1) subdivision of the water column according depth, topography and amount of light penetration

2. According to depth or topography of the seafloor

a. The sea floor is divided according to topography and depth into continental shelf, continental slope and oceanic floor (oceanic plain).

Continental Shelf:

This part of sea extends from the shore line (high tide line) to depth of about 200 m where the gently sloping shelf floor becomes steep. This part of sea is a photoic and high energy and highly affected by turbidity and fresh water influx of the neighboring lands. This part (or zone or basin) is called carbonate factory) when there is no river delta when delta exist if accumulate clastic sediments (shale and sandstone).Its bottom and water column are very rich with flora and fauna organism.

Continental Slope:

This part of the sea (or basin) is located between shelf and oceanic floor and it is the steepest part of the sea and has convex shape. It extends from 200m to 6000 meter of depth. The slope is zone of both erosion and transportation (by passing) of sediment (both siliciclastics and carbonate) by turbidity current and mass wasting.

Oceanic floor (oceanic plain)

Oceanic floor is generally flat and starved from normal sedimentation. It covered with thin layer of recent sediments of pelagic and hemipelagic origins (marl and lime mud with clays, radiolarian and calcareous ooze. Only the area neat the continental slope receive turbidite sediments.

The shelf (or platform) is subdivided to smaller parts (zones) into to littoral (intertidal) zone, sublittoral (or subtidal) Zone.

a. Littoral zone (or intertidal Zone)

It refers to as intertidal or coastal zone. It includes the area between high tide and low tide. During high tide, this zone remains covered with water for several hours. When low tide returns, it is exposed to air for many hours. Thus, organisms living in this region have adapted to both the conditions.

b. sublittoral (subtidal) zone

Includes the water column and sea bottom from the shoreline to the edge of continental shelf and further overlies the continental shelf. Sunlight penetrates the entire water column. It extends up to a depth of only 200 meters. This environment is generally more productive than the open ocean because more nutrients and light are available. This part of the water column is also susceptible to wave action, turbulence and coastal currents.

c. Pelagic zone (open sea)

It used for water surface and column of oceans, organisms in this region float and swim on the surface in the ocean. It is the waters of the open ocean, extending from the edge of the continental shelf to other edge of ocean. Pelagic zone is divided vertically into different depths based on conditions depth into:
a.epipelagic or photoic zone (0-200 m deep), b. Mesopelagic (200to 1000 m deep), c. bathypelagic (1000 to 2000 m deep), d. abyssal pelagic 2000 to 6000 m deep) e. Hadalpelagic more than 6000 m deep) (Fig.2.1)

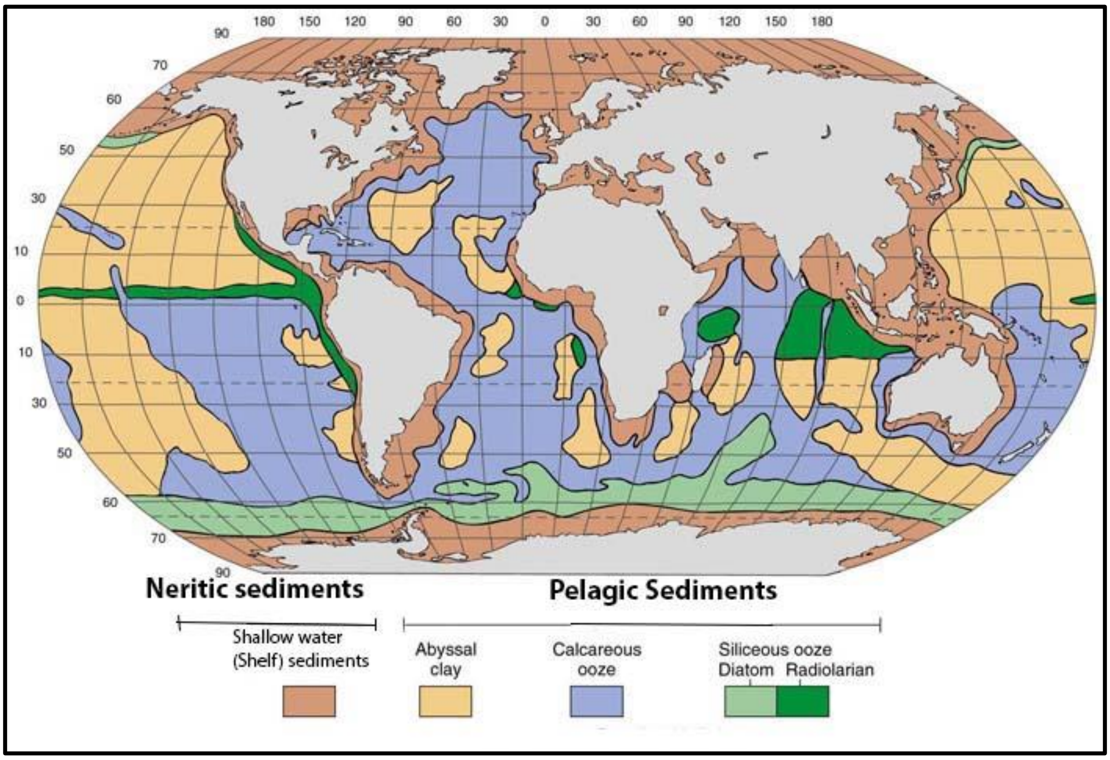

Fig.(2.2) distribution of neritic and pelagic sediments in word continental margins and oceans

3. According to trace fossils

The depth, topography and environment of the sedimentary basin can be indicated by accurate inspection of the out crop of the sedimentary rocks in the field. One tool for indication is trace fossils content of the sediments. After identification the traces are classified and type of basin (depth and environments) are asigned fig.(2.2)

4. According to habit of Organisms

Each basin can be classified into part according of the living condition of organisms

a-Pelagic organisms

They are those organism that live in the column of Water Ocean

b-benthic or benthonic organisms

They are those organism that live on the bottom of ocean

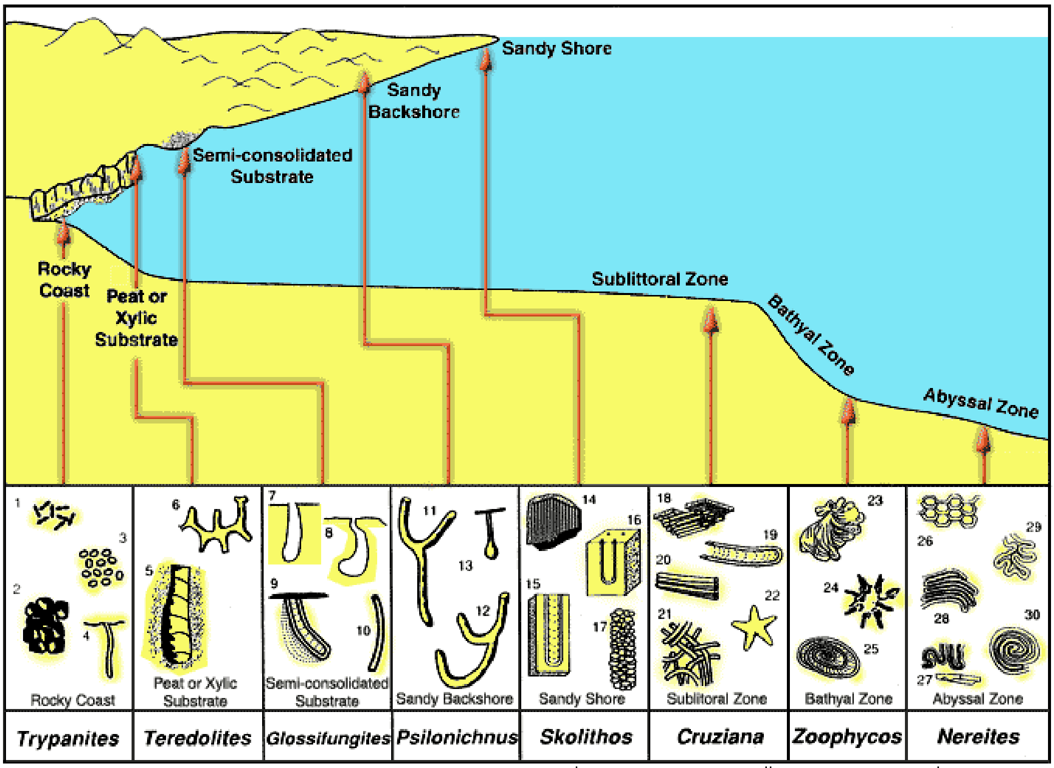

Fig. (2.3) the depth and topography of the sedimentary basin can be indicated by trace fossils

5. According to type of sediments

a. Carbonate dominate basin (shelf), b. siliciclastic dominated shelf (or basin), c. Mixed carbonate-siliciclastic basin or shelf, d. Evaporite dominate basin

7. According to nearness (proximity) to the shore: 1- backshore (Supertital), 2- foreshore (intertidal), 3-shore face (subtidal), offshore (Fig.2.3a and b)

a. Backshore (supertidal). An area of beach that is affected only by waves during tsunami or exceptional very high tides or very severe storms. The area (belt) may be historically affected by seawater activities. Its sediments are coarse

b. foreshore (nearly equal to intertidal)

The part of a shore between high- and low-water marks, or between the water and cultivated or developed land.

c. Shoreface (nearly equal to subtidal) zone is an area of the shore that permanently covered by water and located between low water line (low tide) and normal wave base (fair-weather base). This zone is characterized by well-sorted cross-bedded sandstone

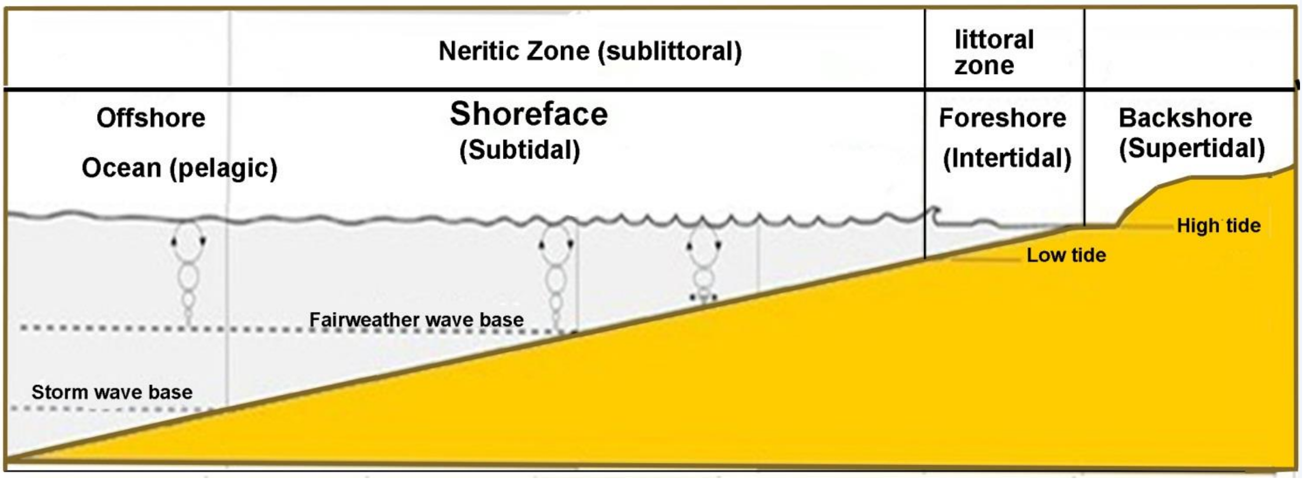

Fig. (2.4a) classification of the basin according to nearness from the shore

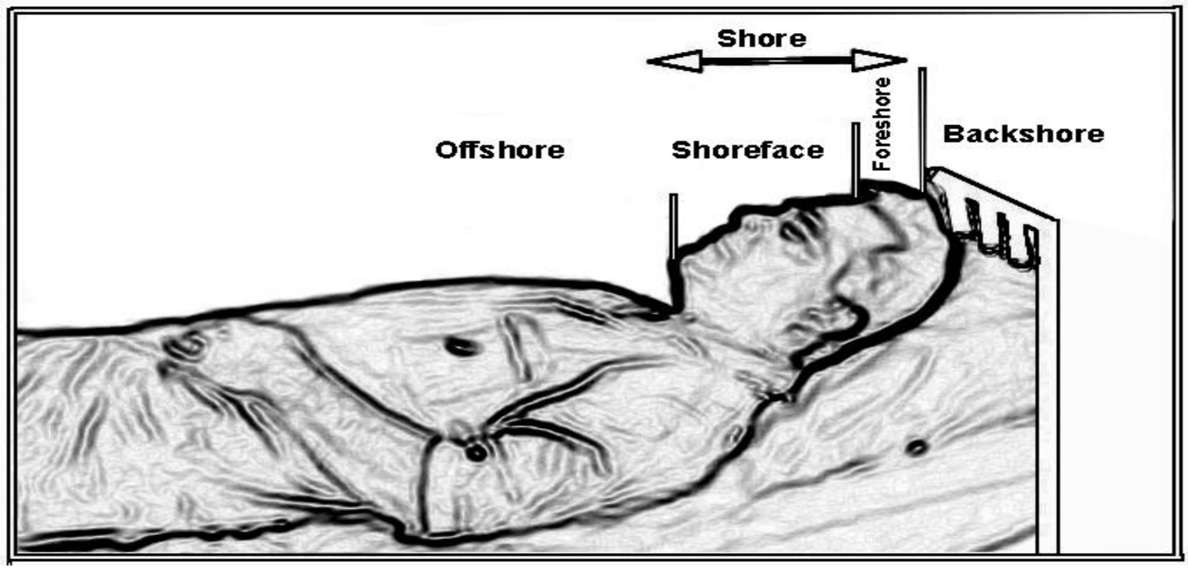

Fig. (2.3b) The terms backshore, shore, foreshore, shoreface and offshore are similar to back head, foreface and chest of body of a seeping man on back respectively.

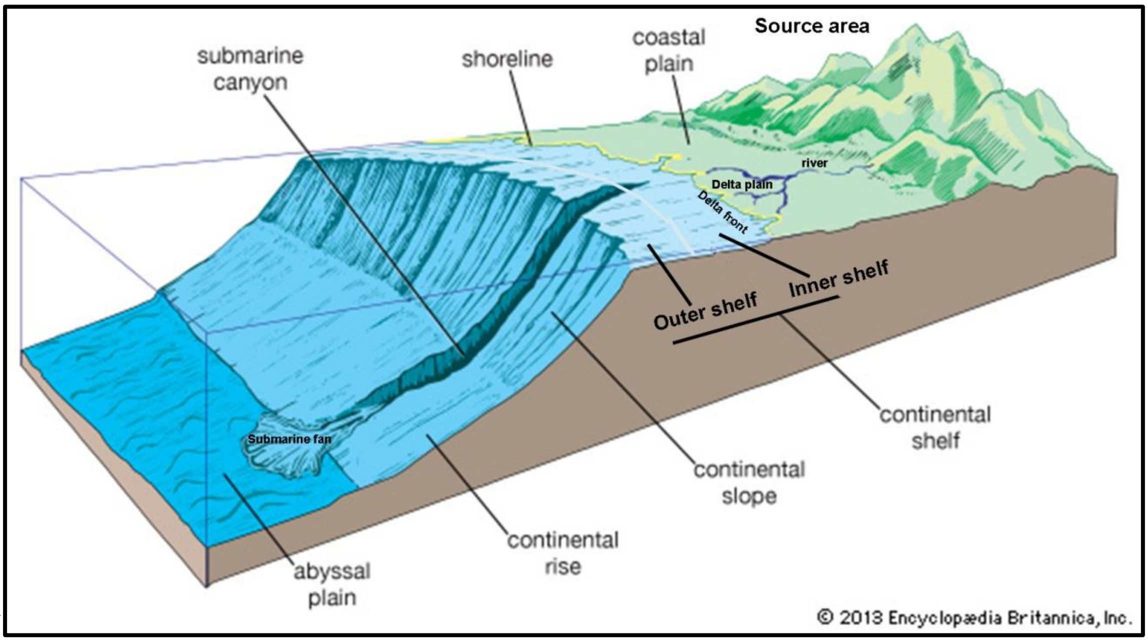

Fig. (2.4) Topographic and depth dividing of continental margin into its environments

8. Subdivision of the shelf according to water circulation

a. Lagoon

A lagoons occur on shelf and isolated platforms and consist of is a shallow body of water separated from a larger body of water by barrier islands or reefs. Lagoons are commonly divided into coastal lagoons and atoll lagoons. It is more salaline than open sea and contain those animals (fossils) that tolerant salinity and oxygen deficiency

b. bay

A bay is a similar to lagoon but more smaller and has more restricted circulation

c. Estuary

An estuary is a partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea. Estuaries form a transition zone between river environments and marine environments (Fig.2.5).

d. open sea

It is normal sea, which, connected to main oceans, and its content of oxygen and salt is similar to ocean.

e. Shoal

It is high energy and clear water coastal subtidal part of shelf in which carbonate lithoclast and bioclast sediments dominate.

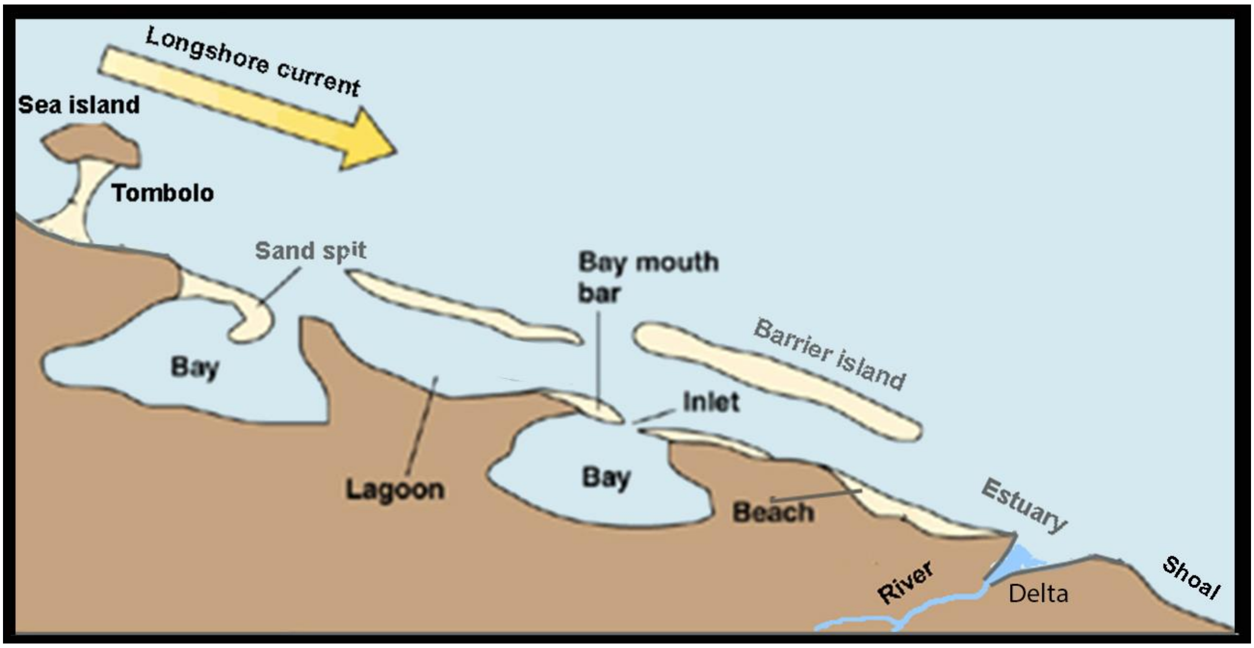

Fig. (2.5) dividing shelf into several small part According to water circulation

9. According to type of platform,

a. Attached platforms

They are those platform that exist on continental margin (exist on continental crust or we can say attached to continental). There are three types of attached platforms, a. ramp, b. non-rimmed shelf, c. Rimed shelf.

b. Isolated platforms are those platforms that are located in the ocean and surrounding by oceanic crust. They have flat topped and accounted as important carbonate factory in the oceans such as Bahama Island (or platform).

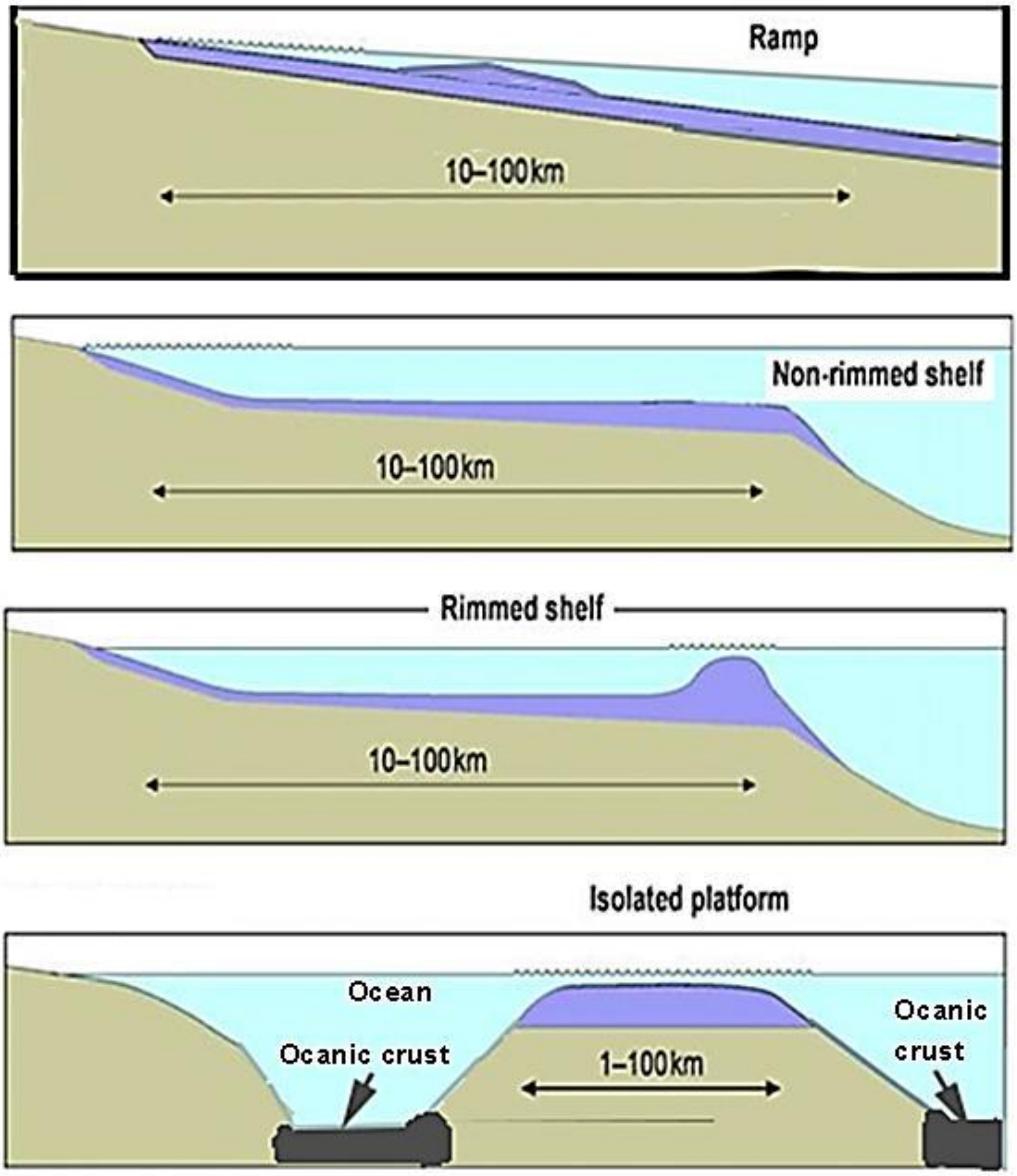

Fig. (2.6) types of carbonate platforms

3. Type of the sedimentary basins (depositional basins) of the formations of the Kurdistan

The stratigraphic units (formations) of Kurdistan and whole Iraq can be grouped in to three types according to the type of the basin in which they are deposited. The formations are deposited in three main basins; these basins are trench, continental margin, foreland basin and back arc basins (table 1) and (Fig.3.1).

The geodynamic of the evolution of the basins of the formation are reflected different tectonic setting and environments as cited below.

1. The southern Neo-Tethys was relatively small and narrow which was opened (at divergent Phase) during Triassic-Jurassic. During this time Avroman and Lower part of Qulqula Radiolarite Formations had deposited on isolate platform and in the respectively.

2. The convergent phase is started at the beginning of the Cretaceous due to total widening of the Neo-Tethys (See fig.2-2). By the diverging, the Iranian and Arabian plates had advanced toward each others. During the converging a deep trench basin is formed. In this trench upper part of Qulqula Radiolarian Formations had deposited while Sarmord, Balambo Fms were deposited on the slope of the passive continental margin.

3. As a result continuous diverging of Arabian plate under the Iranian one, huge (voluminous) amount of the Radiolarites and Ophiolites (Trench materials) are accumulated as submarine accretionary prism and thrown (override) on Arabian plate. This ridding and accumulation exerted high pressure on Arabian plate and formed a forebulge on which Qamchuqa Formation was deposited (Fig.3.1C)

4. The further advance and accumulation of the accretionary prism had forced the forebulge to subside (drown) during the downing Gulneri Formation is deposited. While after drowning, the Kometan and Bekhme Formations are deposited (Fig.3.1B).

5. The further advance of the Iranian plate forced the accretionary prism to be uplifted as terrestrial land and further thrown on to Arabian platform (Arabian continental crust). This throw of radiolarites and ophiolite on the Arabian Platform had formed a continental land and a foreland basin formed during Campanian (Fig.1.3A) which called Zagros Early Foreland basin by (Karim 2004).

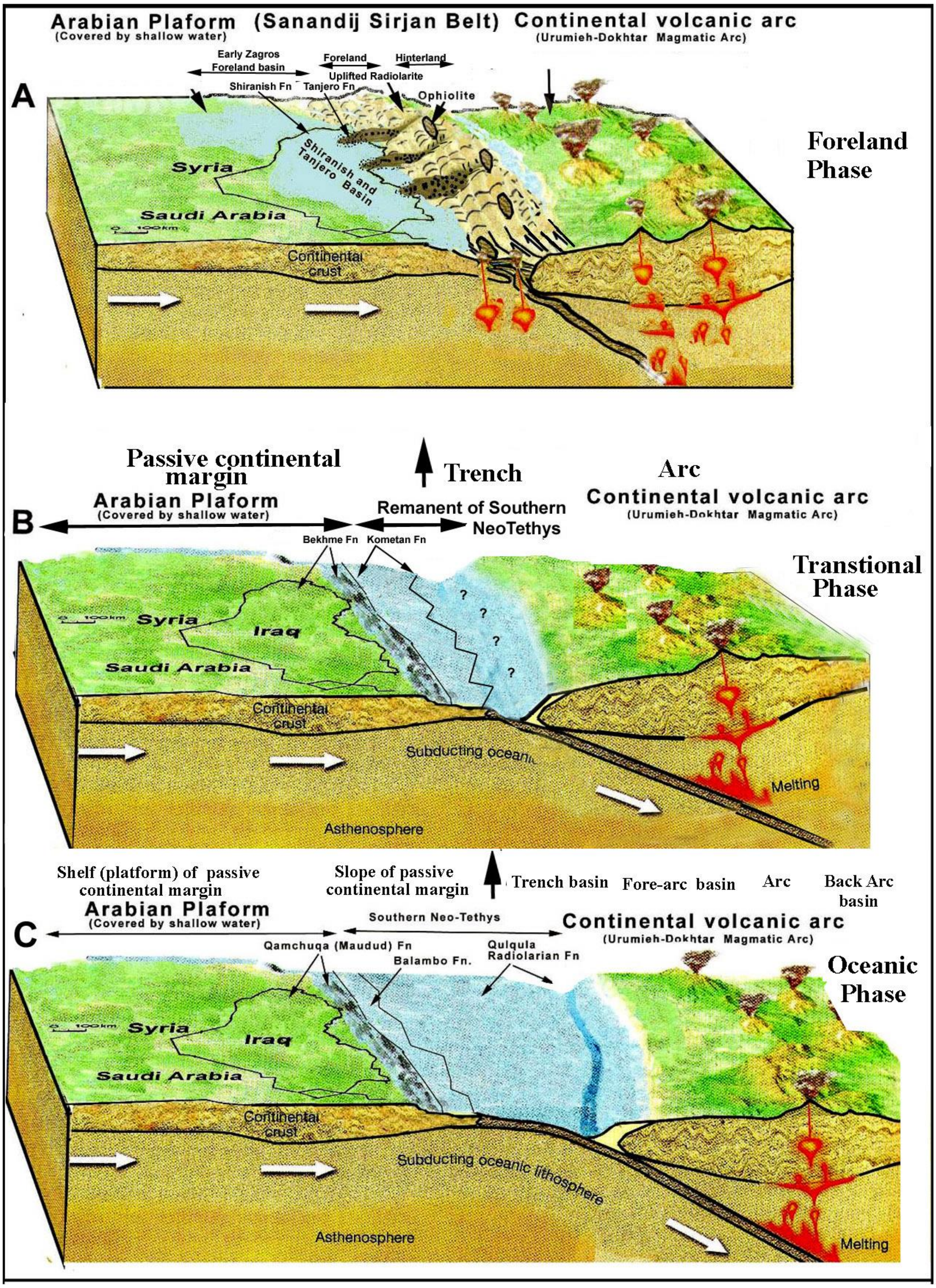

Fig.(3.1) (A)Foreland basin in Iraq during Maastrichtian, B) Final stage of Oceanic basin, trench basin, continental margin basin during late Cretaceous, C) Mature stage of Oceanic basin, trench basin, continental margin basin during Early Cretaceous in Iraqi Kurdistan. In three figures tectonic and paleogeographic locations of the related formation are shown

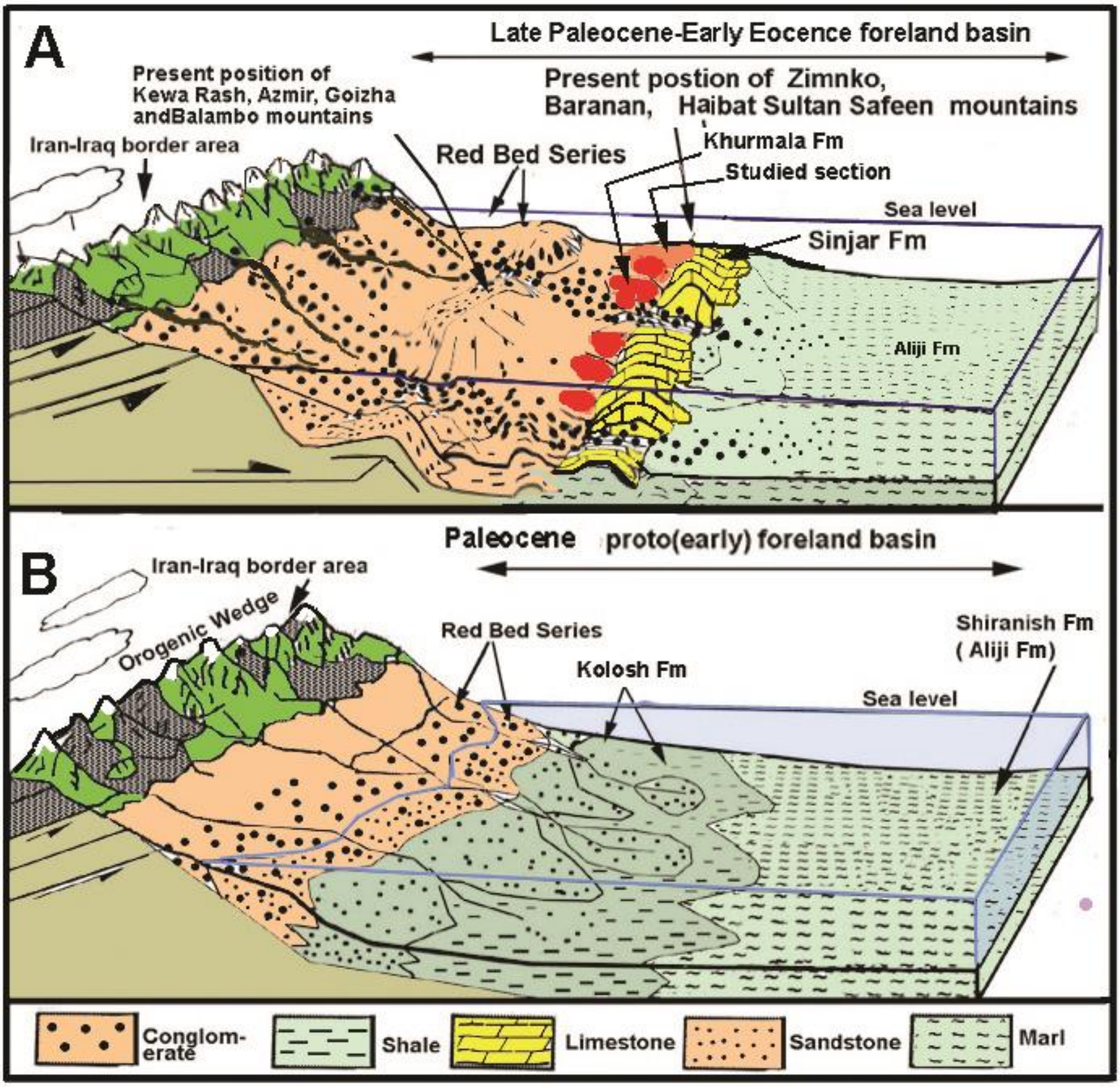

Fig.(3.2) (A) Zagros foreland basin during Eocene, B) Foreland basin during Paleocene in Iraqi Kurdistan. In the two figures tectonic and paleogeographic locations of the related formations are shown

Table (1) the names and Sedimentary basins of some Formation of Kurdistan and Iraq

Name of the formations	Name of the sedimentary basins	Name of the formations	Name of the sedimentary basins
Upper Bakhtiary (Bai Hassan)	Coastal area of Late foreland basin	Shiranish	Deeper part of Early (Initial) foreland basin
Lower Bakhtiary (Mukdadyia)	Coastal area of Late foreland basin	Aqra	Reef of Early foreland basin
Upper Fars (Injana)	Coastal area of late foreland basin	Bekhme	Reef basin on passive continental margin
Lower Fars (Fatha)	Closed basin of Late foreland basin	Mashura	Final stage of passive continental margin
Kirkuk Group	Shelf in the Late foreland basin	Kometan	Slope of final stage of passive continental margin
Euphrates	Lagoon in the Late foreland basin	Dokan and Gulneri	Final stage of passive continental margin
Pila Spi	Lagoon in Late foreland basin	Upper Qamchuqa (Mauddud)	Shelf of passive continental margin
Avanah	Reef in Late foreland basin	Lower Qamchuqa (Shuaba)	Shelf of passive continental margin
Gercus	Distal fan coast of Late foreland basin	Balambo	Slope of passive continental margin
Jaddala	Deep basin of Late foreland basin	Sarmord	Slope of passive continental margin
Sinjar or Khurmala	Reef of early Foreland basin	Qulqula Radiolarian (bedded chert unit)	Trench
Walash Nauperdan	Possible Back arc	Qulqula Radiolarian (limestone Unit)	Active continental margin
Red Bed Series	Proximal fan of the coastal area of Early Foreland basin	Chia Gara	Slope of passive continental margin
Kolosh	Depocenter of Early Foreland basin	Barsarine and Naokelekan	Shelf of passive continental margin
Tanjero	Depocenter of Early foreland basin	Sargelu	Possible Oceanic basin
		Avroman	Isolate platform

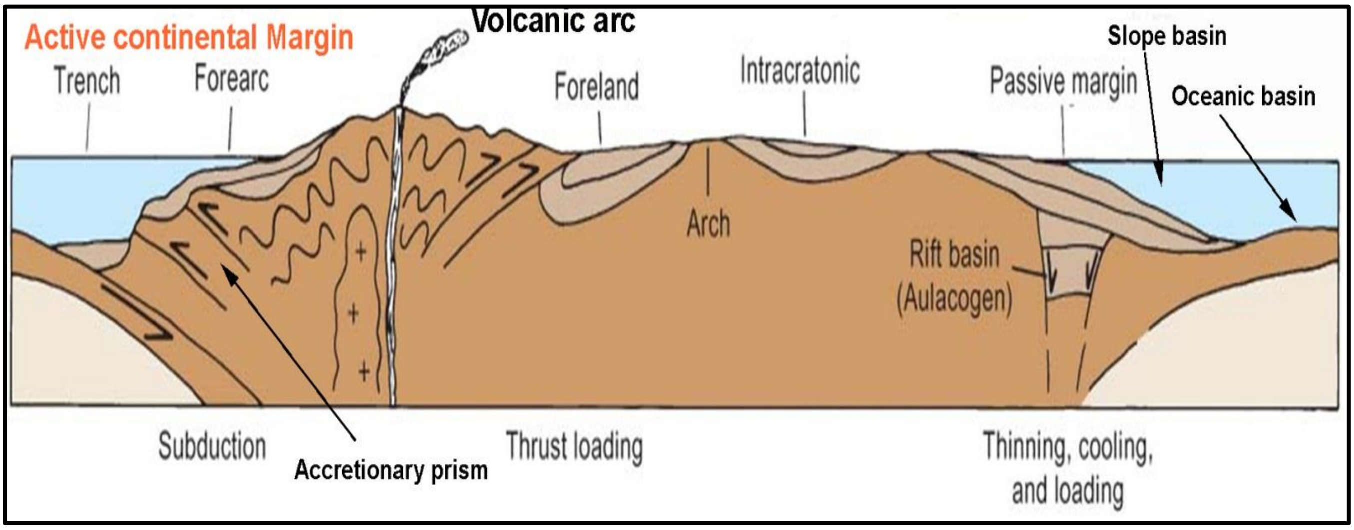

Fig.(3.3) Present day and previous sedimentary basin can exist in and area together

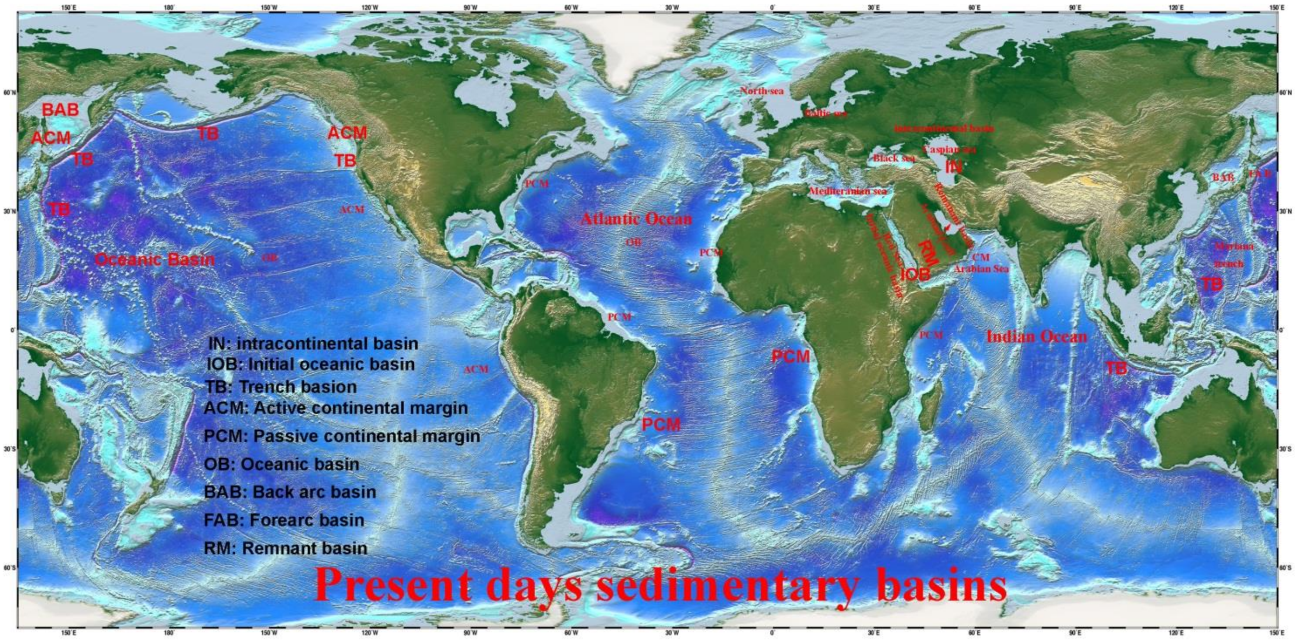

Fig.(3.4) main Present days Sedimentary Basin

4-Sedimentary basin Analysis

4.1. Paleocurrent Analysis of the sedimentary basin

In the previous lectures we have the classified the sedimentary basins in both Global and local scale. We have referred to the main characteristics of each basin but the most important property of basin is its direction of sediment direction transport. This direction is known as basin Paleocurrent direction and by this the physigraphy, environment and tectonic can be indicated for sedimentary rocks in outcrop and wells. When outcrops are studied accurately, many sedimentary structures and aspects can be found by which the Paleocurrent direction of the basin can be found as shown below.

1-Types of sediments and facies

Mapping the social (space) distribution of facies (type of sediments) is most important means for paleocurrent direction indication (Fig.4.4). In the figure we can see distribution of facies of Tanjero Formation during Maastrichtian. The direction is toward decrease of sediments caliber (size).

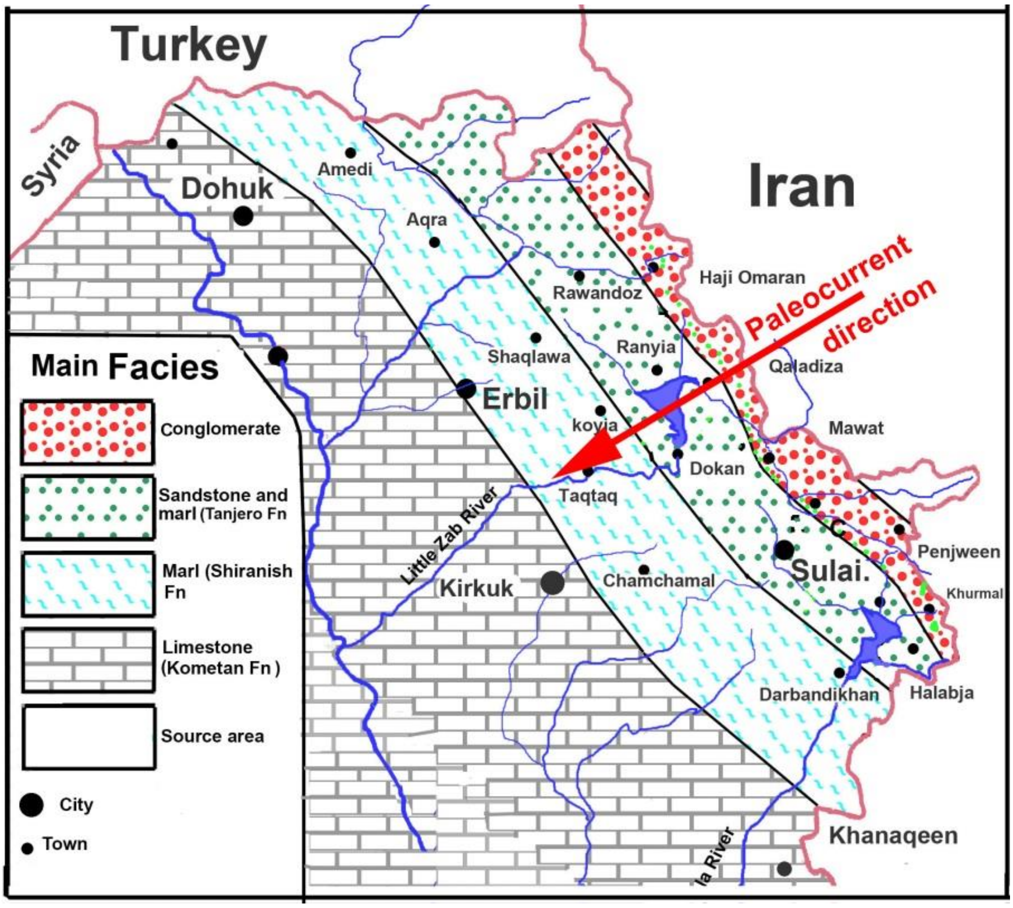

Fig.(4.1) facies (sediment types) distribution of Tanjero Formation during Maastrichtian. The direction is toward decrease of sediments caliber (size).

2-Unidirectional Sedimentary Structures

They are those structure that have tends not direction, this means that trend has two directions for example, SW and NE, N and S, E and W. the expels of these stricture are parting lineation (Fig.4.2), lineation of elongate fossil and plant debris (Fig.4.3 and 4.4).

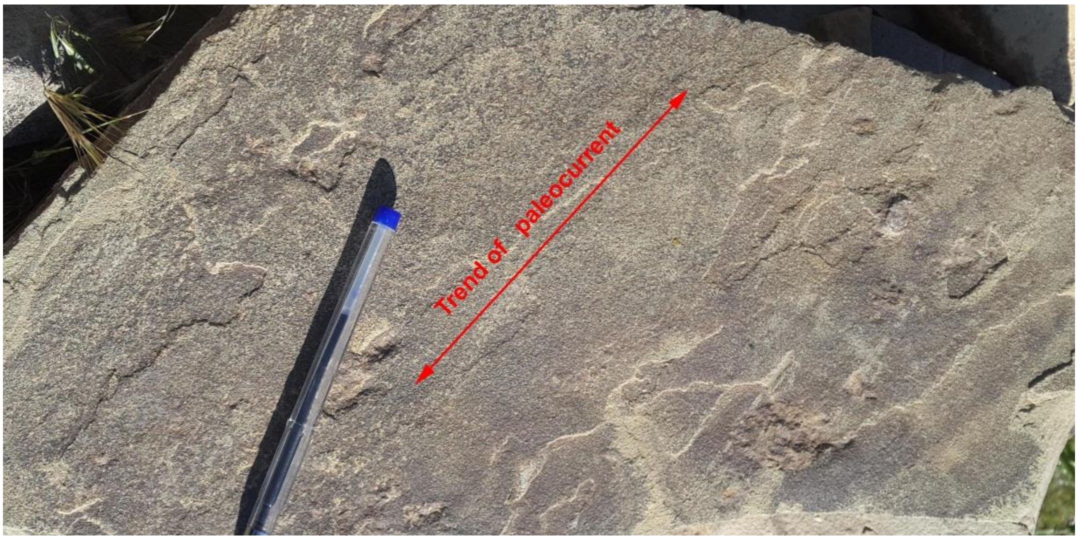

Fig.(4.2) parting lineation on the sandstone bed of Tanjero Formation in the Chaqchaq valley, near Lower Hanaran village

Fig.(4.3) parallel arrangement of plant debris on bedding surface of Kolosh Formation near Zarain town, Darbandikhan area. These debris are bidirectional structure show only trend.

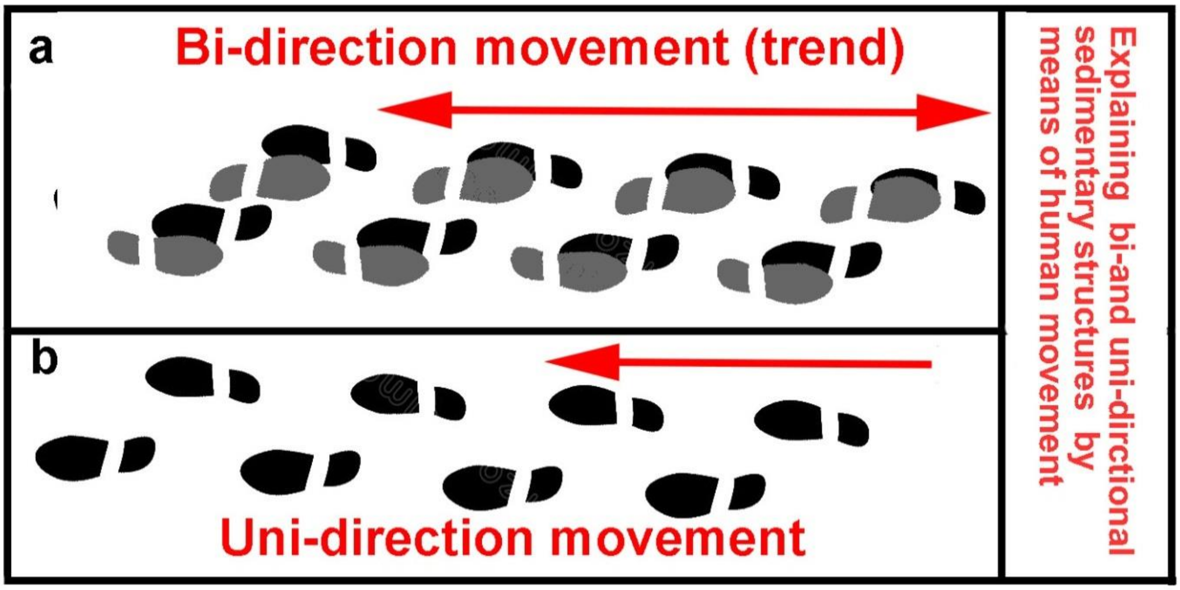

Fig.(3.4) example of bidirection and unidirection movement of human

3-Imbricated pebbles

This structure is common on streambeds where flowing water tilts the pebbles under the effect of upper flow regime near the bottom of the stream. The flat surfaces of these pebbles dip upstream but the paleocurrent direction is opposite to the dip (Fig.4.5).

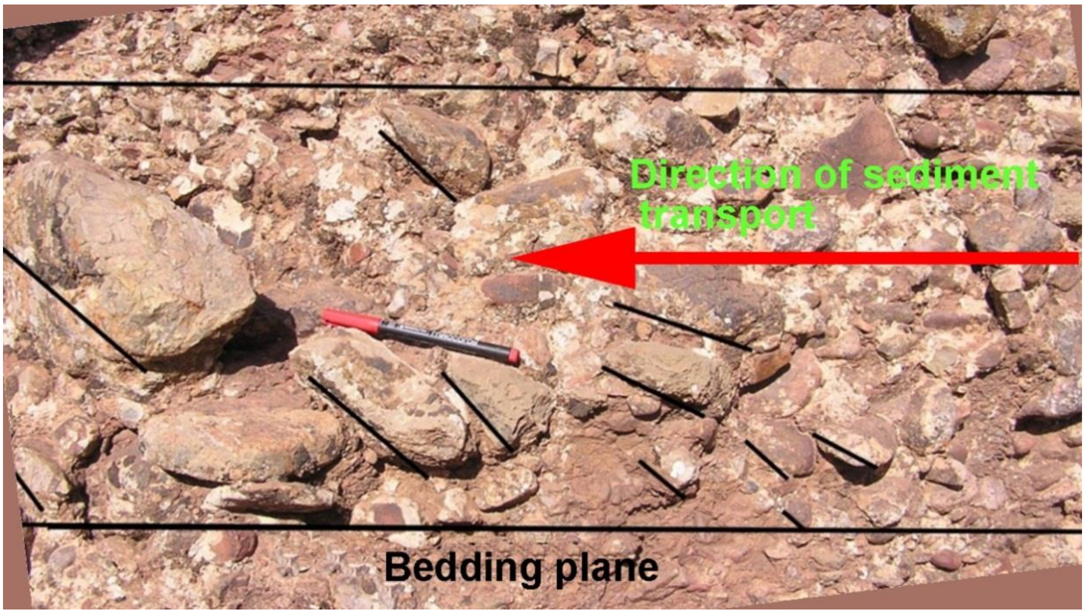

Fig.(4.5) imbricate pebble in the Lower Part of Tanjero Formation (Kato Conglomerate) on Kato mountain 5 km east of Chwarta town. They show the flow direction during Maastrichtian which was toward southwest

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4. Cross bedding

This feature occurs at various scales, and is observed in sandstones and conglomerates which show the transport of gravels and sand by currents that flow over the sediment surface. It is generally formed in environments such as sand in river channels or coastal environments. Cross bedding is formed by deposition and erosion in small scale (migrating of bed form) by which there are inclined deposition of laminae or beds with truncation at upper ends, The truncated layers provide an easily determined depositional top direction (Fig.4.6).

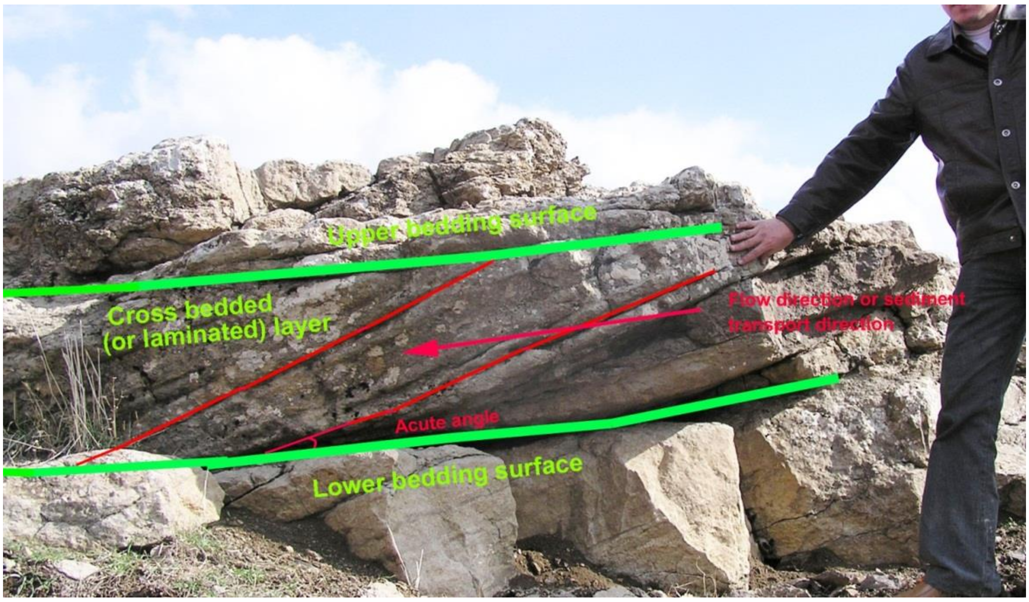


Fig.(4.6) cross beds in detrital limestone of Aqra Formation near Zarda bee village Chwarta area

5. Flute cast

Flute casts are very useful for paleocurrent indication which is formed by erosion on the beds surface and formed before deposition of the overlying beds. They form in large scales when the source area is near the depositional environment. This kind of sedimentary structure will form in sediments, which passes downward into the turbidite deposits on the channels floor. These structures are like spoon and they are narrower, in plain view, at one end and widening out at the tapered end, which is scoured by eddy turbulent currents. The paleocurrent is indicated by narrow end (Fig.4.7)

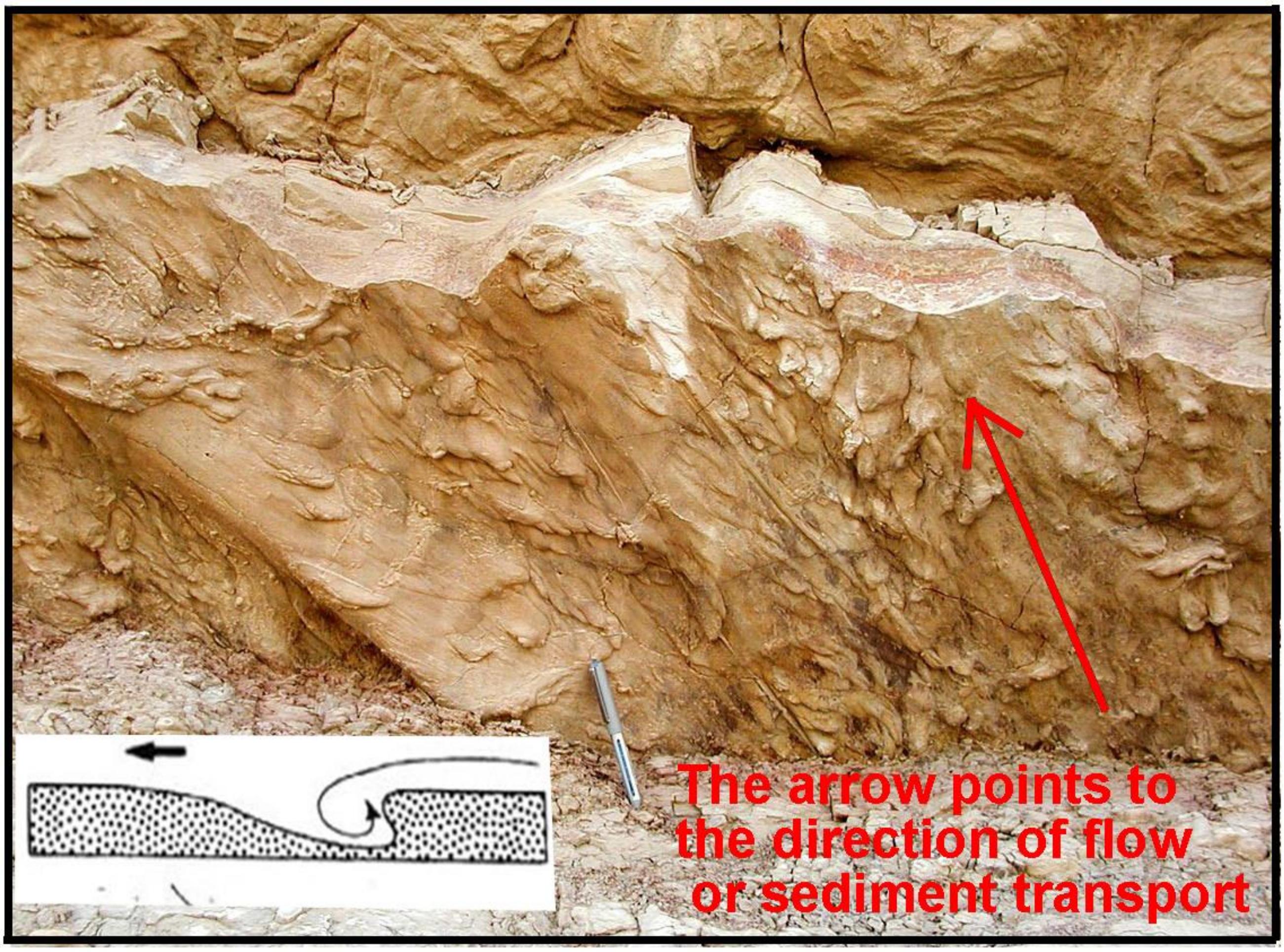


Fig. (4.7) flute casts in the unit three of Red Bed Series in Chwarta area at 100m west of Diralla village on the road between Chwarta and Mawat towns. This structure is associated with grove cast, striation casts and channels.

5-Ripple Marks

There are two types of ripple marks, a. unidirectional ripples generated by current during lower flow regime and can be used for paleocurrent directing. They are or asymmetrical ripple marks and asymmetrical in profile, with a gentle up-current slope and a steeper down-current slope (Fig.4.8 and 4.9). These commonly form in fluvial and aeolian depositional environments, and are a signifier of the lower part of the Lower Flow Regime.

Fig. (4.8) current ripple marks (asymmetrical ripple marks) in the Lower Fars Formation near Shiwiqazi village

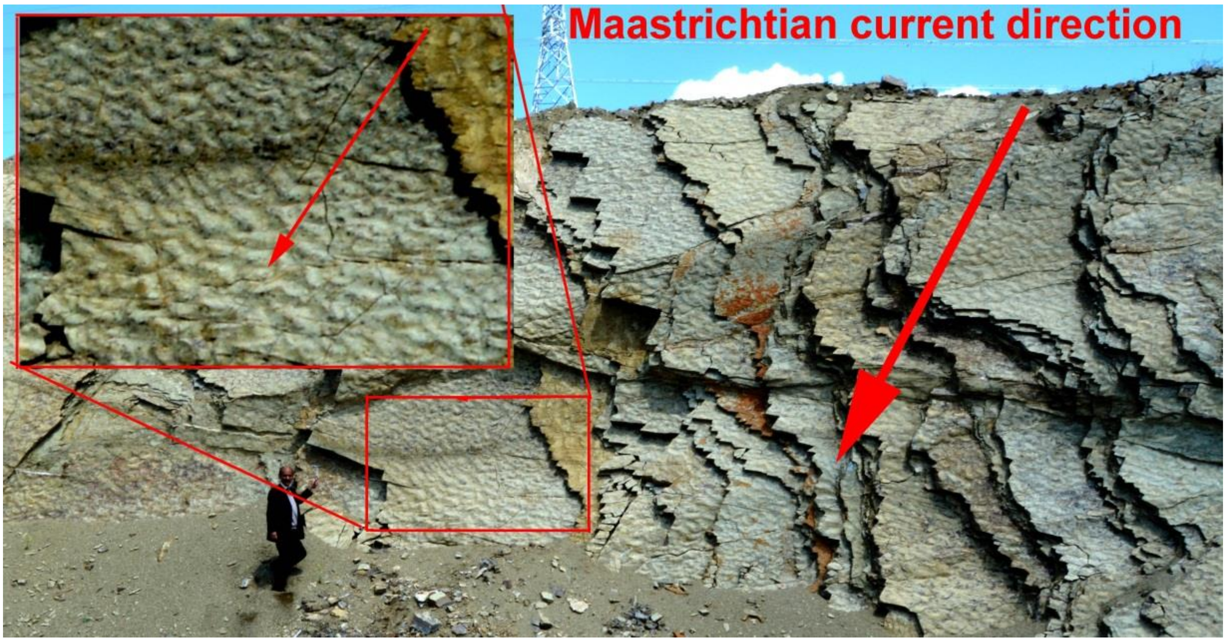


Fig. (4.9) linguidal ripple marks in Lower part of Tanjero Formation at northern boundary of Sulaimani city near Kurdsat Tv station

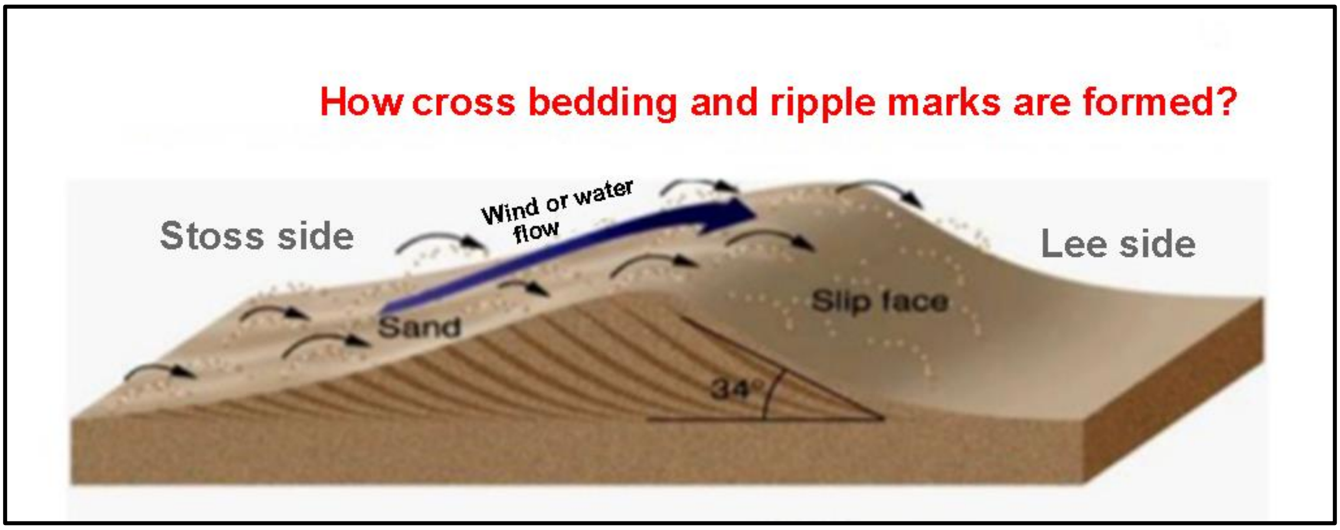


Fig.(4.10) Ripples bare characterized internally by cross bedding. Cross beds are formed from in fluid or wind flow as sediment is eroded and transported up the relatively gently stoss side of the ripple and deposited as avalanches on the steeper lee side

4.2. Analysis of rock secession in sedimentary basins

a) By lithiostratigraphy

b) By allostratigraphy

c) By biostratigraphy

d) Sequences stratigraphy

a) Lithiostratigraphy

This branch of stratigraphy is a method of classification (division) of rocks succession known as **lithostratigraphy** by which geologists interpret, correlate, map and subdivide sedimentary rocks into formations based on similarities in lithology and/or lithofacies. The practice of interpretation, correlation, and mapping based on this branch often ignores significant breaks in the sedimentary section, including those caused by unconformities, erosion surface, non-depostion, and flooding surfaces. This can lead to significant mis-correlations, particularly if it is assumed that the lithostratigraphic units accumulated over the same interval of time.

b) Allostratigraphy

This branch includes stratigraphic interpretation, correlation, and mapping which uses unconformities and erosion surfaces (discontinuities) to subdivide the sedimentary section (Bhattacharya and Walker, 1991a) into allomembers (alloformations or allogroups)

Allomembers are defined as representing succession that contain different lithologies and may contain different formations. So allomember boundaries cut across the conventional lithostratigraphic boundaries and better illustrate the genetic relationships between the different lithostratigraphic units (Bhattacharya, 1994).

c) By biostratigraphy

This branch of stratigraphy concerned with subdivision of sedimentary succession to many biozones according to index fossils content (fossil of short lifetime). According to index fossil content, the sedimentary succession is divided to total range zone or concurrent range zone, interval biozone, assemblage biozones and partial range zone.

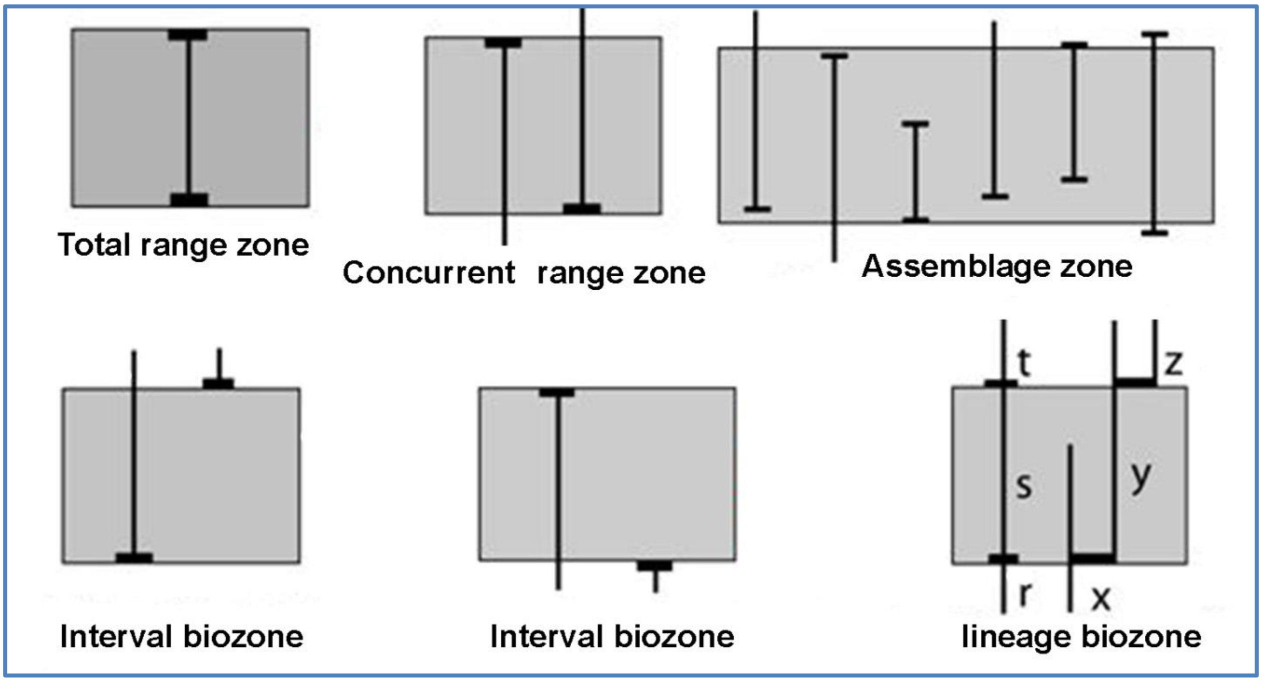


Fig.(4.11) Main types of biozones used for subdivision and aging of sedimentary basins

The sequence stratigraphic approach is a higher order of allostratigraphy that assumes a connection of the discontinuities and surfaces used to subdivide the sedimentary section to changes in base level. It also tends to give unconformities a higher level of significance, when subdividing the sedimentary section, than ravinement surfaces and/or flooding surfaces. Unconformities are used to bound packages of sedimentary rock and subdivide them into sequences. "sequence stratigraphy" involves the study of rock relationships within the chronostratigraphic framework of a sequence, which in turn is acyclic succession of rocks composed of genetically related units of strata (Posamentier et al., 1988).

Allostratigraphy (Unconformity-bounded unit)

A sedimentary succession bounded above and below discontinuities that may be angular unconformities, discontinuities of preferably of regional or interregional extent. The properties used to recognize these stratigraphic units are its two designated bounding unconformities." International Stratigraphic Guide (Salvador, 1994).

Unconformity

Unconformity is a surface between successive strata representing a missing interval of rocks in the geologic record of time, either produced by an interruption in deposition or by the erosion of depositionally continuous strata followed by renewed deposition. "Unconformities, where recognizable objectively on lithic criteria, are ideal boundaries for lithostratigraphic units" (NACSN, 2005).

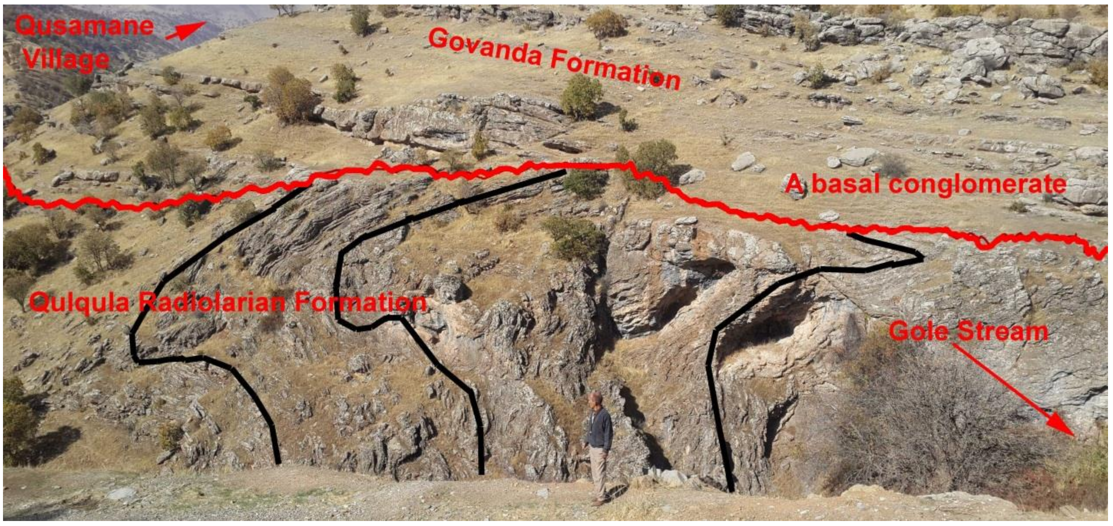


Fig.(4.12) an angular unconformity between Govanda and Qulqula Radiolarian Formation

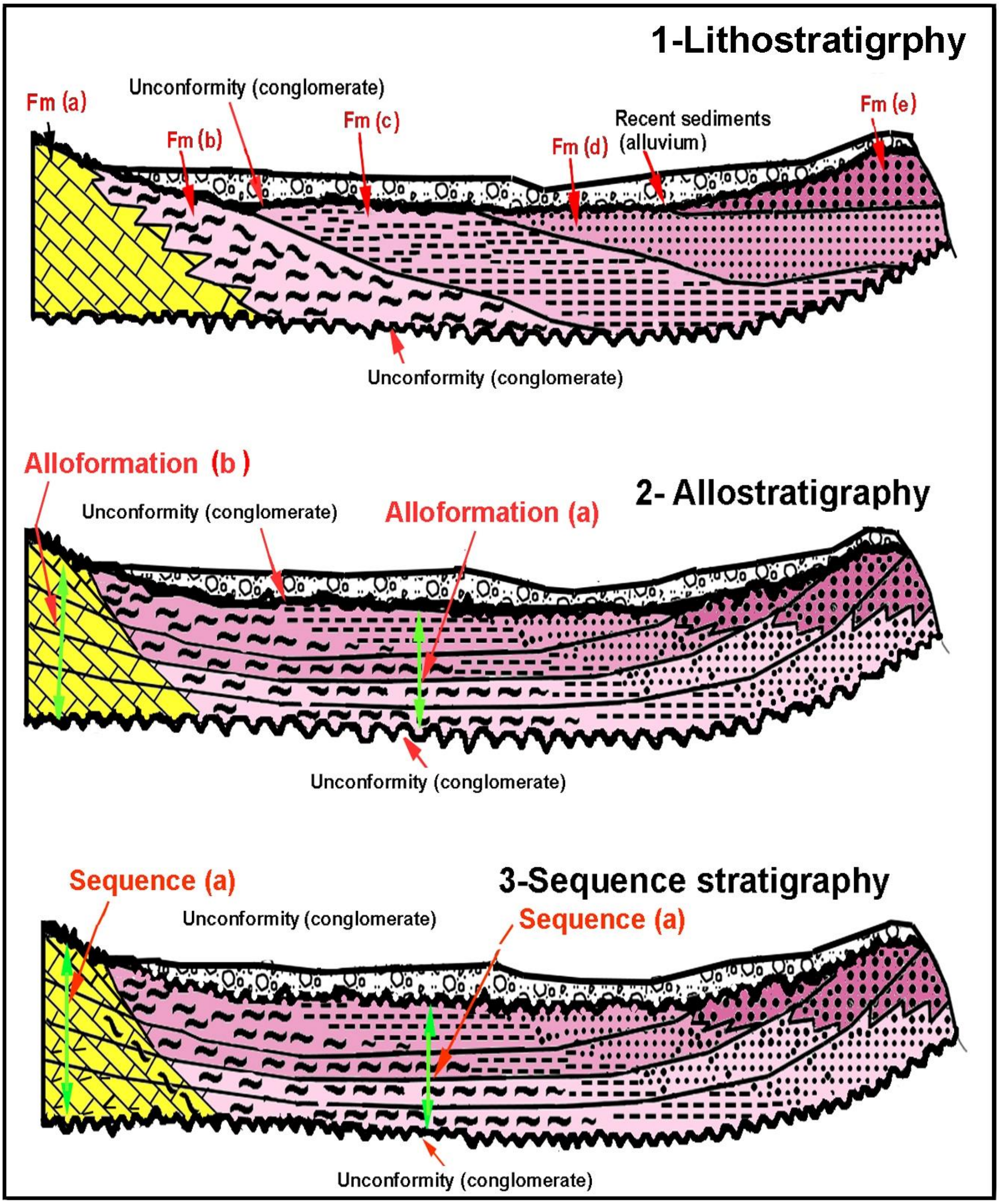


Fig. (4.13) Difference between lithostratigraphy, allostratigraphy and sequence stratigraphy when three applied to analysis (division) of the same succession with two unconformities. In the first, there are 5 formations while in the 2nd three are two alloformations but in the third there is only one sequence

5. References

1-The published papers of professor: Kamal Haji Karim, University of Sulaimani, kamal.karim@univsul.edu.iq which can be downloaded from Walash Naoperdan Series. kurdistan-geology.com

2-Einsele, G. 2000. Sedimentary Basin. 2nd ed. Springer, Verlage Berlin 792p.

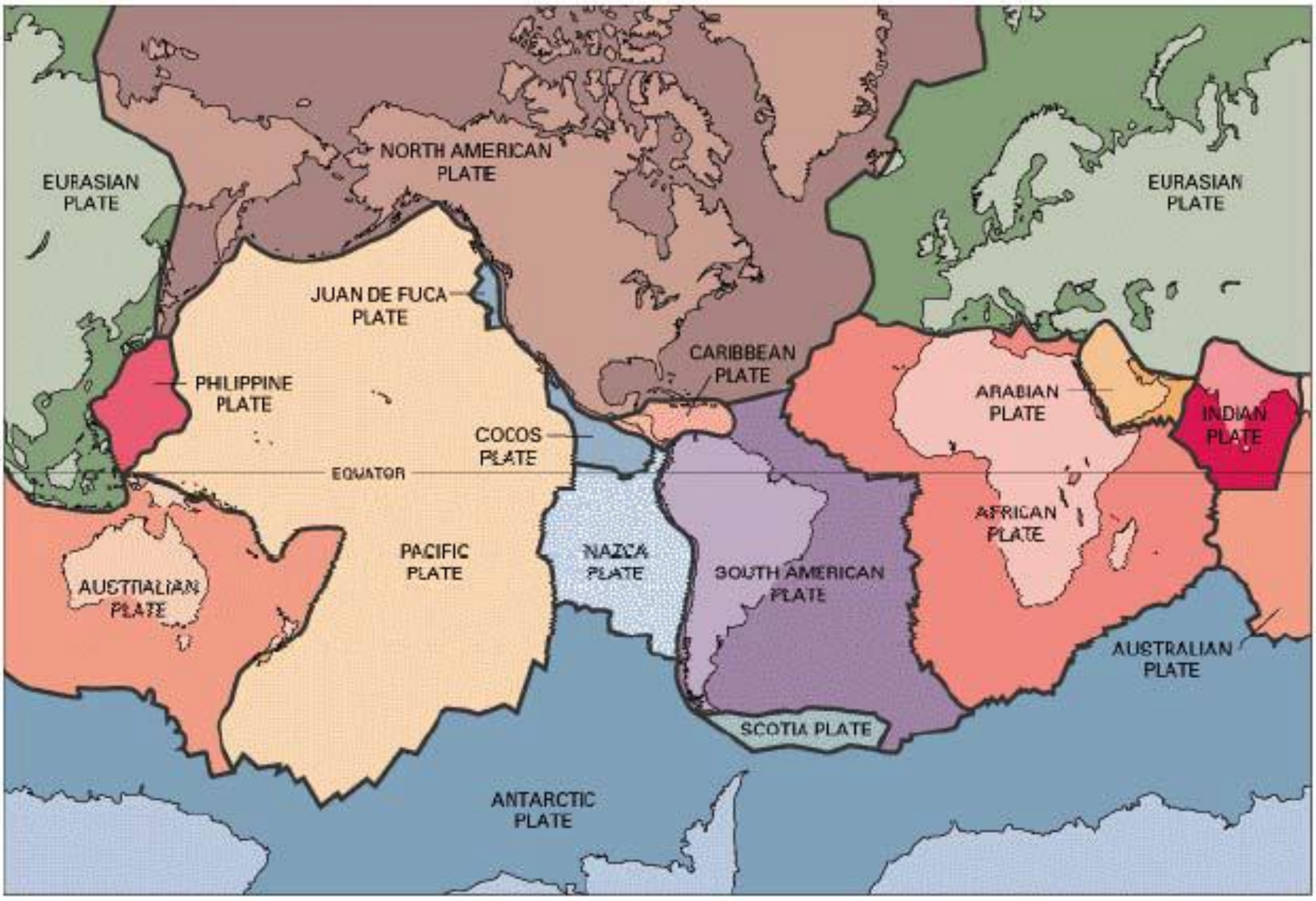
3-Catuneanu O (2004) Retroarc foreland systems—evolution through time Journal of African Earth Sciences 38 (2004) 225–242.

4-Sosson M (2010) Sedimentary Basin Tectonics from the Black Sea and Caucasus to the Arabian Platform, Geological Society of London, - Science - 509 page.

5-Wangen M (2010) Physical Principles of Sedimentary Basin Analysis, Cambridge University Press, p. 527.

6- Miall A (2013) Principles of Sedimentary Basin Analysis, Springer Science, Science – 616 pages.

7-Turcotte, D L and Schubert G (2002) Geodynamics, Cambridge University Press, 2002 - Science - 456 pages.



Main tectonic plates of the earth crust