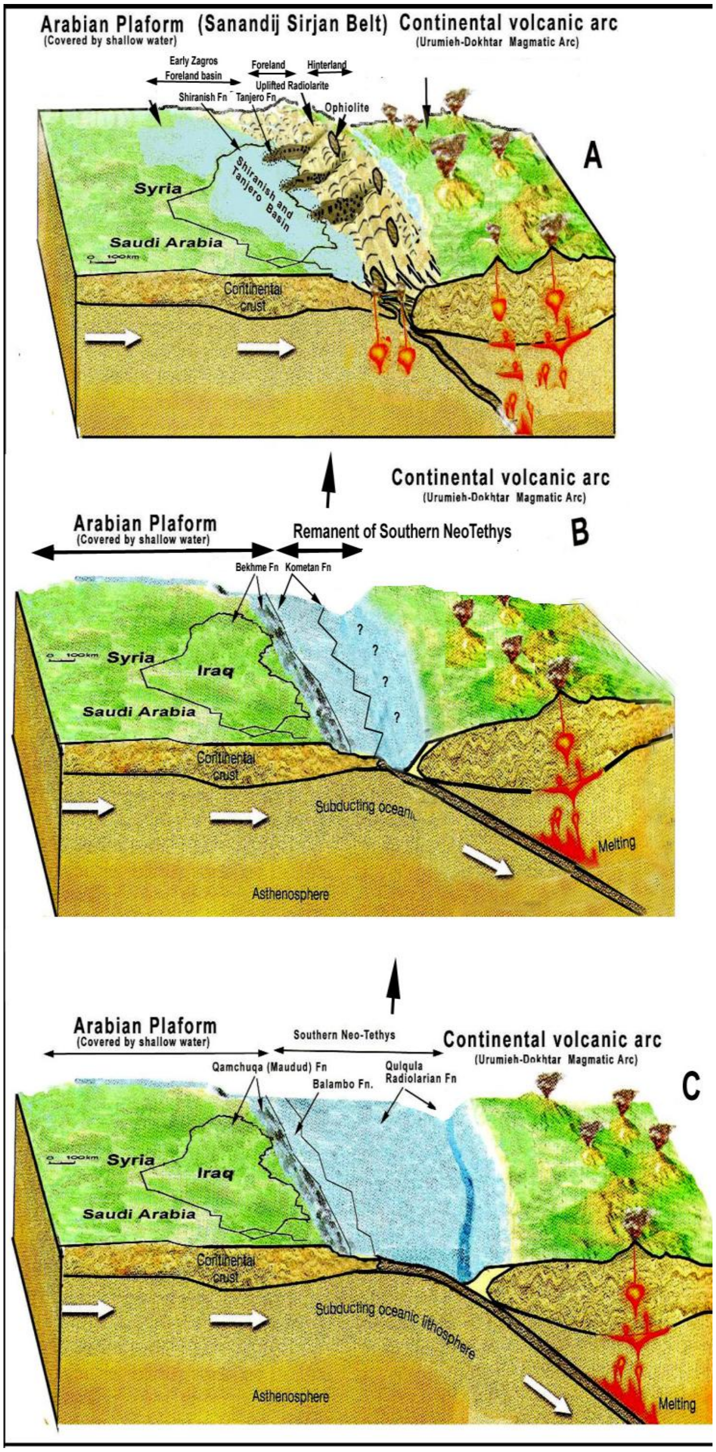


Geology of Iraq: Basic Principles

Description of stratigraphy, tectonics and boundary conditions of the some Rock units in Iraq and Kurdistan during Cretaceous and Tertiary

By professor: Kamal Haji Karim Ahmad

1-Introduction

1-1-Definition:

The geology of Iraq and Kurdistan is subject which try to describe and divide systematically the outcropped and subsurface rock column into small stratigraphic interval (or parts or units) such as groups, formations, members and beds). These parts (units) are grouped according to tectonic development and depositional history of the region.

1-2- Why do we study the geology of Kurdistan and Iraq?

A-Acadimic purpose for: a- understanding history of the area, b- Writing geological reports
B-Practical purpose: for knowing, a- seismic risk of the area, b- finding groundwater and oil accumulation of an area.
C- Finding raw material for cement, gypsum aggregates and metallic minerals
D-For understanding the engineering properties of formation in case of dam and other large structure building.

1-3-The subject of the geology of Iraq depends on many facts as follows:

1-3-1-Language (used terms or wordology)

The students must know that, as **all sciences, the geology of Iraq has its language (wordology) which taken from the science of stratigraphy, petrology, tectonic and sedimentology. The student must know the definitions of the scientific words or terms in order to understand them. Some of these terms are such as 1-Group, formation, member, beds, 2- Eon, Era, Period, Epoch, Age, 3-Eonothem, Erathem, System, Series, Stage. 4-Paleozoic, Mesozoic, Cenozoic, 5-Cambrican, Ordovician, Silurian, Devonian, Carbnoniferous, Triassic, Permian, Jurassic, Cretaceous, Paleogene, Neogene. 5-Ooid (oolite), peloid, pellet, bioclasts, foraminifera, gastropod, pelecypod, rudist, bivalve, coral, algae.**

1-3-2- Geology of Iraq deals mainly with formation as the main rock stratigraphic unit (part) (lithostratigraphic units).

1-3-3-Definition of Formation

It is a lithostratigraphic unit (rock unit) which has certain lithology and mapable. When new formation is found it is named by geographic name with term formation (such as

Tanjero Formation, Pila Spi Formation). In a certain basin or certain tectonic activity many formations are deposited such as Maastrichtian Foreland basin in which Tanjero, Shiranish, Aqra, Digma and Tyiarat Formations are deposited.

1-3-4- Present structure of Iraq

Iraq can be consider as a large anticline (or anticlinorium) which has the trend of NW-SE and contain many small folds (syncline and anticlines). The northeastern limb of this anticline has suffered from recumbence and then thrusting over the southwestern limb. Because of colliding of Arabian and Iranian plates now Iraq is divided tectonically to , Western desert, Mesopotamian (Unfolded Zone), Low Folded, High Folded, Imbricated and Thrust Zones from southwest toward northwest (figs.1-3-4-1 and 1-3-4-2).

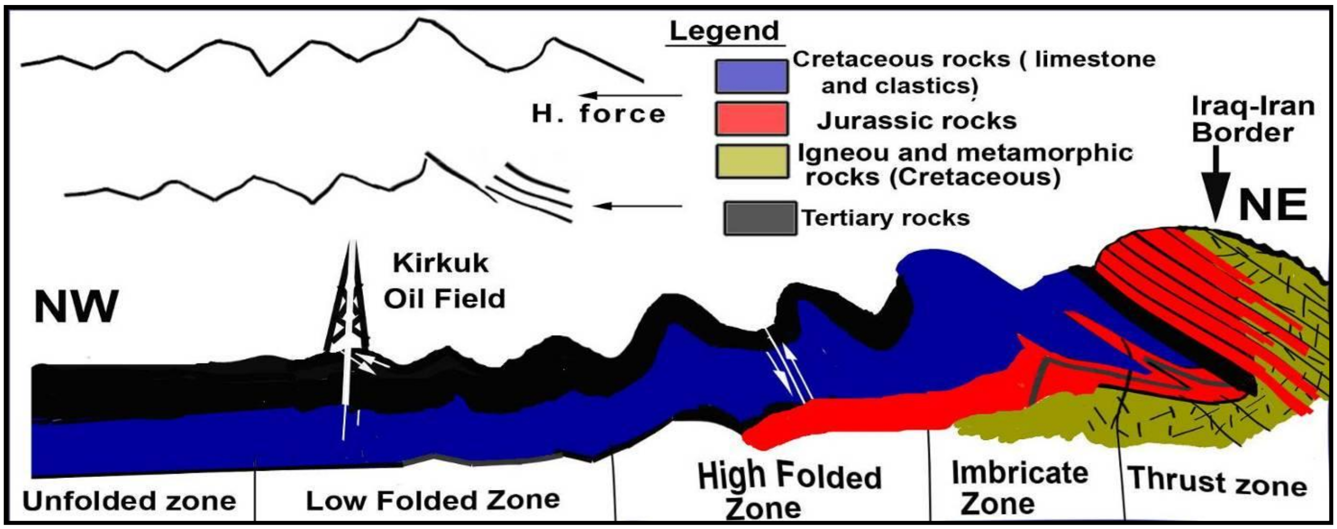


Fig.(1-3-4-1) Tectonic subdivision of Iraq

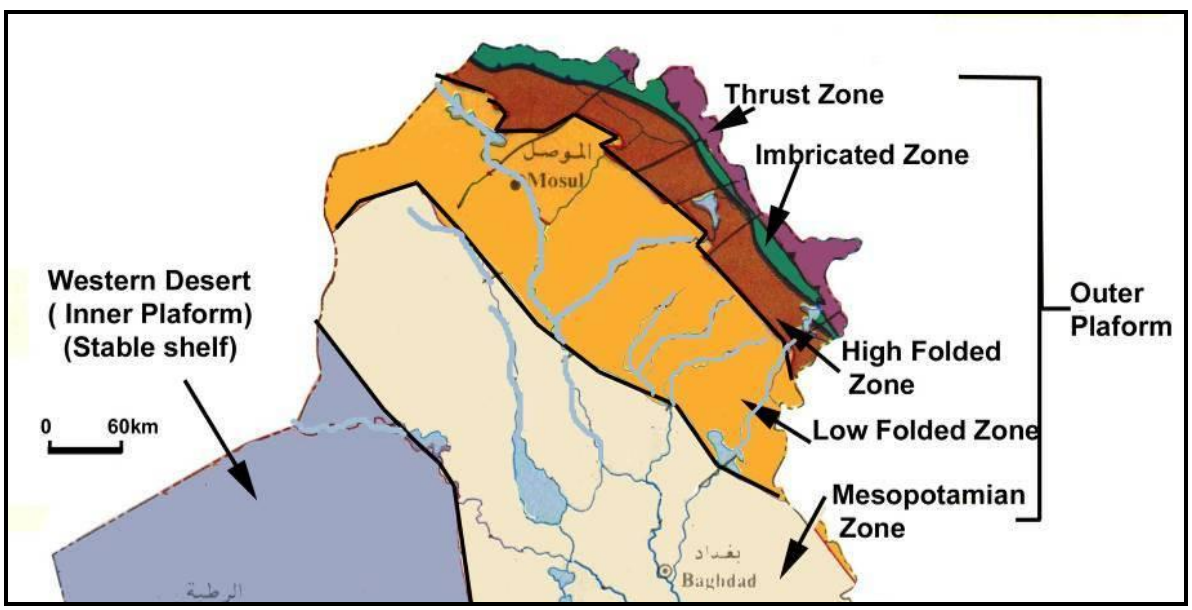


Fig.(1-3-4- 2) Iraq map shows the most realistic (useful) tectonic subdivision of Iraq (Budy,1980 and Buday and Jassim,1987)

1-3-5-Time expanded stratigraphic (chronostratigraphic) column of Iraq.

It is that type of stratigraphic column in which the lithology are indicated from older to younger from bottom to top respectively. The missing ages (those ages that have not representative Lithology) are expanded and shown on the column (see figure1-3-5-1).

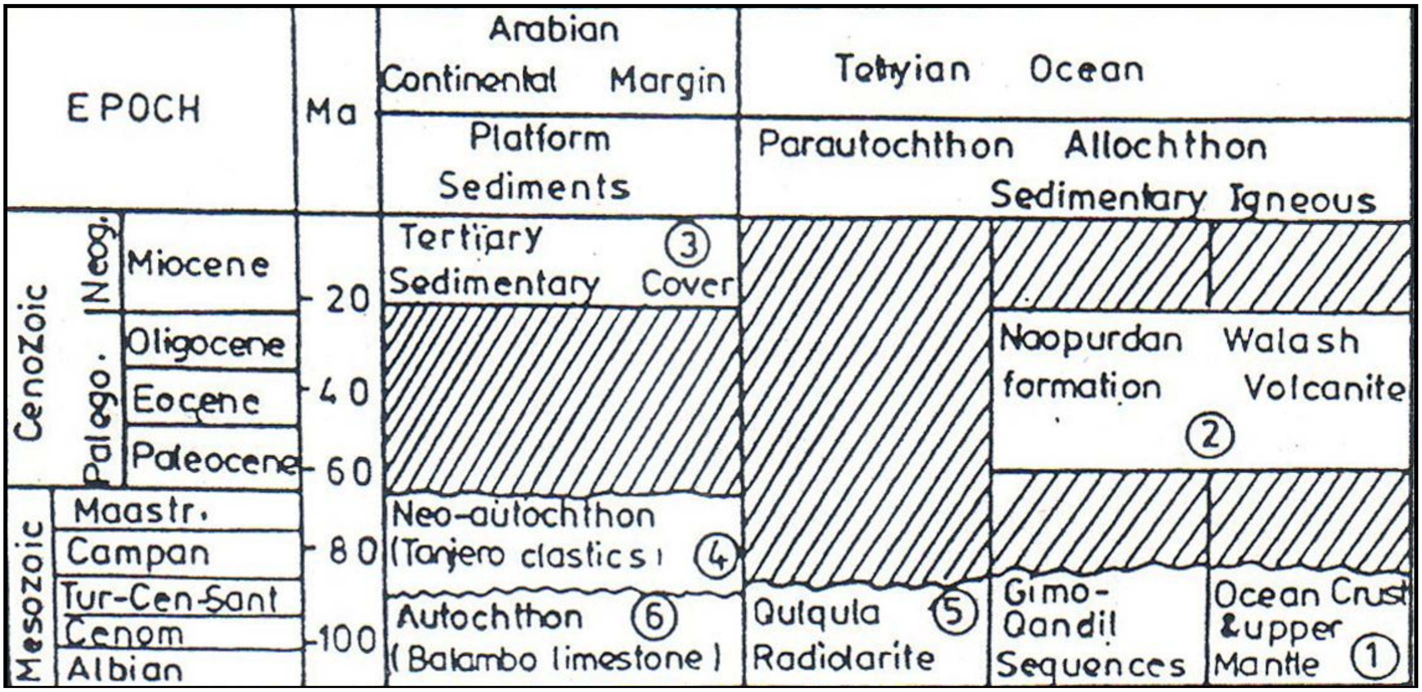


Fig.(1-3-5-1) time expanded stratigraphic column of Kurdistan during Mesozoic and Cenozoic (Aswad, 1999).

1-3-6-Normal stratigraphic column

It is that type of stratigraphic column in which the age, lithology are indicated from older to younger from bottom to top respectively. The time of non-deposition or erosion is indicated by zig zag line (Fig.1-3-7-2)

1-3-7-<u>Field work</u>

The geology of Iraq and Kurdistan cannot be understandable without the field observation of:

1-lithologies and their colors, 2- bedding pattern, 3- thickness and fossil contend 4- nature of lower and upper contact, 5- Stratigraphic position. Plotting the formation on prepared geological map. 5- Classification (division) of the existed rocks to stratigraphic units. Many tools are used during fieldworks such as hand lens (of 10X magnification) and compass (fig.1-3-7-1) in addition to hammer.

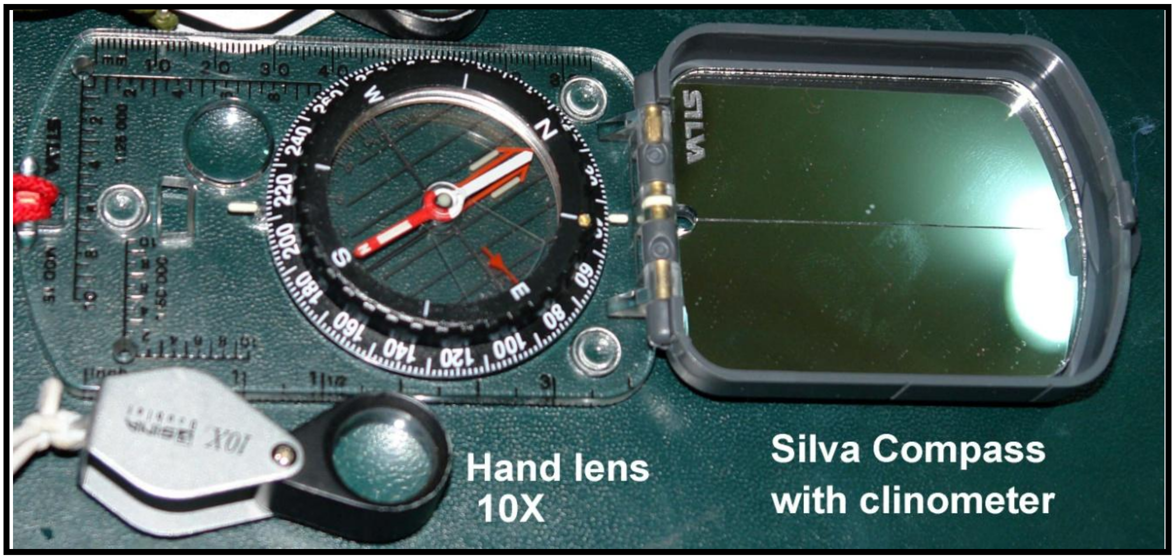


Fig.(1-3-7-1)some of the tools that are used during fieldworks

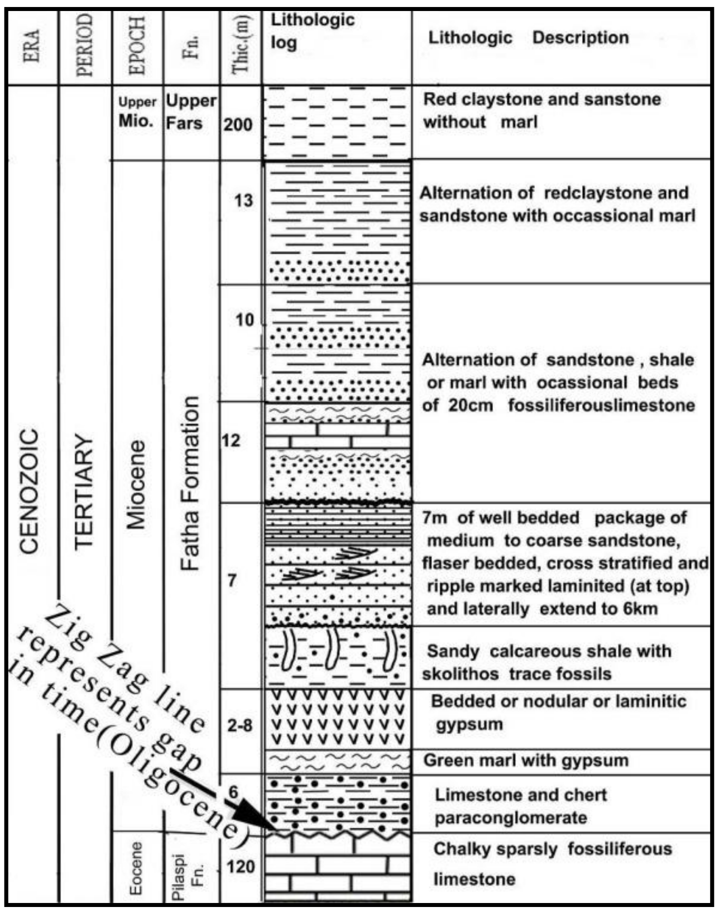


Fig.(1-3-7-2) Normal stratigraphic column of Kurdistan during Middle Eocene -Miocene in which Oligocene missed (has not representative rocks) (Ameen, 2007).

Fig. (1-3-7-3) field work by 4th year students (2003) on the border with Iran at the west of Mawat town

1-3-8-Neotethys sea

It is that elongated and deep basin (ocean) that located between Arabian plate (or Afro-Arabian plate) and Iranian Plate. It is consisted of two parts: 1-Southern Neo-Tethys and 2-Northern Neo-Tethys. The Southern one was covered Kurdistan and Iraq and nearly half of the Iran (fig.1.3.8). The Neo-Tethys Sea has passed through two main phases:

1-3-9- oceanic phase

This phase was existing during Jurassic and Early Cretaceous and the Neo-Tethys was consisted of relatively deep ocean in which radiolarites was depositing on its basin plain and trench while on its continental margin (platform) carbonate or evaporites were depositing (fig.1.8.3C).

1-3-9-Foreland basin phase (During Late cretaceous and Tertiary)

It is defined as:

It is a basin that is formed in front of moving (advancing) orogenic belt. It is formed on a stable area (former platform) which is marginal to an orogenic belt, toward which the rocks of the orogenic belt were thrust or over folded. Generally, the foreland is a continental part of the crust and is the edge of craton or platform area. The reliefs (mountains) are created by uplifting of the orogenic wedge. The erosion of these mountains supplies detritus to fill the foreland basin (Fig.18.3A)
There is two types of Foreland basin:

1-3-9-1-Underfilled Basin or stage during late Cretaceous

In this stage, it is deep and underfilled (not filled) foreland basins in which turbidite or flysch is deposited: like basin of Tanjero and Kolosh Formations.

1-3-9-2-Overfilled basin (During Eocene and later ages)

it the last stage of development of foreland basin in which molasses sediment are deposited such as basin of Red Bed Series, Gercus and Upper Bakhtiary Formations.

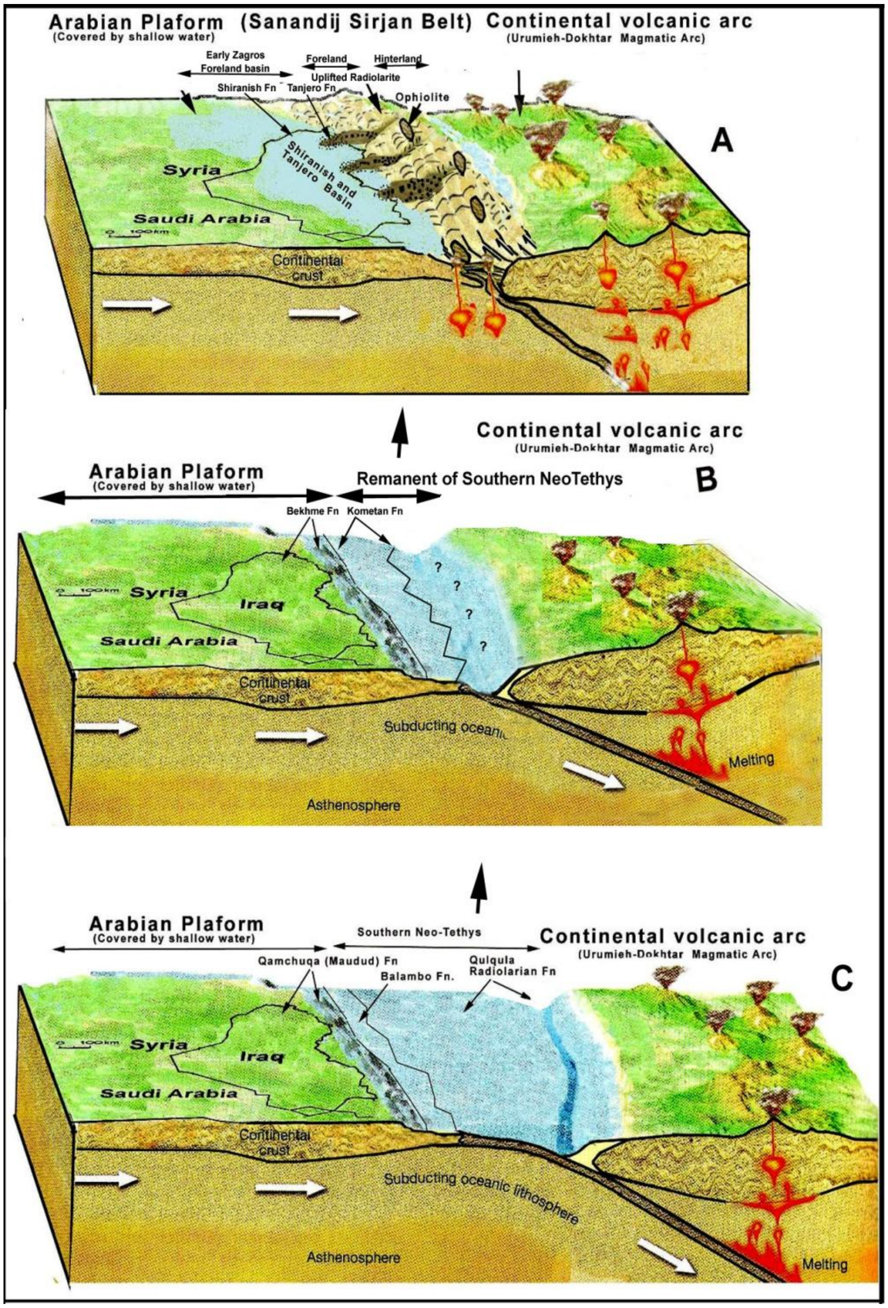


Fig.(1-3-8) Three different stages of the evolution of the Neo-Tethys, C) Ocenic stage which has the continental margin (Arabian platform) on which most Iraq and Kurdistan were located in Early Cretaceous. A) Foreland basin phase which started during late Cretaceous (Campanian) after closure of the southern Neo-Tethys. B) Transitional phase between the two above phase in which Tethys became narrower and shallower than C phase.

1-3-10-Facies maps (lithofacies maps)

These types of maps are useful in studying geology of Iraq and Kurdistan. They are those maps that show aerial (geographic) distribution of the rocks and their thickness map is very useful for understanding environment and tectonic of an area (see figure 1-3-10-1).

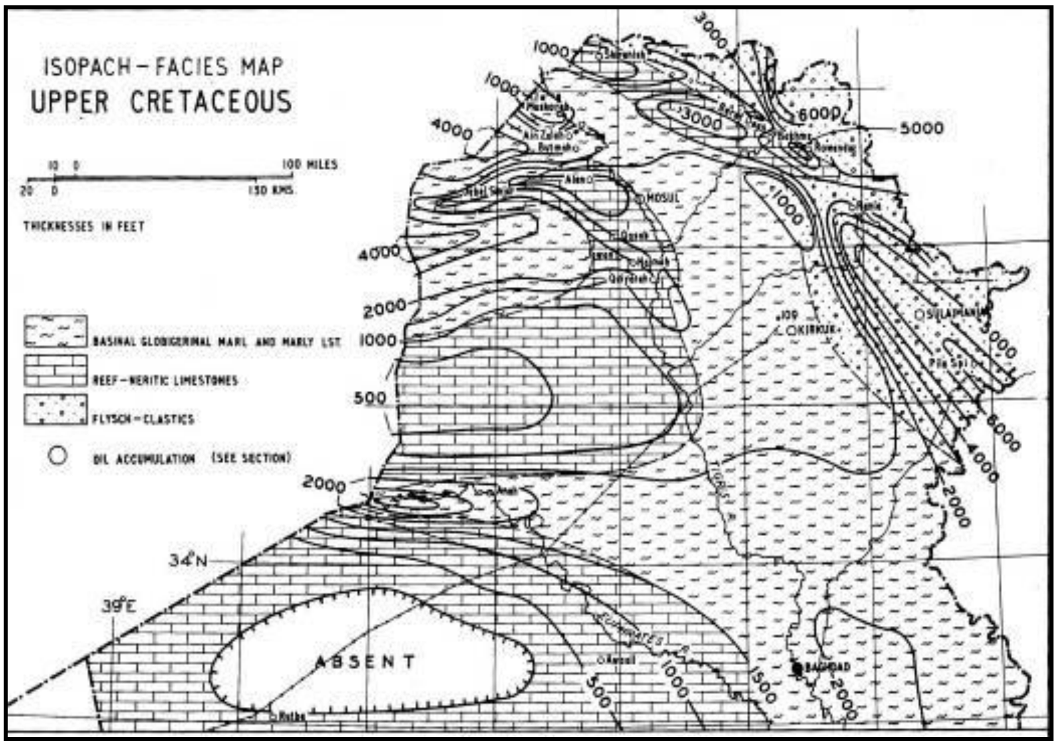


Fig.(1-3-10-1) Isopach facies map of Late Cretaceous (Dunnington, 1958) shows lithofacies and thickness distribution of Late Cretaceous (Maastrichtian).

1-3-11-Alluvium deposits (Quaternary deposits)

Alluvium sediments and soil cover most part of the Iraq that make identification and geological mapping of the surface formations (rocks) are difficult. Therefore, it is important to differentiate these sediments from older rocks (formations).

1-3-11-1- Definition of the alluvium

They are all loose (in some case they are lithified) sediments that deposited by running water which include:

1-Alluvuial fan deposits which consist of boulder, gravel, sand silt and clay deposits. The boulder and gravel are generally: 1- angular, 2- Badly sorted, 3-Mineralogically immature, 4- they have fan shape (Fig.1-3-11-1 and 1-3-11-2).

2-River bed deposits: they consist of sorted, rounded and mature boulder gravel and sand (Fig.1-3-11-3).

3-Flood plain sediments: they are fine detrital sediments that deposited during very large flooding (Fig.1-3-11-1).

Fig. (1-3-11-1) Deposit of alluvium fan at west of Sulaimani city underlain by flood plain clay.

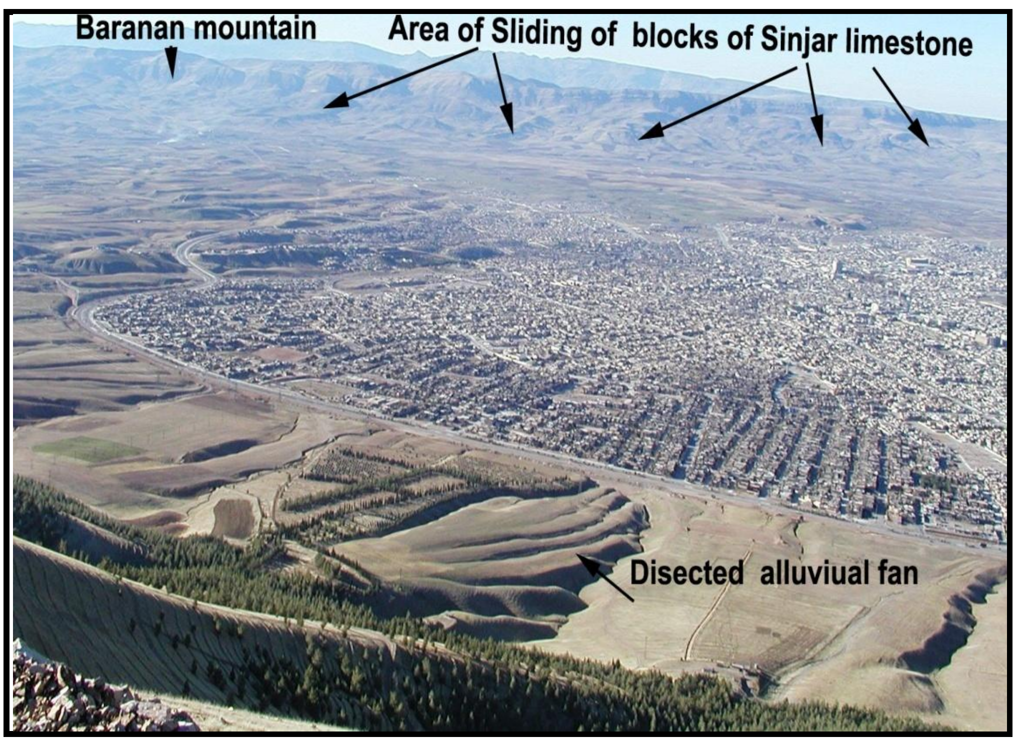


Fig. (1-3-11-2) Foreground: northeastern of Sulaimani city (pediment of Goizha Mountain) shows proximal part of several alluvial fans (Ali, 2007). Background: Baranan Mountain which contains area of sliding of blocks of Sinjar Formation on Kolosh Formation.

Fig.(1-3-11-3) Riverbed deposits of a braided river near Darbandikhan town which is mostly consist of gravel and boulder

1-3-11- boundary condition

The most important feature or property of any formation is its boundary condition. This characteristic includes the vertical and lateral lithological and facies changes. The vertical changes show if the boundary is conformable or unconformable and what is the transitional zone when the boundary is conformable. The lateral change indicates the basin extent and location of the shoreline in the basin. On the outcrops, the indication of the boundary condition depends on the large scale fieldwork during which the sedimentology, sequence stratigraphy and structure of the area of the distribution of the formation are studied. In the subsurface it depends of the large numbers of wells and seismic reflection data.

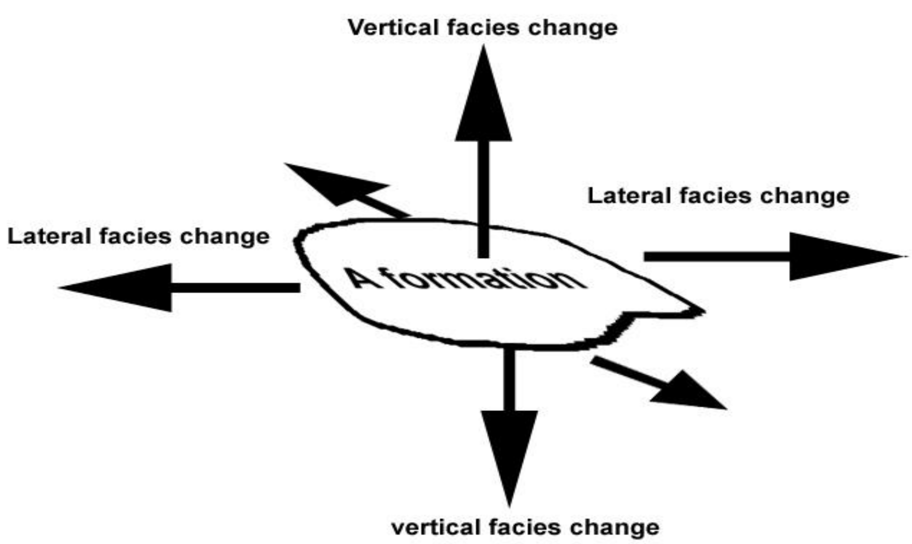


Fig. (1-3-11-1) boundary condition of a formation must be studied in all direction and may extend to tens or hundreds of kilometers far from formation border.

2-Main steps (or phases) of development of the Geology of the Kurdistan

The present existed formations are deposited in different basins and reflect 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 which the Lower part of the Qulqula Radiolarite Formation is deposited (Fig.2.1).

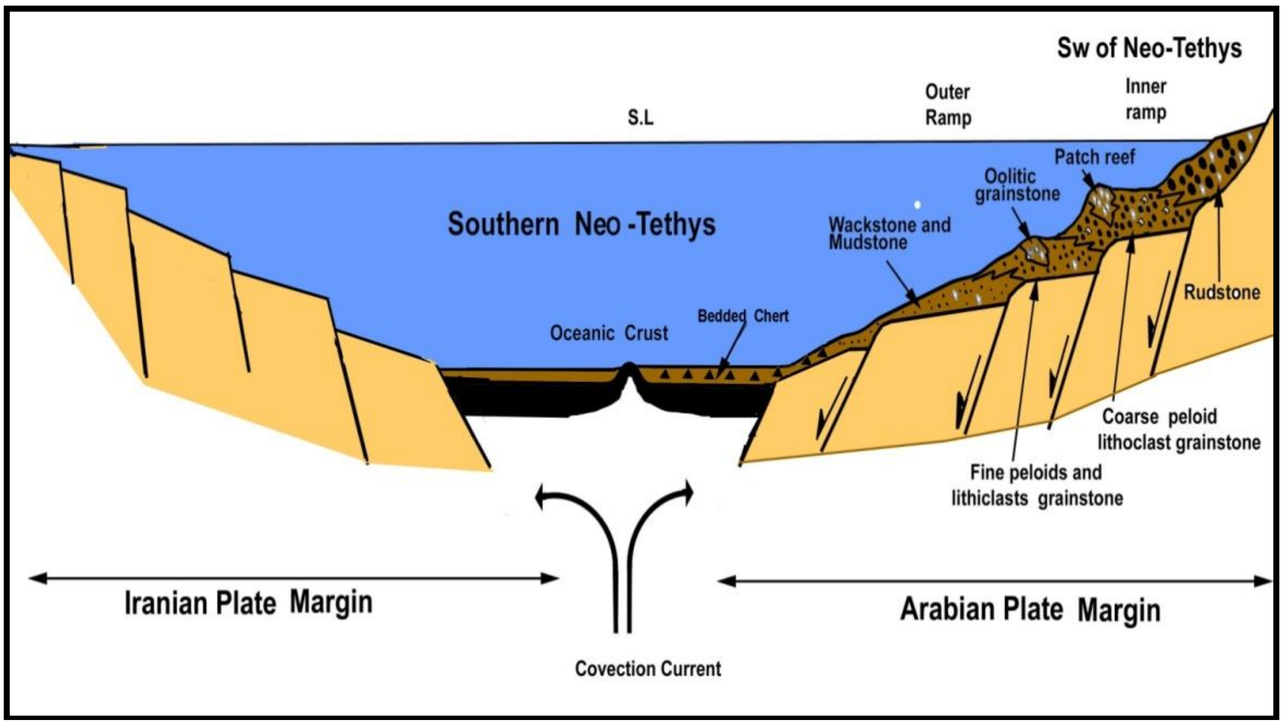


Fig.(2-1)Tectonic model of the Southern Neo-Tethys during Jurassic in which Lower part of Qulqula Radiolarian Formation is deposited (Baba Shekh, 2009). The basin was relatively small and narrow. At the beginning of Cretaceous, it had changed from divergent to convergent.

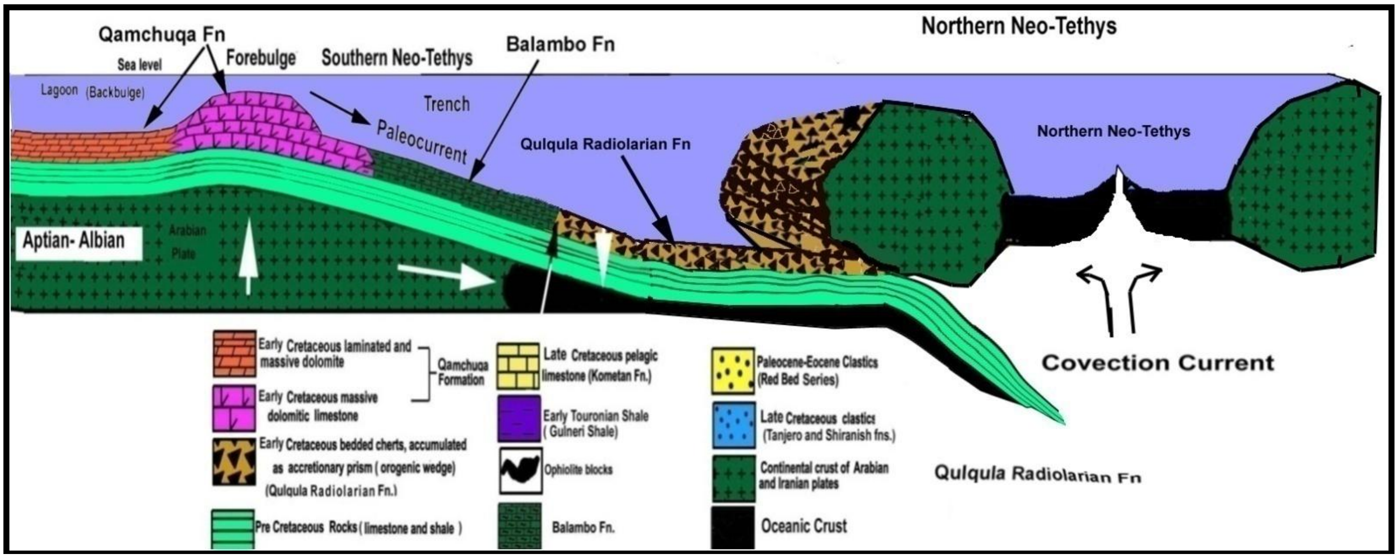


Fig.(2-2)Tectonic model of the Southern and northern Neo-Tethys during Early Cretaceous upper part of the Qulqula Radiolarian Formation as equivalent of Balambo and Qamchuqa Formations. The basin was relatively small and narrow. At the beginning of Cretaceous, it had changed from divergent to convergent.

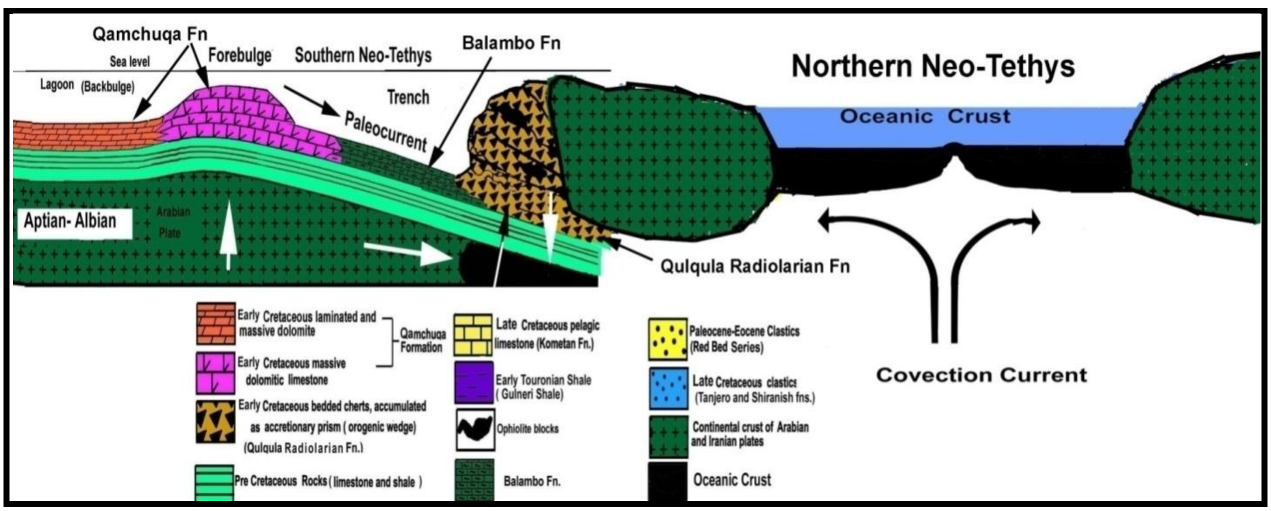


Fig.(2-3) The convergent of the southern Neo-Tethys is most possibly due to pushing stress of the Northern Neo-Tethys which was at the divergent phase.

2- The convergent phase is started at the beginning of the Cretaceous due to widening of the Northern Neo-Tethys, the pulling force of which was more than that of the southern one (See fig.2-2). By this pulling the Iranian plate had advanced toward southwest (toward Iraq).

3- The huge amount of the Radiolarites and Ophiolites (Trench materials) are accumulated in the trench between the two plates (See figure 2-3 and 2-4). This accumulation formed a forebulge on which Qamchuqa Formation was deposited

4- The further advance and accumulation of the accretionary prism has forced the forebulge to subside (drown) during the downing Gulneri Formation is deposited. While after drowning the Kometan Formation is deposited (fig.2.6).

5- The further advance of the Iranian plate forced the accretionary prism to be thrown on to Arabian platform. This throw of radiolarite and ophiolite on to Arabian Platform had formed a continental land and foreland basin during Campanian (Fig.2.7).

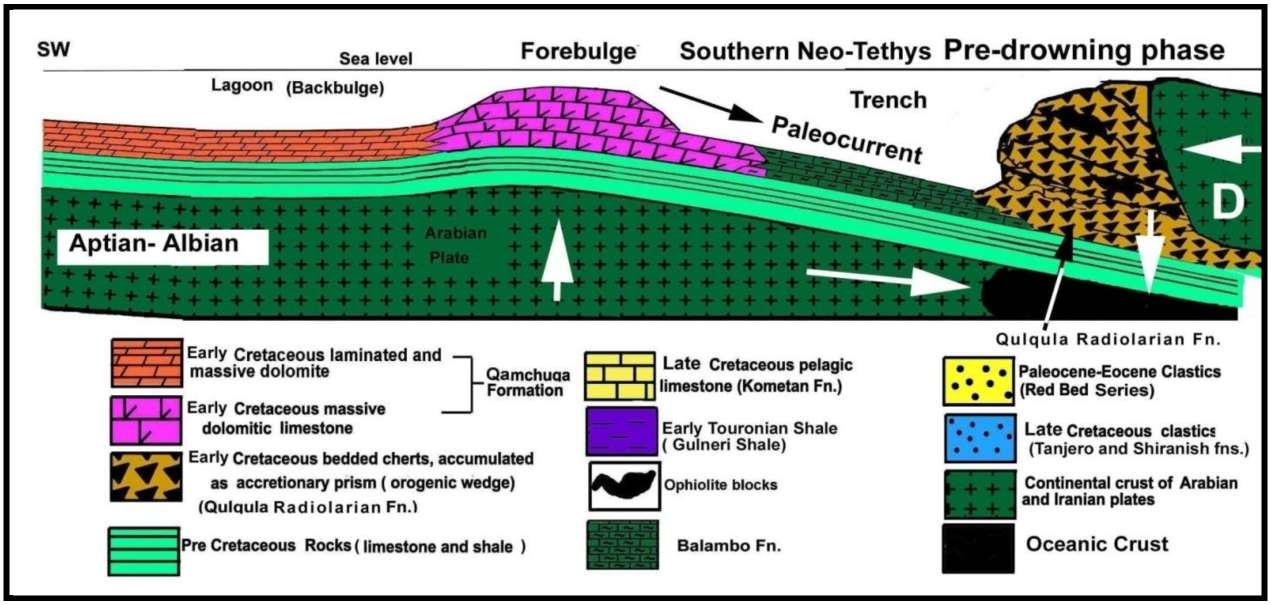


Fig.(2-4) Depositional history of Early Cretaceous basin in which Qamchuqa and Balambo and Qulqula Radiolarite Formations are deposited (Ameen, 2008). Under the load of the trench materials (accretionary materials), the Arabian plate is suffered from flexure which is formed forebulge (submerged high). On this paleohigh Qamchuqa Formation is deposited as reefal and lagoonal sediments.

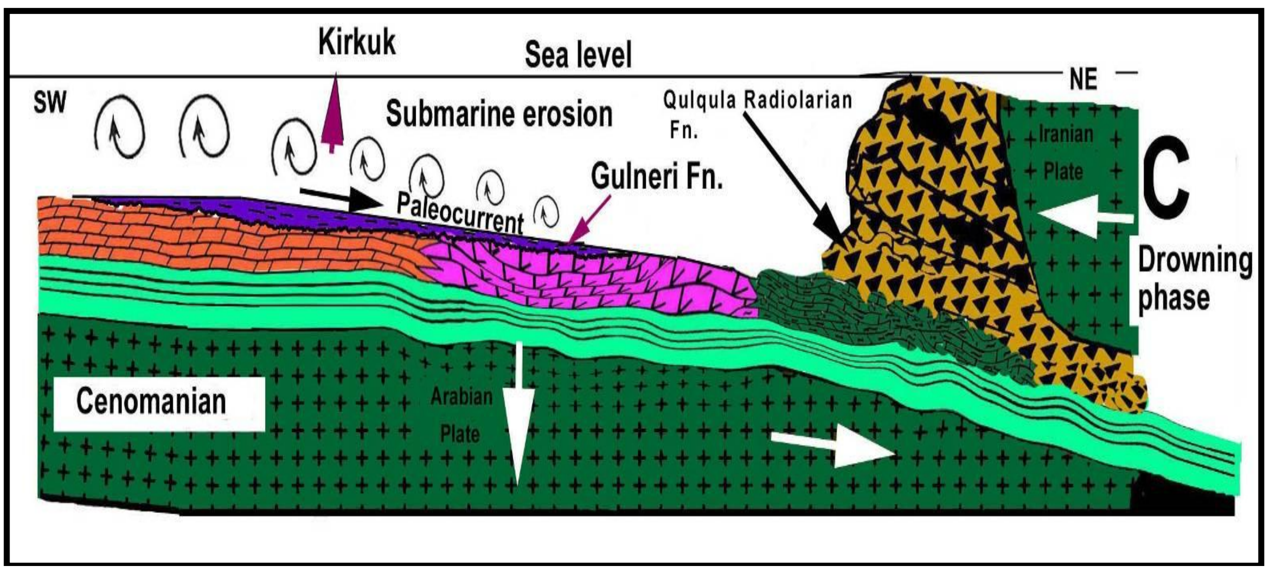


Fig.(2-5) Tectonic and depositional model of the Upper (Late) Cretaceous (Cenomainan) basin in which Kometan is deposited. The Kometan Formation is deposited after drowning of the Arabian Platform (Qamchuqa Formation) under the load of the Trench material (accretionary prism materials) and Iranian plate. The forebulge is subsided and during subsiding Dokan and Gulneri Formations are deposited as Transitional facies (as sediments of intermediate depth between shallow (Qamchuqa) and deep (Kometan) facies (Taha, 2008)

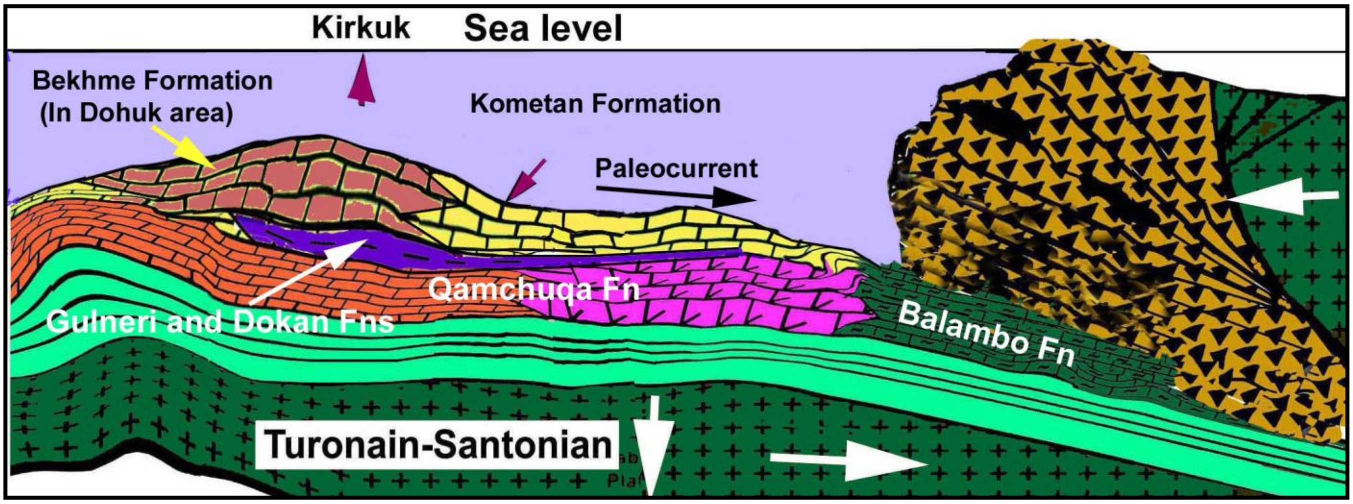


Fig.(2.6) Tectonic and depositional model of the Upper (Late) Cretaceous (Turonian-Campanian) basin in which Kometan and Bekhme Formation are deposited. The Kometan Formation is deposited after drowning of the Arabian Platform (Qamchuqa) Formation under the load of the both Trench materials (Accretionary prism materials) and the Iranian plate, forebulge subsided (deepened). The paleocurrent was toward northeast. On this forebulge Qamchuqa Formation is deposited.

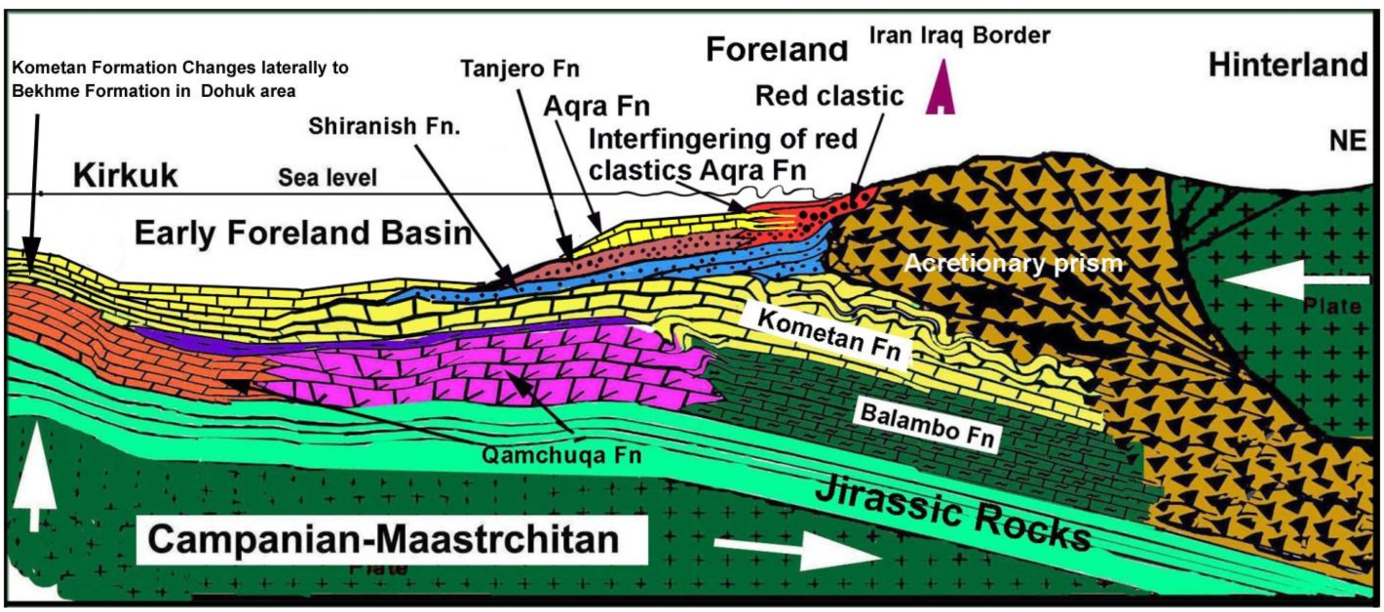


Fig.(2.7) Combination of tectonic and depositional setting of Upper (Late) Cretaceous basin in which Shiranish and Tanjero Formation are deposited (Karim, 2008). During Campanian the Continental parts of the Iranian and Arabian plates are collided. By this, the trench materials (Accretionary materials) are thrown (pushed on to) the Arabian Platform. Due to this colliding a terrestrial land had generated during Campanian and the paleocurrent is reversed toward southwest. In addition to that a Foreland basin is formed in front of the Iranian Plate as can be seen from figure above (Karim, 2004).

6- The further advance of the Iranian plate forced the accretionary prism to be thrown on to Arabian platform. This throw of radiolarite and ophiolite on Arabian Platform had formed a continental land and foreland basin in front of the land during Campanian (Fig.2.7).

7-The condition of the geological setting of the foreland basin was very similar to that of Campanian-Maastrichtian. In the foreland basin the Kolosh Formation is deposited as lateral facies change of Red Bed Series in the deeper part of the basin. In the coastal area of the basin Red Bed Series are deposited in continental environment which was rich in oxygen. Aliji is deposited in deeper part of the basin toward southeast (Fig.2.8).

7- During Eocene, the geological setting of the foreland basin was very similar to that of Paleocene except for more advance of the front of the orogenic wedge toward southeast. The source had suffered from some subsidence and the basin becomes shallower due to filling with sediments. The basin topography had changed by which some submerged paleohigh raised and on these pleohighs the Sinjar Formation was deposited in between Red Bed Series and Jaddala Formations (Fig.2.9).

8- During Middle Eocene the foreland basin was divided to two parts , in the northeastern part Walash-Nauperdan was deposited while in the southwestern one Pila Spi Formation was deposited (Fig.2.10)

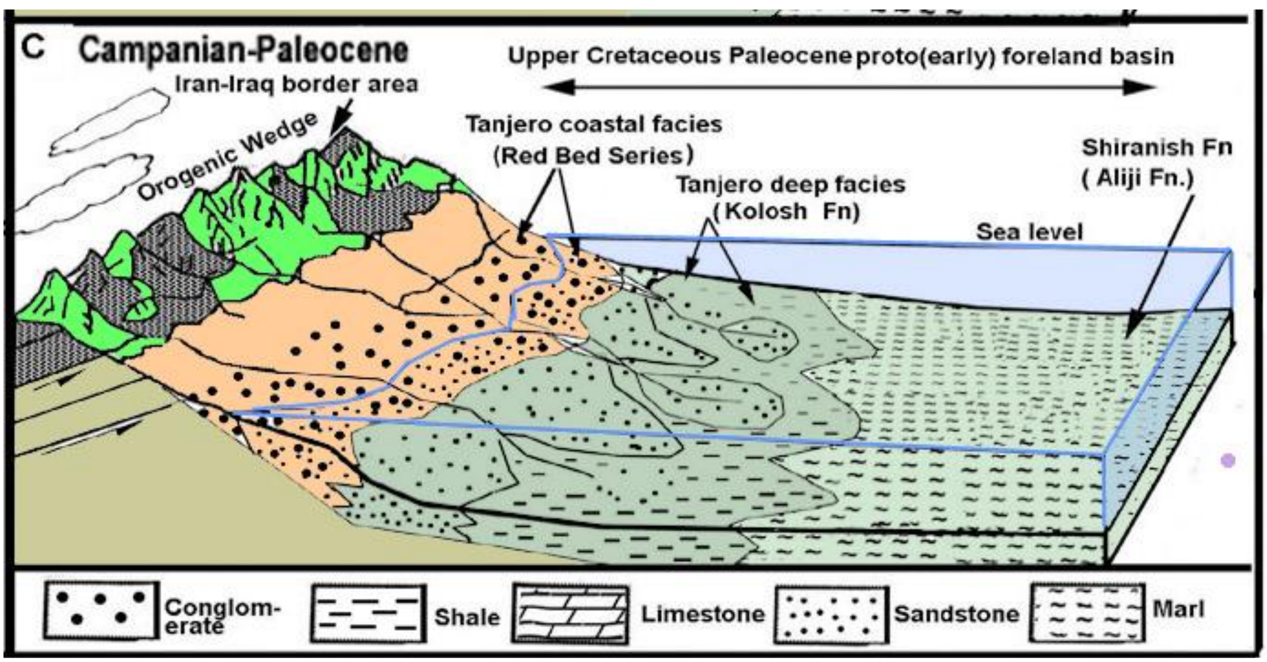


Fig.(2.8) Tectonic and depositional model which is fit (suitable) for both Upper (Late) Cretaceous and Paleocene basins in which Tanjero and Kolosh formations and Red Bed Series are deposited during Maastrichtian and Paleocene respectively (Karim, et al, 2008).

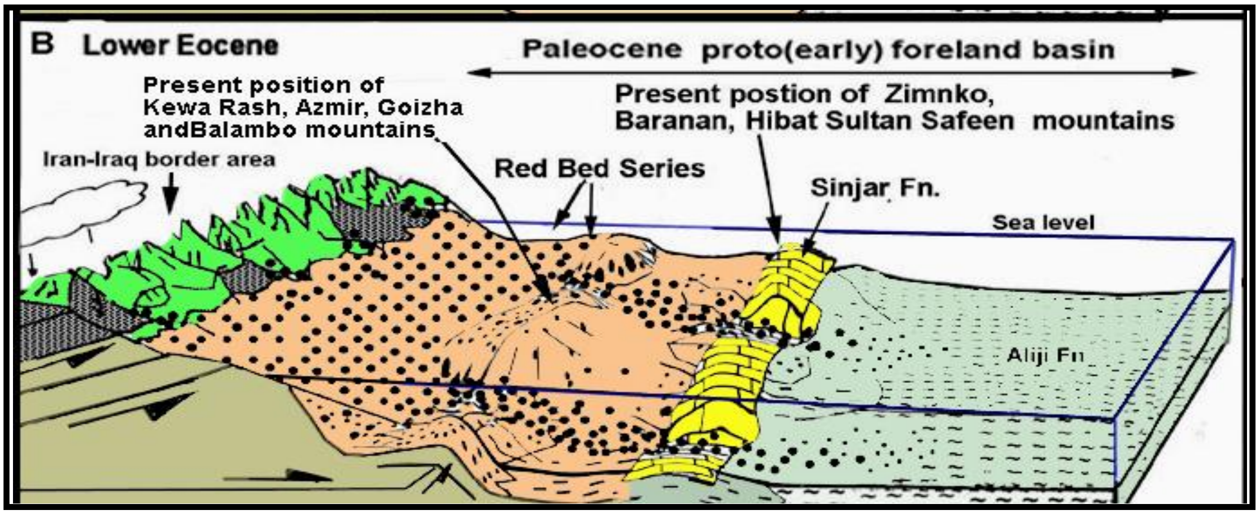


Fig.(2.9) Tectonic and depositional history Paleocene basins which is nearly similar to that of the Paleocene except for existence of some submerged highs on which Sinjar Formation is deposited as seen in the figure above (Karim, et al, 2008).

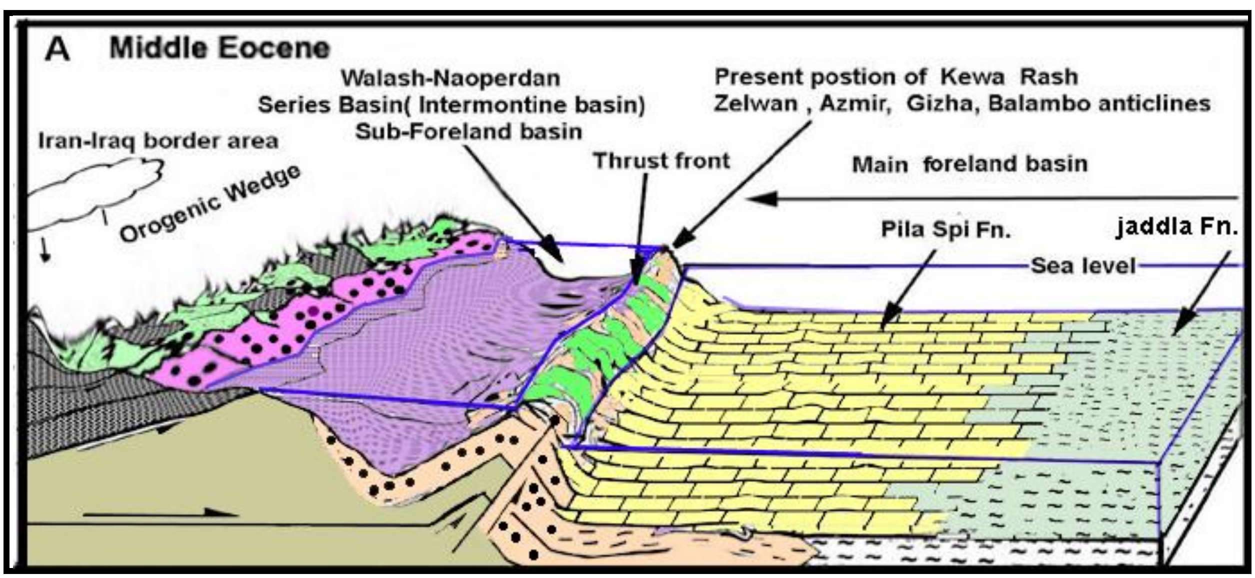


Fig.(2.10) Tectonic setting of Middle Eocene basins in which the Zagros Foreland basin is separated into two smaller basin in which Walash-Naoperdan Series and Pila Spi Formation are deposited in the northern and southern basin respectively as seen in the figure above (Karim, et al, 2008).

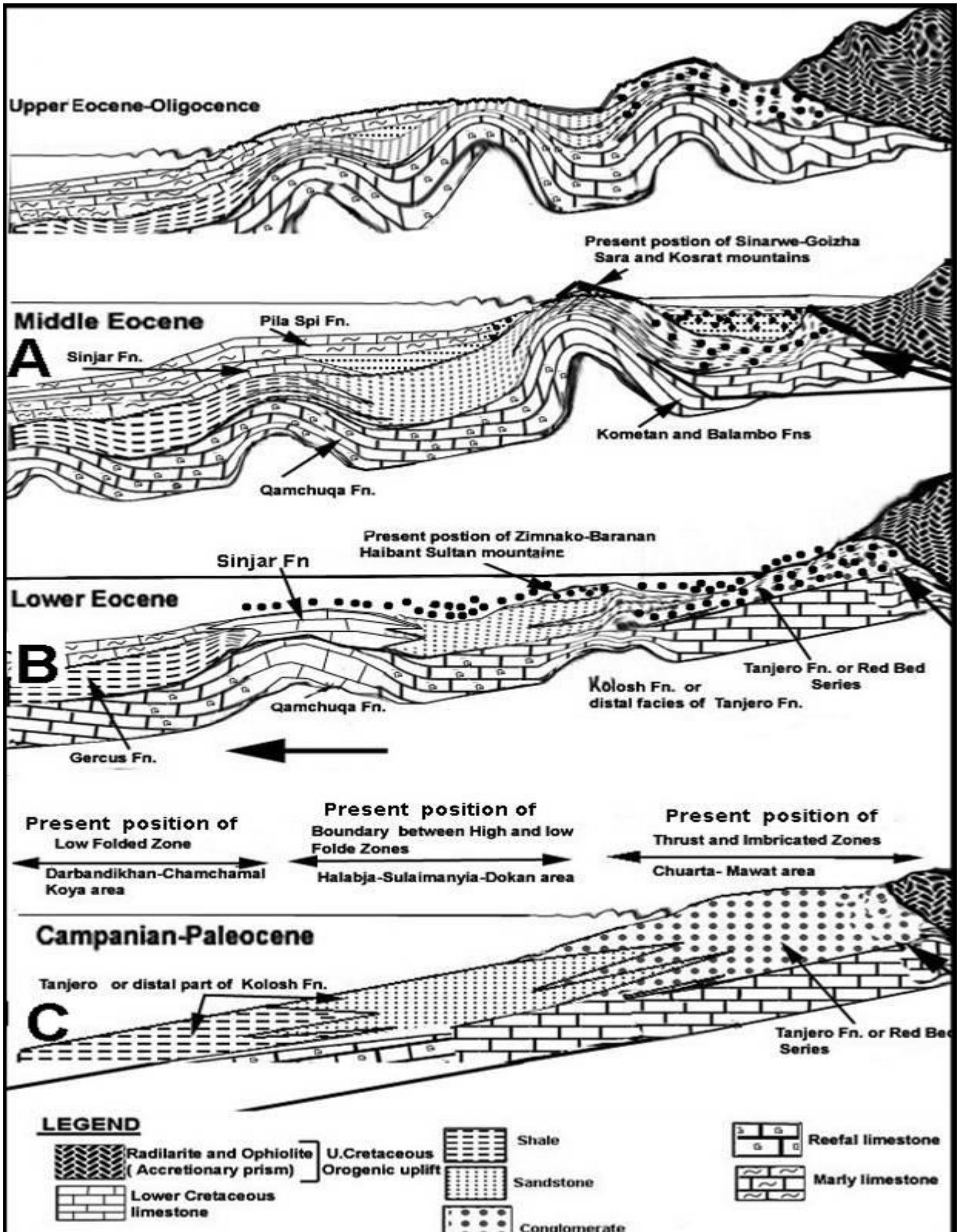


Fig.(2.13) Different cross section of the same ages and models that are shown in the previous page (fig.24) showing generation of intermountain basin during Middle Eocene (Karim et al, 2008).

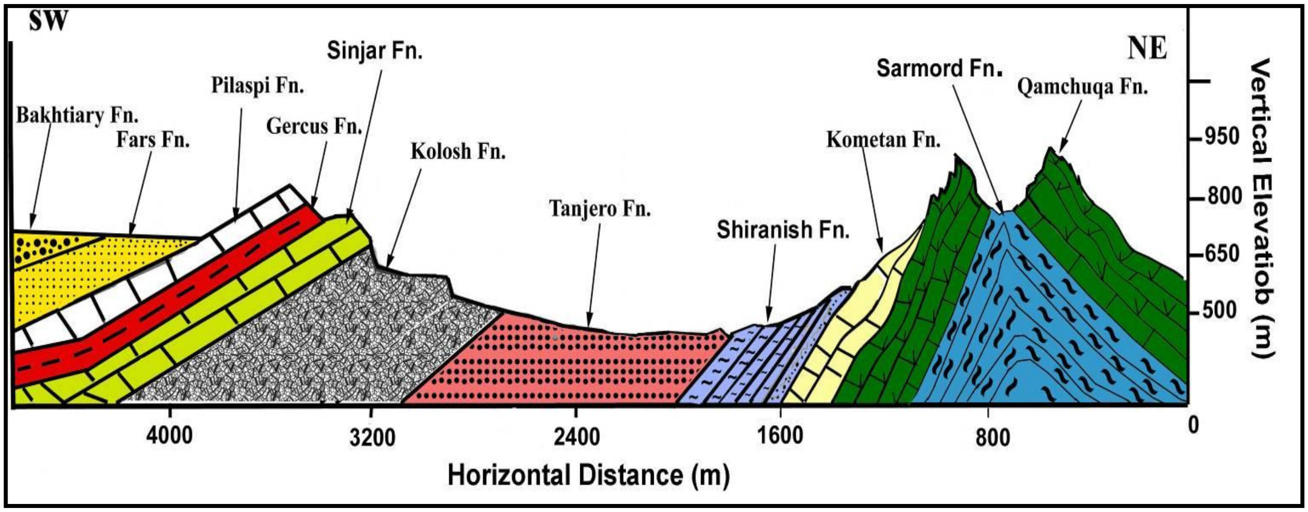


Fig.(2.14) Geologic Cross section of the Piramagroon anticline, Jarmaga Valley and Chaqizm mountains (Taha, 2005).

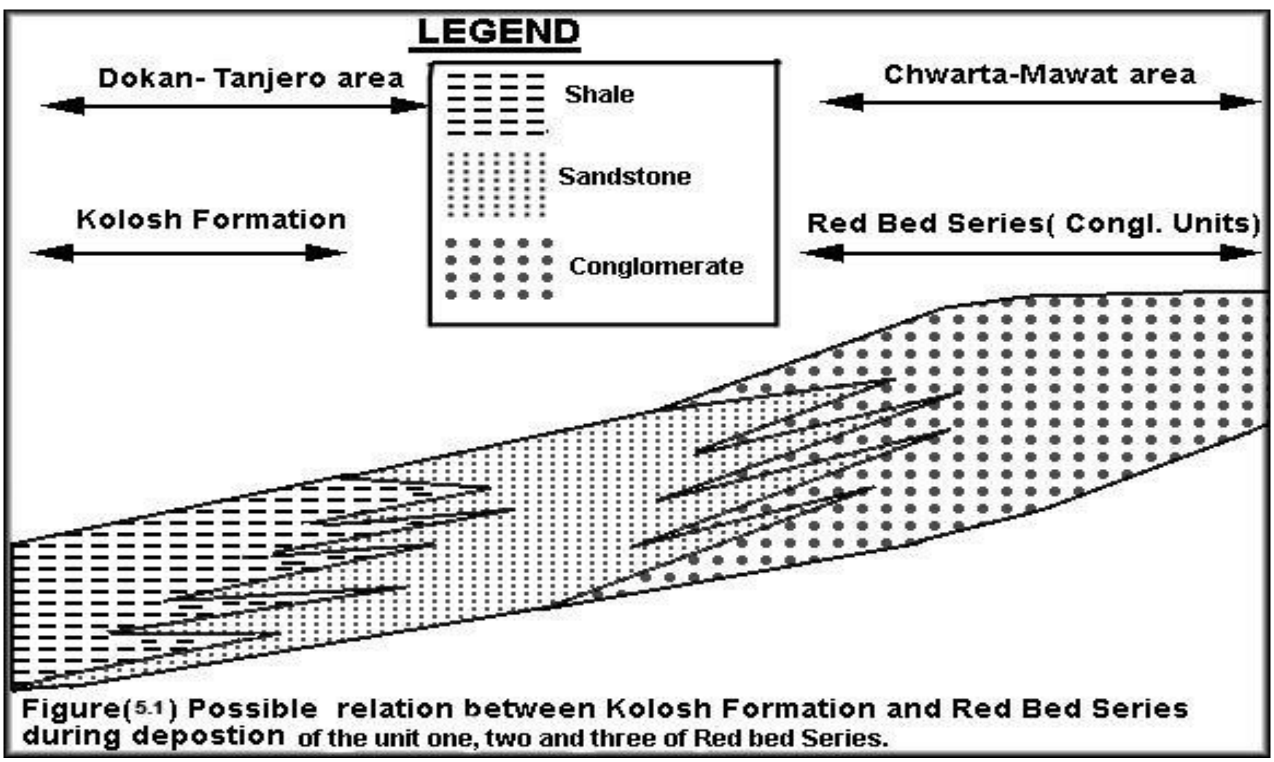


Fig.(2.15) Diagram shows relation between unit one and two of Red Bed Series and Kolosh Formation (Al-Barzinjy, 2006).

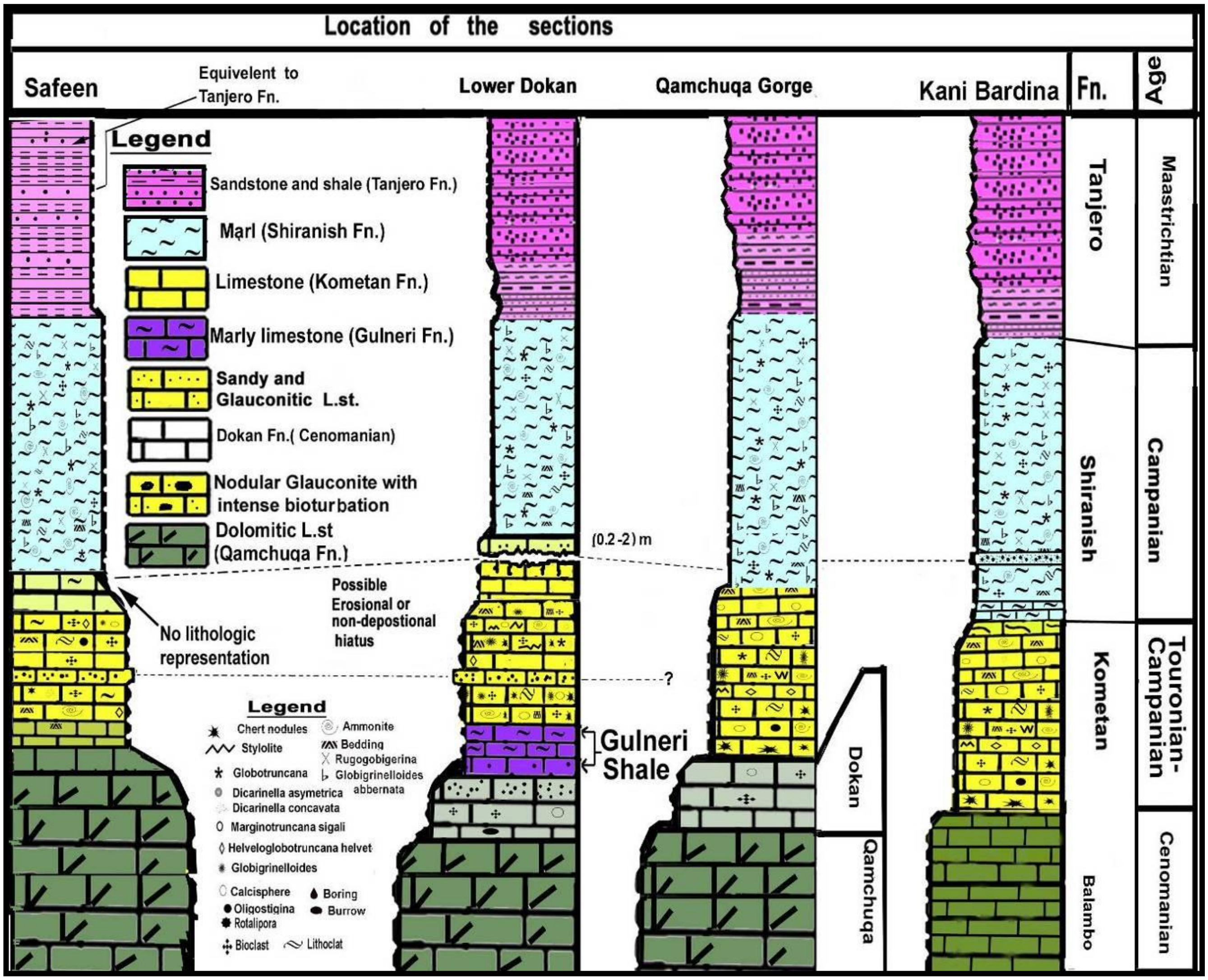


Fig.2.17: Stratigraphic column of the different areas (as indicated above each column) of the Lower and Upper Cretaceous units. It also shows that the contact between Kometan and Shiranish Formations is conformable (Modified from Karim, et al 2008).

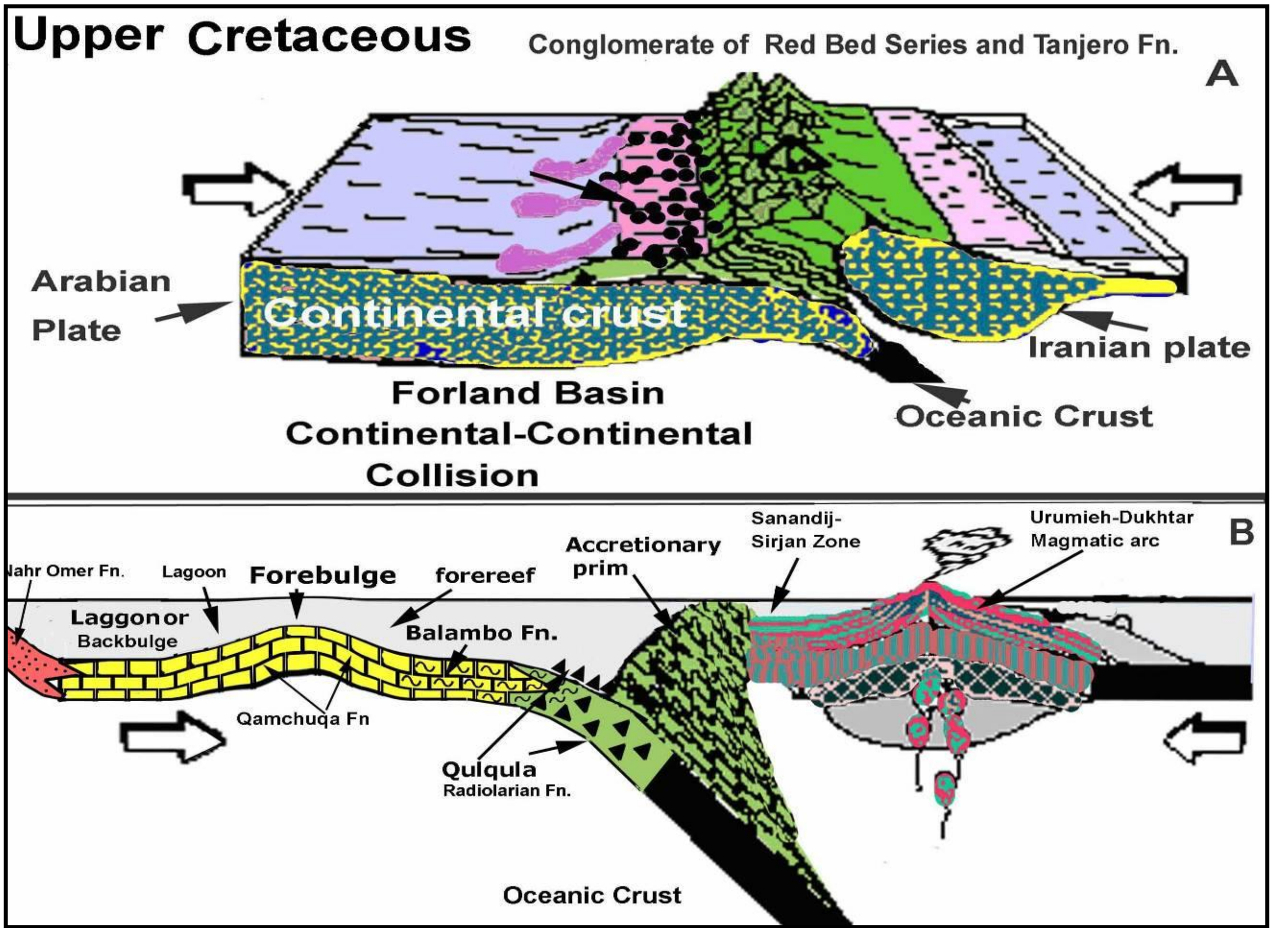


Fig.(2.18) Tectonic setting and position of the indicated formations within: A: Late Cretaceous Foreland Basin , B: Early Cretaceous Southern Neo-Tethys.

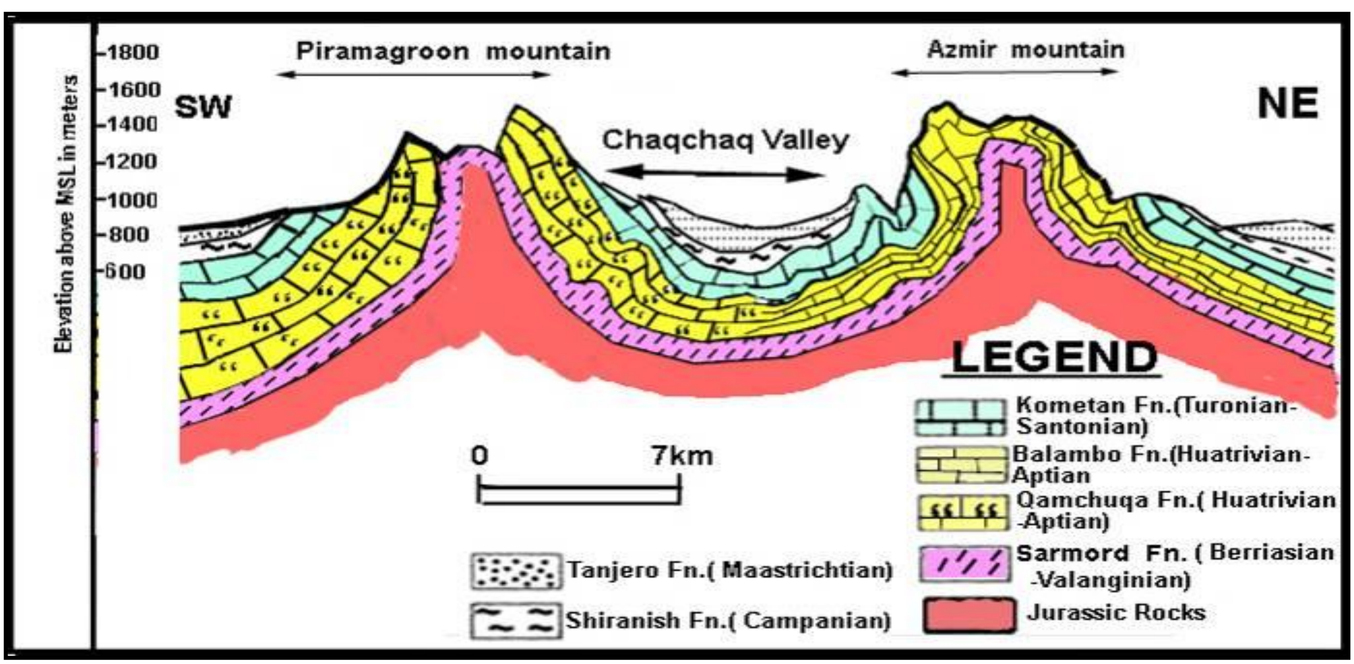


Fig.(2.19)Geologic cross section of Azmir and Piramagroon anticlines showing main lithostatigraphic units (formation) (Ali, 2007).

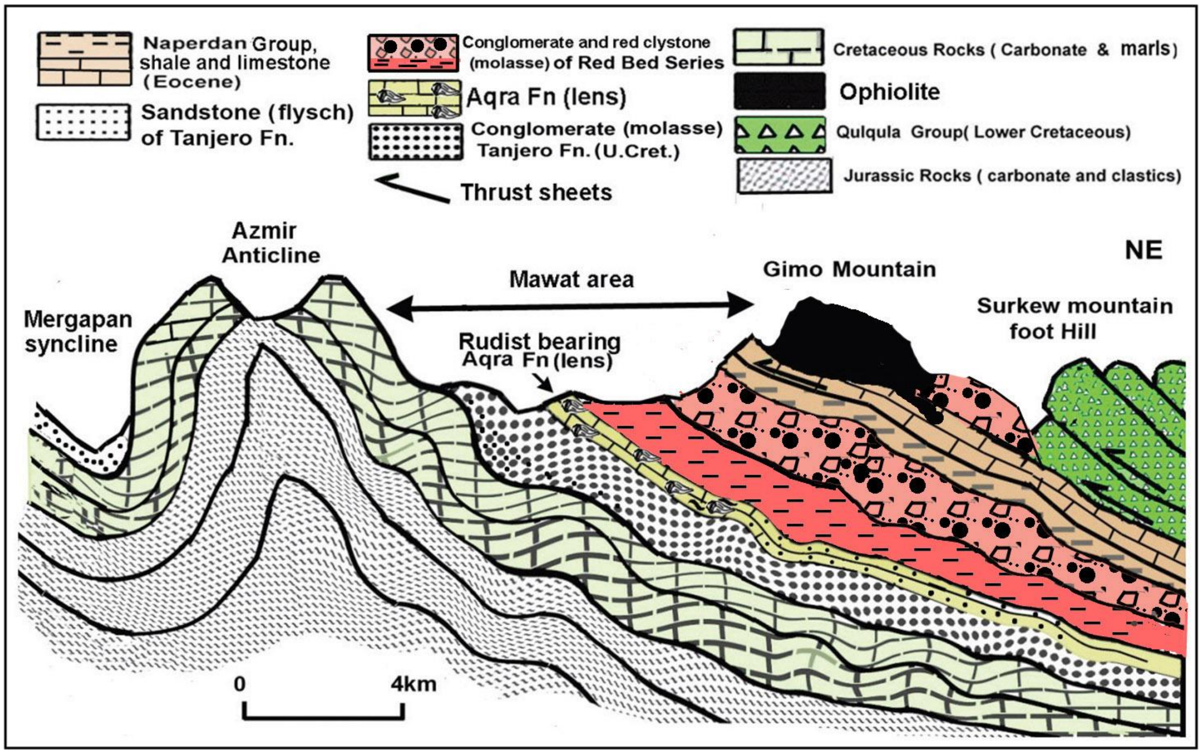


Fig.(2.20)Simplified geologic cross section passing through Chaqzh, Piramagron and Surkev mountain

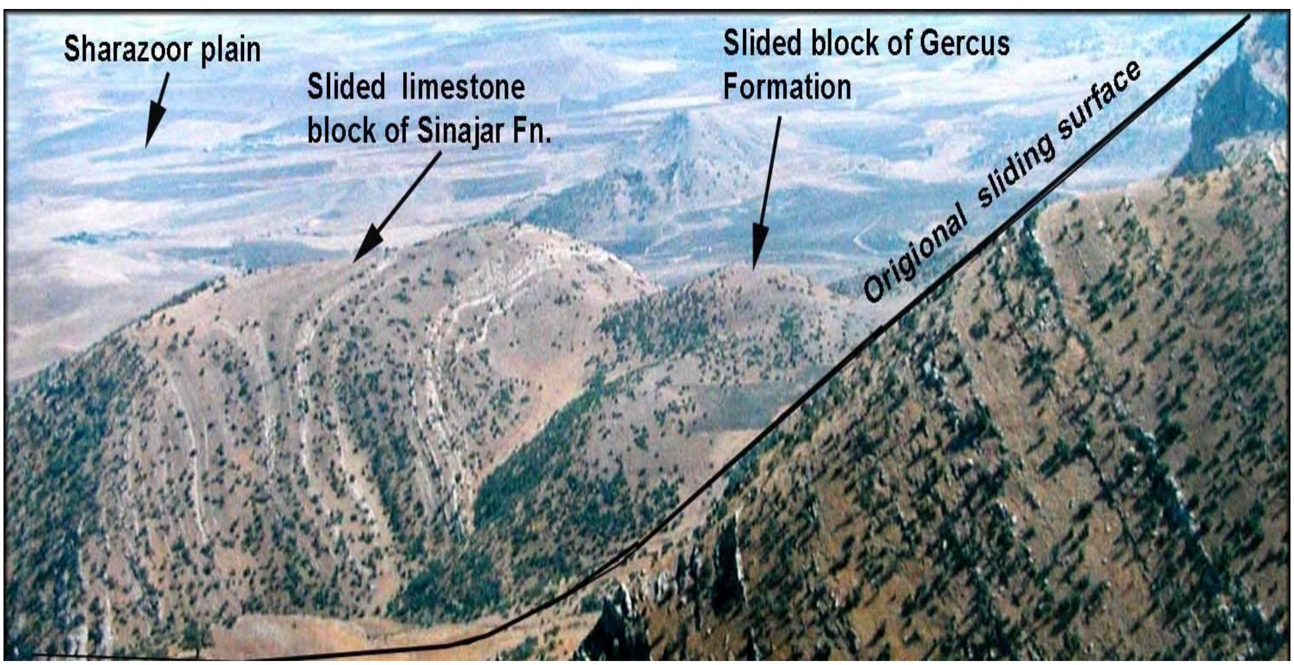


Fig.(2.21) Photo of part of northeastern side of Baranan mountain (Glazarda mountain) at south of Sulaimani city showing large landslide (weighted more than 200,0000 tons)Karim and Ali,2004).

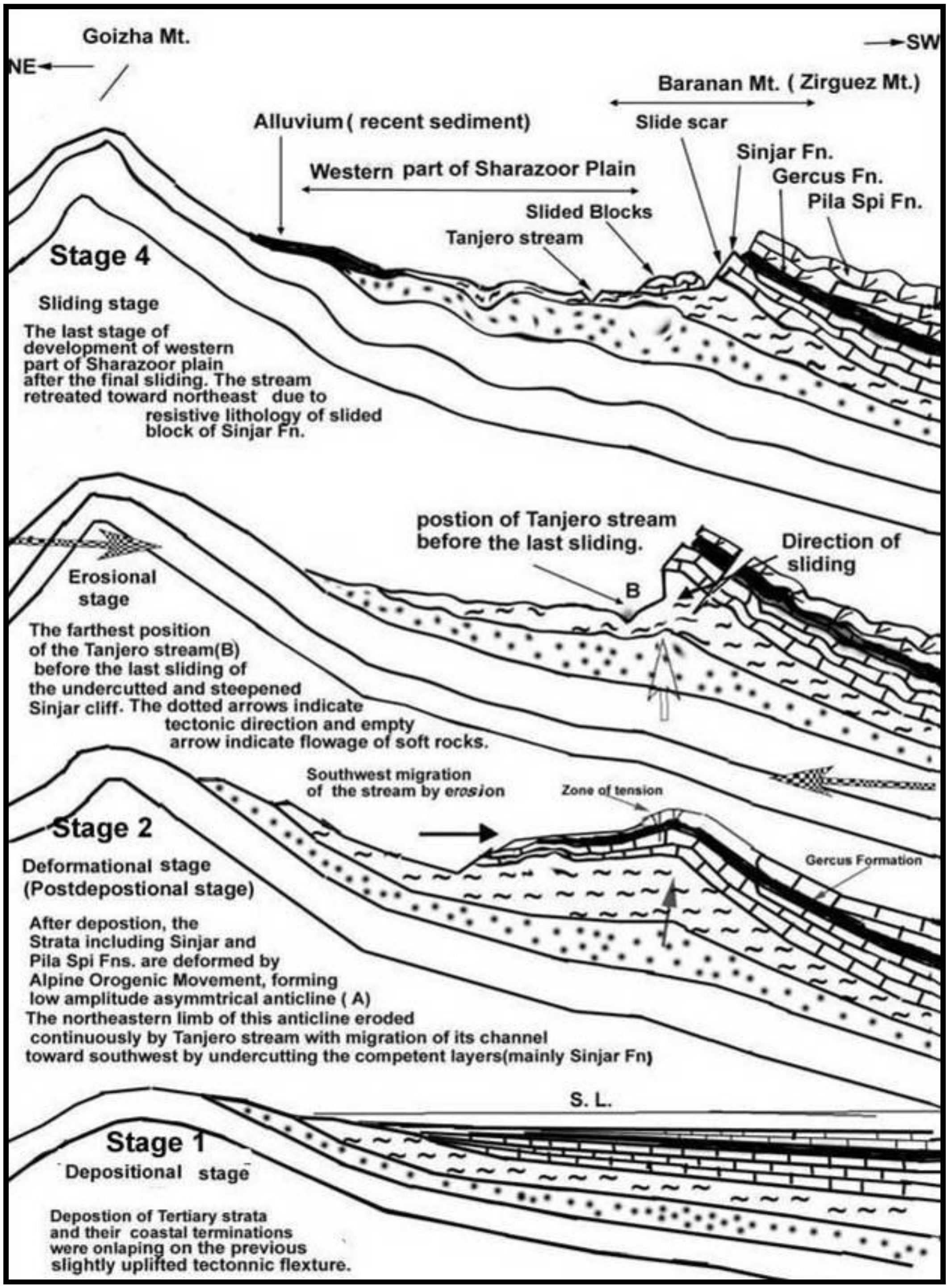


Fig.(2.22) shows how western part of Sharazoor plain are developed through different stages by tectonic stress, sliding and stream erosion from middle Miocene to present (Karim and Ali, 2005).

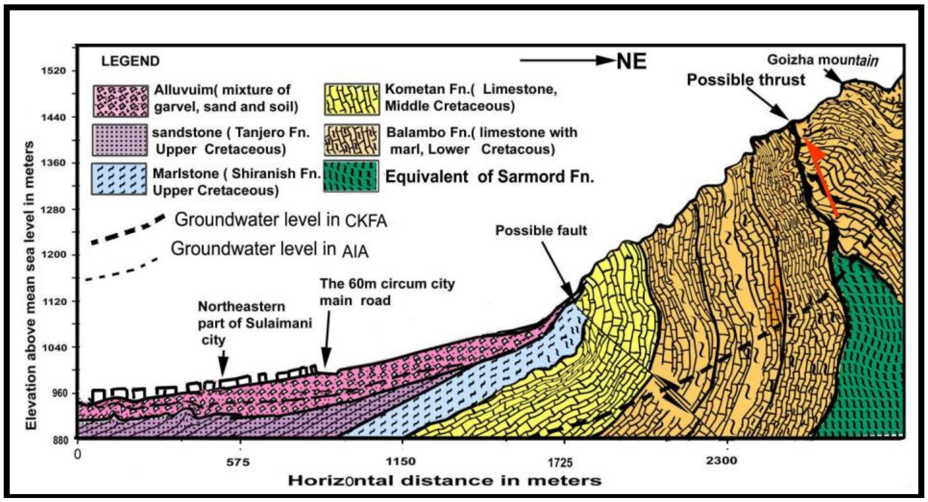


Fig.(2.23) Simplified geologic cross section of southeastern limb of Goizha anticline that is passing through Sulaimani city showing lithostratigraphic units (formations).

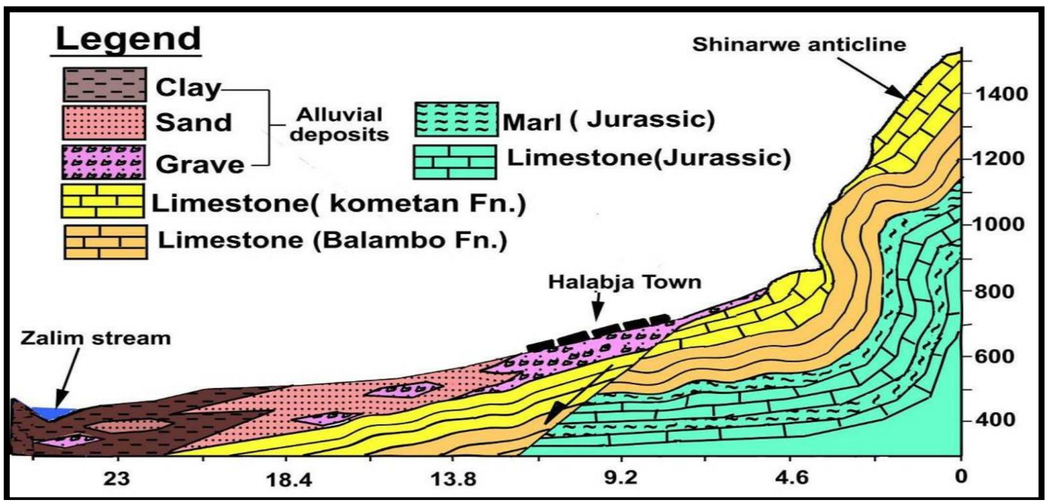


Fig.(2.24) Simplified geologic cross section of Shinarow mountain that pass through Halabja town(Ali, 2007).

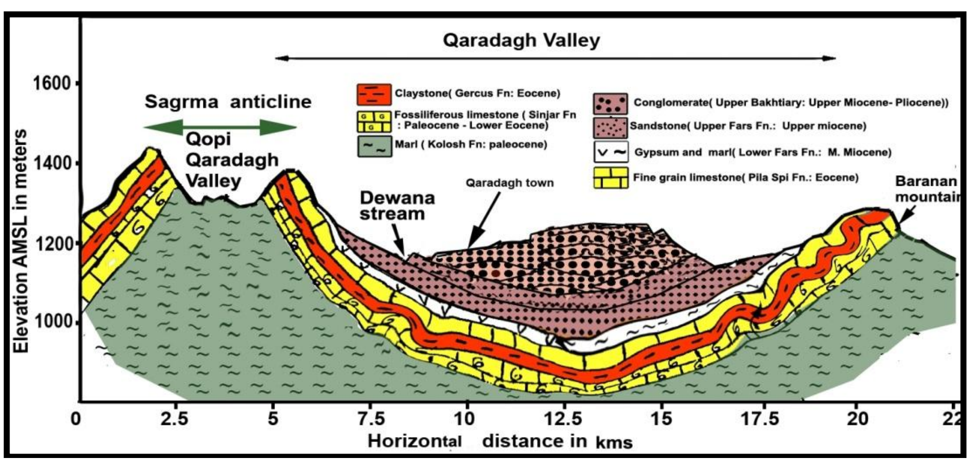


Fig.(2.25) Simplified geologic cross section Qaradagh area showing structures and lithostratigraphic units (formations).

Fig.(2.26) Burning of bitumen in Aqra area. The name Aqra (or Agre) is come from fire or (Agir).

Fig.(2.27) Burning of bitumen in Aqra area form volcanic–Like flow structures of hot bitumen. The name Aqra (or Agre) is come from fire or (Agir).

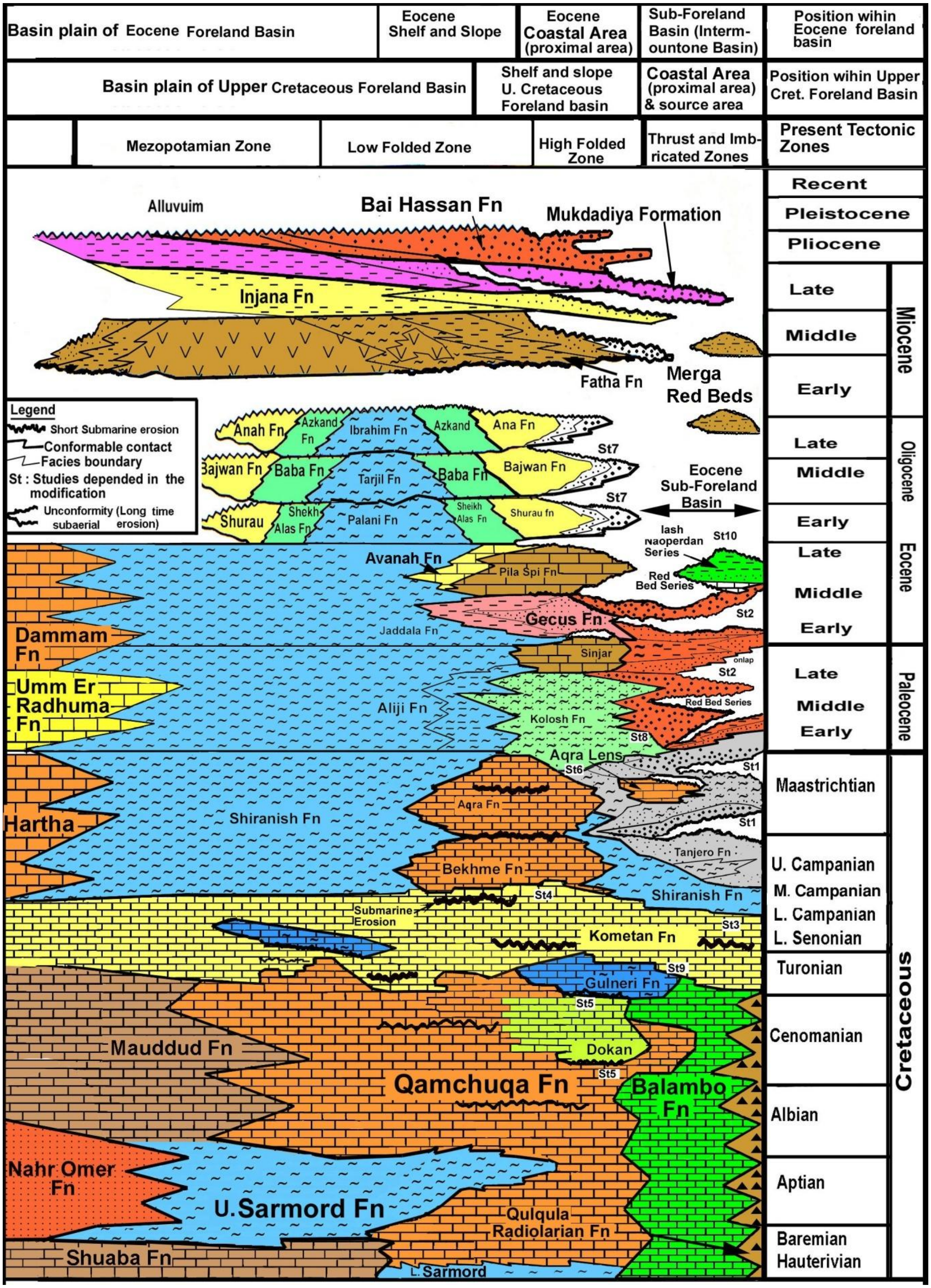


Fig. (2.38) Chronostratigraphic column (time-rock column) of Kurdistan during Cretaceous and Tertiary (Karim, 2009, in press) in which the dependent studies are shown as (St).

3-Stratigraphic units

3-1-Quaternary deposits

3-1-1-Alluvium deposits

Alluvium sediment and soil cover most part of the Iraq that make identification and mapping of the surface formation (rocks) difficult. Therefore, it is important to differentiate these sediments from older rocks (formations).

Definition

They are all loose sediments that deposited by running water which include:
1-Alluvuial fan deposits (boulder, gravel, and sand silt and clay deposits)

Kurdistan contains high mountains which made up of different type of limestones and bedded chert, sandstone and igneous rocks. These mountains dissected by tens of the perennial and emepheral streams. These streams scored more or less deep valleys in the rocks of the mountains by erosion and with the aid of mass wasting. The products of erosion and weathering consisted of angular clasts which are accumulated in the steep valley sides and in the valley bottoms. The accumulated rock fragments are transported seasonally by stream floods during heavy rainfall. Then huge quantities of boulder, gravel and sands are carried to downstream and deposited on the plains and lower slopes of mountain sides.

These sediments are deposited as debris flow on the gently sloping pains or as the channel deposits (lag and channel fills deposits) or as channel margin deposits and over bank deposits.

Tens of large and small alluvial fans start from the feet of the High Mountain such as Piramagroon, Azmir, Goizha, Avroman, Surren, Shinarwe and Balambo. These fans elongate from the mouths (outlets) of large or small valleys of these mountains into the lowland of Sharazoor and Piramagroon plains (Fig.). The fans are formed when the heavy loaded flood or debris flow reach the narrow outlets of the deep valleys and in this outlet the flow attain high thickness. Then when pass through tight passage and reach the plain the debris flow spread over downstream plain as fan shaped deposits. The spreading is due to decrease of both slope and channel depth (abrupt widening) as compared to steep slope and lightness of the valleys.

Most of the large fans are prograded into the central part of the Sharazoor plain. Now these fans hardly can be distinguished from their fan-like shape. This is because they dissected by several small emepheral streams which modified the shape. Another reason is that the adjacent fans are coalesced (joined) laterally so that single fan cannot be separated. Nevertheless these fans can be distinguished from their sediment which is consisted of heterogeneous, unsorted and angular rock fragments and clay. In rare case the alluvial fan can be identified from map and Images of Earth Google.

These fans are very common in the areas that have semi arid climate and has intermittent seasonal rain fall. The absence of weak vegetation and loose soil cover are main factor for generation of alluvial fans.

3-1-2-Recent limestone

Many caves, streams and few lakes contain limestone rocks, such as those exist in the Kona Ba cave at southeast of Darbandikhan town and in the Ganau Lake at the southeast

of Ranyia Town. The limestone of the Ganau Lake consist of about 2m of detrital, oolitic and stromatolitic limestone which shows cross lamination. The grains (allochems) of the limestone mainly consist of fragments of characea algae which binded by bacteria secreted lime materials (Fig.3.1.2).

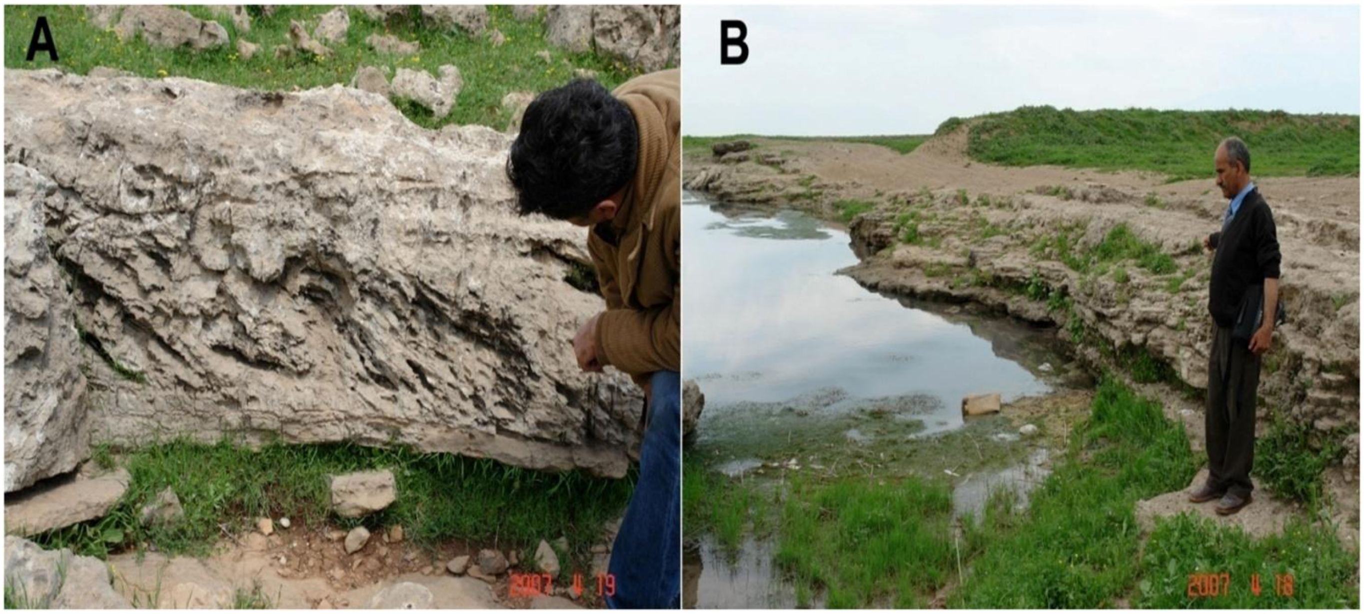


Fig. (3.1.2) Cross bedded ooids (micro-oncoids) on the southwestern bank of the Ganau lake. B) Bedded and laminated ooids limestone, contain both stromatolite and thrombolites.

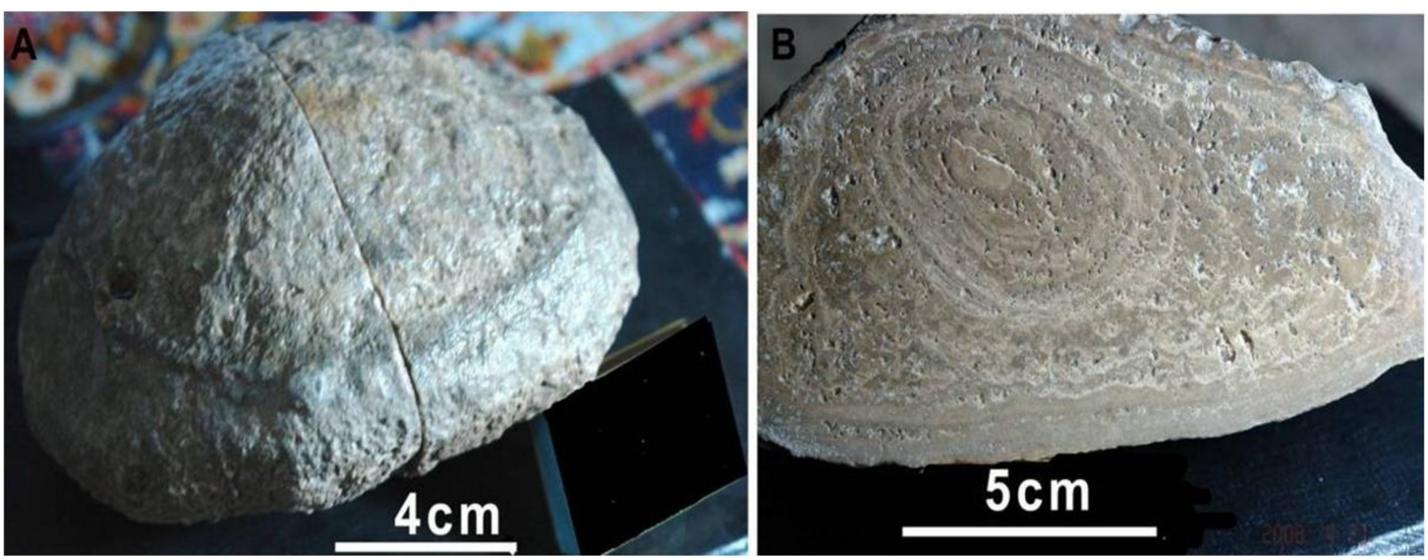


Fig. (3.1.3) large saucer-sized oncoids on the periodically flooding side of the lake. B) Polished surface (A) after cutting into two equal halves showing internal structure of the left side which shows development of a lager oncoids around an older smaller one.

3-2-Late Miocene-Pliocene

3-2-1-<u>Upper Bakhtiary (Bai Hassan) Formation</u>

Lithology: Very thick alternation of polygeneic and polymictic conglomerate, sandstone and red claystone. In Dokan area it consist of limestone conglomerate which is studied by Karim and Taha , 2012)
Age: Pliocene
Tectonic condition: Deposited on the plains that were bordering the Late Zagros Foreland basin during the maximum uplift of Kurdistan
Environment: deposited in braided fluvial (river) and delta environments.
Thickness: about 500-1000m
Area of distribution: Low Folded and Mesopotamian Zones
Fossil content: Trace fossil and vertebrate skeletons
Sedimentary structures: bedding, Cross bedding, imbricated pebble, traverse and longitudinal bars
Stratigraphic position: Located between Lower Bakhtiary Formations and alluvium at the base and top respectively.
Boundary condition: It is conformable laterally and vertically with underlying Lower Bakhtiary Formation while is unconformable with Quaternary alluvial deposits
Sequence stratigraphy: deposited as sediment of Low stand Fan delta

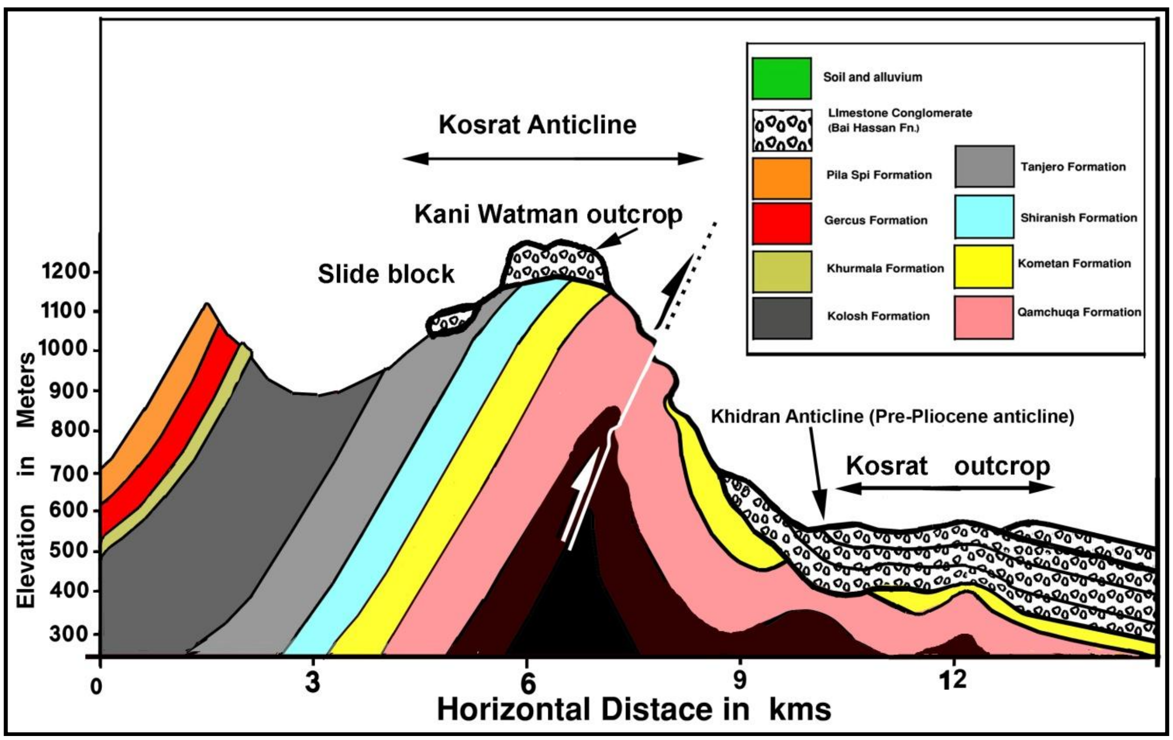


Fig.(3-2-1) geologic cross section of the northwestern part of Kostrat anticline show limestone conglomerate (Dokan conglomerate or Upper Bakhtiary Fn)

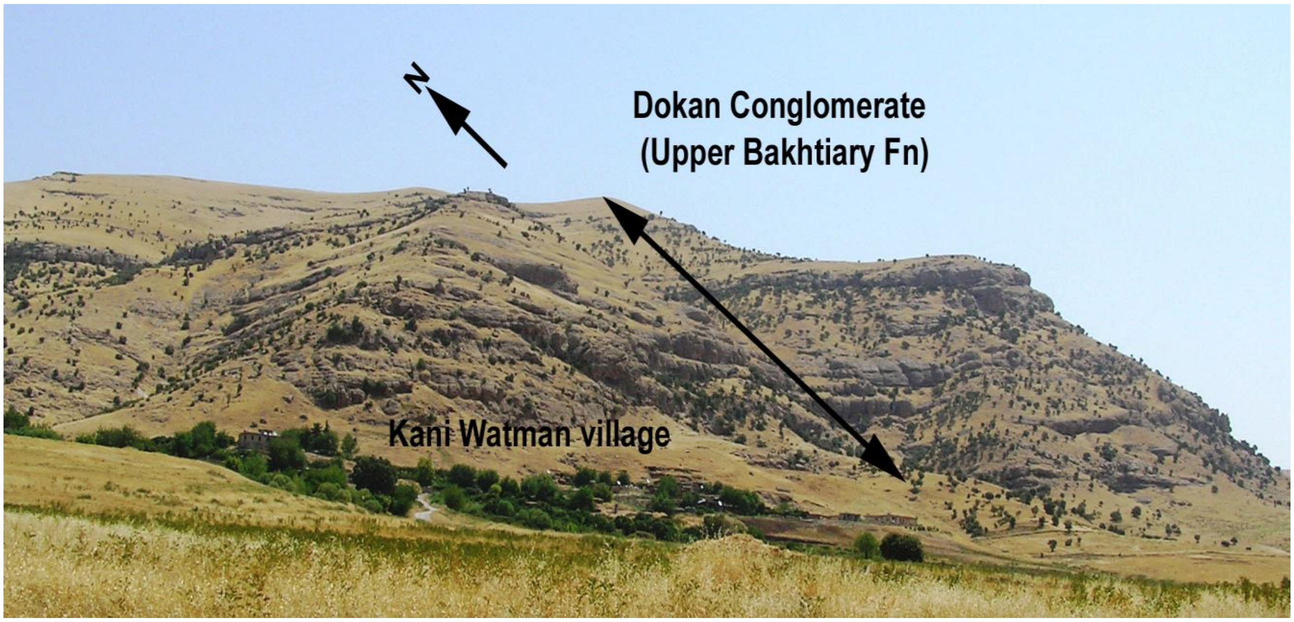


Fig.(3-2-2) Northwestern part of Kostrat anticline show limestone conglomerate (Dokan conglomerate or Upper Bakhtiary Fn) at the northeast of Kani Watman village.

3-2-2-Lower Bakhtiary (Mukdadyia) Formation

Lithology: Very thick alternation of red claystone and Pebbly sandstone
Age: Upper Miocene- Early Pliocene
Tectonic condition: Deposited on the plains that were bordering the Late Zagros Foreland basin uplifting of Kurdistan
Environment: High energy deltaic and fluvial environments.
Thickness: about 500-1000m
Area of distribution: Low Folded and Mesopotamian Zones
Fossil content: Trace fossil and vertebrate skeletons.

Sedimentary structures: bedding, lamination, Cross bedding and trace fossils
Stratigraphic position: located between Upper Fars and Upper Bakhtiary (Bai Hassan) Formations at the base and top respectively.
Boundary condition: It is conformable laterally and vertically with underlying Lower Bakhtiary Formation while is unconformable with Quaternary alluvial deposits
Sequence stratigraphy: deposited as sediment of Low stand Fan delta

3-2-3-Upper Fars (Injana) Formation

Lithology: Very thick alternation of red claystone and sandstone
Age: Upper Miocene
Tectonic condition: Deposited during final uplift of Kurdistan and deposited in coastal area of Upper Miocene Foreland basin
Environment: High energy deltaic and shallow marine environment.
Thickness: about 500-1000m
Area of distribution: Low Folded and Mesopotamian Zones
Fossil content: Planktonic forams, pelecpod and ostracod

Sedimentary structures: bedding, lamination, Cross bedding and trace fossils
Stratigraphic position: located between Lower Fars and Lower Bakhtiary (Mukdadyia) Formations at the base and top respectively.
Boundary condition: It is conformable laterally and vertically with underlying and overlying Upper Bakhtiary and Lower Fars Formations respectively
Sequence stratigraphy: deposited as sediment Flood plain of Low stand fan delta.

3-3- Lower and Middle Miocene

3-3-1-Lower Fars (Fatha) Formation

Lithology: Very thick alternation of Gypsum (or anhydrite), Salt, marly limestone in the basin center while it may contain fossiliferous and oolitic limestone, sandstone and red claystone in the basin periphery.
Age: Middle Miocene
Tectonic condition: Foreland basin
Environment: restricted and evaporitic shallow and deep Laggonal environment
Thickness: about 100-800m
Area of distribution: Mostly in Low Folded and Mesopotamian Zones
Fossil content: Planktonic and benthonic forams, pelecpod and ostracod
Sedimentary structures: bedding, lamination, trace fossils
Stratigraphic position: located between Pila Spi and Upper Fars (Injana) Formation at the base and top respectively in the High folded Zone while it located between Kurkuk group (at the base) and Upper Fars (Injana) (at the top) formations in the Low Folded and Mesopotamian Zones.
Boundary condition: It is conformable with overlying formation but it is unconformable with and Jaddala (at the base) formations in the low folded and Mesopotamian Zones while it is unconformable with underlying Pila Spi (or Anah) formation in the High Folded Zones.
Sequence stratigraphy: deposited as sediment of High Stand system tract

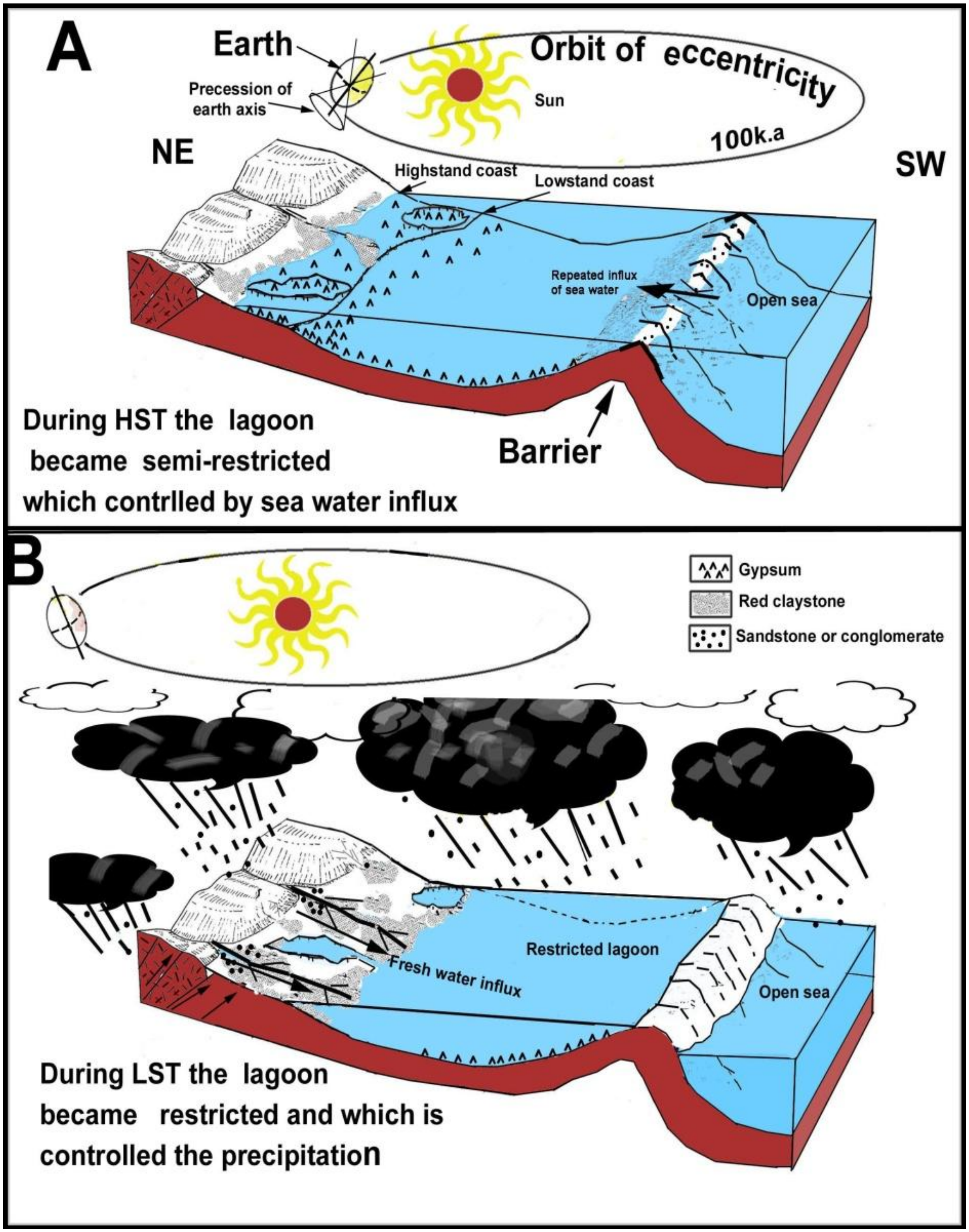


Fig.(3.3.1) Effect of eccentricity and precession of climatic change in the northern hemisphere during Middle Miocene. A: High eccentricity and precession generate HST and high evaporation in which gypsum deposited. B: Low eccentricity and precession generate LST and influx of fresh water to the closed lagoon.

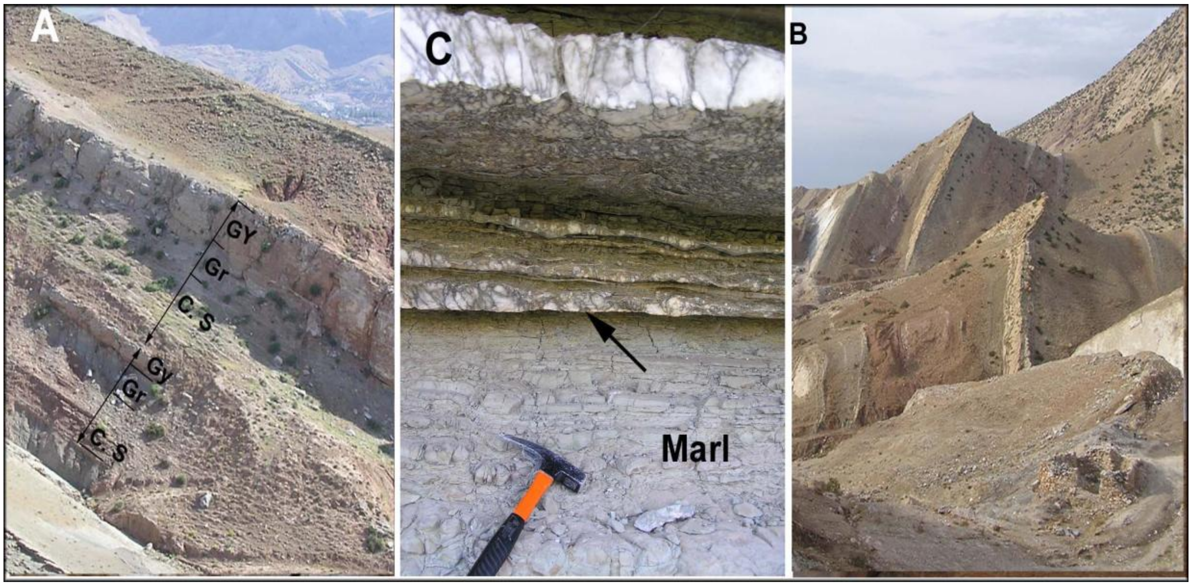


Fig. (3.3.2) A: Two ideal cycles of depositions red claystone (C.S), green marl (Gr) and gypsum (GY) at southeastern plunge of Sagrma anticline. C: Gradational contact between marl and gypsum, which is manifested by alternation of laminae of marl and gypsum (above the arrow). B: Common geomorphologic feature (iron flats) formed by limestone and gypsum beds (southeast limb of Qishlagh anticline.

3-4-Oligocene

3-4-1-Kirkuk Group

The Kirkuk Group is nine formations that are deposited during Oligocene. These nine formations can be grouped into three types according to environment. 1- Basinal (deep marine) formation, they are: Ibrahim, Palani and Tarjil Formations. 2- Lagoonal and reefal Formations, they are: Anah, Bajwan and Shurau Formations, 3- Reefal and fore reefal Formations: Azkand, Baba and Shekh Alas Formations (Fig.3.4.1 and 3.4.2) .

These formations are deposited in relatively small normal marine basin in Kirkuk, south of Sulaimani and Ramadi areas. The shape of this basin was elongate and trended northwest-southeast which was opened to open marine (ocean) from south and west .The reef and fore reef formations are good reservoir for oil accumulation and actually they now penetrated for oil production. Recently Khanaqa et al. (2009) have extended the distribution of the group to the inside High Folded Zone (Fig.3.4.3)

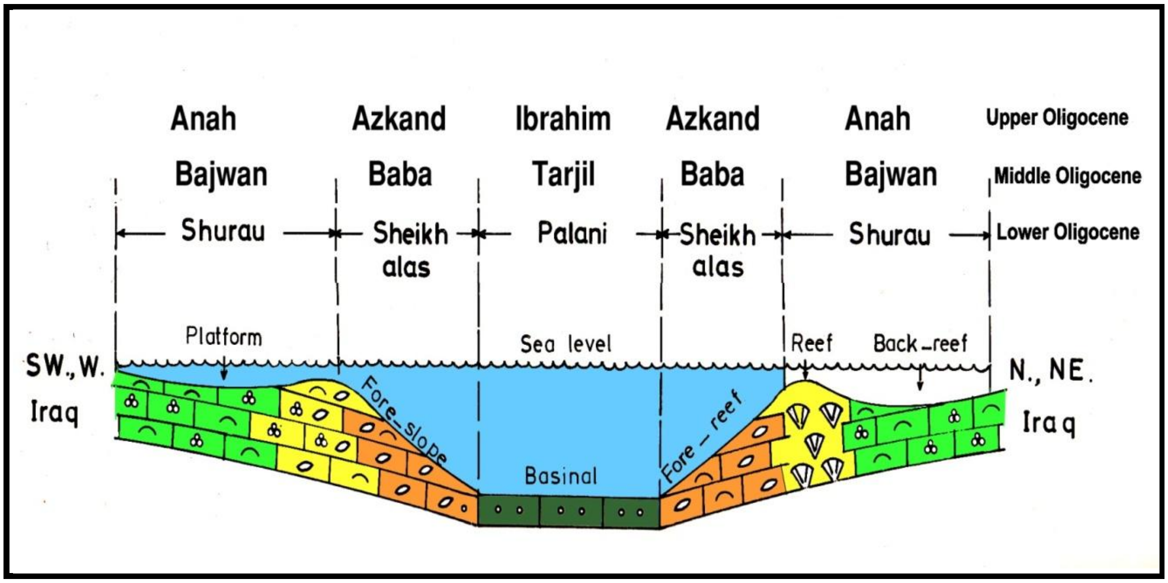


Fig.(4.3.1-) Geologic cross section of Oligocene showing formations of Kirkuk Group (Al-Hashimi and Amer, 1986).

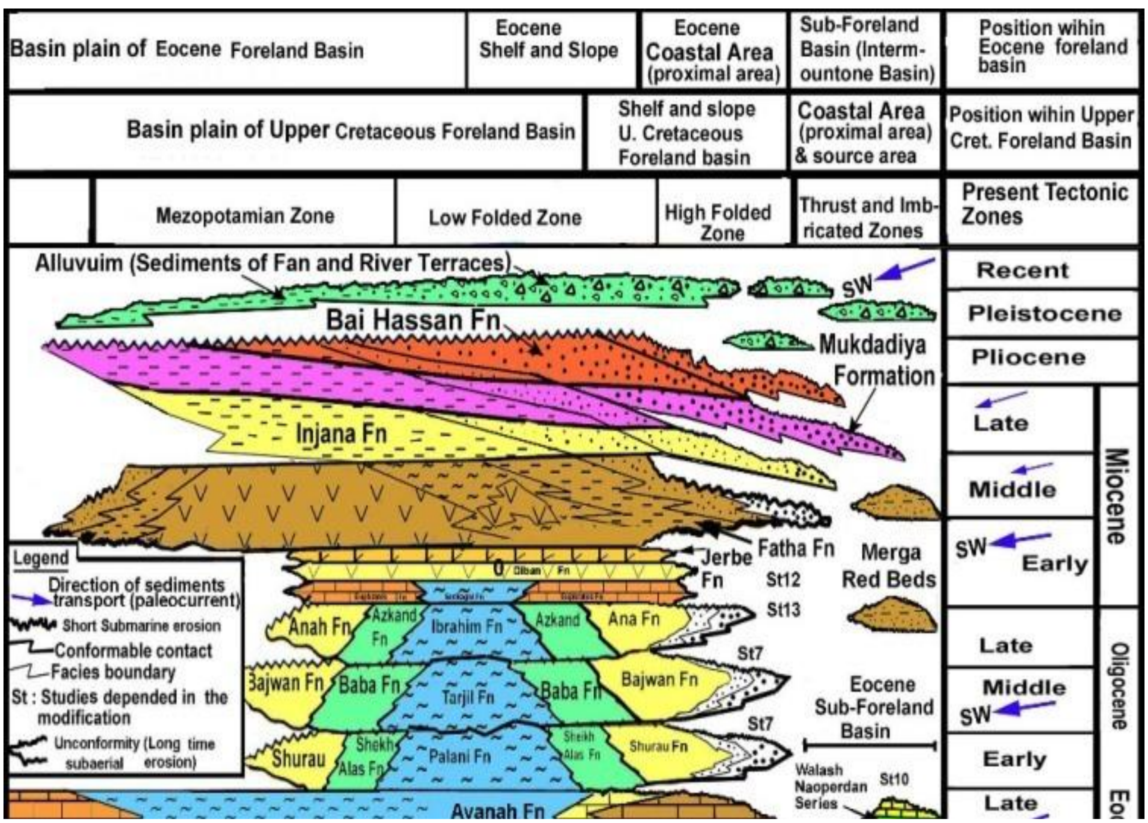


Fig. (4.3.2) Chronostratigraphic column of Late Tertiary and Quaternary shows Kirkuk Group (Karim, 2010)

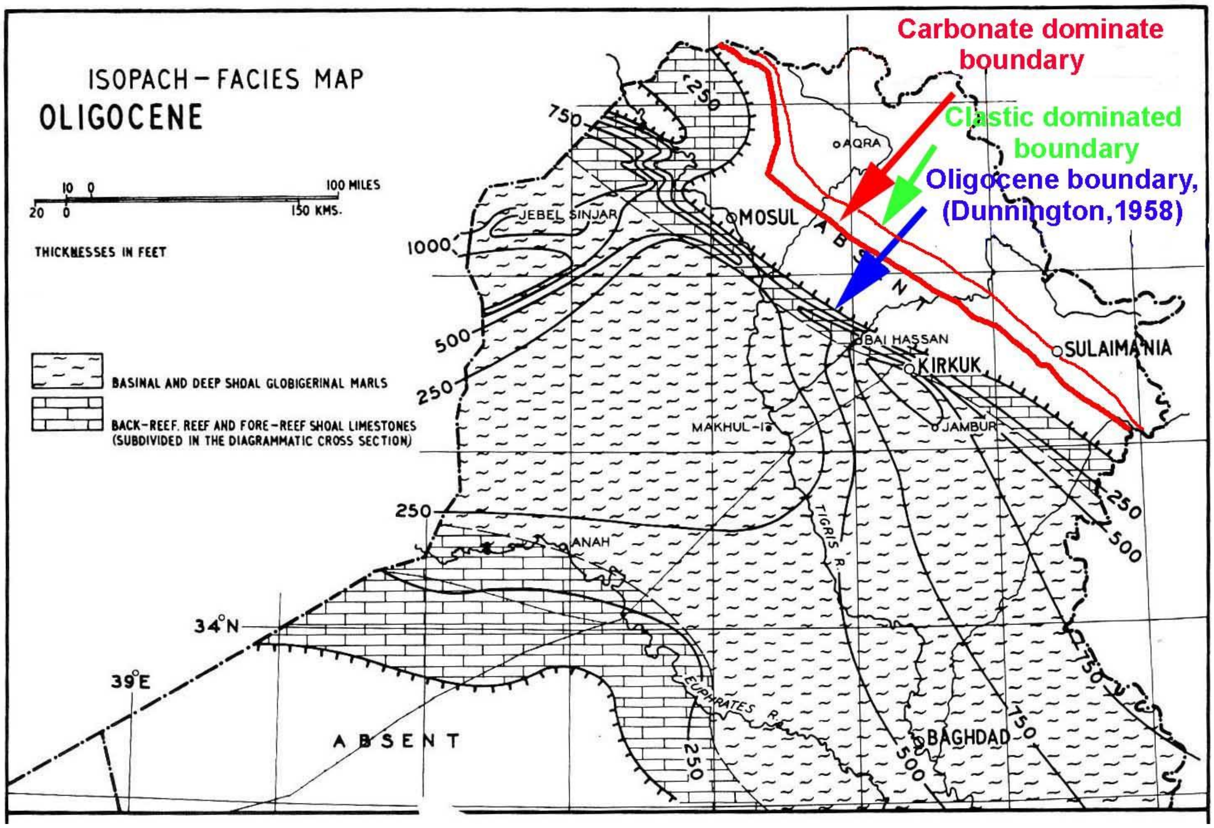


Fig. (3.4.3)Facies map during Oligocene showing basinal, and reefal facies (formations) of the Kirkuk Group with northeast southwest cross section of the basin.

3-5-Eocene

3-5-1-Pila Spi Formation

Lithology: white or milky limestone or dolomitic limestone
Age: Middle Eocene
Tectonic condition: Deposited after separation of the Zagros Foreland basin into two basins (main foreland basin in which Pila Spi Formation is deposited) and Sub-foreland basin in which Walash Naoperdan Series is deposited
Environment: mainly deposited in semi-restricted lagoon and partly in reef and environments
Thickness: about 40-150m
Area of distribution: High Folded Zones and Low Folded Zones
Fossil content: green algae, bryozoa, miliolids, alveolina ,pelecypod and gastropods (Fig.3.5.1) .
Sedimentary structures: bedding, lamination, trace fossils
Stratigraphic position: located between Gercus and Anah or Lower Fars Formations at the base and top respectively.
Boundary condition: It is unconformable with overlying Lower Fars formation but it is conformable with underlying Red Bed Series. it changes laterally to Avanah and Jaddala formations toward southwest
Sequence stratigraphy: deposited mainly as sediment high stand system tract

Fig.(3-5-1) Polished slab of chalky limestone of Pila Spi Formation of Glazarda Area showing Algae and Bryozoa.

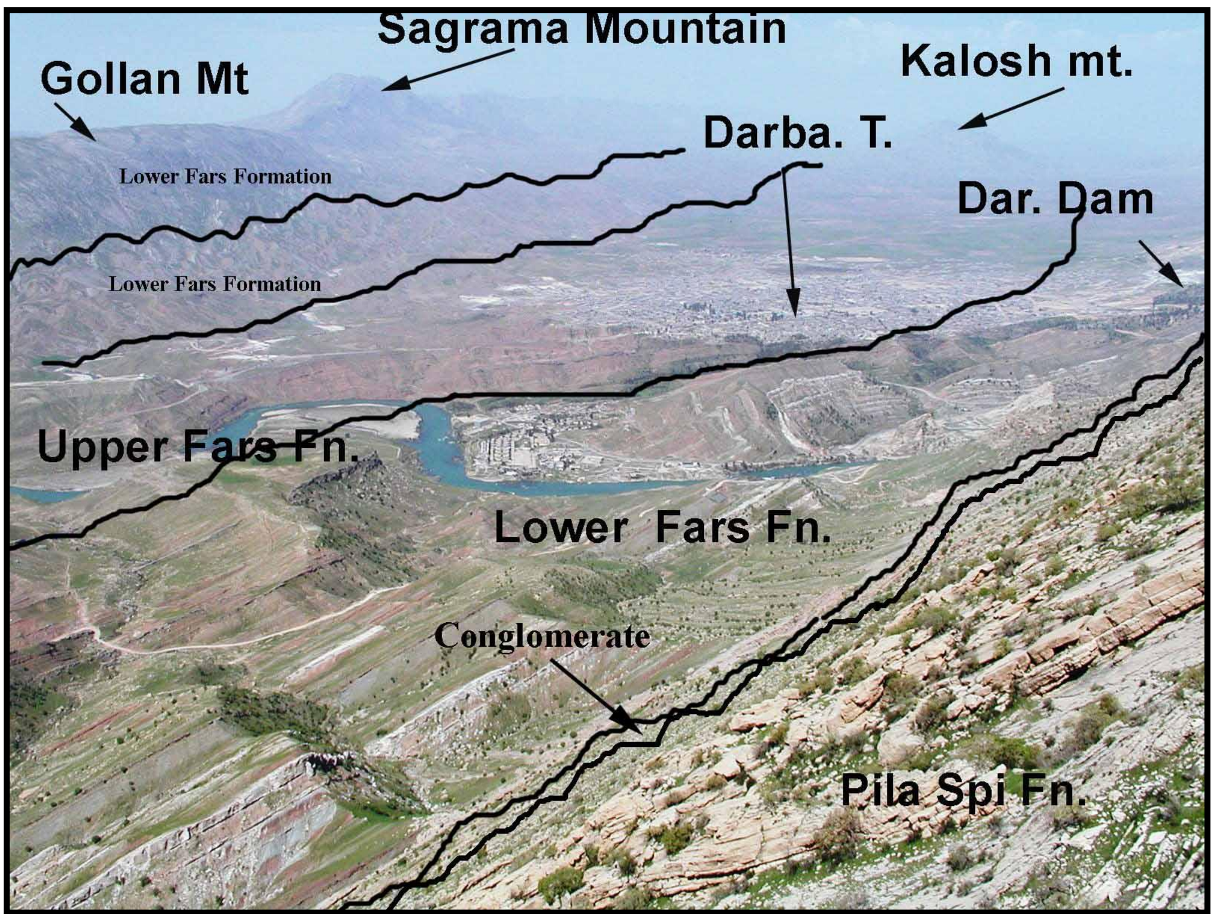


Fig.(3-5-2) The area around Darbandikhan town showing the exposed formation.

3-5-2-Gercus Formation

Lithology: Red or grey sandstone, claystone and conglomerate
Age: Lower Eocene
Tectonic setting: Deposited in near shore area of Eocene Foreland basin as distal alluvial fan, delta plain and front in high tectonic activity phase.
Environment: distal alluvial fan, delta plain and delta front deposit i
Thickness: about 40-70m
Area of distribution: High Folded Zones
Fossil content: rare
Sedimentary structures: bedding, lamination, cross bedding, parting lamination and imbricated pebbles.
Stratigraphic position: located between Kolosh and Pila Spi Formations at the base and top respectively.
Geographic distribution: Low and High Folded Zone
Boundary condition: It is unconformable with overlying Pila Spi formation but it is conformable with underlying Sinjar (or Khurmal) Formation. It changes laterally to Jaddala or Avanah formations toward southwest and to Red Bed Series toward northeast
Sequence stratigraphy: deposited mainly as sediment low Stand system tract on low stand delta plain

3-5-3-Avanah Formation

Lithology: White to milky fossiliferous limestone with some dolomitic limestone
Age: Eocene
Tectonic condition: Slightly agitated Eocene Foreland basin
Environment: slightly restricted to normal shallow marine environment
Thickness: about 50-250m
Area of distribution: Low Folded and Mesopotamian Zones
Fossil content: Algae, coral, benthonic foram such as alveolina and miliolid
Sedimentary structures: bedding, lamination, trace fossils
Stratigraphic position: located between Khurmala Formations and Lower Fars Formation at the base and top respectively.
Boundary condition: It is unconformable with overlying Pila Spi and underlying Gercus formations. It changes laterally to Jaddala Formations toward southwest and to Gercus or Plia Spi toward northeast
Sequence stratigraphy: deposited mainly as sediment of different system tracts (high and Low)

Fig.(3.5.3)Weathered white limestone of Avanah Formation of showing Alveolina forams in Sartak Bamo Area.

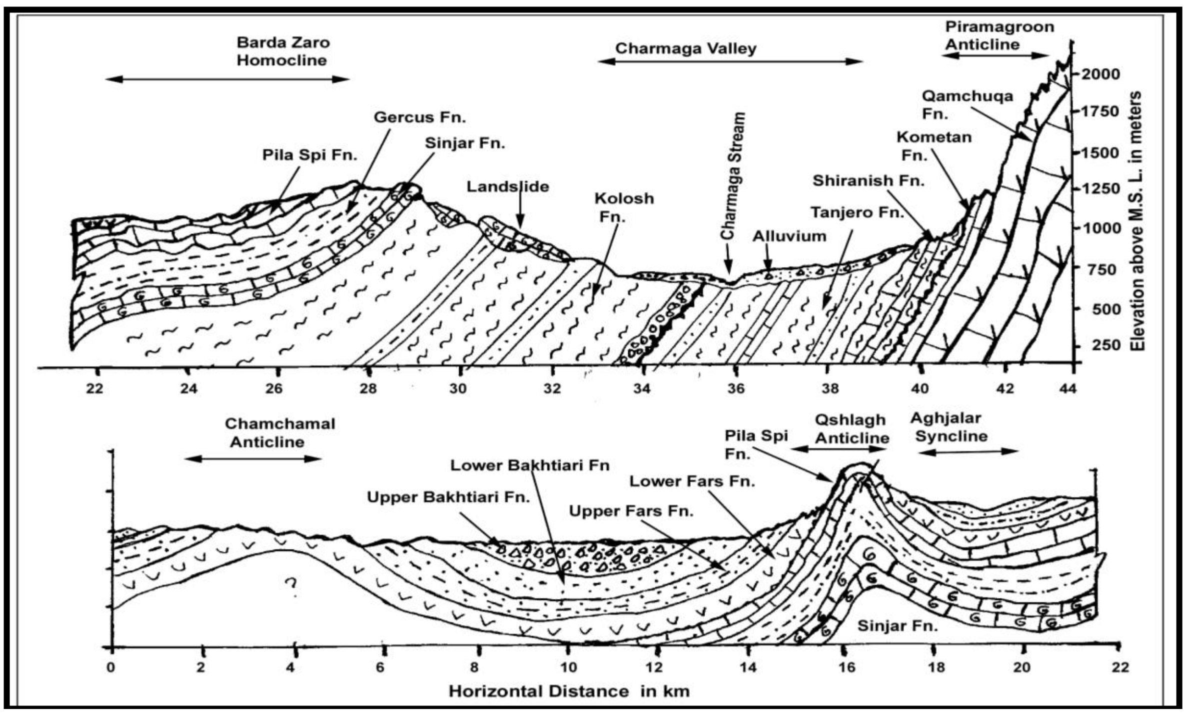


Fig.(3.5.4) Two geologic cross sections passing through southwestern limb of Piramagroon (northeast) Qashlagh anticline and Chamchamal town. The two sections can be combines together at 22km distance.

<u>3-5-4-Sinjar Formation</u>

Lithology: mainly consists of grey coarse grain detrital and fossiliferous limestone and partly contain some dolomitic limestone (Fig.3.5.5)
Age: Upper Paleocene – Lower Eocene
Tectonic condition: Deposited on submerged highs in the near shore area of Tertiary Foreland Basin
Environment: reef, fore reef and lagoon environments
Thickness: about 70-200m
Area of distribution: Low and High Folded Zones

Fossil content: Algae, coral, brayozoa, nummulite, miliolid , gastropod and pelecypods
Sedimentary structures: bedding, lamination, trace fossils and concretions
Stratigraphic position: located between Kolosh and Gercus Formations at the base and top respectively.
Boundary condition: It is conformable with overlying Gercus and underlying Kolosh Formations. It changes laterally to Jaddala formations toward southwest and to Red Bed Series toward northeast (Fig.3.5.6)
Sequence stratigraphy: deposited mainly as sediment of high system tracts

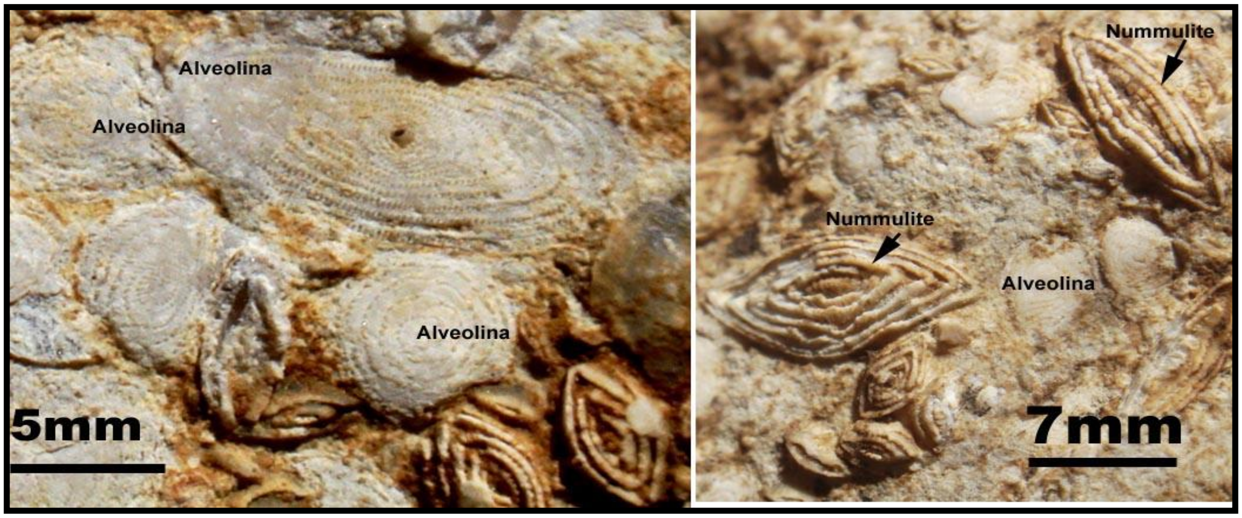


Fig.(3.5.5) Weathered outcrop of Sinjar Formation in Sartak Bamo Area showing Nummulite and Alveolina forams.

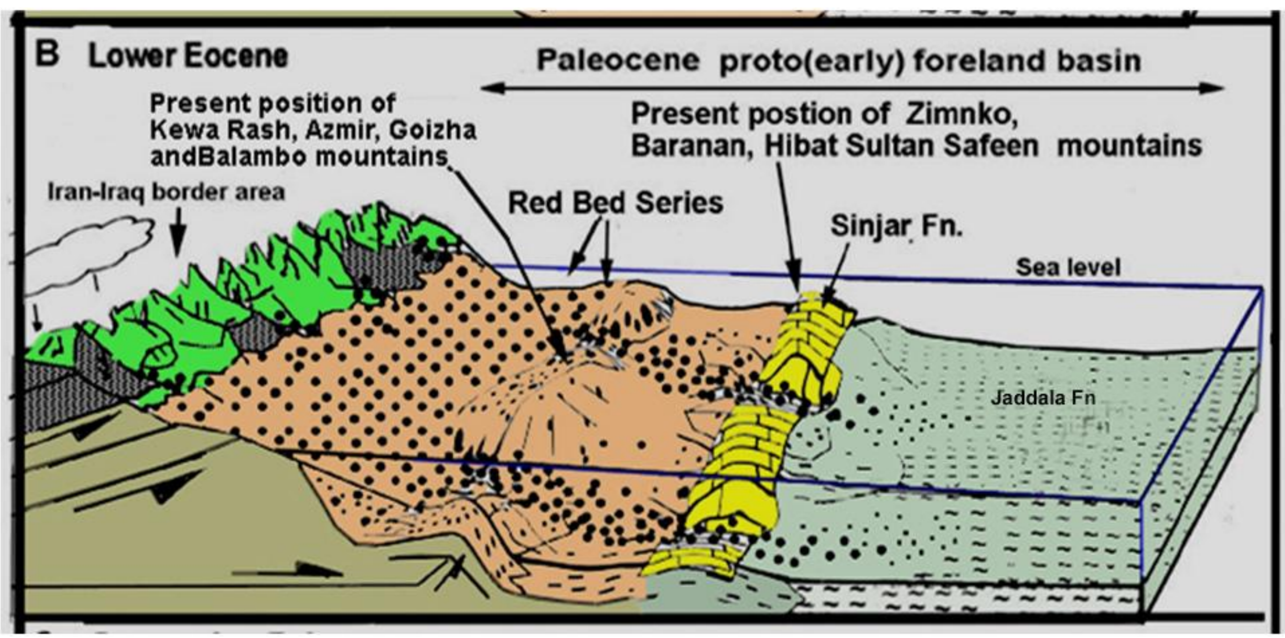


Fig.(3.5.6) Tectonic setting of the Foreland basin during Paleocene-Early Eocene shows the environment and lateral changes of Sinjar Formation

3-5-5-Khurmala Formation

Lithology: Grey dolomitic limestone and marly limestone
Age: Upper Paleocene – Lower Eocene

Tectonic condition: Deposited in Tertiary in Foreland Basin
Environment: Lagoon (back reef)
Thickness: about 20-70m
Area of distribution: Low and High Folded Zones
Fossil content: algae, large forams, pelecypod and gastropods
Sedimentary structures: bedding, lamination, trace fossils
Stratigraphic position: located between Kolosh and Gercus Formations at the base and top respectively in Sulaimani and Arbil areas while it is located between Aqra and Gercus Formation in some places of Dohuk area.
Boundary condition: It is conformable with overlying Gercus and underlying Kolosh Formations. It changes laterally to Jaddala formations toward southwest and to Red Bed Series toward northeast and to Sinjar toward southeast.
Sequence stratigraphy: deposited mainly as sediment of high system tracts

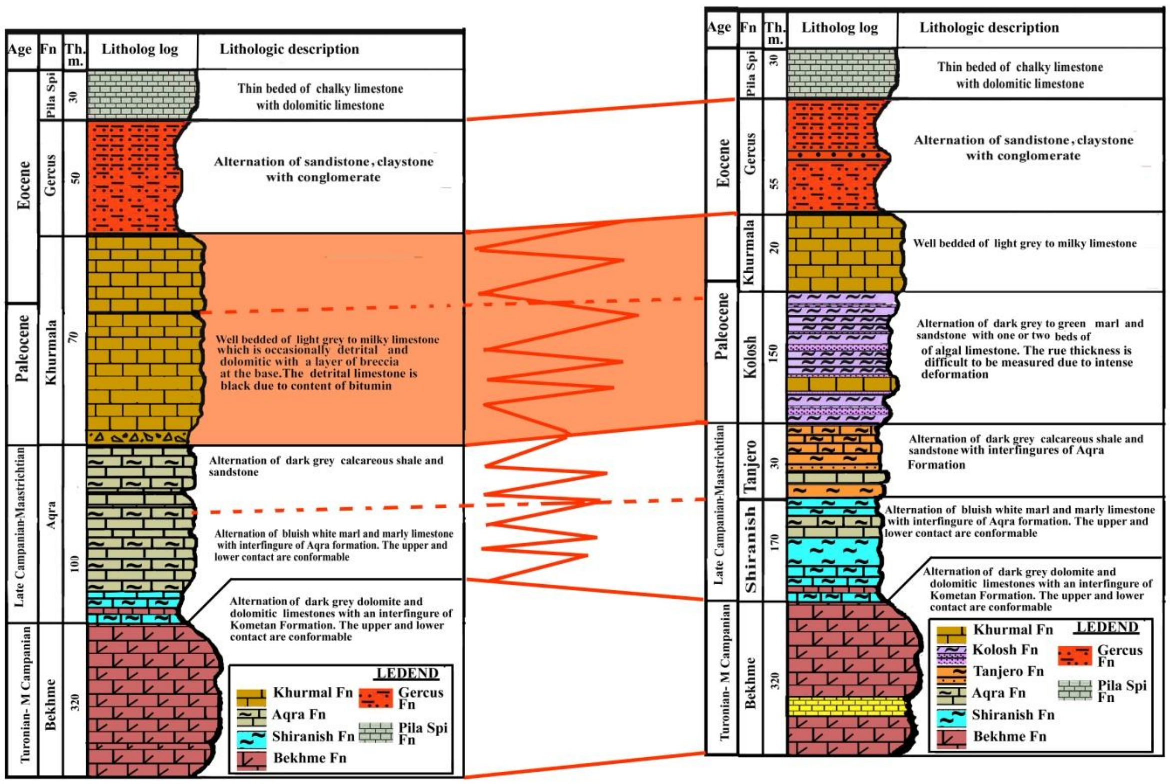


Fig. (3.5.6) a correlation of Bekhme and Saru Kani sections which shows the total lateral facies change of Kolosh (green marl) to Khurmala formations

3-5-6-Jaddala Formation

Lithology: Marl and marly limestone
Age: Eocene
Tectonic condition: Basin plain of Eocene Foreland basin far from tectonic activities.
Environment: Basin plain (Offshore).
Thickness: About 350m
Area of distribution: Low Folded and Mesopotamian Zones
Fossil content: Planktonic foram (globogerina)
Sedimentary structures: bedding, lamination, trace fossils
Stratigraphic position: located between Aliji Formations and Kurkuk Group at the base and top respectively.

Boundary condition: It is conformable with overlying Kirkuk group and underlying Aliji Formations. It changes laterally to Gercus, Sinjar, Khurmala and Pila Spi formations toward northeast
Sequence stratigraphy: deposited mainly as different system tracts

3-6-Paleocene

3-6-1-Kolosh Formation

Lithology: Alternation of sandstone and calcareous shale with interbeds of conglomerates
Age: Paleocene
Tectonic condition: Slope and basin plain of Tertiary Foreland basin in front of southwest advancing of Iranian Plate
Environment: slope and basin plain
Thickness: about 400- 1200m
Area of distribution: Mainly High Folded Zones
Fossil content: Planktonic and benthonic forams and gastropods with Nereite, skolithos trace fossils
Sedimentary structures: tool marks, flute casts, cross bedding, graded bedding.
Stratigraphic position: located between Tanjero (and Aqra) Formation at the base and Sinjar (or Khurmala) Formation the top.
Boundary condition: It is conformable with overlying Sinjar Formation and underlying Tanjero Formation at distal areas. But it may be unconformable in proximal area in some places. It changes laterally to Red Bed Series toward northeast while it changes to Aliji Formation toward southeast (Fig.3.6.1).
Sequence stratigraphy: Deposited mainly as low system tracts

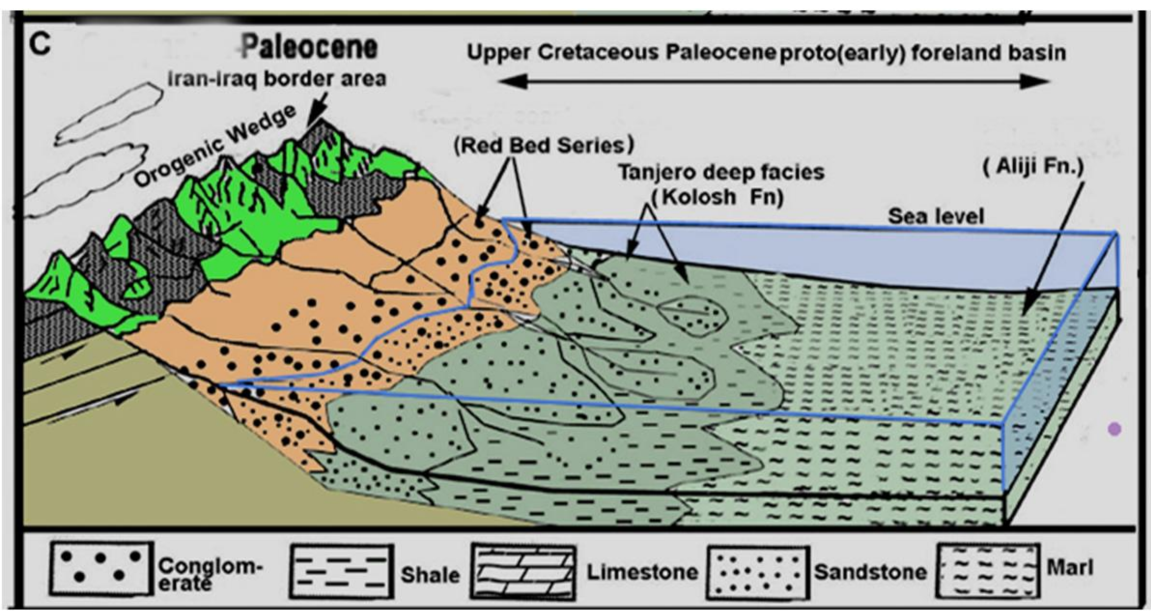


Fig.(3.6.1) Tectonic setting of the Foreland basin during Paleocene shows the environment and lateral changes of Kolosh Formation

3-6-2-Aliji Formation

Lithology: Marl and Marly limestone

Age: Paleocene
Tectonic condition: Basin plain of Paleocene Foreland basin away from tectonic activities.
Environment: basin plain
Thickness: about nearly 100-300m
Area of distribution: Low Folded and Mesopotamian Zones
Fossil content Planktonic foram (globogerina)
Sedimentary structures: bedding and lamination
Stratigraphic position: located between Shiranish and Jaddala Formations at the base and top respectively.
Boundary condition: It is conformable with both overlying and underlying formations formation in the High Folded Zones.
Sequence stratigraphy: deposited as sediment of low stand system tract

3-6-3-Red Bed Series

Lithology: Thick successions of red or grey sandstones, claystones and conglomerate
Age: Paleocene-Eocene
Tectonic condition: Costal area of large Tertiary Foreland basin in front of southwest advancing of Iranian Plate. It is equivalent to Kolosh Formation in lateral facies and in age
Environment: Alluvial plain, delta and delta front environment is mostly continental facies
Thickness: about 1500m
Area of distribution: Imbricated Zone and thrust Zone
Fossil content: Mostly reworked fossils
Sedimentary structures: imbricates pebbles, cross bedding and lamination and tool marks
Stratigraphic position: located between Tanjero Formation at the base and but the top is not known.
Boundary condition: It is conformable in some place and unconformable in others with both overlying unit and underlying Tanjero Formation. it is laterally changes to Kolosh, Sinjar and Gercus Formations toward southwest
Sequence stratigraphy: Deposited as sediment of mainly low stand system tract with minor high stand system tract (Fig.3.6.2)

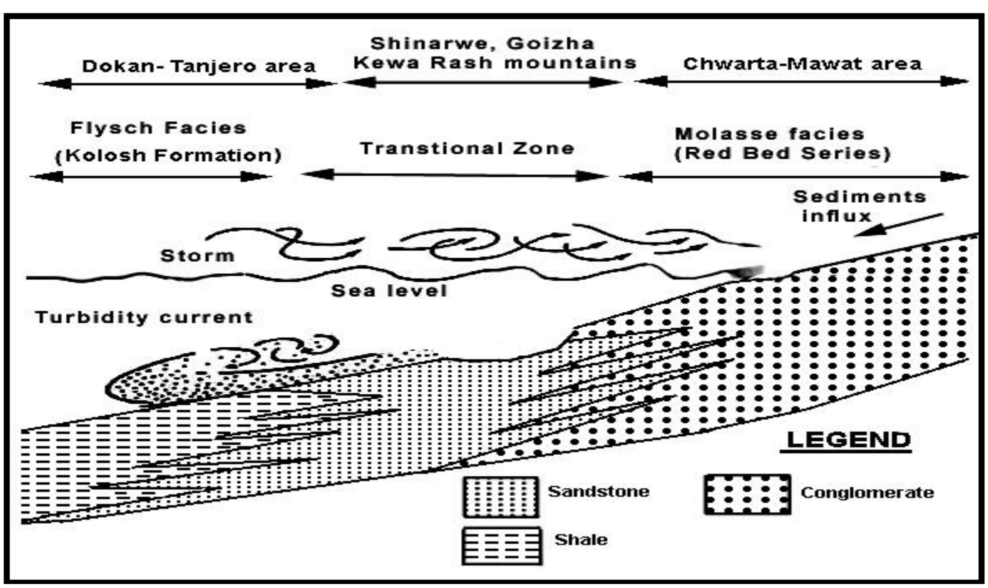


Fig.(3.6.2) Both Kolosh Formation and lower part of Red Bed Series are deposited in same foreland basin in basin plain and coastal area respectively. There is a transitional Zone (environment) between the two facies but now it is eroded

3-7-Maasrichtian-Campanian

3-7-1-Aqra Formation

Lithology: Reefal and lagoonal massive grey and black limestone
Age: Maastrichtian-Campanian
Tectonic condition: deposition on submerged paleohigh (forebulge) of Early Cretaceous Foreland basin in front of southwest advancing of Iranian Plate
Environment: reef, forereef and lagoon
Thickness: about 350m
Area of distribution: Low and High Folded Zones and Imbricated Zone
Fossil content: rudist, Pelecypod, large forams (omphalocyclus, luftusia orbituids) coral, Echinoderms, gastropods and pelecypods.
Sedimentary structures: bedding and lamination
Stratigraphic position: located between Kolosh Formation at the top and Tanjero Formation at the base in Sulaimani area. In Duhok areas it located between Khurmala (at the top) and Bekhme Formation at the base.
Boundary condition: It is conformable in some place and unconformable in others with both overlying Red Bed Series and underlying Tanjero Formation. it is laterally changes to Shiranish and Tanjero Formation toward southeast
Sequence stratigraphy: Deposited as sediment of both low and high stand system tracts (Fig.3.6.2)

3-7-2-Tanjero Formation

Lithology: Alternation of sandstone and calcareous shale on the slope and basin plain while changes to conglomerate and biogenic limestone on the shelf and coastal (Chuarta and Mawat Area) area
Age: Maastrichtian
Tectonic condition: Near shore area of Cretaceous Foreland basin in front of southwest advancing of Iranian Plate
Environment: Delta, shelf, slope and basin plain
Thickness: about 50- 600m
Area of distribution: Thrust, Imbricated and High Folded Zones
Fossil content: Pelecypod, large forams, rudist (in Aqra lens) and gastropods with Nereite, skolithos and planolites trace fossils.
Sedimentary structures: tool marks, flute cast, groove cast, cross bedding, graded bedding
Stratigraphic position: located between Kolosh and Red Bed Series at the top and Shiranish Formation at the base.
Boundary condition: It is conformable with both overlying Red Bed Series and underlying Tanjero Formation. It is laterally changes to Shiranish and Aqra Formations toward southeast and west
Sequence stratigraphy: Deposited as sediment of both low and high stand system tracts (Fig.3.7.1)

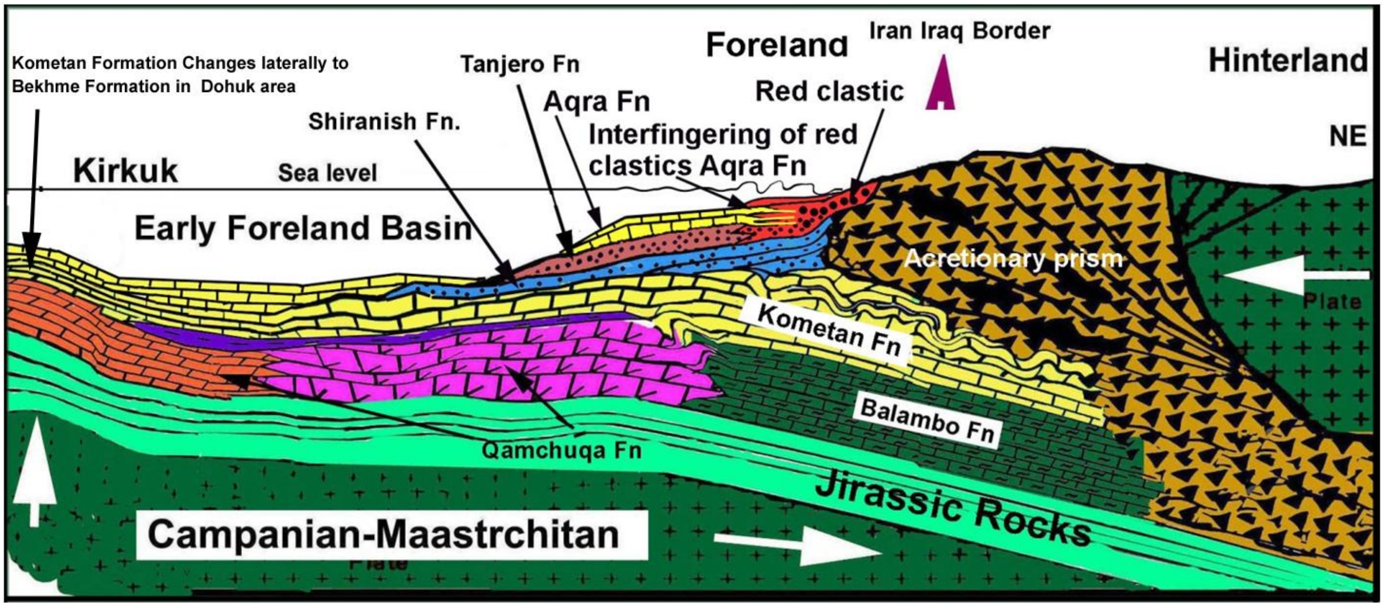


Fig.(3.7.1)Combination of tectonic and depositional setting of Upper (Late) Cretaceous basin in which Shiranish and Tanjero Formation are deposited (Karim, 2008).

3-7-3-Shiranish Formation

Lithology: Alternation well bedded bluish white marls and marly limestone
Age: Campanian-Maastrichtian
Tectonic condition: off -shore area of Cretaceous Foreland basin in front of southwest advancing of Iranian Plate
Environment: slope and basin plain
Thickness: about 200m
Area of distribution: Thrust, Imbricated and High and low Folded Zones and Mesopotamian Zone
Fossil content: Planktonic forams, ammonites, pelecypods
Sedimentary structures: bedding and lamination
Stratigraphic position: located between Tanjero Formation at the top and Kometan Formation at the base.
Boundary condition: It is conformable with both overlying Tanjero Formation and underlying Kometan Formation. It is laterally changes to Tanjero and Aqra Formations toward southeast
Sequence stratigraphy: Deposited as sediment of both early low stand system tracts (Fig.3.7.1)

Hartha Formation

Lithology: Reefal and lagoonal limestone with some dolomite and terrigenous sandstone with some oolitic limestones.
Age: Maastrichtian and Campanian (equivalent to Shiranish and Tanjero Formations)
Tectonic condition: Deposited in the foreland basin.
Environment: reef, forereef and lagoon
Thickness: about 200m
Area of distribution: Mesopotamian and Western Desert Zones
Fossil content: Rudist, Pelecypod, large forams, gastropods and pelecypods.
Sedimentary structures: Bedding and lamination
Stratigraphic position: Located between Saadi (at the base) and Tayarat at the top)

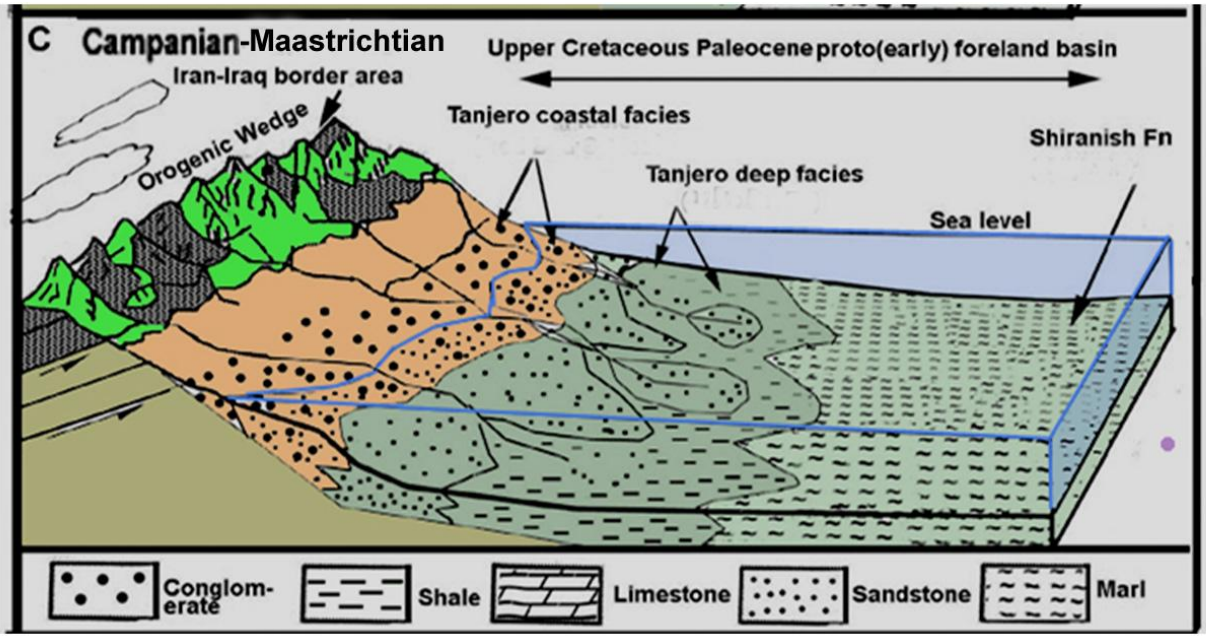


Fig.(3.7.2)Combination of tectonic and depositional setting of Upper (Late) Cretaceous basin in which Shiranish and Tanjero Formation are deposited (Karim, 2008).

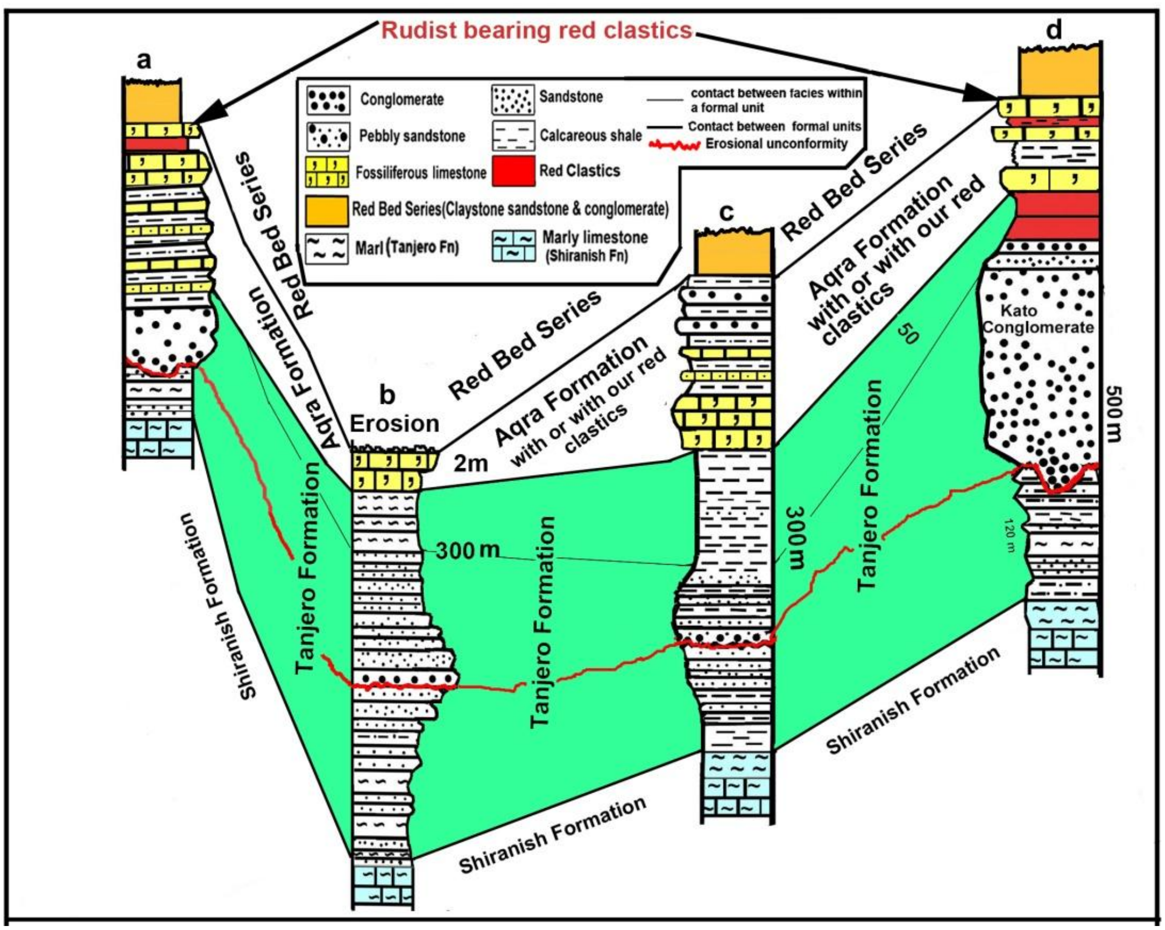


Fig. (3.7.2) Correlation of the Campanian-Maastrichtian formation in the Sulaimani area (modified from Karim, 2004)

3-8- Campanian-Turonian

3-8-1-Bekhme Formation

Lithology: Reefal and lagoonal massive dolomite and dolomitic limestone
Age: Middle Campanian-Turonian
Tectonic condition: Deposited on the continental margin (or oceanic margin) of Neo-Tethys basin
Environment: reef, forereef and lagoon
Thickness: about 300m
Area of distribution: Imbricated, Low and High Folded Zones
Fossil content: Rudist, pelecypod, large forams, gastropods and pelecypods.
Sedimentary structures: Bedding and lamination
Stratigraphic position: Located between Aqra (or Shiranish) Formation at the top and Qamchuqa Formation at the base.
Boundary condition: It is conformable with both overlying Shiranish Formation and underlying Qamchuqa Formation. It is laterally changes to Kometan Formation Formations toward southeast
Sequence stratigraphy: Deposited as sediment of both High stand system tracts (Fig.3.7.1)

3-8-2-Kometan Formation

Lithology: White well bedded fine grain limestone
Age: Turonian- Middle Campanian
Tectonic condition: Deposition on the continental margin (or oceanic margin) of Neo-Tethys basin
Environment: Slope and forereef
Thickness: about 70-120m
Area of distribution: Imbricated, High Folded, and Low Folded Zones
Fossil content: Planktonic Forams, ammonite
Sedimentary structures: Bedding, lamination and chert nodules
Stratigraphic position: Located between Qamchuqa Formation at the base and Shiranish Formation at the top.
Boundary condition: It is conformable with both overlying Shiranish Formation and underlying Gulneri (or Qamchuqa or Dokan Formations). It is laterally changes to Bekhme Formation toward northwest.
Sequence stratigraphy: Deposited as sediment of High stand system tracts (Fig.3.8.1 and 3.8.2)

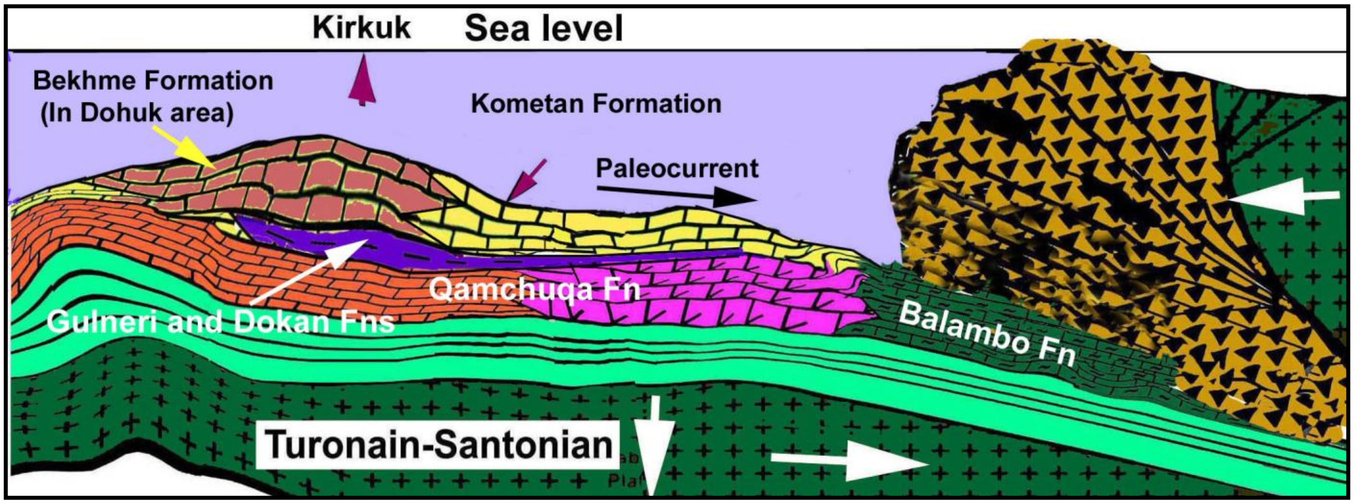


Fig.(3.8.1)Combination of tectonic and depositional setting of Upper (Late) Cretaceous basin in which Kometan is deposited (Modified from Karim, 2013 and Taha, 2008).

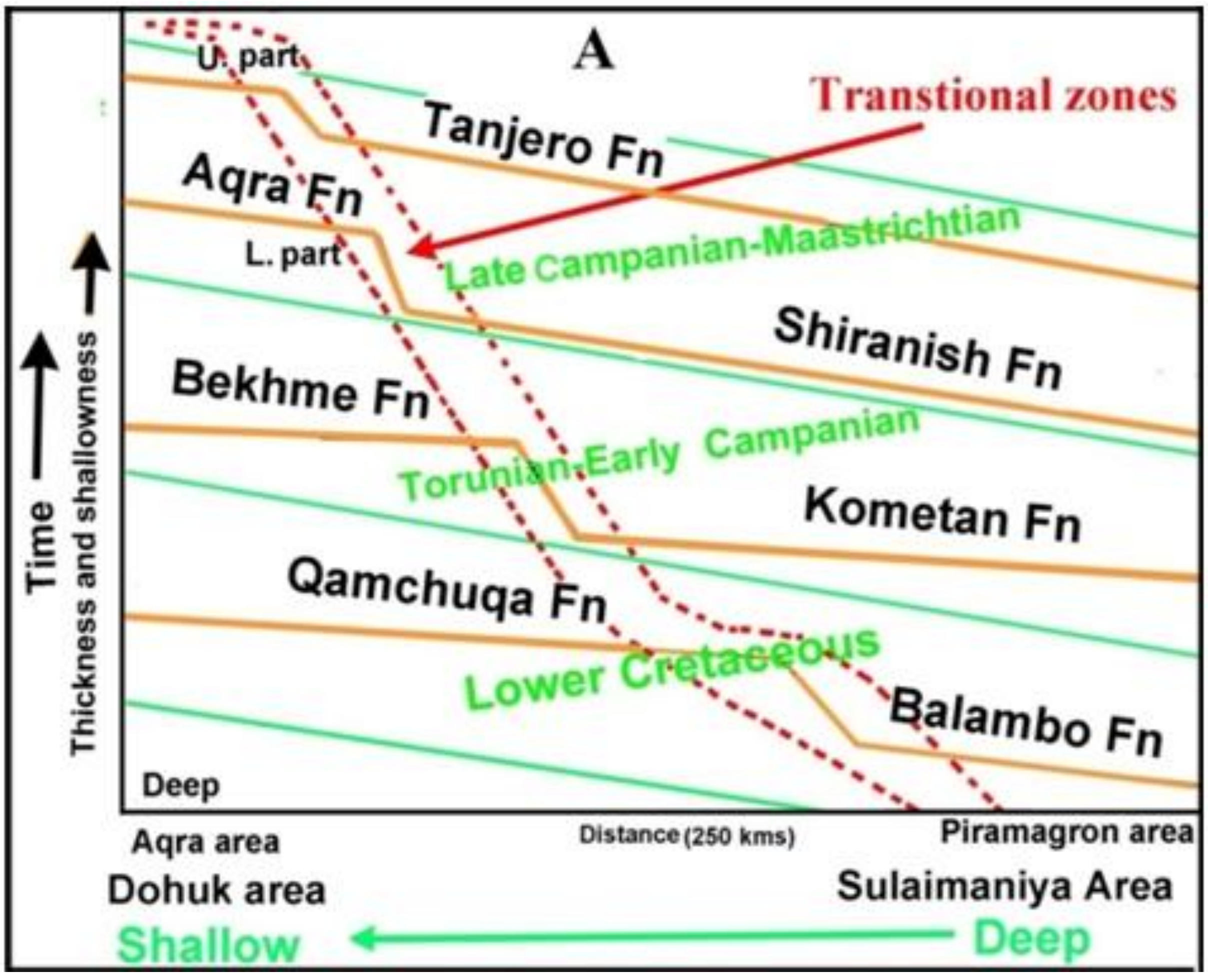


Fig.(3.8.2) Relation between deep and Shallow Facies (formations) during Cretaceous in Dohuk and Sulaimani Governorates (Karim et al., 2013)

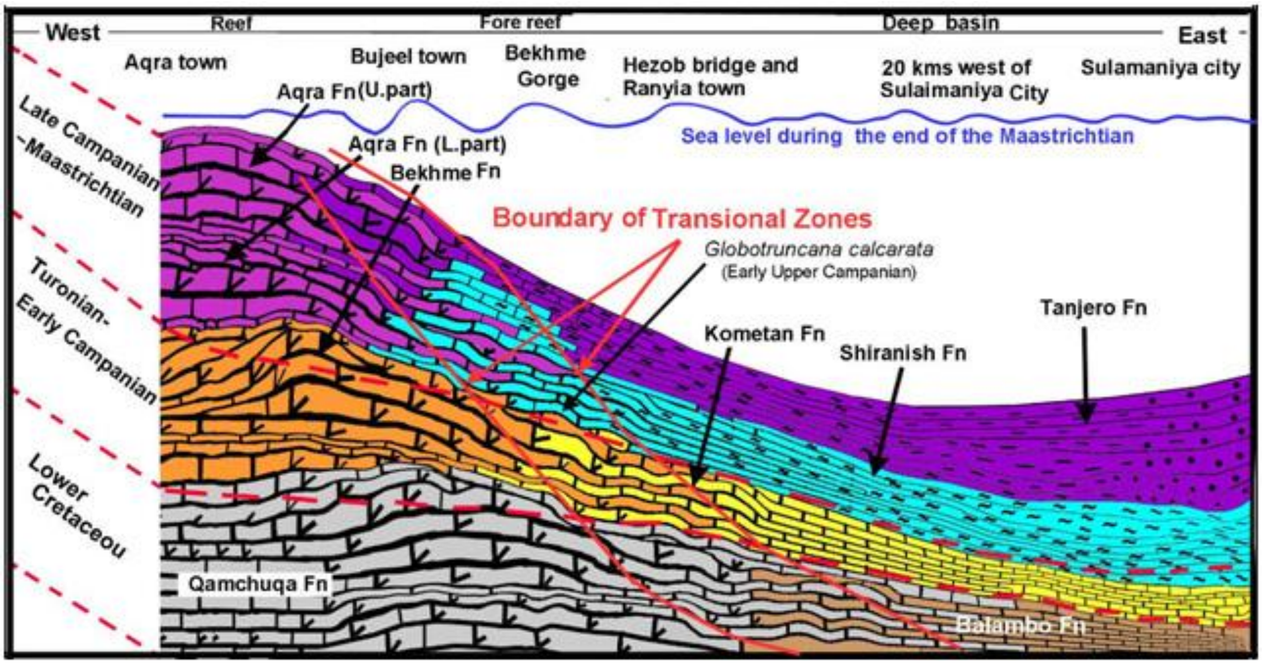


Fig.(3.8.4) Relation between deep and Shallow Facies (formations) during cretaceous in Dohuk and Sulaimani Governorates (Karim et al., 2013)

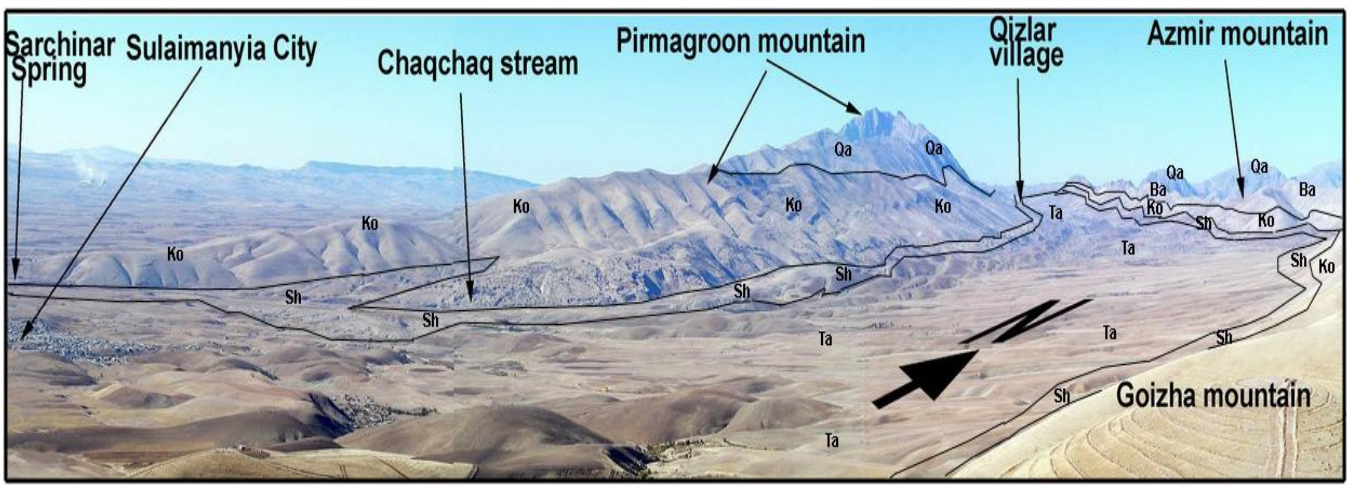


Fig.(3.8.4) Chaq Chaq valley (Dolla Root) valley showing Lower and upper Cretaceous Formations (Ali, 2007).

3-8-3-Gulneri Formation

Lithology: Grey, black or pink of highly deformed marl and marly limestone
Age: Late Cenomanian- Early Turonian (fig. 3.8.6)
Tectonic condition: Deposition on the continental margin (or oceanic margin) of Neo-Tethys basin
Environment: Slope and basin plain
Thickness: about 1.5-3m
Area of distribution: Imbricated, High Folded, and Low Folded Zones
Fossil content: Planktonic forms and nannofossils,
Sedimentary structures: Bedding, lamination and ball and pillow

Stratigraphic position: Located between Kometan Formation at the top and Qamchuqa Formation at the base.
Boundary condition: It is conformable with both overlying Kometan Formation and underlying Dokan (or Qamchuqa) Formations. It is laterally changes to Kometan Formation or Qamchuqa or Balambo Formations
Sequence stratigraphy: Deposited as sediment of High stand system tracts (Fig.3.8.5 and 3.8.2).

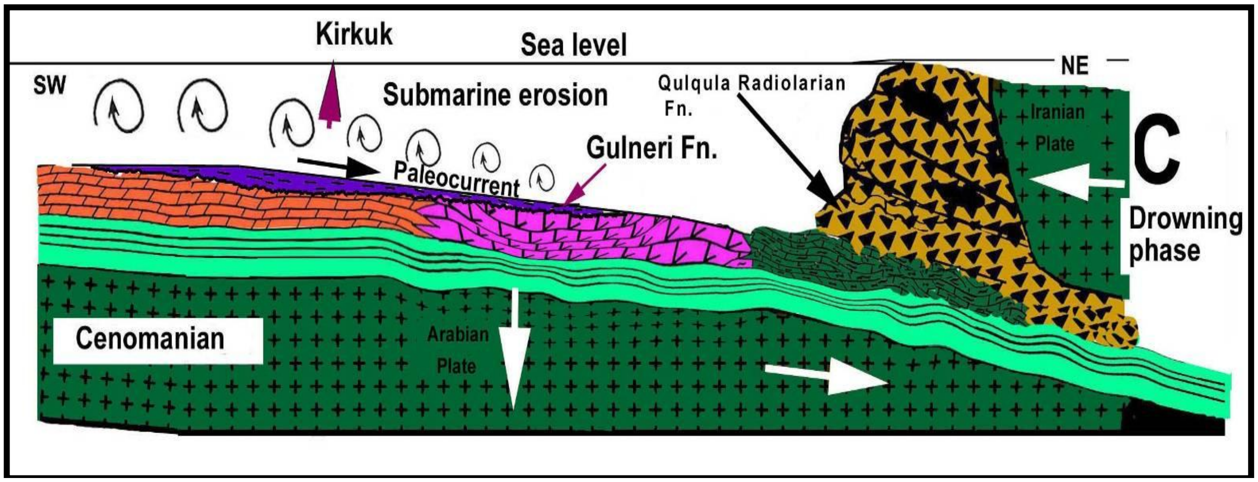


Fig.(3.8.5) Combination of tectonic and depositional setting of Middle Cretaceous basin in which Gulneri Formation is deposited (Taha,2008)

Fig.(3.8.6) Gulneri Formation on the Salta Re Hill at north of Sulaimani city show pink marl and marly limestones

3-8-4-Dokan Formation

Lithology: Grey thick bedded oligostiginal limestone
Age: Middle Cenomanian
Tectonic condition: Deposition on the continental margin (or oceanic margin) of Neo-Tethys basin
Environment: forereef (intermediate in depth between Kometan and Qamchuqa Formations
Thickness: about 5m

Area of distribution: High Folded Zone
Fossil content: Planktonic forms (oligostigina)
Sedimentary structures: Bedding, lamination
Stratigraphic position: Located between Gulneri Formation at the top and Qamchuqa Formation at the base.
Boundary condition: It is conformable with both overlying Gulneri Formation and underlying Qamchuqa or Balambo Formations. It is laterally changes to Kometan Formation or Qamchuqa or Balambo Formations. It is represent transitional facies from Qamchuqa Formation to Kometan Formation
Sequence stratigraphy: Deposited as sediment of early low stand system tracts (Fig.3.8.5 and 3.8.2).

3-9-Early Cenomanian- Aptian

3-9-1-Qamchuqa Formation

Lithology: Reefal and lagoonal massive grey limestone
Age: Aptian- Early Cenomanian
Tectonic condition: Deposition on submerged paleohigh (forebulge) of Lower Cretaceous Foreland basin on the continental margin (or oceanic margin) of Neo-Tethys basin
Environment: reef, forereef and lagoon
Thickness: about 600m
Area of distribution: Imbricated, thrust, High Folded, Low Zones and Mesopotamian Zone (Shuaiba and Mauddud as equivalent of Qamchuqa Formation in the southern Iraq.
Fossil content: Rudist, pelecypod, coral, algae, gastropods and pelecypods.
Sedimentary structures: bedding, lamination and stromatolite
Stratigraphic position: located between Kometan or Bekhme Formation at the top and Sarmord Formation at the base
Boundary condition: It is conformable with both overlying Dokan Formation and underlying Sarmord Formations. It is laterally changes to Balambo Formation.
Sequence stratigraphy: Deposited as sediment of high stand system tracts (Fig.3.9.1 and 3.9.2).

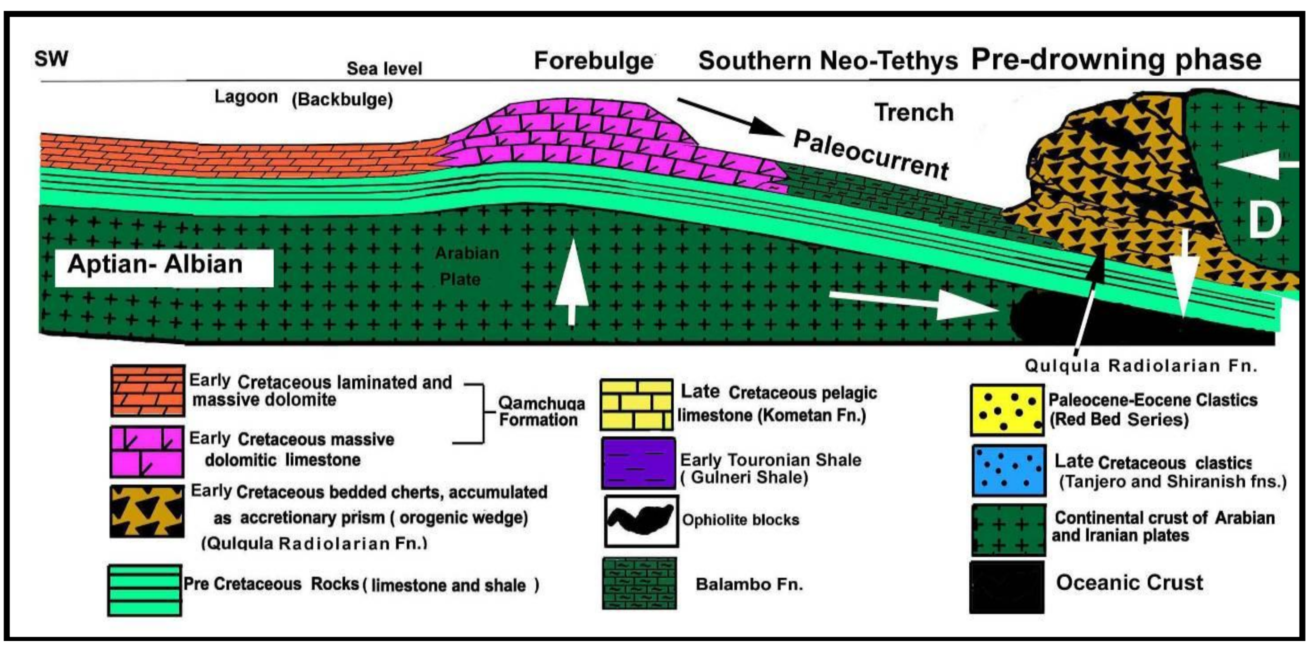


Fig.(3.9.1) Combination of tectonic and depositional setting of Lower (Early) Cretaceous basin in which Balambo, Qamchuqa and Qulqula Radiolarian Formations are deposited (Ameen,2008).

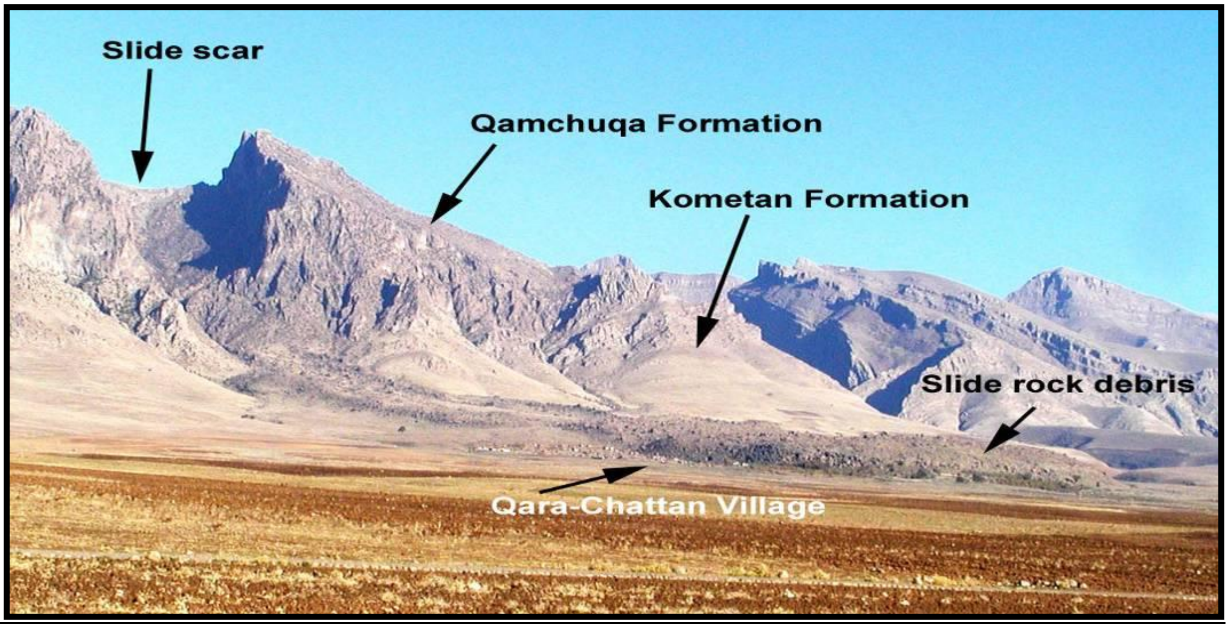


Fig. (3.9.2) Southwestern limb of Piramagroon anticline shows the exposed formations and Qara Chattan Rock slide.

3-9-2-Balambo Formation

Lithology: light grey or milky well bedded limestone and marly limestone with local dolomitic limestone beds
Age: Aptian-Cenomanian
Tectonic condition: Deposition in Southern Neo-Tethys during convergence of Arabian and Iranian Plates (deposited in foredeep basin). We can say that it deposited on the slope of the continental margin of Neo-Tethys Ocean
Environment: slope and Basin plain (Deep basin)
Thickness: about 200- 350m
Area of distribution: certain areas of Thrust, Imbricated, High Folded Zones
Fossil content: ammonite, planktonic forams, nannofossils
Sedimentary structures: bedding, lamination and chert nodules
Stratigraphic position: located between Kometan (or Gulneri) Formation at the top and Sarmord or Chia Gara Formation at the base.
Boundary condition: It is conformable with both overlying Kometan Formation (or Gulneri) Formation and underlying Sarmord Formations. It is laterally changes to Qamchuqa Formation toward west and to Qulqula Radiolarian Formation toward northeast.
Sequence stratigraphy: Deposited as sediment of high stand system tracts (Fig.3.9.1 and 3.9.2).

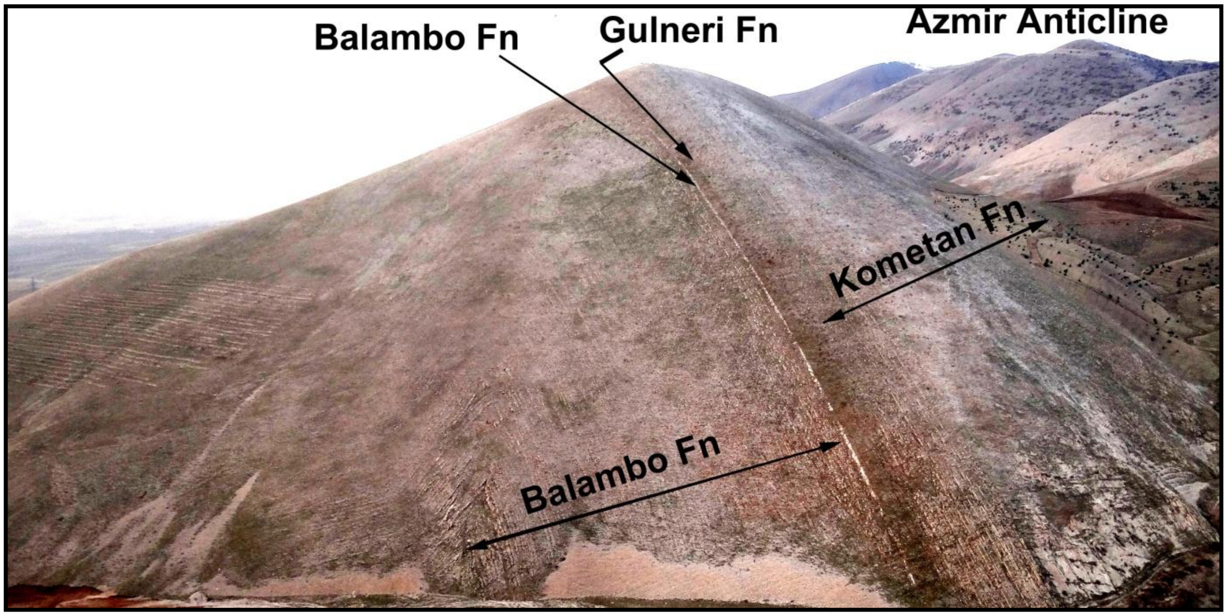


Fig. (3.9.3) Southwestern limb of Azmir anticline shows exposed formation on the Naugrdan hill which located 300m to the west of the southern end of the Azmir tunnel. There are no any sign of the unconformity between the formations

3-9-3-Sarmord Formation

Lithology: light grey marl and marly limestone with local pelagic fine grain limestone
Age: Valanginian-Aptian
Tectonic condition: Deposition in southern Neo-Tethys before converging of Arabian and Iranian Plates. We can say that it deposited on the slope of the continental margin of Neo-Tethys Ocean
Environment: Fore reef and slope.
Thickness: about 350m
Area of distribution: Imbricated, High Folded Zones
Fossil content: Orbitolina formas, Planktonic formams, nannofossils
Sedimentary structures: bedding, lamination
Stratigraphic position: located between Qamchuqa Formation at the top and Chia Gara Formation at the base
Boundary condition: It is conformable with both overlying Qamchuqa (and Balambo) Formation and underlying Chia Gara Formation. It is laterally changes to Nahr Umer toward south and to Qulqula Radiolarian Formation toward northeast.
Sequence stratigraphy: Deposited as sediment of high stand system tracts (Fig.3.9.1 and 3.9.2).

3-9-4-Qulqula Conglomerate Formation

This formation is refused by many authors and must be abandoned, see (www.kurdistan-Geology.com) for the evidence of refusing

3-9-5-Qulqula Radiolarian Formation

Lithology: Alternation of bedded chert, marl, shale and well bedded limestone
Age: Lower Cretaceous
Tectonic condition: Deposition in southern Neo-Tethys in the trench or basin plain between Arabian and Iranian Plates.

Environment: Deep basin (Trench or Basin plain)
Thickness: about 1500m
Area of distribution: Thrust Zones
Fossil content: Radiolaria and foraminfera in the limestone beds
Sedimentary structures: bedding, cross lamination and chert nodules
Stratigraphic position: not known
Boundary condition: It is conformable with both overlying Qamchuqa (and Balambo) Formation and underlying Chia Gara Formation. It is laterally changes to Nahr Umer toward south and to Qulqula Radiolarian Formation toward northeast.
Sequence stratigraphy: Deposited as sediment of high stand system tracts (Fig.3.9.1 and 3.9.2).

Chia Gara Formation

Lithology: marl and marly limestone
Age: Late Jurassic- Early Cretaceous
Tectonic condition: Deposition in southern Neo-Tethys before converging of Arabian and Iranian Plates.
Environment: Slope and basin plain
Thickness: about 200m
Area of distribution: Imbricated, High Folded Zones
Fossil content: Ammonite and Planktonic formams
Sedimentary structures: bedding, lamination
Stratigraphic position: Located between Barsarin and Sarmord Formation at the base and top respectively.

Khabour Quartzite Formation

Lithology: Thick alternation of sandstone and shale
Age: Ordovician
Tectonic condition: Deposited during high tectonism of Ordovician
Environment: shallow and deep environment
Thickness: about 800m
Area of distribution: Imbricated, High Folded, Low Folded Zone
Fossil content: Pelecypods and Trilobite.
Sedimentary structures: bedding, lamination and Cruziana trace fossils
Stratigraphic position: not certain

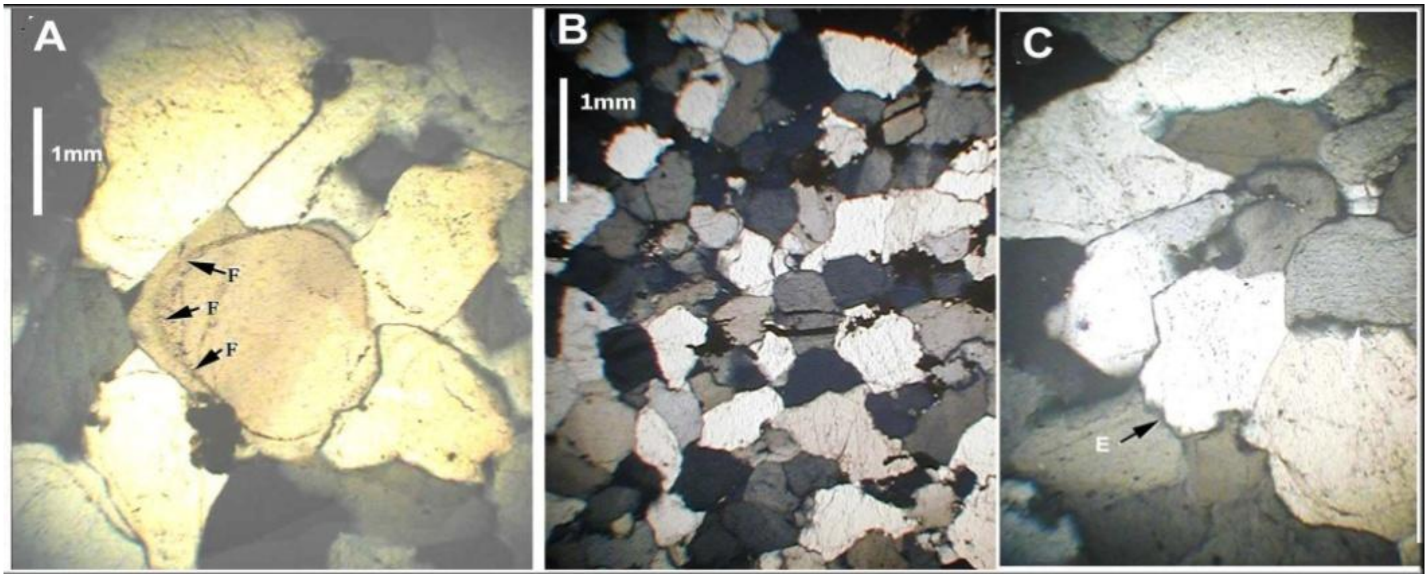
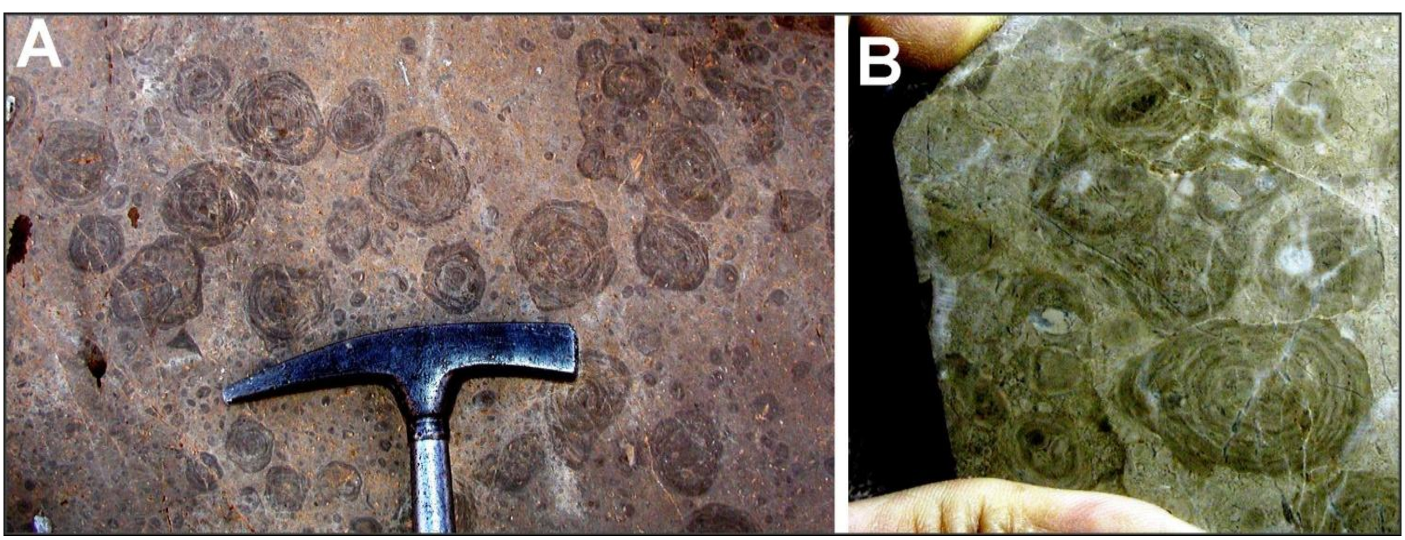


Fig. (60) Three thin sections (under plane polarized light) of the Khabour sandstone. Arenite of Khabour Formation composed mainly of quartz grains with well developed sutured contacts (E) and grains overgrowth (F).

Avroman Formation

Lithology: Thick alternation well bedded to massive gray fossiliferous limestone
Age: Triassic
Tectonic condition: Deposited on Isolated Platform
Environment: shallow reef and fore reef environment
Thickness: about 600m
Area of distribution: Thrust Zone on the border with Iran and form part of Avroman Mountain
Fossil content: Pelecypods and foram, algae, foram, echinoderm.
Sedimentary structures: bedding, lamination and stromatolite (oncoid) see below figures
Stratigraphic position: Not known.



Fig(61): A: Simple and composite oncoids in the limestone of the Avroman Formation as seen in polished slabs, B: the well developed laminae can be seen, some time disrupted by post positional fracturing.

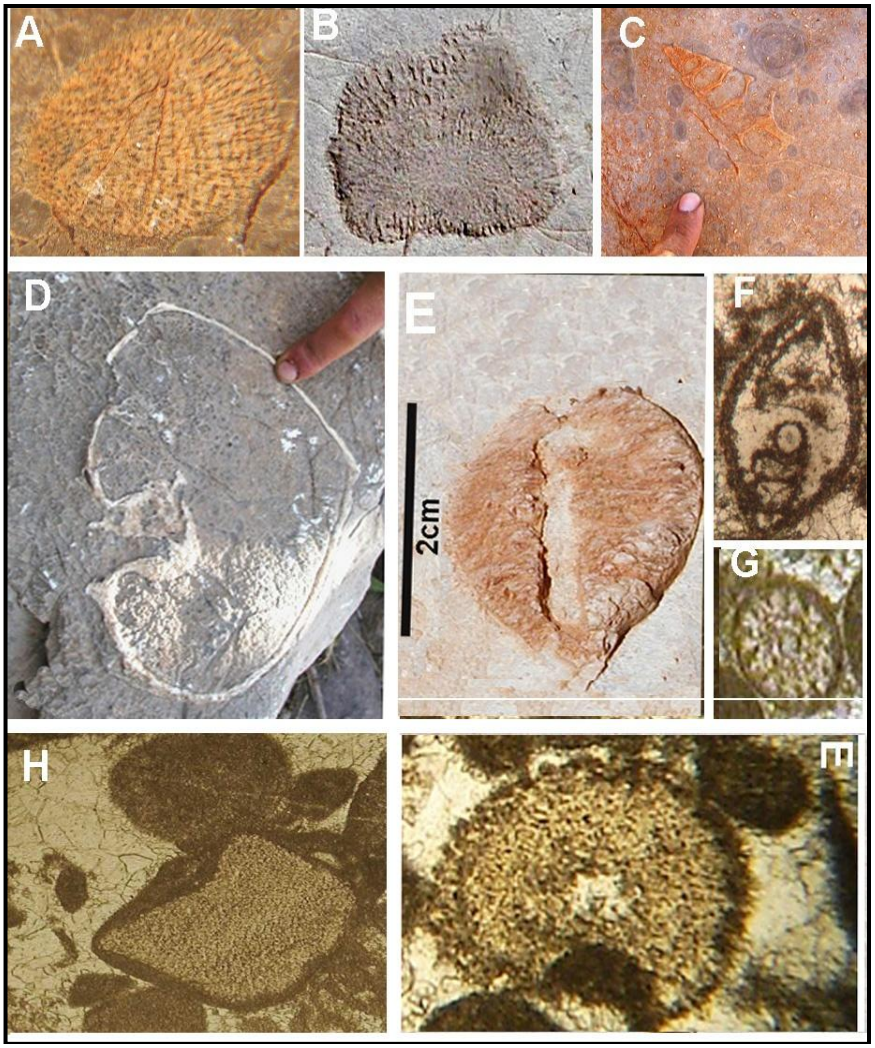


Fig. (62) Different types of fossils and their bioclasts in Avroman Formation. A and B) solitary colony of green algae, X5. C: Gastropod shell in oncolites bearing limestone. D and E) two different type of echinoderm. F) Unknown foraminifera, X20, PPl. G: Cross section of green algae steam, X30, PPL. H and I) Echinoderm plate and spine cross section, PPL X30, X50.

Equivalent of the formations in southwestern Iran

During Jurassic, Cretaceous and Tertiary the southwestern Iran and Iraq was covered by one large basin. This basin was called Southern Neotethys which consisted of foredeep (a basin consisted of trench) during Lower Cretaceous while it was changed to foreland basin at the beginning of Campanian and remained so till the present. Therefore, the formations in the southwestern Iran (Khuzistan and Ilam governorates) and Iraq are nearly the same with some minor differences. Only the name of the formations is different due to independent geological survey in the two countries by different oil companies. Another reason for the similarities of the formations is that the irregularities in the Neotethys are parallel to the trend of the oil field (present trend of Zagros Fold Thrust belt).Below a table shows equivalent name.

Name of the formations in Iraq	Name of the formations in Iran	Name of the formations in Iraq	Name of the formations in Iran
Upper Bakhiary (Bai Hassan)	Bakhiari	Aliji	Pebdah
Lower Bakhtiary (Mukdadyia)	Aghajari	Aqra	Seymare or Tarbur
Upper Fars (Injana)	Mishan	Tanjero	Upper part of Gurpi
Lower Fars (Fatha)	Gachsaran	Shiranish	Lower Part of Gurpi
Kirkuk Group	Kalhur and Shahbazan		
Euphrates	Asmari	Kometan	Ilam
Pila Spi	Jahrum	Dokan and Gulneri	Surgeh
Gercus	Kashkan	Upper Qamchuqa (Mauddud)	Sarvak
Avanah	Pebdah	Lower Qamchuqa (Shuaba)	Darian
Jaddal	Pebdah		
Sinjar	Teleh Zang	Balambo	Garau or Kazhdumi
Kolosh	Amiran	Sarmord	Gadvan

3. Main modifications (changes) of Geology of Kurdistan which are achieved in Department of Geology

Many modifications (changes) are achieved in the geology of Kurdistan during the recent years. Most of the changes are published in specialized geological journal in Iraq and Kurdistan. Some of the modifications are taken from M Sc and Ph d thesis that are achieved in Department of Geology, University of Sulaimani. The main modifications are as following:

1-Refusing the unconformity between Shiranish and Kometan formations

2- Refusing the unconformity between Qamchuqa and Bekhme formations.
3-Refusing the unconformity between Qamchuqa and Kometan Formations
4-Refusing the Qulqula Conglomerate Formation and combining it with Red Bed Series.
5-Refusing unconformable contact between Dokan and Qamchuqa formations and changing it to conformable contact.
6-Refusing the unconformable contact between Gulneri Formation and both Kometan and Dokan Formation.
7-Refusing that Gulneri and Dokan Formation are deposited in relict and euxinic basin but they are included in the Tethys basin.They are deposited on the continental margin of the basin.
8-Indicating the tectonic position of Qulqula Radiolarian Formation as deposits of trench and later accumulated as accretionary prism between the two plates.
9- Refusing existence of mio- and Eu-geosyncline in Kurdistan during Cretaceous and Tertiary and changing them to foreland basin.
10- Proving that the collision of continental part of Iranian and Arabian is occurred at Campanian not in Eocene as indicated before.
11-Proving that the paleocurrent was toward south and southwest during Upper Cretaceous and Tertiary.
12-Proving that western part of Sharazoor basin is formed by erosion and sliding which both activated by Tanjero stream .
13- Finding four incised valleys in the topography of Upper Cretaceous during deposition of Tanjero Formation for the first time in Iraq.
14-Lower part of the Tanjero Formation contains 500m of conglomerate instead of Upper part as suggested before.
15- Putting both Kolosh Formation and Red Bed Series in one foreland basin considering them as lateral facies changing of each other.
16- Putting both Upper part of Red Bed Series with Gercus Formation in single foreland basin and considering them as lateral facies changing of each other.
17- Proving that there are no any paleohighs between Kolosh Formation and Red Bed Series during Paleocene.
18- Proving that the Ball-and pillow structures in Tanjero and Kolosh Formations are not sedimentary structures (as considered before) but they are tectonic or diagenetic structures.
19- Proving that Chuwarta–Mawat area consist of a large graben.
20-Finding foot prints of birds and mammals in Lower Bakhtiary Formation (10m.y) before present
21-Proving that Qamchuqa Formation is deposited on a forebulge formed by tectonic load of Iranian plates.
22-Refusing that Guneri formation is composed of shale, but composed of limestone and marl.
23-Refusing most of the cycles of the Cretaceous and Tertiary that are previously established. The number of these cycles (cycles of uplifts and subsidence) is more than ten in Buday (1980) but most of them refused.
24-New chronostratigraphic column are drawn for Cretaceous and Tertiary which is completely different from previous one.

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