FACIES ANALYSIS OF AQRA FORMATION IN CHWARTA-MAWAT AREA FROM KURDISTAN REGION, NE–IRAQ

A THESIS

SUBMITTED TO THE COLLEGE OF SCIENCE, UNIVERSITY OF SULAIMANI, IN PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR

DEGREE OF MASTER OF SCIENCE

IN GEOLOGY

BY

Deren Mohamad Sdiq

B.Sc. in Geology-1998

(Sulaimani University)

Under Supervision Of:

Dr. Sherzad Tofiq Mohamad

Assistant Professor

March., 2010 ***Kurdish, 2710***

Supervisor Certification

I certify that this thesis has been prepared under my supervision in the Department of Geology of the University of Sulaimani, in fulfillment of the requirement for the degree of M.Sc. in Geology.

Signature:
Name: *Dr. Sherzad Tofeeq Mohammad*
Title: *Assistant professor*
Address: *University of Sulaimani*
College of Science
Department of Geology
Date: / /

The Certification of the Chairman of the Committee of Higher Student. According to the recommendation submitted by the supervision, I nominate this thesis for discussion.

Signature:
Name: *Dr. Kamal Haji Karim*
Title: *Assistant professor*
Address: *University of Sulaimani*
College of Science
Department of Geology
Date: / /

We, the examining committee, her by certify that we have read this thesis and examined the student in its contents and whatever relevant to it and, in our opinion; it is adequate with "   ” standing for the Degree of master of Science in Geology/Sedimentology.

Signature:
Name:
Title:
Address:
Date: / /
(Chairman)

Signature:
Name:
Title:
Address:
Date: / /
(Member)

Signature:
Name: *Dr.*
Title: *Assistant professor*
Address: *University of Sulaimani*
Date: / /
(Supervisor and Member)

Signature:
Name:
Title:
Address:
Date: / /
(Member)

Approved by the Council of the College of Science

Signature:
Name: *Dr. Parekhan M. Abdul-Rahman*
Title: *Assistant professor*
Date: / /

<u>Dedicated:</u>

To:

My Father

My Mother

My daughter

My Sisters and my Brother

To Whom Search for Truth

And

<u>With my love and respect</u>

<u>Deren</u>

ACKNOWLEDGEMENTS

I am deeply indebted to Dr. Sherza Tofiq Mohamad for undertaking the task of supervising this thesis and for offering many suggestions and corrections during the stages of the work in the field and lab. My best regards to the presidency of university, the dean of the College of Science and head of the of Department of Geology for their generous support including equipments facilities that offered to this work.

I would like to express my gratitude to the Dr. Kamal Haji Karim and Zardasht Ahmad Taha of Geological Department for their field support. My sincere thanks to my friends in Geological Department, University of Sulaimani for their laboratory help. The effort of Dr.Khalid Mahmood Ismail in identifying some of the fossils of this study is highly appreciated.

Finally, I would like to express my gratitude and appreciation for my parents, for their continuous support and encouragement, and I would like to extend my thanks to all who helped me during my study.

Deren Mohamad Sdiq

ABSTRACT

The present study is concerned with facies analysis of the Late Cretaceous outcrops of Aqra Formation (Aqra lens) in Chwarta-Mawat area, Sulaimanyia Governorate, northeastern Iraq. This area is located within Imbricate Zone which includes Chwarta and Mawat towns. The microfacies and Lithofacies of the formation are studied in addition to stratigraphy in three selected outcrop sections. The study also includes the inspection of its boundary conditions in the surrounding areas.

Aqra Formation (Late Maastrichtian) area mainly consists, in Chwarta-Mawat, of biogenic and detrital limestones. These rocks appear as thick succession of light grey and well bedded or massive beds which can be seen along both sides of the existed streams and gorges. The boundaries with both underlying Tanjero Formation and overlying Red Bed Series are gradational and the contact is conformable.

The fossil content are rich and belongs mainly to foramol association which includes large forams (*Loftusia, Omphalocyclus and Orbitoids*) with mollusks (*Gastropod and Pelecypods, including Rudist*) in addition to echinoderm and rare ammonites and solitary corals. The main facies are floatstone, mixstone, rudstone, packstone, and Bafflestone. The allochems of these facies consist of the skeletons of one or more of the above fossils or their bioclasts.

The Lithofacies such as terrigeneous conglomerate, marlstone and red clastics of Tanjero Formation and Red Bed Series exist at the underlying and overlying boundaries the important for tectonic and environment reconstruction of the formation. Most of the litho and microfacies can be

identified by eyes or hand lens due to large size of the fossils the matrix is consist mainly of sand or silt sized bioclasts with more or less micrite.

These facies are deposited in shallow and high energy platform (basin) of mid-latitude temperate climate with high rate of sedimentation. The basin is supplied by terrigenus clastics from source area and appeared in some place as bed or lens of sandstone interbedded with the biogenic limestones.

The initial growth of the reefal and biogenic limestones were depended on the low stand fan sediments (accumulation of graves and boulders) which acted as hard substrate for stabilization reefal growth (biostromes and bioherms) and decreasing turbidly. This does not mean that there was no turbidity as there were many streams in Chwarta-Mawat area during late Maastrichtian. These streams were small and low energy which were reaching the foreland basin and supplying the sediments and nutrients to the basin. The roles of the coarse sediments are very clear from two field observations. The first is that the thickness of the conglomerate is high the thickness of the Aqra Formation is high too as can be seen in the Kato and Kele sections with 100 and 80metter thickness. The second is that at the base of the both sections the conglomerate alternate with biogenic limestone as discussed in the conglomerate lithofacies.

Facies analysis appears that the energy was high during the deposition of the formation and during Late Maastrichtian. But it was higher in the lower part than upper part this is clear from reworked Loftusia and broken skeleton debris that can be seen more frequently in the lower part. Because of this, even the floatstone of rudist and large pelecypod contain bioclasts and lithoclasts. The low occurrence of the grainstone is attributed to high rate of deposition and influx of terrigenus clay from outside of the basin.

LIST OF CONTENTS

Subjects

Chapter One: Location and Geomorphology

Chapter Two: Lithology and Stratigraphy

Chapter Three: Facies Analysis

Chapter Four: Depositional Environment and Tectonics

List of Figures

Fig. No.	Titles	Page no.

Chaptor One

LOCATION AND GEOMORPHOLOGY

1.1- Introduction:

Aqra Formation is a reefal limestone; which was first studied from Aqra area, Kurdistan Region- Iraq. Aqra formation was defined by Bennett (in1945) from the Aqra anticline of the High Folded Zone (Bellen et al., 1959). According to same author, at the type section, it is consisting of massive detrital bituminous partially siliceous reefal limestone.

The limestone is reefal and progressed to fore reef and withdraws to shoal limestone. The equivalent formation of Aqra Formation is Bekhme Formation. Some time it is not easy to make distinguishing between both Formations. On the base of the available index fossils, it confirmed that age of the Aqra Formation is Maastrichtian. The overlying Formation in the type area is Kolosh-Khurmala Formations; the contact is unconformable since there is conglomeratic bed at the base of Aqra Limestone (Buday, 1980).

In the studied area the formation is regarded as lens inside the Tanjero Formation by Karim (2004), as there are a grey clastic intervals above the Aqra lens and between former formation and Red Bed Series, but it is assigned as interfinguring with Tanjero Formation by Lawa, et al 1998.

According to Buday, (1980) the underlying formation (lower boundary) is probably not seen in the type section, while in the studied area it is considered to be Tanjero Formation and the citation of (Karim, 2004) is ascertained (being it appears as a lens in the Tanjero Formation). Field study showed that Tanjero formation, in the studied area, is not connected with the Aqra Formation. This means that in this area Aqra Formation surrounded by Tanjero Formation from all sides.

Aqra Formation was deposited in a reef environment ranges from back reef to fore reef, it known from the relatively shallow-water paleoenvironment located in the outer parts of the Late Cretaceous Tethyan platforms. This Formation is cropping out around Aqra Town, Gali sheikh Abdul Aziz, Gara Mountain, Zinta Gorge, Bekhme, Dar-e- Tesu, Diza, Gundi-i- Shikavt, Zibar, Chalki, Ser Amadia, Hadiena, Rowanduz and Chwarta-Mawat area.

The equivalents of Aqra Formation are Bekhme Formation from Kurdistan, but its equivalents from southern Iraq are called Hartha and Tayarat Formations.

1.2- Location and geomorphology:

The area of the study is located in the Zagros Mountain belt near the border between Iran and Iraq, at 30km to the north and northeast of Sulaimani city (Fig. 1.3 and 1.4). The area includes famous Chwarta, Mawat and Basini towns at its eastern, western and northern boundaries respectively (Fig.1.3 and 1.4). The area consists of large valley (Chwarta-Mawat valley) which is surrounded by several mountains from east, northeast and north by Kato, Sarsir, Gimo, Pyr Mohammad and Gawraqul mountains. From southeast, south and southwest it surrounded by Goizha, Azmir and Jafayati Mountain respectively (Fig 1.6).

This large valley compartmentalized by three large perennial streams such as Goga Sur (Kele or Mokaba), Tagaran and Sywail (Fig.1.5 and 1.7). From catchment area, these large streams flow toward southwest and finally meet near Mokaba village forming larger stream known as Mawat stream. Near this latter village, the stream diverts toward north till meet with Do Awan stream (up stream of Little Zab River) where again divert toward southwest. The Aqra Formation is exposed along the valley sides and gorges that are related to the above streams.

1.3- Geological and Structural Setting:

The geology of the area has structural and stratigraphic complexity as it is partly located in the Thrust and partly in Imbricated Zones of Buday, (1980), Buday and Jassim (1987) and Jassim and Goff (2006) (Fig.1.1 and 1.2) . The area represents the northeastern margin of the Arabian plate where the continental part of Iranian and Arabian plates occurred during Eocene (Numan, 1997 and Surdashy, 1997) or during Upper Cretaceous (Karim, 2004 and Karim and Surdashy 2006).

The northern part of the area is occupied by Ophiolite and Naoperdan Series thrust sheets while the northeastern part one covered by Qulqula Formation. In the south and southwest of the Cretaceous rocks are exposing (Fig. 1.3, 1.4, 1.5 and 1.6).

According to Karim (2006), the area consist of large graben which formed by two transverse normal faults. These faults have the direction of northwest southeast north and one of them located two the southeast of Chwarta town while the other one located to the northwest of Mawat town (Fig.1.7).

Muhammad (2004) studied the geochemistry of the Mawat ophiolite and he assigned that the area has suffered from extension during Eocene. The outcrops of these rocks form a tongue, which elongates from the north (from Iranian border) towards the south and ends near Chwarta Town. Its central part consists of ophiolite and metamorphic rocks surrounded by the outcrops of Red Bed Series and Nauprdan Series. This tongue is called Mawat Nappe by Al-Mehaidi (1975) who studied that this Nappe which is thrusted over Red Bed Series and Cretaceous rocks.

Tectonically, the area is located in the Zagros Thrust-Belt and include two different zones which are Thrust and Imbricate Zones (Sissakian et al, 1996). According to (Jassim and Goff, 2006), the studied area located inside the Balambo-Tanjero Zone (Fig.1.1).

The field study in the northeastern Iraq revealed that the thrust has the attitude of $10^{o} - 35^{o} / 35^{o}$. The low dip angles ($10^{o} - 20^{o}$) is exist in the low lands such as Mawat-Chuarta area while the high angle ($20^{o} - 35^{o}$) exist where the thrust climbs the elevated anticlines in the Avroman–Surren and Kaolos–Chuarta areas, in the latter cases the thrust can be called reverse fault (Karim, et al, 2007). Due to imbrications, the anticlines and syncline cannot be distinguished and all the strata are dipping about 20 degrees toward northeast.

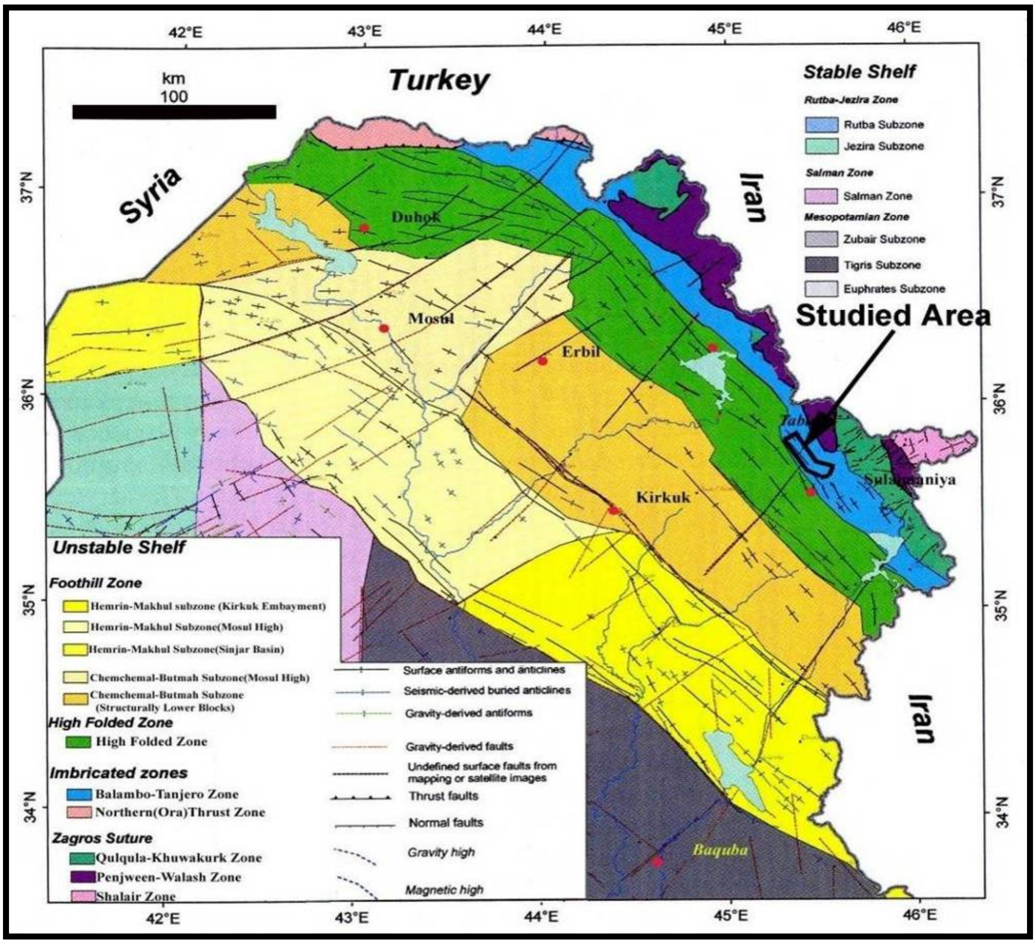

Fig.(1.1) Tectonic classification of the north Iraq (Jassim and Goff, 2006) showing the studied area.

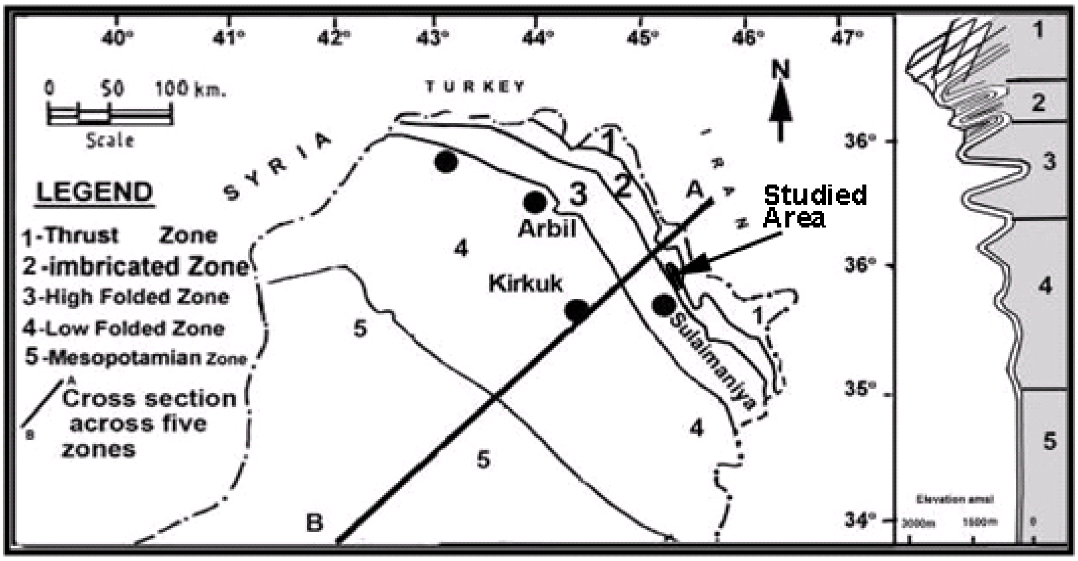

Fig. (1.2) Boundaries of the tectonic subdivision of the Western Zagros in Iraq (modified from Buday and Jassim, 1987).

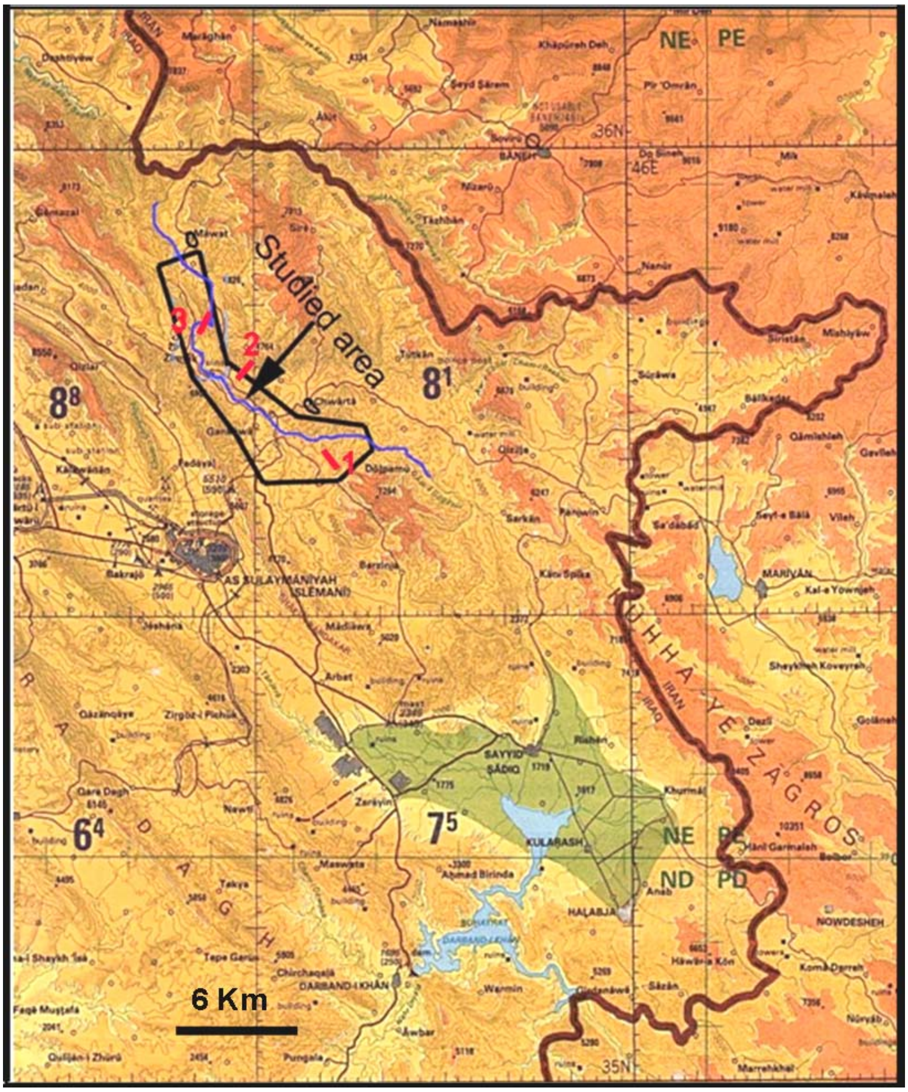

Fig (1.3) Northeastern Iraq map (from site of Iraq Map) shows the location of the studied area.

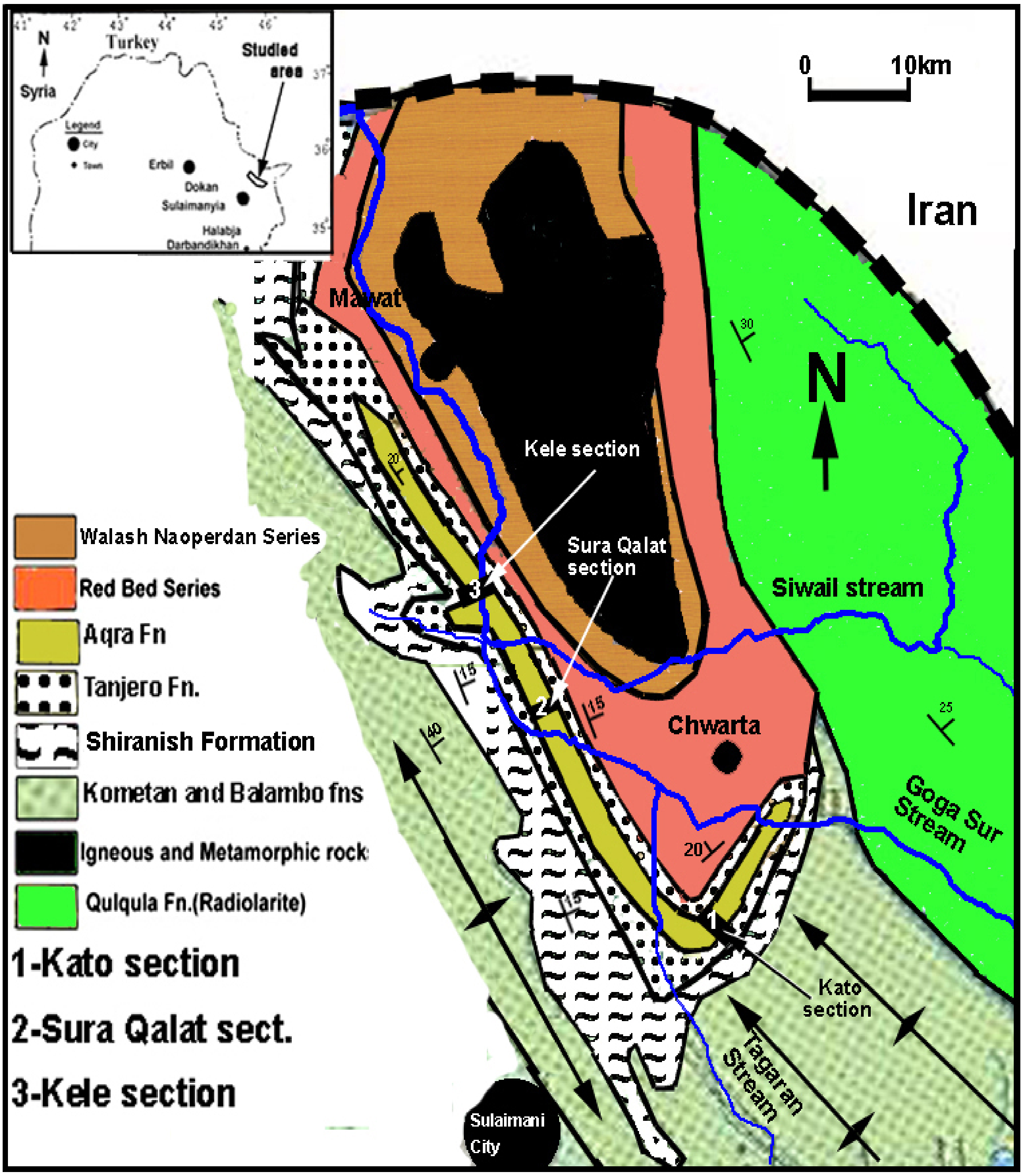

Fig (1.4) Location and geological map of the studied area (modified from Sissakian, 2000)

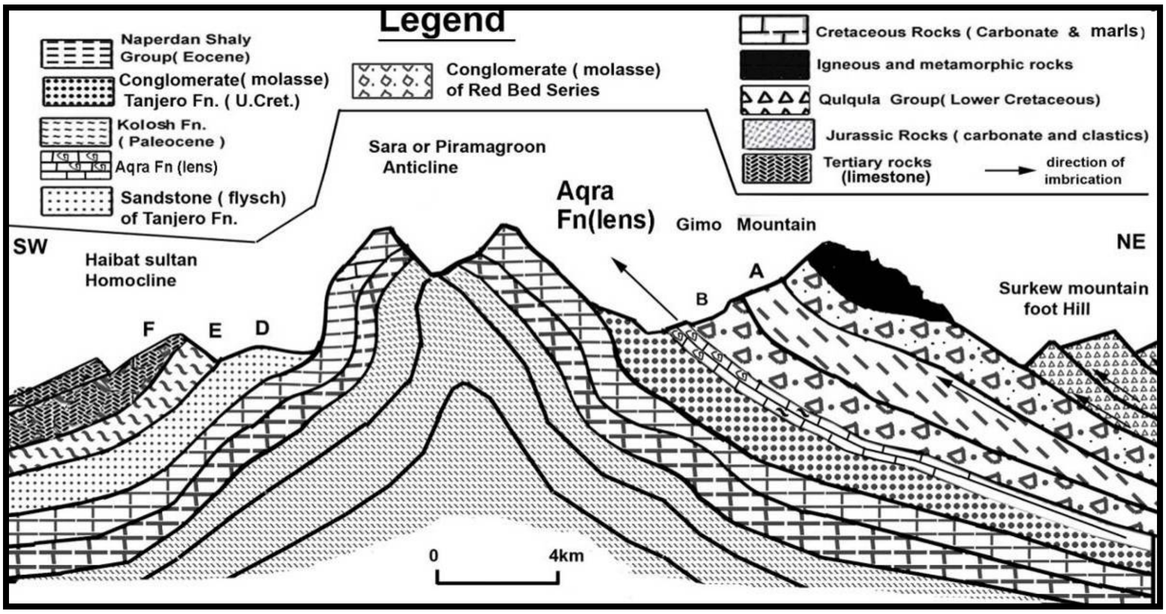

Fig.(1.5) Geologic cross section passing through Piramagroon and Gimo mountain in addition to Mokaba stream showing the stratigraphic and geomorphologic position of the Aqra lens.(Karim et. al., 2007) .

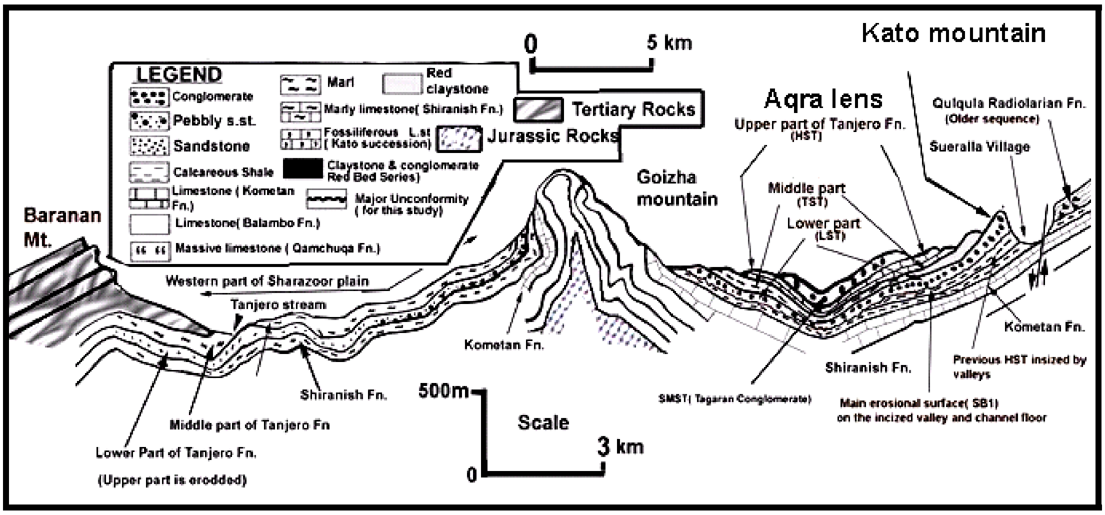

Fig.(1.6) Geologic cross section passing through Kato, Goizha and Baranan mountains showing the stratigraphic and geomorphologic position of the Aqra lens.(Karim, 2004)

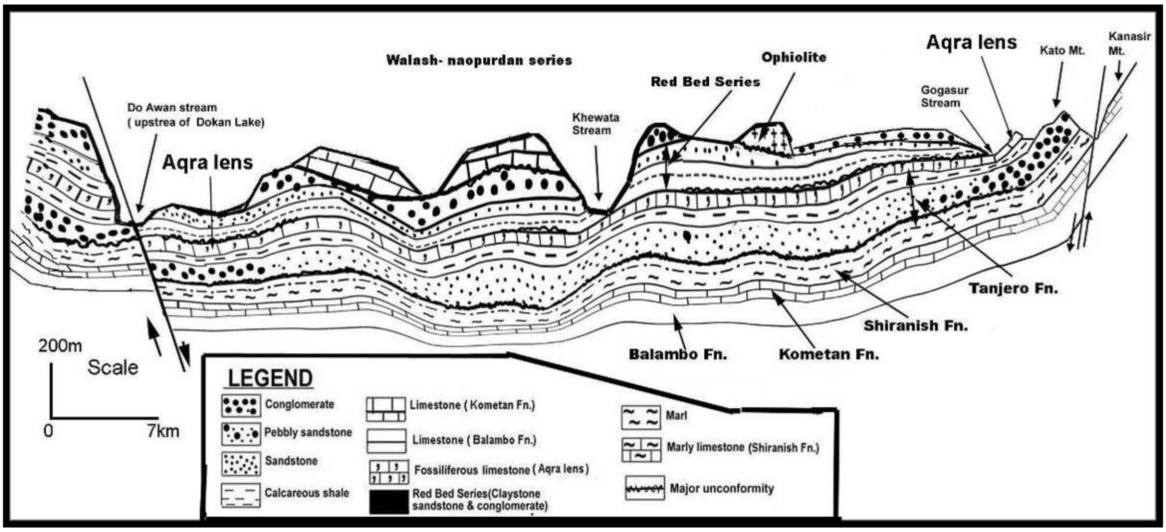

Fig.(1.7) geologic longitudinal section of the Chwarta-Mawat area showing the two normal fault and the Aqra lens(Karim,2006).

1.4- Studied sections:

Geographically, studied area located at Northwest of Sulaimani city; between Chwarta-Mawat districts, Northeast limb of Azmr Mountain (fig 1.3and1.4)

In the studied area (350) samples were collected from three selected sections (Kato, Sura Qalat and Kele) and chosen samples depended on facies changes.

1.4.1- Kato section:

This section is located about 6 kilometers to the east of Chwarta town, at the toe of Kato Mountain (lower part of northwestern side of the mountain). The base of this section is located at the intersection of Latitude (N: 35 39 24. 36) and longitude (E: 45 35 25. 55), while the top is located in intersection of Latitude (N: 35 39 31.87) and longitude (E: 45 35 17. 88). The section runs along a meandering stream at 2km to the southeast of Harmin village. The strata are dipping 25 degrees toward the northwest (Fig1.8).

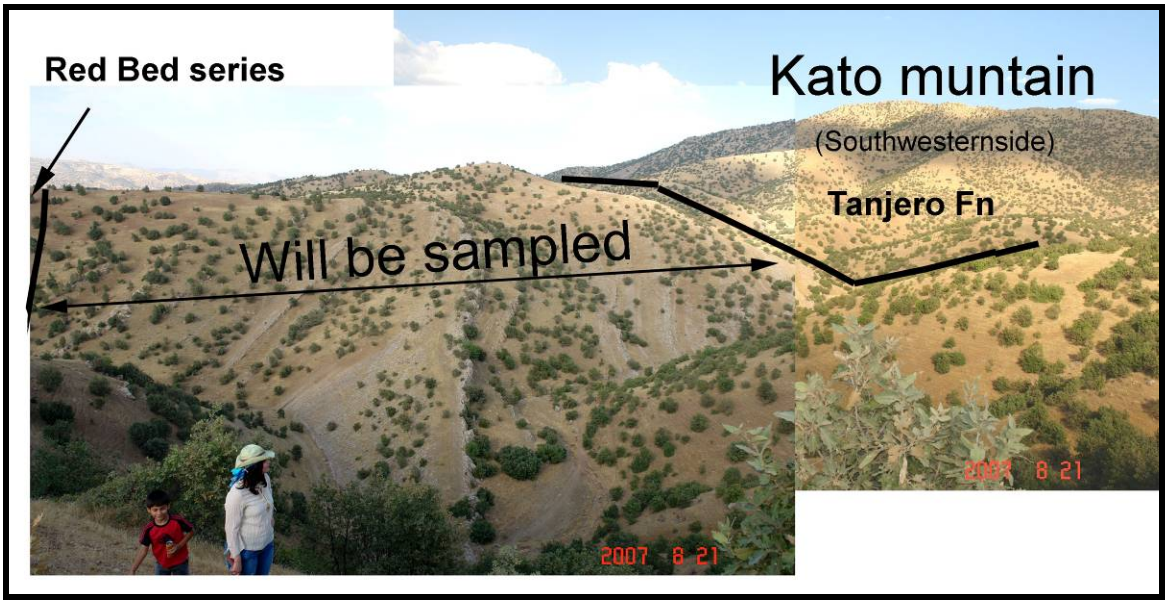

Fig.(1.8) Limestone succession of Aqra Formation in Kato section (sampled)

1.4.2- Sura Qalat section:

This section is located about 10 kilometers to the Southeast of Mawat town. The base of the section is located at the intersection of Latitude (N: 47 35 48.05) and longitude (E: 45 26 24.27), while the top is located in intersection of Latitude (N: 46 35 55.56) and longitude (E: 45 26 26.13). It located along the northeastern valley side of the Mokaba (or Qalachuallan) stream (Fig1.9).The strata are dipping 16 degrees toward northeast and are highly deformed which appear as faulting and fracturing.

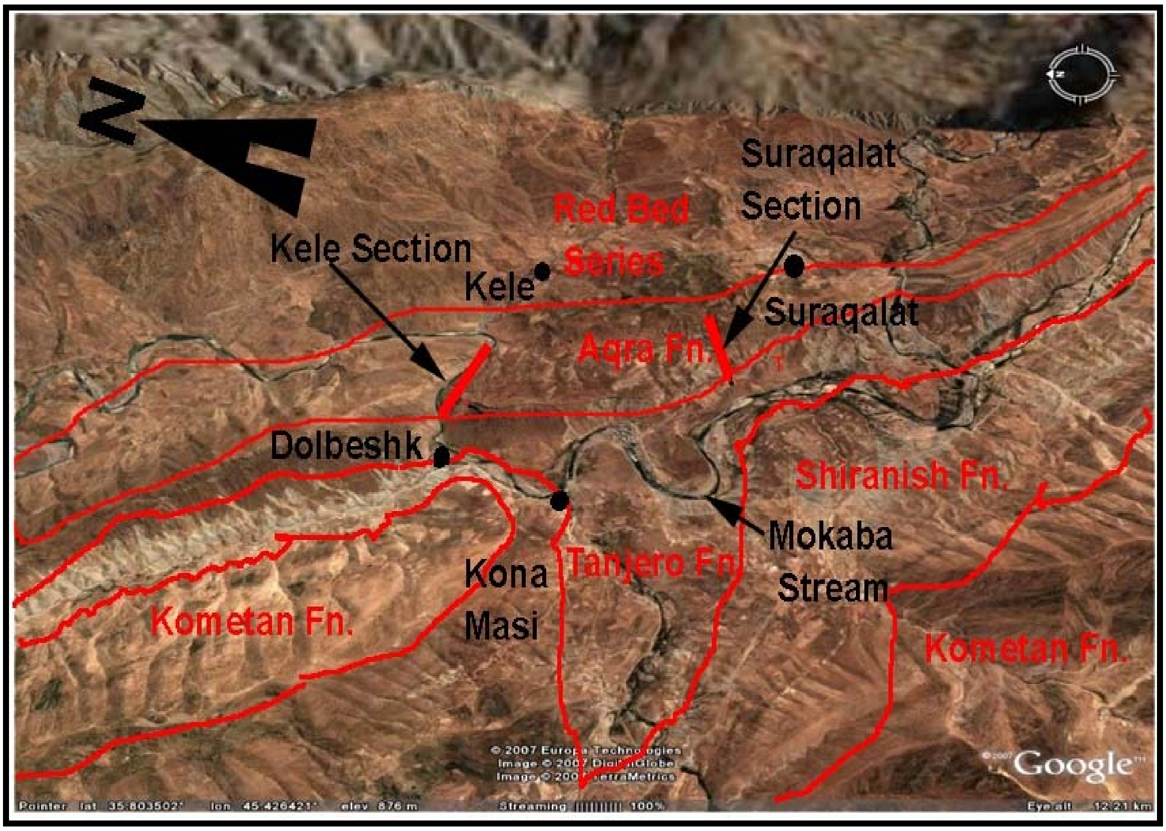

Fig (1.9): Location map of the Kele and Sura Qalat section, as viewed from west, Satellite Image (from Google, 2007).

1.4.3- Kele section:

This section is located at 7kilometer to the southeast of Mawat town. The base of this section is located at the intersection of Latitude (N: 35 48 42.83) and longitude (E: 45 25 56.52.), while the top is located in intersection of Latitude (N: 35 48 57.32) and longitude (E: 45 26 31.27). The section runs along the sides of the Dolbeshk or (Mawat) stream and consists of high erosional cliff (Fig, 1.10 and 1.11). A part (about 30m) of the section is located on the right side of the stream while the rest is located on the left side. The strata are thick and occasionally massive which dipping 20 degrees toward northeast.

Fig.(1.10) Part of Kele section as exposed along the Dolbeshk Gorge (lower and upper contact are not appeared).

1.5 - Aims of the study

The main aim of the current study is to analyze the microfacies and lithofaces of Aqra limestone Formation from the Chwarta-Mawat regions, and to reconstruct the paleogeographic and depositional environment aspect of the basin.

In addition to that, the study also includes the study of lithology and stratigraphy and characteristics and comparison with that of the type locality to establish a complete configuration of the basin during the deposition of the formation.

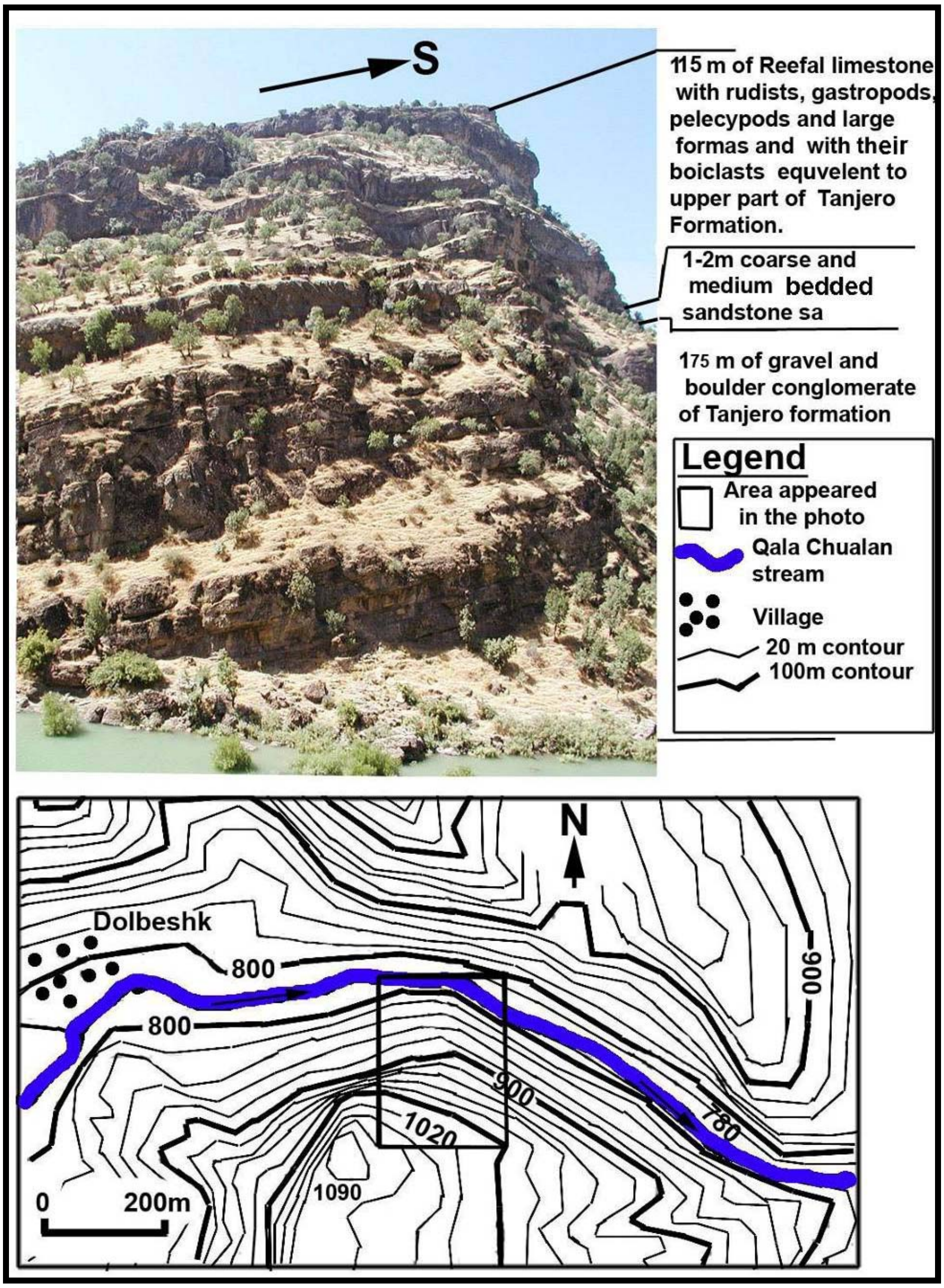

Fig (1.11) Representation of the Kele section, as viewed from western side of Dolbeshk stream which flow across Dolbeshk Gorge (Karim et al, 2007)

1.6- Methods of Study:

1.6.1- Sampling and Field trips:

This study is achieved through field trips and laboratory works. During field survey, nearly ten field trips (reconnaissance and detail survey) were performed at the studied area; it included observations and searches for the exposed and conspicuous outcrops around the area during which three sections are selected for sampling and description.

Field trips included lithology description, measuring thickness, vertical and lateral lithology changes. For the current study, about two hundred rock samples have been collected from Kato, Sura Qalat and Kele sections. From these samples 100 thin sections are made for the petrographic studies under the microscope. Sample collection depended on the variation in lithology; that is rock samples have taken according to the lithological characteristics and change in the stratigraphic column of the studied area. Detailed field study of the outcrops done to get a general view of the distribution of the lithological changes in addition to vertical (stratigraphic) and (geographic) lateral lithofacial variations and indication of most suitable sections for sampling.

1.6.2- Laboratory works

To achieve the aims of this study, the following works are conducted:

1- Study of about 100 thin sections of the collected samples of all outcrops of area and description of the sections.

2-Thin section studies under binocular and polarizer microscopes for differentiation of the constituents and photographing the most useful samples.

3-Calculating percentage of the constituents (for identification of facies and rock types) by using point counter. The method of(Flugel, 2004, in: Betzer, et al., 2005) is used for point counting in which void with in particles were counted as constituent of the particles. The slides and samples that contain few allochems the visual estimation by using the charts prepared by Folk et al., (1970) and Tucker (1989).

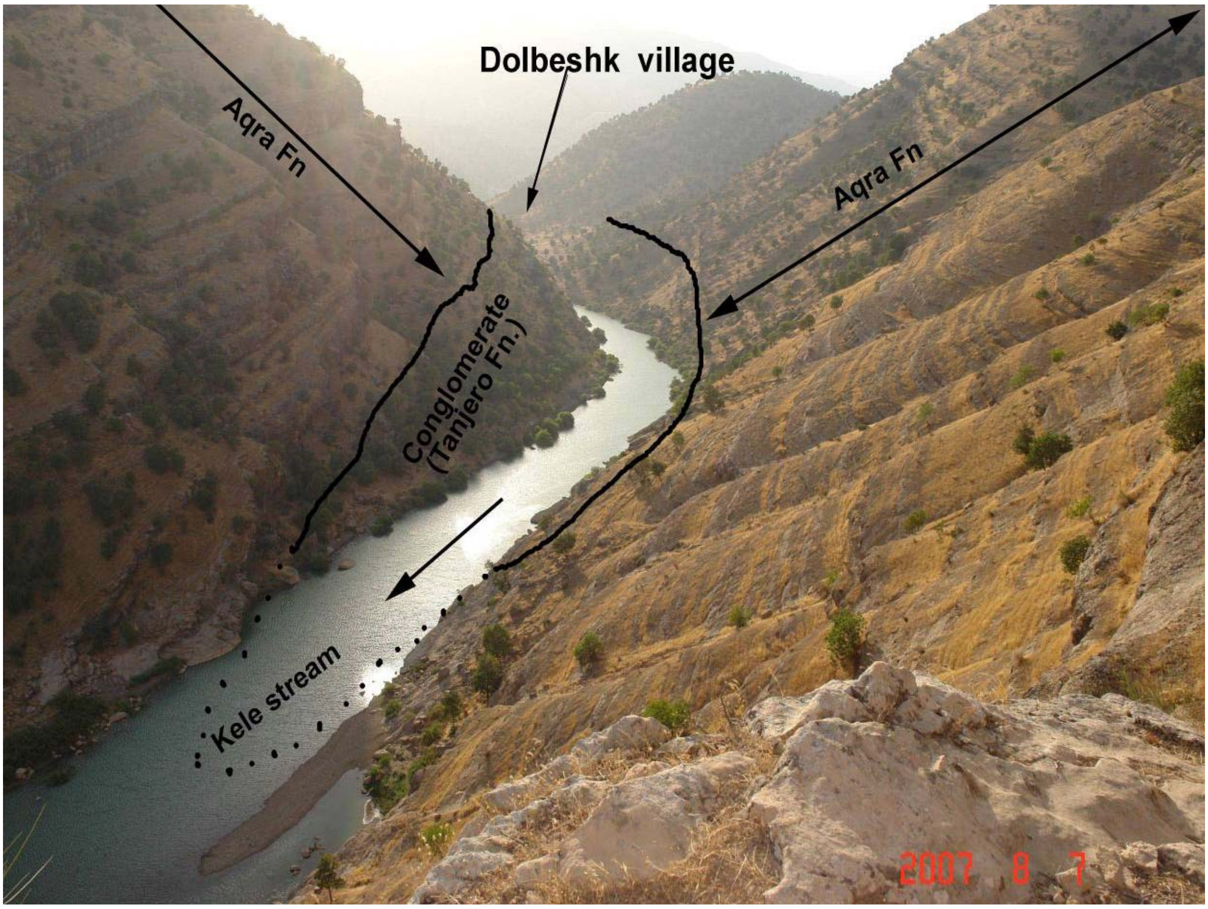

Fig.(1.12) Kele section in which Aqra Formation is underlain by conglomerate of Tanjero Formation with about 300m. high.

1.7- Previous Study:

Aqra Limestone Formation was first described by the two Germany researchers (Kuhn and Kumel, in Lawa, 1983). They said that the formation, in the type locatlity, is formed from calcareous rocks and is saturated by bituminous materials. Depending on some Foraminifera (*Lepiorbitoides socialis* (Meric, 1965) ; *Loftusia elongate* (Cox, 1937) ; Echinoderms, Brayozoa and Brachiopoda; they indicated the age of the Formation is Upper Campanian-Maastrichtian. Wetzel (1947. In Bellen et al 1959) described the formation and he said that the formation is calcareous and saturated with bituminous materials, it is partially dolomitized, siliceous and containing Loftusia. He mentioned that the upper part contain quartz bearing bands which composed of yellow calcareous rocks containing geode of Quartz alternating with marl layers. The latter author added that the thickness of the formation in the Gali Sheikh Abdul Aziz is about 813m. Andre,1949 in Lawa (1983) in his study pointed to many sections of Aqra Formation like Asmawa, Gali Sheikh Abdul Aziz, Gali Zinta …etc. all of these sections are composed of dolomitized calcareous rocks containing bitumen, he recorded some fossils like: *Rudist, Corals, Gastropoda and Pelecepoda*.

Henson (1950) assigned the Aqra Formation as one of the Middle East reefal formation with Upper Cretaceous age. In his report about Aqra Formation, Dunnington (1953), mentioned many different Benthonic and Planktonic Foraminifera and he recorded the presence of Encrusting Algae and calcareous green algae.

Bellen et al. (1959) mentioned that Aqra Formation composed of calcareous reefal rocks with shallow reef of rudist and calcareous fore reef rocks and is partially dolomitized and siliceous, which contains bitumen in some layers. They indicated that the Upper surface of the Formation is Unconformable with Kolosh and Khurmala Formations and the age is Maastrichtian.

Kureshy (1969) referred possibility of the existing age correlation between the rock successions of Pilsner Formation in Aqra area . Lawa et al (1998) concluded that the Aqra Formation, in the Chwarta-Mawat area is interfinguring with Tanjero Formation and connected with rock of the type area.

Al-Amery and Lawa, (1986) studied paleontological model (Fig.1.13) and funal interaction in Aqra Limestone Formation in the type section in Dohuk area. They recorded seven biofacies which are: type one, two, three, four …. … and type seven which are all consisted of packstone or grainstone.

Karim (2004) concluded that it consists only a lens that has no lateral continuity with that of the type area. He assigned the rock of the lens as the sediments of high stand systems tract which deposited in proximal area of a foreland basin.

Al-Kubaisy (2008) studied Biostratigraphy of Aqra Formations in Chwarta area found three zones of large foraminiferas and proved that the age of the formation is Late Maastrichtian.The recorded zones are:

1-*Lepidorbitoides* Range Zone

2-*Omphalocyclus-Orbitoides medius-Siderolite Calcitrapoides* Assemblage Zone

3-*Loftusia morgani* Range Zone.

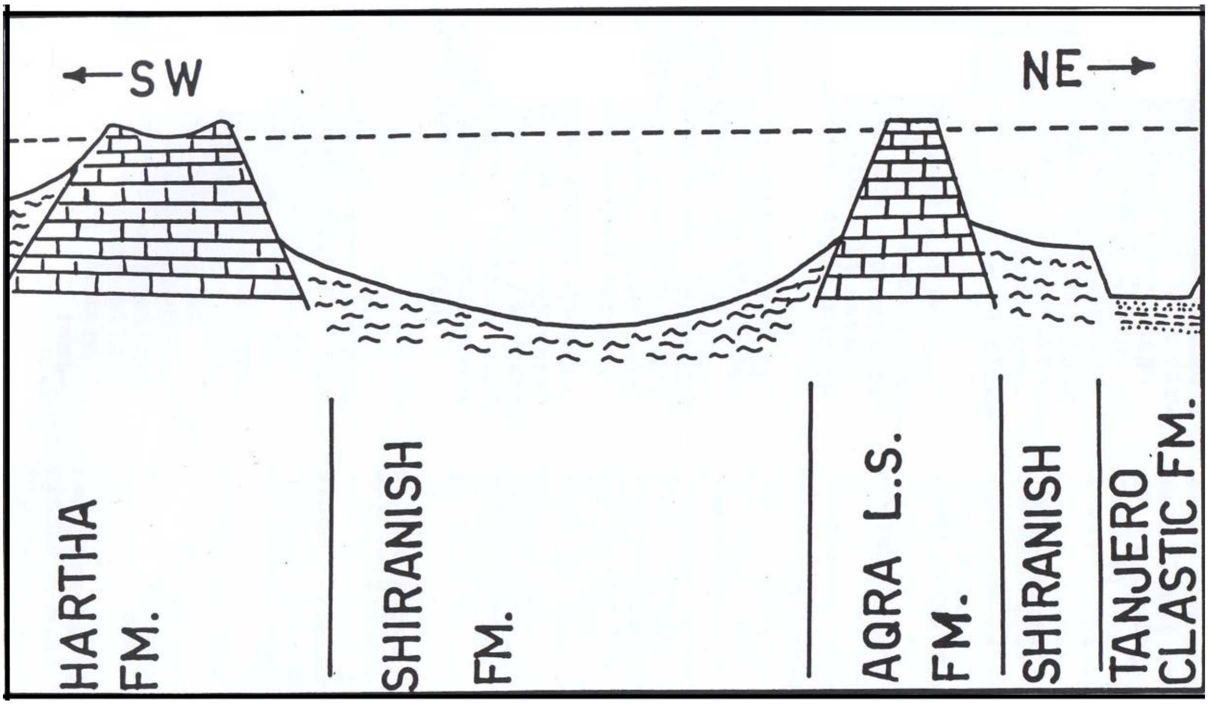

Fig.1.13 Paleogeographical model of Maastrichtian (Al-Ameri and Lawa, 1986)

Abid and Al-Kubaysi (2009) studied microfacies and depositional environment of the Aqra Formation in Chwarta area. They recorded four microfacies as follows:

1- Pelagic Lime Wackestone Facies
2- Foraminiferal Lime Wackestone Facies
3- Larger Foraminiferal Lime Wackestone Facies
4- Larger Foraminiferal Lime Packstone Facies

Depending on the high diversity in the species of different groups of foraminiferal assemblage, they concluded that the depositional environment of Aqra Formation which suggested by application of the environment triangle, showed that the depositional environment extends from near pelagic area to the toe of slope area and its continuation to the shallow water area, and the rudist reef body, although the counting of the fossils content of the foraminiferal species showed that Aqra Formation (in Zarda Bee section) was deposited in deeper environment.

Chaptor Two

LITHOLOGY AND STRATIGRAPHY

2.1-Preface:

This chapter deals with the detailed study of lithology and stratigraphy of the Aqra Formation which mainly consists of biogenic and detrital limestones. The lithology and stratigraphy is necessary for facies analysis of Aqra Formation to indicate constituents of each interval and their stratigraphic position.

According to Westphal and Munnecke (2003), the distribution of carbonate deposits is dependent on paleoenvironmental conditions such as temperature, salinity, and nutrient levels. The vertical (time) and lateral (geographic) relationships between different parts of the formation in one side and with underlying and overlying formations are deciphered by field and laboratory studies.

These relations as the boundary condition are extremely necessary for tectonic, environmental and paleogeographic modeling. The study of the contacts let the geologist to put the formation and neighboring units either in a one basin or in several basins by applying Walther Law as cited in Blatt et al., (1980).This is also useful for tectonic consideration of the formation, and it's depositional basin during Late Cretaceous.

.

2.2-Carbonate constituents (allochems):

Carbonates, unlike siliciclastics, are "born, not made" in the depositional setting (Goldhammer et al., 1990) which means considerable information can be obtained about their generation from the sediment character (allochems). This is because specific carbonates accumulate in specific settings which means that carbonate production, in a certain conditions, must have been met and maintained certain condition in order to sustain a particular character. Thus the depositional environment must have been just in proper condition for the production of particular carbonate, meaning that the sea may not have been too warm, or not been too cold; not been too shallow, or not been too deep; not been too fresh, nor been too saline; had not too many nutrients; while the sea floor had not too fast a subsidence, was not too stable; and there was not too rapid sea rise or fall; (Goldhammer et al. 1990).

In Aqra Formation, the allochems are mainly consisting of either fossils skeletons or their bioclasts and lithoclasts with lesser amount of terrigenus (extraclasts)ones. The fossil shells are large which range between 0.1-150 mm and extraclast and intraclasts are range from clay to gravel size. The most abundant skeletons are those of benthonic large forams such as Loftusia, Omphalocyclus and Orbitoids. The next one in abundancy is mollusk of which the extinct genus Rudist is the most common and next comes Pelecypods and Gastropods.

The shells of Echinoderms can be observed frequently while the Ammonites are very rare and can be observed in the deeper part of the basin. The main facies are floatstone, mixstone, rudstone, grainstone, packstone and bufflestone (Pillarstone). Each of these facies consists of the skeleton of one or more than one of the above fossils or their bioclasts.

These fossils are useful for environment and age determination such as foraminiferas, which is used as index fossils for the age determination because of short age. In this connection, Al-Kubaisy (2008) studied biostratigraphy of Aqra Formation in Chwarta area and found three zones of large foraminiferas and proved that the age of the formation is Late Maastrichtian. The recorded zones are:

1-Lepidorbitoides Range Zone

2-Omphalocyclus-Orbitoides medius-Siderolite Calcitrapoides Assemblage Zone

3-Loftusia morgani Range Zone.

Rudist is very sensitive for the environment depth and it lives above 50m depth.Bellen et al (1959) recorded the following fossils from Aqra Formation in the type area (From the top to the bottom). They are:

(Top): *plagioptychus sp*, cf. *Biradiolites sp*.; *Arcopegia cf*. *numismalis* (d,Orbigny); *Bournonia* aff. *Judacia* var. *Lavies* Blankenhorni; *Praeradiolites Saemmani* Bayle; *Rhyncopygus* cf.*Thebensis* de Loriol; R. sp.; *Ampullosprira incerta* Forbes; *Solarium; cardita sp*; *Cyclolites* sp., *Elphidella* multiscissurata Smout; *Loftusia persica* Brady; *Omphalocyclus macropora Chrysalidina* sp*.; Cymopolia tibetica* Morellet; *Cymopolia* sp. Nov. Elliot MS…

(Base): *plagioptychus* sp Bournoni cf. *Excavata* (d,Orbigny); *Sauvagesia* sp.; cf. *Radiolites* sp.; *Sphaerulites* sp.; *Acteonella* sp., *Praerdiolites haydeni* (Douville); *Vanikora* cf. *asiatica*; *Tylostoma cf. rachaiti* (d,Orbigny); *Omphalocyclus macropora* (La Marck); *Monolepidorbis sp.; Orbitoides media* (d,Archiac); *Discocyclina* Schlumbergeri Munier-Chalmas; *Cunneolina cylindrica* Henson; *Dicycloconella complanata* Henson; *Elphidiella truncana stuarti* (de Lappaarent); *Cymopolia tibetica* Morellet; *cymopolia* sp. Nov. Elliot MS.

2.2.1-Loftusia:

Loftusia is benthic foraminifera of Maastrichtian age and it known from outer platform facies of the Tethys Ocean. The genus Loftusia is characterized by planispiral fusiform test which has non-lammilar agglutinated with calcareous cement, calcitic wall structure. The shell has labyrinthic wall with Irregular septa and chamberlets (Fig.2.1 and 2.3).

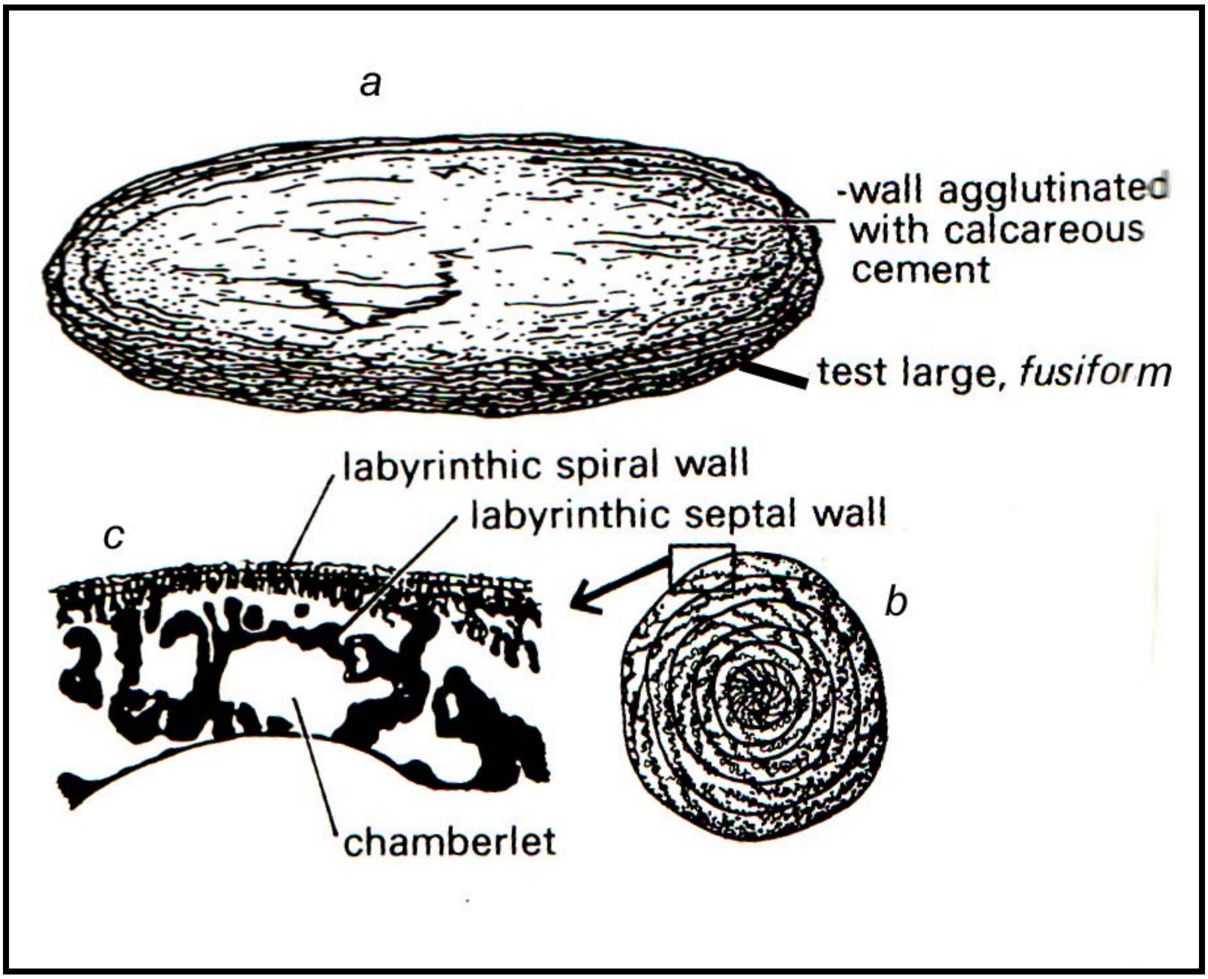

Fig.(2.1) General view of fusiform test of loftusia (a), equatorial section(b) and cross section of wall(c) (Bracier,1980)

The genus is abundant in Arabo Iranian platforms and rare in eastern Mediterranean and totally absent in western Mediterranean.This genus with larger benthonic genera with complex chamber wall that are represented by several species confining mostly to Maastrichitian and are reported from Middle East, Eastern Turkey, Iran, Iraq, Qatar and Oman in the Tethys and no record further in the east (Meric and Mojob, 1977). The restricted distribution of this Late Cretaceous taxon is suggesting small dispersal potential possibly due to ecological constraints (Govindan, 2008).

Al-Omari and Sadek (1977) investigated microscopically and statistically specimens of *Loftusia* from the Maastrichtian of Northern Iraq (Aqra Formation). They noticed that during this period the genus exhibited a gradual increase in size (length and diameter).

Thus, they recognized an evolutionary line for the development of Loftusia considering the forms of the early stages of the genus' development. In addition theirs recorded a tendency for tighter forms during the transition from Mid to Late Maastrichtian.

Sartorio and Venturini (1988) during their study of Southern Tethys Biofacies recorded these fossils from Maastrichtian time such as: *Loftusia*, *Omphalocyclus* macroporus, Rotaliidae and Miliolidae from Maastrichtian age of parnezam, Zagros, Iran. In addition to that they also recorded Rotalia skourensis, Orbitoididae and Loftusia from Maastrichtian age of Ras Shrawayn of Yemen.

They also claimed *Orbitoides* from Maastrichtian age of Gianna 2 well, Adriatic Sea. And *Orbitoides, Siderolites Calcitrapoides* and *Omphalocyclus* macroporus from (LAMARCK) and rudist fragments from Maastrichtian of Emilio 5 well, Adriatic Sea also figured out by them.

They recorded *Lepidorbitoides, Orbitoides, Siderolites* calcitrapoides (LAMARCK) *Pseudedomia* and Rotaliidae from Maastrichtian age of Fartaq of Yemen and Rhapydionina liburnica (STACHE), Miliolidae and Montcharmontia from Maastrichtian age of Vremski Brilot, Yugoslavia.

They concluded that Loftusia is very common in the Middle East, the genus Rotalia already present in the Early Cenomanian shows a marked differentiation during the Maastrichtian and *Orbitoides* is very common during and at the end of the Maastrichtian. In Greece it has so far been reported from two sites:

1. On Kassidiaris mount as debris in bioclastic upper Cretaceous limestones of the internal zones (Ferrière, 1982), and on mounts Valtou in an occasionally bioclastic conglomerate which is limited by faults that prohibit us from observing its relation with the surrounding formations (Fleury et al., 1990).

2. In the area of Boeotia, on mount Ptoon, a horizon rich in Loftusia cf. anatolica has been found in an undisturbed sequence of Upper Cretaceous limestones up to Paleocene flysch of the Eastern Greece zone. This recovery is considered very important for the paleogeography of the Tethys Ocean during late Cretaceous.

Őzcan (2006) studied the Latest Cretaceous benthic foraminiferal on the Arabian platform, Southern Turkey, he suggested that diversified foraminiferal assemblages including genera such as Orbitoides, Siderolites, Omphalocyclus, Loftusia, Lepidorbitoides, Sirtina and other benthic taxa suggesting a Maastrichtian age.

The Ődemis Formation in Turkey was deposited in neritic environments, and it consists of conglomerate, nodular limestone, sandy limestone and claystone, interbedded with volcanic. The sandy limestone contains the benthic foraminifera Orbitoides aff. medius (d,Archiac), O. aff. *apiculatus* Schlumberger, *Sirelina orduensis* Meriç and Inan, *Omphalocyclus macroporous* (Lamarck), Sirtina orbitoidiformis Brönnimann and Wirtz, Praestorrsella roestae (Visser), *Laffitteina* bibensis Maria, Laffitteina boluensis Dizer, Laffitteina aff. Marsicana Farinacci, Smoutina aff. *cruysi* Drooger, *Siderolites Calcitrapoides* Lamarck, and *Selimina spinalis* Inan, *Praestorsella roestae* (Visser) was abundant. This foraminiferal assemblage indicates an upper Maastrichtian age.

2.2.2-Omphalocyclus:

Omphalocyclus is orbitoidal benthic foraminifera, known from the relatively shallow-water paleoenvironment located in the outer parts of the Late Cretaceous Tethyan platforms. The mineralogy of this type of the forams is calcitic by which the shell microstructure is well preserved which similar to orbitoid but with larger and discoidal shape (Fig.2.2 ana 2.3) Instead of fusiform. It is a relatively common taxon with a geographic distribution from Europe to North Africa, India and as far as Indonesia in the east, and to Caribbean in the west.

Apart from its debatable diagnosis only in the (late) Maastrichtian of western Tethys, the genus has been discovered in Turkey in further much older beds in association with Orbitoides and Lepidorbitoides having rather primitive developmental stages (Özcan, 2006). He also suggested that the morphometric analysis of A-forms in successive assemblages (based on seventeen populations in seven sections located in Sakarya, Eurasian and Arabian plates), ranging in age from (late) Campanian to terminal Maastrichtian, enables the documentation of phylogenetic changes for the first time. Since these horizons contain a rather rich assemblage of accompanying specimens of *Orbitoides* and *Lepidorbitoides*, a correlation of the phylogenetic changes of the genus to that of *Orbitoides* and *Lepidorbitoides*, rather well-known in Europe, can also be made.

The most conspicuous phylogenetic change in the equatorial layer of *Omphalocyclus* is found to be the general increase in the size of embryon, which on average doubles by the end of the Maastrichtian. This trend is followed by the increase in the number of epi-embryonic chamber lets, which is however not as significant as the former parameter.

Omphalocyclus in the stratigraphically lowermost populations has mainly three to four primary epiembryonic and no accessory epi-embryonic chamber lets. With the introduction of radial stolons which seems to have taken place in horizons referable to the *Gansserina Gansseri* Zone, only several accessory

epi-embryonic chamberlets arise from the tritoconch. Instead, epi-embryonic chamberlets become rather larger in size and also they cover a wider portion of embryon along its thick outer wall. Considering the suitable changes in embryon size, and also some other morphologic features in successive populations, two new species, *O.anatoliensis* sp. nov. and O. *cideensis* sp. nov. have been erected in late Campanian and late Campanian-early Maastrichtian populations, respectively.

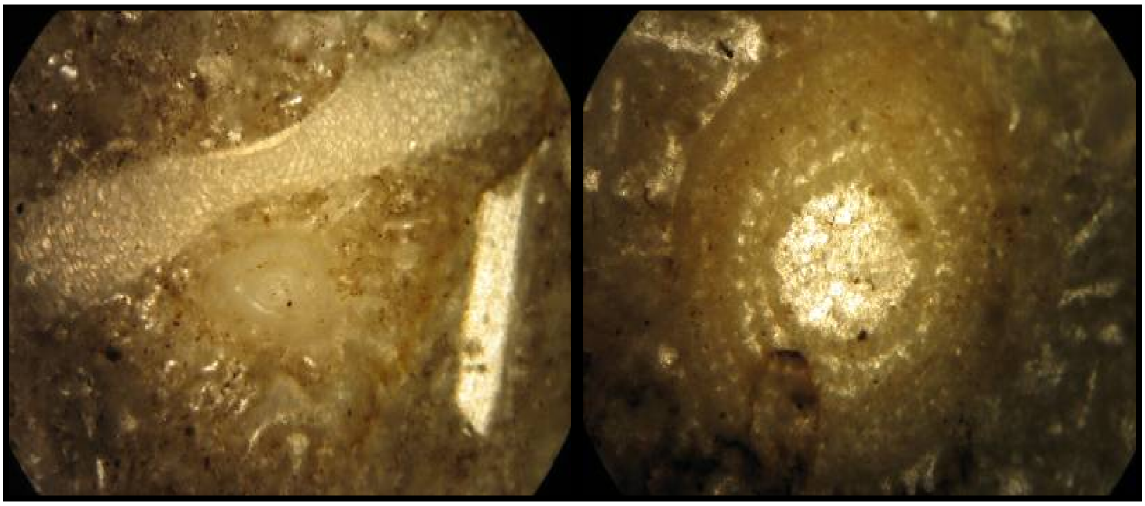

Fig. (2.2). **Left** Cross section of Omphalocyclus *macropora*, Aqra Fn., Kato section, 20X slide No.KA3.

Right Longitudinal section of Omphalocyclus *minor*, the central area is white due to thinner shell at center which not cut by the section, Aqra Fn., Kato section, 20X slide No.KA10.

Fig.(2.3) current accumulated shells of Omphalocyclus and Loftusias of a bed 30cm thick (near Homaragh village) .

2.2.3-Rudist:

According to their life habit, rudist morphotypes are classified as 'elevators', 'clingers' or 'recumbents', each morphotype being adapted to specific environmental conditions (type of sediment, sedimentation rate, current regime) (Skelton 1991, and Steuber and Loser,2000).

According to Flugel (2004), the rudists are sessile gregarious bivalves characterized by lower attached and an upper opercular valves of different sizes. The group appeared in the late Jurassic and disappeared at the end of the Cretaceous. Rudists were common throughout the Cretaceous and diversity dropped during the Early Aptian and the Latest Cenomanian and increased significantly in the Early Maastrichtian.

He added those major subgroups are differentiated by shell morphology, the number and position of the teeth, accessory cavities, canal, pores and pillars. Thin sections exhibit characteristic microstrucutre patterns. The shells consist of an inner and middle aragonitic layer (nearly always recrystalized and replaced by blocky calcite) and an outer Low-Mg calcite layer with compact and \or cellular microstructures. The shells of the hippuritid rudists exist as densely packed biostromes which are characterized by pillars with in shell wall (Fig. 2.4 and 2.5B). The radiolitids rudist shells exhibit reticulate pattern cased by the calcitic cellular prismatic outer layer, and a compact inner layer (Fig2.5A 2.6b and 2.7).

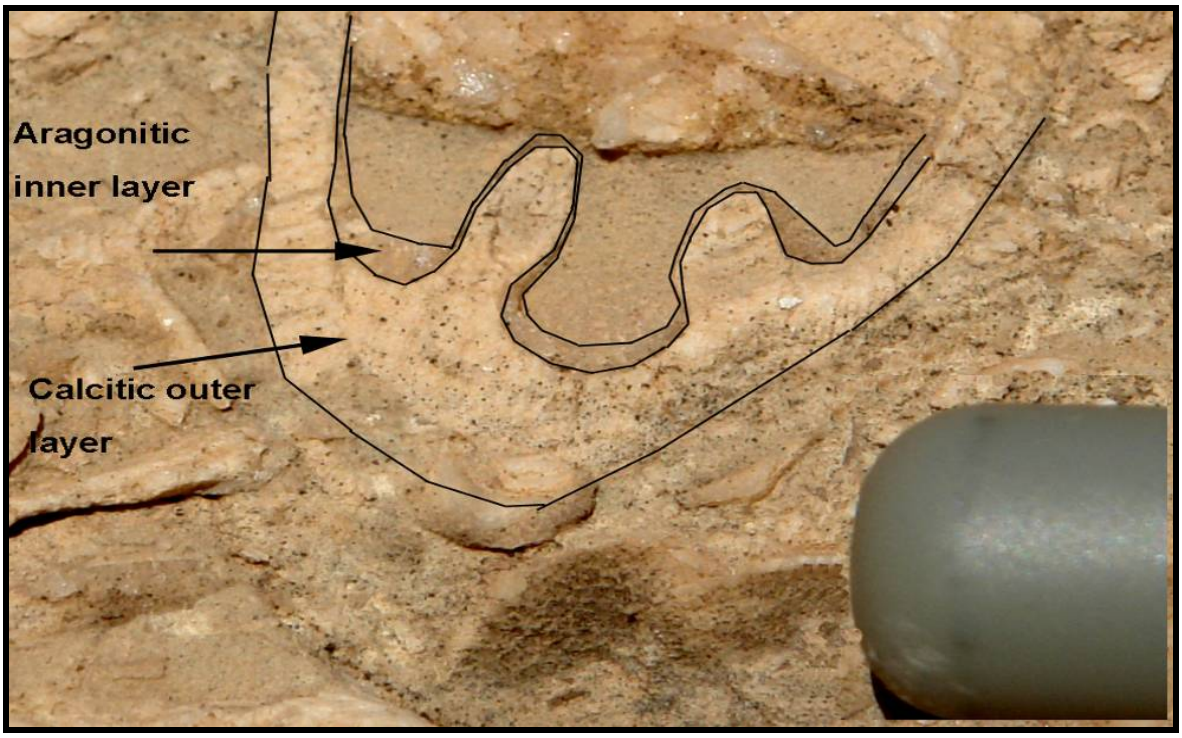

Fig.(2.4) Outer and inner layers of the hippuritid rudist shell. The inner layer is replaced by secondary calcite.

Fig. (2.5). **A)** longitudinal section of the shell of radiolitid rudist in life position showing outer reticulate layer(o) cased (covered from inside) by the calcitic cellular prismatic, and a compact inner layer(i) s.n.14, Kele section. **B)** Cross sections of hippuritid rudists characterized by pillars within shell wall (small black spots indicated by letter p and teeth (t). s.n.24, Kele section.

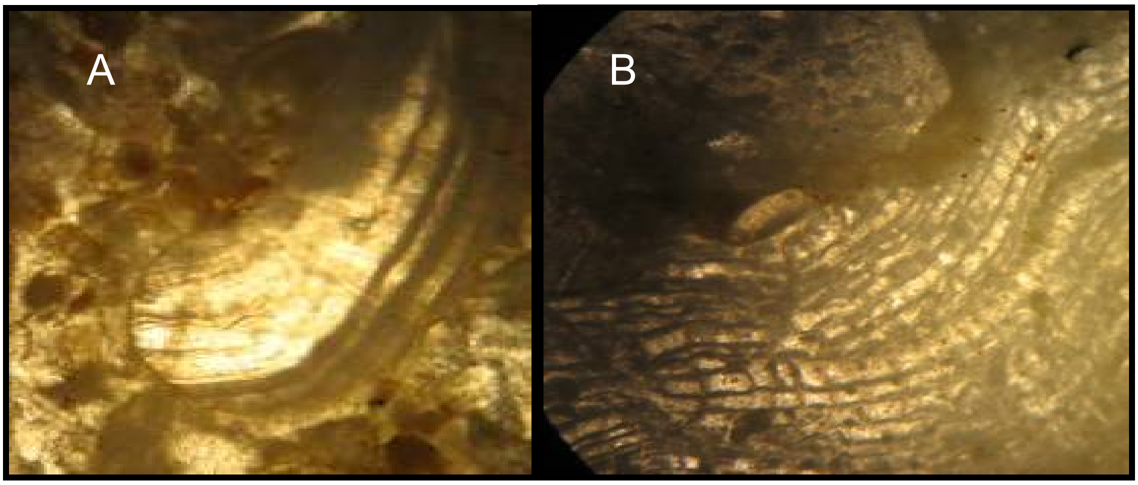

Fig.(2.6) **A)** Fragment of pelecypod, Aqra Fn., Kato section, 20X slide No.KA1
B) Reticulate shell of radiolitid rudist Aqra Fn., Kato section, and 20 X slide No.KA4.

Rudists are anomalous bivalves which developed massive sessile shells, often with two valves showing strong asymmetry (Dechaseeaux et al, 1969) and were adapted to filter feeding. Many forms show the strong development of the attached valve and the subsequent reduction of the free valve. In general forms, rudists resemble corals and it has been suggested that rudists displaced corals from reefs during Cretaceous (Kauffman and Shol, 1974: Johnson and Kauffman, 1996) in Mitchell, 1999).

Gilbert et al, (2008) claimed that Maastrichtian strata from the Pachino area (SE Sicily) provide a model of association between rudist-coral framework and submarine volcanic activity. Rudist buildups are probably the result of two interrelated factors: the contemporaneous growth of major structures in the Mesopotamian Basin due to the upward migration of the Infracambrian Hormuz salt, and the geometry of the shelf at that particular time. The effect of salt penetration structures on the nature of the carbonate sediments, particularly during the Cretaceous Period, has been discussed by Sadooni (1993) and

Sadooni and Aqrawi (2000). Gaddo (1971) noticed that rudist buildups were formed where the developing structures were accompanied by regional uplift. Videtich et al. (1988) found an association between the movement of the Infracambrian Hormuz salt and the buildups within the Mishrif Formation in the Fateh Field, Dubai.

They suggested that the rising salt led to the doming of the Fateh structure and at the same time triggered subsidence in the surrounding area of salt withdrawal.

The rudist buildups developed on the flanks of these subsided areas, which were then filled with fore-reef debris.

The common occurrence of these buildups in the crestal wells of southern Iraq (Fuloria, 1976; Sadooni, 1993; Sadooni and Aqrawi, 2000), however, contradicts this model. If rudist buildups commenced on the flanks of the

intervening basins between structures, we would expect the opposite result, viz. rudist buildups in the flanking wells.

Schafhauser et.al., 2003) studied the upper Cretaceous Cardenas Formation (Central Mexico), they showed that swallowing- upward sequences defined by a Hippuritid- acteonellid- coral/rudist facies transition. This cyclic sedimentation pattern is obscured by an episodic input of classic sediments derived from the uplifting Sierra Madre Oriental, which in turn triggered either the development or decline of reefs.

Sadooni, 2005 during his study of the nature and origin of Upper Cretaceous basin-margin rudist buildups of the Mesopotamian Basin, southern Iraq suggested that in the absence of seismic sections it is difficult to comment on details of the geometry and distribution of the rudist buildups within the Cretaceous subsurface carbonates of the Mesopotamian Basin, including those of the Mishrif Formation. However, examination of the geological data collected from the limited scattered outcrops of the M’sad facies (of the Mishrif Formation) in the Western Desert, and the nature of the rock materials (cores and cuttings) from some subsurface wells in the Mesopotamian Basin, yield some insights on the nature and distribution of these buildups. In the Western Desert, outcrops of the M'sad facies of the Mishrif Formation are composed of shelf limestones, reef limestones, shell breccias, micro detrital limestones, chalky limestones of whitish color with pinkish marls and sands, and a thin sandstone tongue near the base (Bellen et al., 1959). The rudist Eoradiolites liratus Conrad and Caprinula sp. were recovered from these outcrops. It has been predicted that the same species will occur in the subsurface of the equivalent strata of the Mishrif Formation to the west (Bellen et al., 1959; Buday, 1980; Sadooni and Aqrawi, 2000).

Fig. (2.7) Top view of the lower valve of the radiolitid rudist with an echinoderm shell. S.n.1, upper part of the Kele section. The white piece of paper is 25cm long.

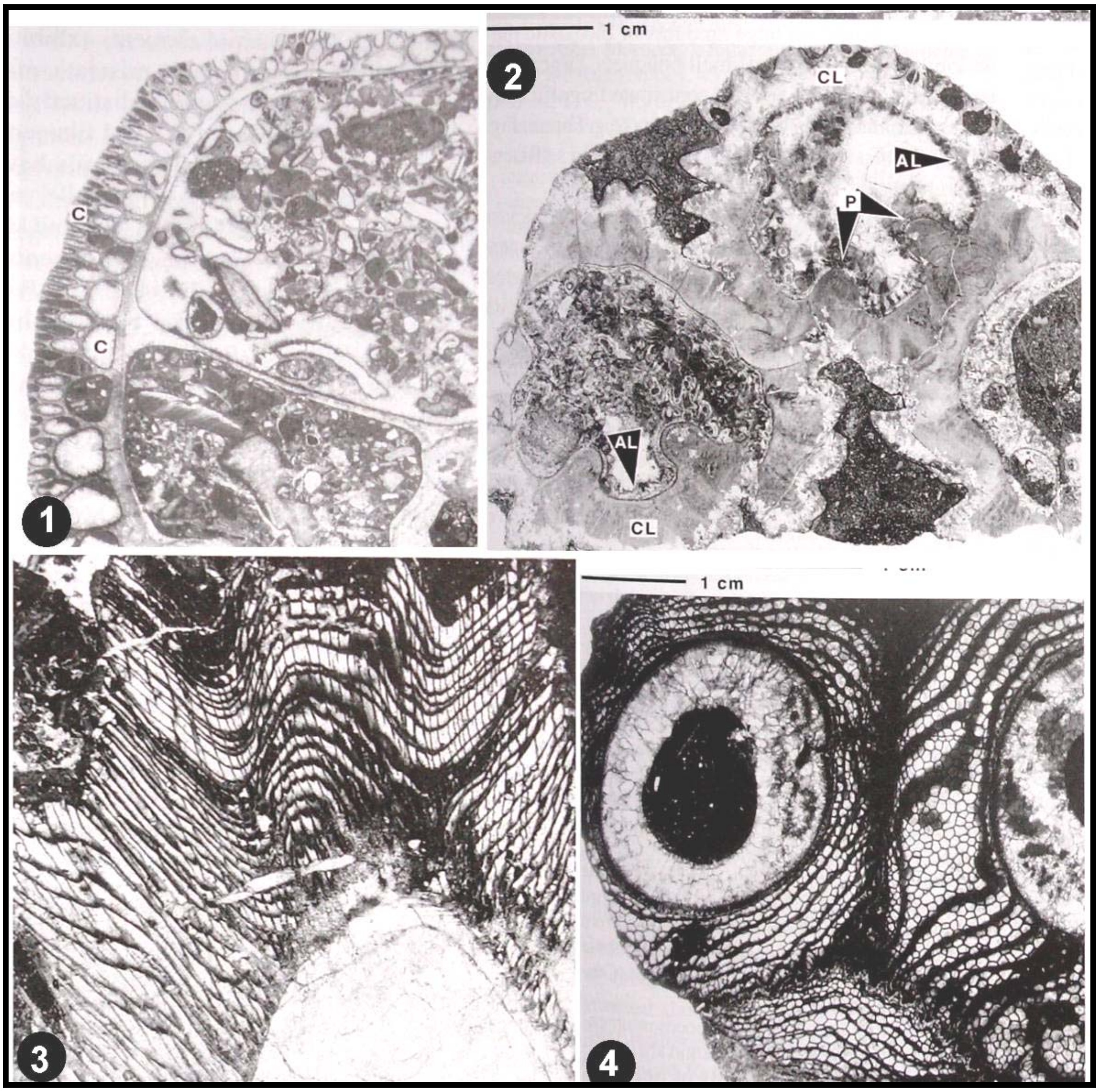

Fig.(2.8) Structure of different types of rudist shells in cross sections (Flugel, 2004).

1-Caprinid rudist showing polygonal canal (c)

2-Hippuritid rudist showing outer (CL) and inner (AL) layers in addition to two pillars (teeth).

3-Radiolitid rudist showing outer folded cellular network cased by the calcitic layer

4-Radiolitid rudist showing outer cased by the calcitic layer.

Steuber at al., (2002) studied the limestone beds of Jamaica and they proposed that species- rich rudist- coral associations persisted into the Latest Maastrichtian (66-65 Ma).

Abdelghany (2003) studied Campanian- Maastrichtian rock strata in the jabal El Aqabah, Jabal El Rawadh and Jabal Malaqet sections, Oman, Emirate, the rock beds (openmarine environment passed laterally into shallower marine conditions) are characterized by larger foraminiferal species including *Loftusia morgani, Orbitoides Media, O. apiculata, Omphalocyclus macropora, Lepiorbitoides minor, Sulcoperculina dickersoni,* and *Sedirolites calcitrapoides.*

2.2.4-Orbitoide:

The genus *Orbitoides* was established by d.Orbigny (1848). The test of Orbitoides is lenticular with a circular outline, and can reach a diameter of up to 5 cm (Loeblich and Tappan, 1988). The test is biconvex, often with one side more elevated. The surface is ornamented with small knobs. The juvenarium consists of three or four chambers and is usually embraced by a thick wall. An equatorial layer is distinct. The mineralogy of the shell of this type of forams is calcite by which the ornamentation of shell preserved and clears under microscopes (Fig. 2.9).

The genus Orbitoides displays some of the widest latitudinal and longitudinal extensions among the larger Upper Cretaceous foraminifera. The particularly wide distribution over the circumtropical warm water belt of the Cretaceous ocean is comparable to the distribution of modern amphisteginids (Langer and Hottinger, 2000) and thus particularly valuable tracer in indicating of circumglobal warm water surface currents and the heat transfer towards higher latitude.

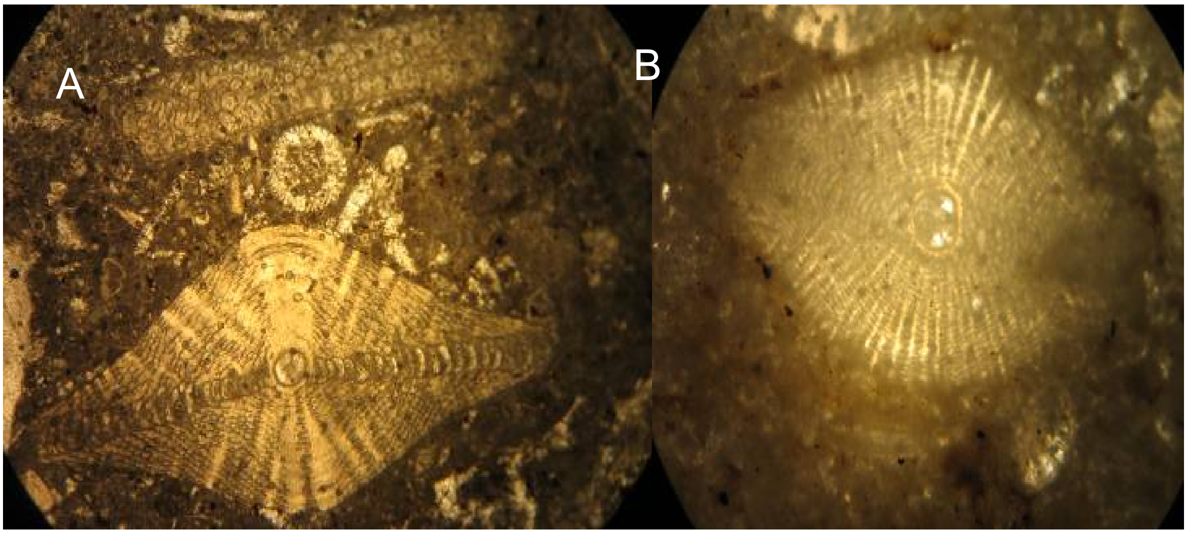

Fig.(2.9) **A**) *Orbitoides*, Aqra Fn., Kato section, 20X slide No.KA3
B) *Orbitoides*, Aqra Fn., Kato section, 20X slide No.KA6.

2.2.5-Actaeonellid gastropods:

Actaeonellids and other gastropods commonly have aragonitic shell which may suffer from two processes. The first one is removal of shell by solution and filling by micrite or secondary calcite. In this case only the mold (general form) remained and microstructure is obscured. The second is replacement by calcite through volume per volume dissolution of aragonite and precipitation of calcite and it is possible that some microstructure is preserved espiciaaly the outer organic rich layer. (Tucker, 1991 and Flugel, 2004). The observed gastropods in the selected samples are suffered from the first process (Fig.2.10 and 2.11).

Fig. (2.10) Cross section of Actaeonellid gastropods which consist of one aragonitic layer, middle of the Kele section, s.n.17.

Fig.(2.11) Actaeonella shells in the lower part of Kele section, S.N.32

2.2.6-Echinoderm:

Echinoderms are marine invertebrates with a multi-plate calcareous internal skeleton embedded in the skin, a marked five-rayed symmetry and a water vascular system through which the water is circulated in the body. Echinderm fragment are present in limestones formed in shallow –marine as well as in deep-marine environment (Flugel, 2004).

The Echinoid and crinoids skeletons are calcitic and their fragment is easily identified since they are composed of large single calcite crystals and each grain shows straight extinction and the spary calcite grow around the grain syntaxially. But the echinoderm grain is distinguished from the sparite by its dusty appearance (Tuker, 1991).

In the study area, many intervals of Aqra Formation contains frequent echinoderm which have good preserved with micro and macrostructures (Fig2.12). But the echinoderm grains (fragments) are rare due widespread of forams and other fragments such as rudist.

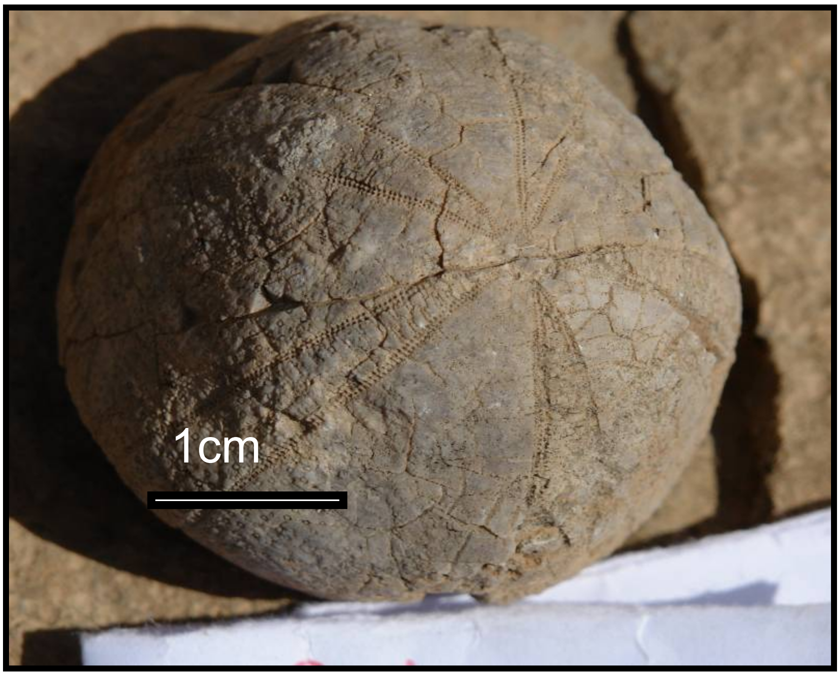

Fig.(2.12) Echinoderm shell showing the arms, lower part of Kato section, S.N.4

2.3-Stratigraphy:

According to Bellen et al (1959) the Aqra Formation is defined by Bennet in 1945 as Aqra Formation in the Aqra area and the section runs along Gali Sheikh Abdul Aziz. According to Bellen et al (op cit) the thickness of Aqra Formation in the area is about 793 meters and the overlying formation is Kolosh Formation which is very thin in the area. The underlying formation is not seen in the type section but they mentioned that it may be continuous with the Bekhme Limestone. They added that the contact with the Kolosh formation is unconformable which is transgressive over eroded Aqra Formation. According to Jassim and Goff (2006), the Upper contact of the Aqra Limestone, in some areas, are marked by an erosional break at the Cretaceous- Tertiary boundary while in other areas trangressively overlies the Tanjero Formation.

At Dar-e- Tesu, and other locations, the Aqra Limestone is developed as isolated tongues and lentils of neritic rudist bearing Limestone, at the top of or within the Tanjero clastic Formation, a variable thickness of Tanjero clastic Formation and or Shiranish Formation intervening between the base of the Aqra Formation and the top of the Bekhme Limestone. Where the Aqra Limestone is superimposed directly up on the Bekhme Limestone, without intervention of Shiranish or Tanjero Formations, the composite name Aqra/ Bekhme Limestone may be used (Bellen et al, 1959).

From the above discussion and according to the field description it appears that Aqra Formation exist as lenses either inside Shiranish Formation (at Aqra area) or inside Tanjero Formation (at Chwarta-Mawat area) (Fig.2.17) .

2.3.1-Lower boundary at the proximal area:

As the Aqra Formation, in Chwarta-Mawat area, located in the Imbricated Zone, therefore the inspection and determination of the nature of the boundary is difficult. This is because the boundary is the zone of combining of two different lithologies; in most cases one of them competent and the other is incompetent. Therefore, the boundary is a zone of different mechanical properties. Thus the boundaries may be zone of faulting, imbrications and even thrusting. However, some ideas are given about the lower and upper boundaries of the Aqra Formation depending on the field observation.

In the studied area as a rule and in the proximal area, the lower boundary is showing signs of gradational and conformable as shown below:

1-Gradational boundary (the conformable contact) with red clastics of Tanjero Formation. The red claystone and sandstone changes upwards to marly limestone and then changes to biogenetic limestone as can be seen at the northwest of Kani Sard village (Fig. 2.13) and near Yalanqoz.

2- Kele and Kato sections show some marine erosion at the lower boundary with the conglomerate of Tanjero Formation (Fig.2.14 and 2.15). In some place, in this section, the biogenic limestone alternate with conglomerate or sandstone but this alternation indicate more or less conformability unconformity.

Fig. (2.13) shows the lower boundary of the Aqra Formation at the northwestern side of Kato mountain which appears gradational.

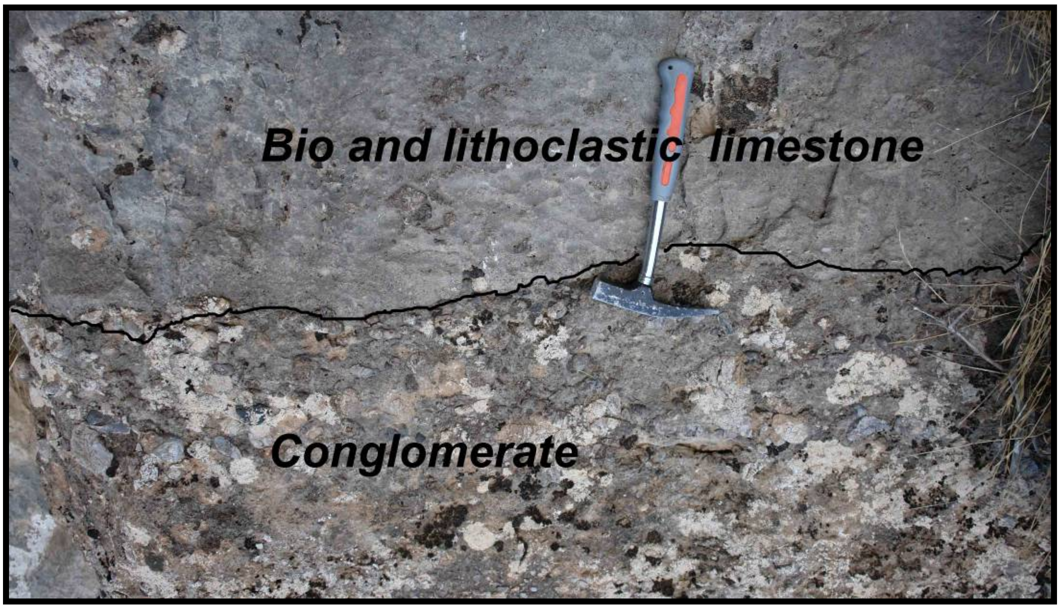

Fig.(2.14) Lower boundary of Aqra Formation with Tanjero Formation at Kele section showing sharp contact between limestone and conglomerate..

2.3.2- The lower boundary at the distal area:

According to paleocurrent analysis of Tanjero Formation (including Aqra lens), the distal area (deeper area of the basin) is located toward southwest (Karim, 2004 and Karim and Surdashy, 2005). This area is relatively far from the source area and tectonic force of the Iranian and Arabian plates. Therefore, this area is less affected by post and syn-depositional tectonic force than the proximal area. Therefore, the realization of the nature of the boundary is easier than the proximal one.

About 200m to the southeast of the Zarda Bee the Aqra Formation succession can be seen in a position, which overlying Tanjero Formation. At this place the Tanjero Formation change upward to marl and marly limestone with some lenses of sandstone and conglomerate. Then, at the contact the lithology changes to thin beds of marly limestone, toward more upward it changes to the laminated, cross bedded and burrowed bioclastic limestone and contain bioclasts of rudist and whole shell of orbitoids (Fig2.15 , 2.16 and 2.17). The present study did not found any sign of unconformity such as conglomerate beds or paleosoil or karstification. Therefore, in the present study it is assigned that the boundary is gradational and the contact is conformable. The conglomerate lenses occur inside Tanjero Formation several meters below the contact and is deposited by reworking transporting from shallow marine to deeper one due to submarine current and don't indicate any sign of subearial erosion. In the area around the Homaragh and Qshlagh villages the condition is the same as that of the Zarda Bee village but without recording of the conglomerate lenses.

In the Sura Qalat section, the gradational boundary is very clear without conglomerate or erosional surfaces. In this section, the upper part of Tanjero Formation is composed bluish grey marl and upwards changes to marly limestone in the transition zone and then fossiliferous limestone in the Aqra Formation (Fig.2.15 and 2.16 and 2.17). From the above discussion and according to the type of the boundaries, the stratigraphic column of the three sections are drawn (Fig. 2.19, 2. 20, 2.21, 2.22 and 2.23). The column of the Kele and Suraqlqat section is drawn in two page dueto high thickness.

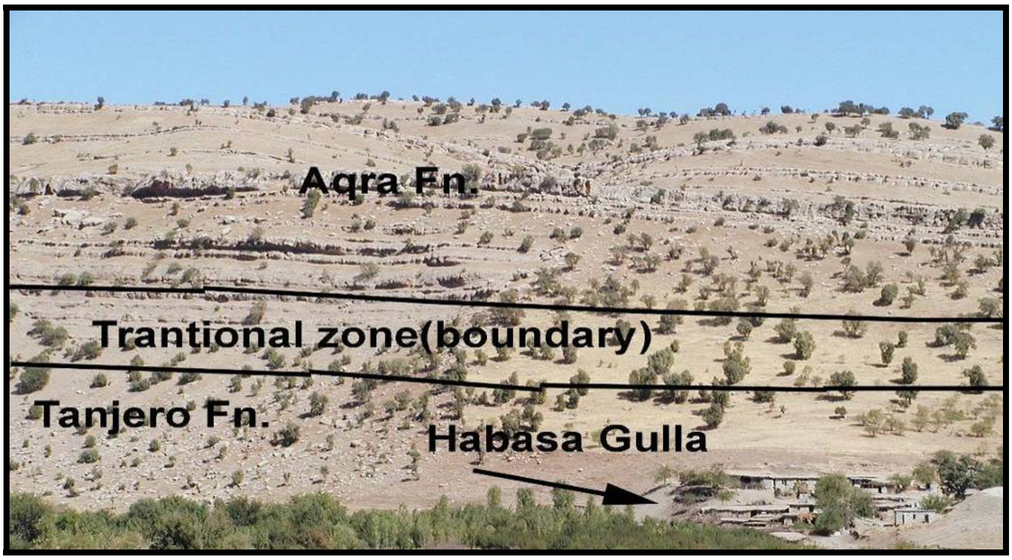

Fig.(2.15) Lower boundary of Aqra Formation with Tanjero Formation at distal area to the northwest of Habasa Gulla village showing gradational boundary and conformable contact.

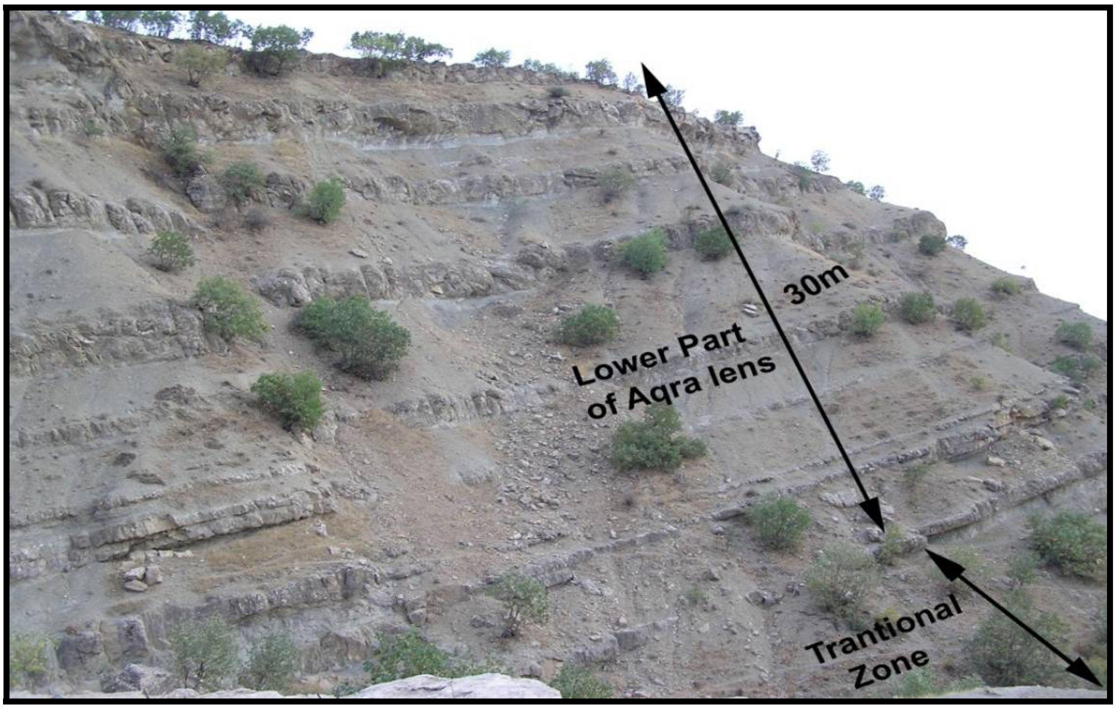

Fig.(2.16) Lower boundary of Aqra Formation with Tanjero Formation at distal area, Sura Qalat section showing gradational boundary and conformable contact

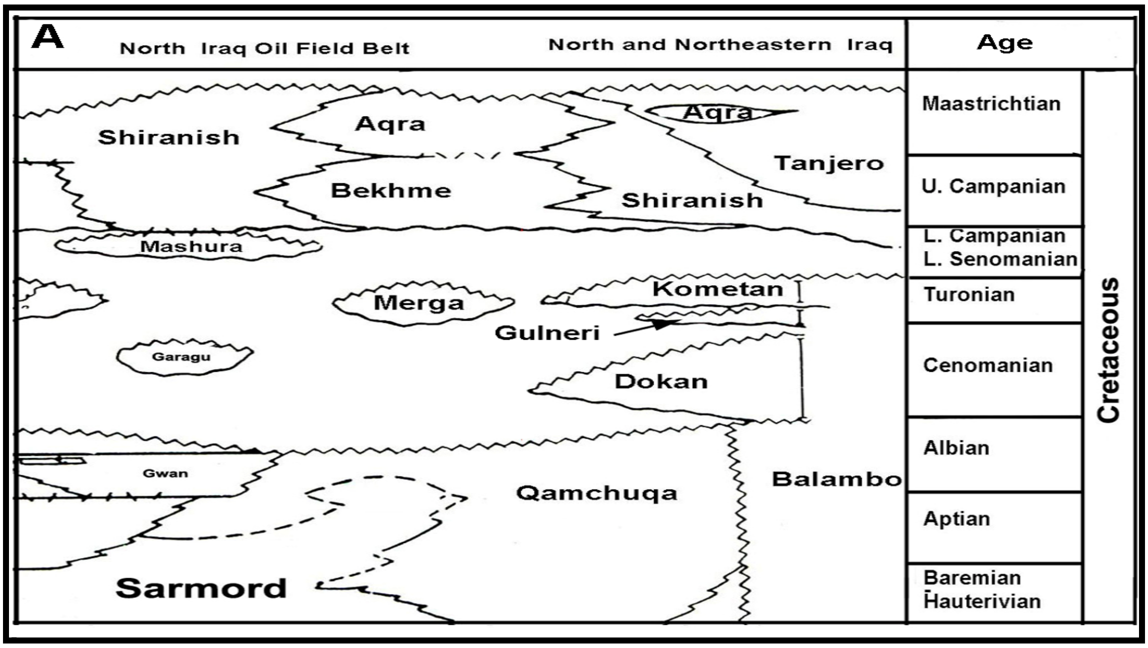

Fig.(2.17) Time expanded stratigraphic column of the Late Cretaceous (Bellen, *et al.,* 1959) showing Aqra Formation as lenses either inside Shiranish Formation (at Aqra area) or inside Tanjero Formation (at Chwarta-Mawat area).

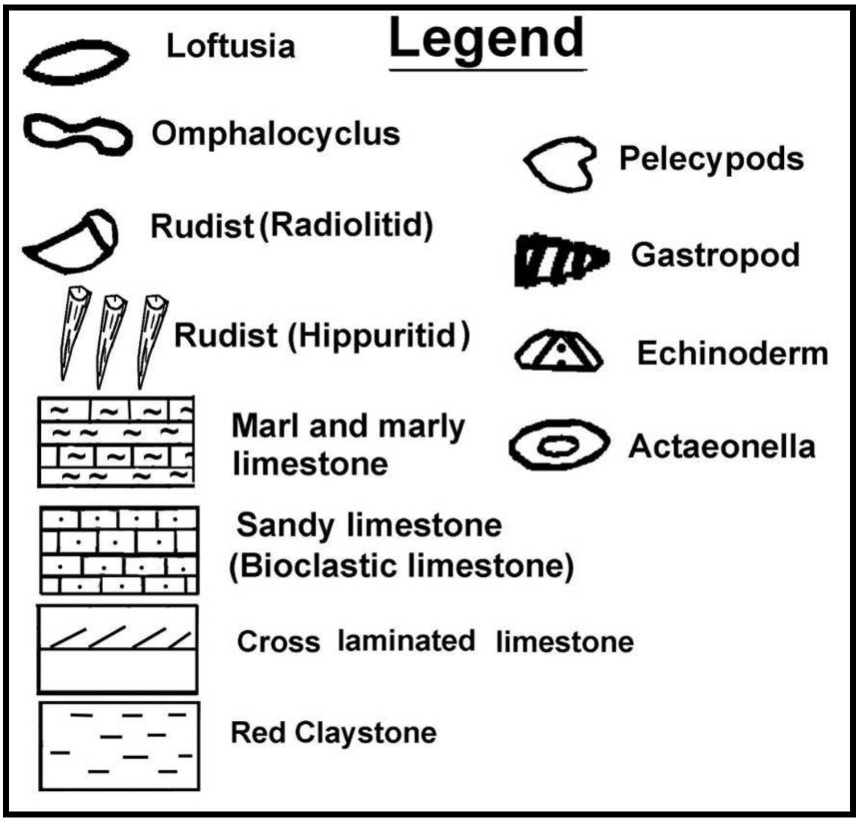

Fig.(2.18) legend of the symbols used in the stratigraphic columns

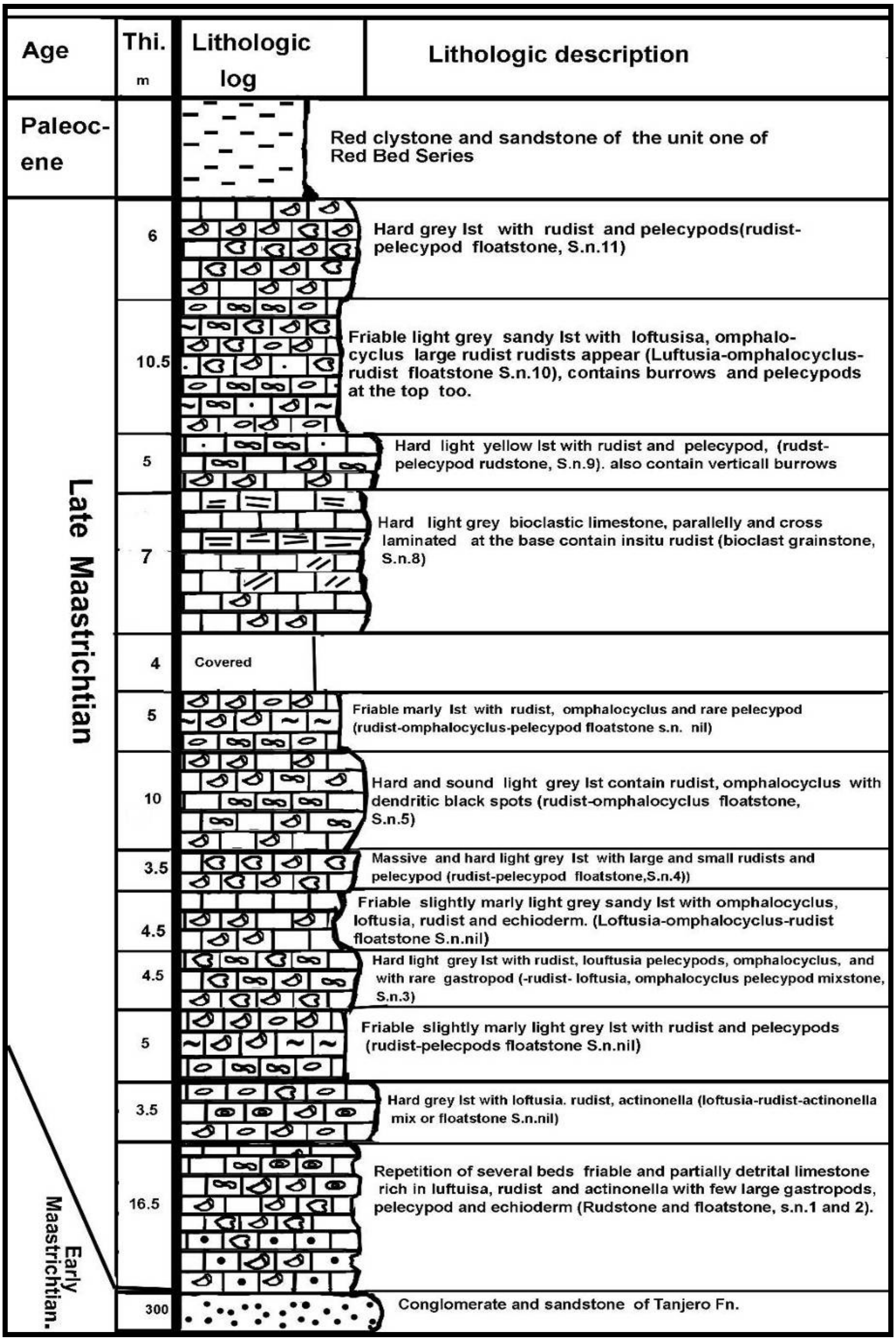

Fig. (2.19) Stratigraphic column of the sampled Kato section (not to scale)

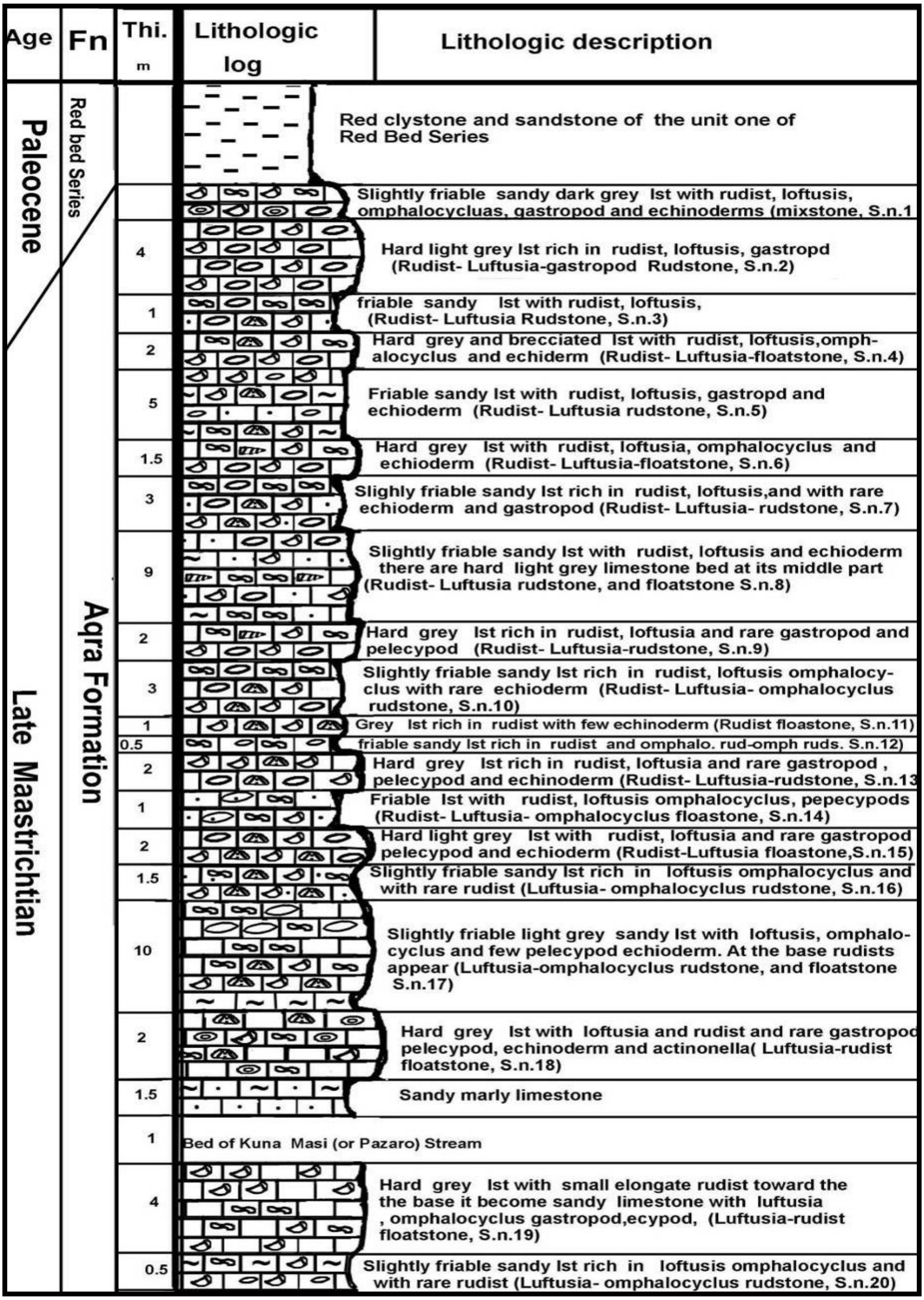

Fig.(2.20) Stratigraphic column of Upper part of Kele section,(not to scale)
(continued in the next page)

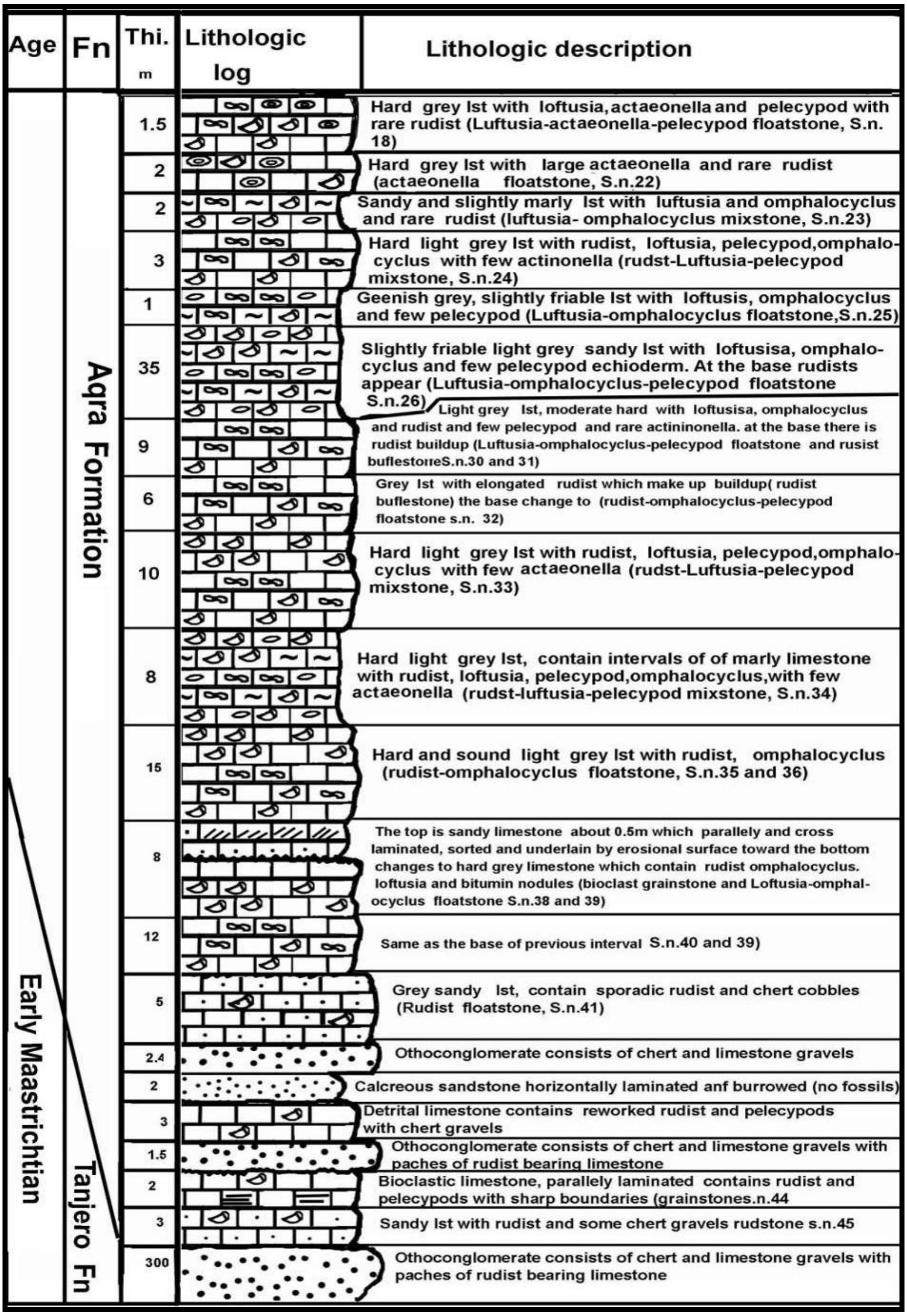

Fig.(2.21) Stratigraphic column of Lower part of Kele section (not to scale)

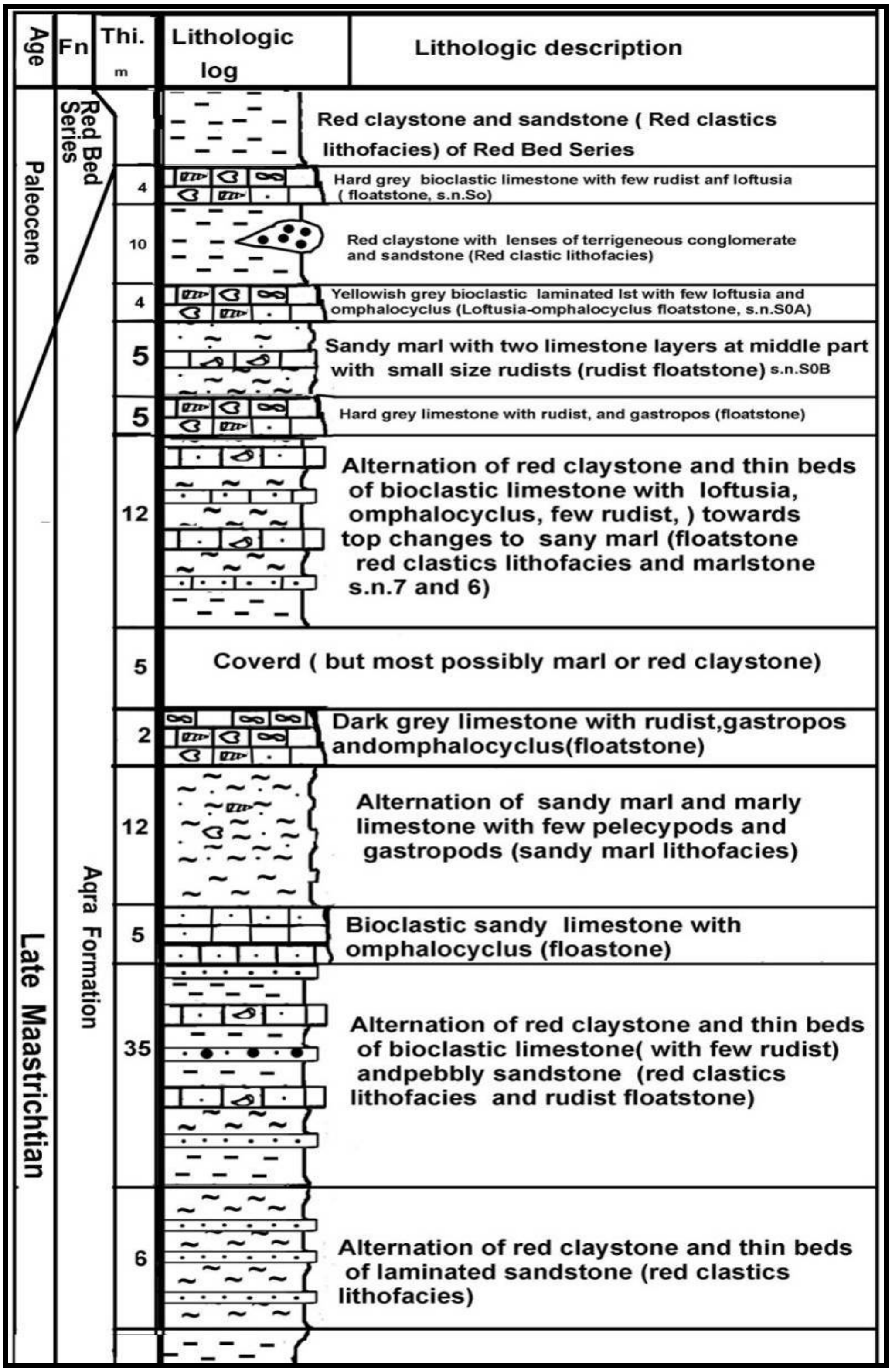

Fig.(2.22) Stratigraphic column of Upper part of Sura Qalat section (not to scale) (continued in the next page)

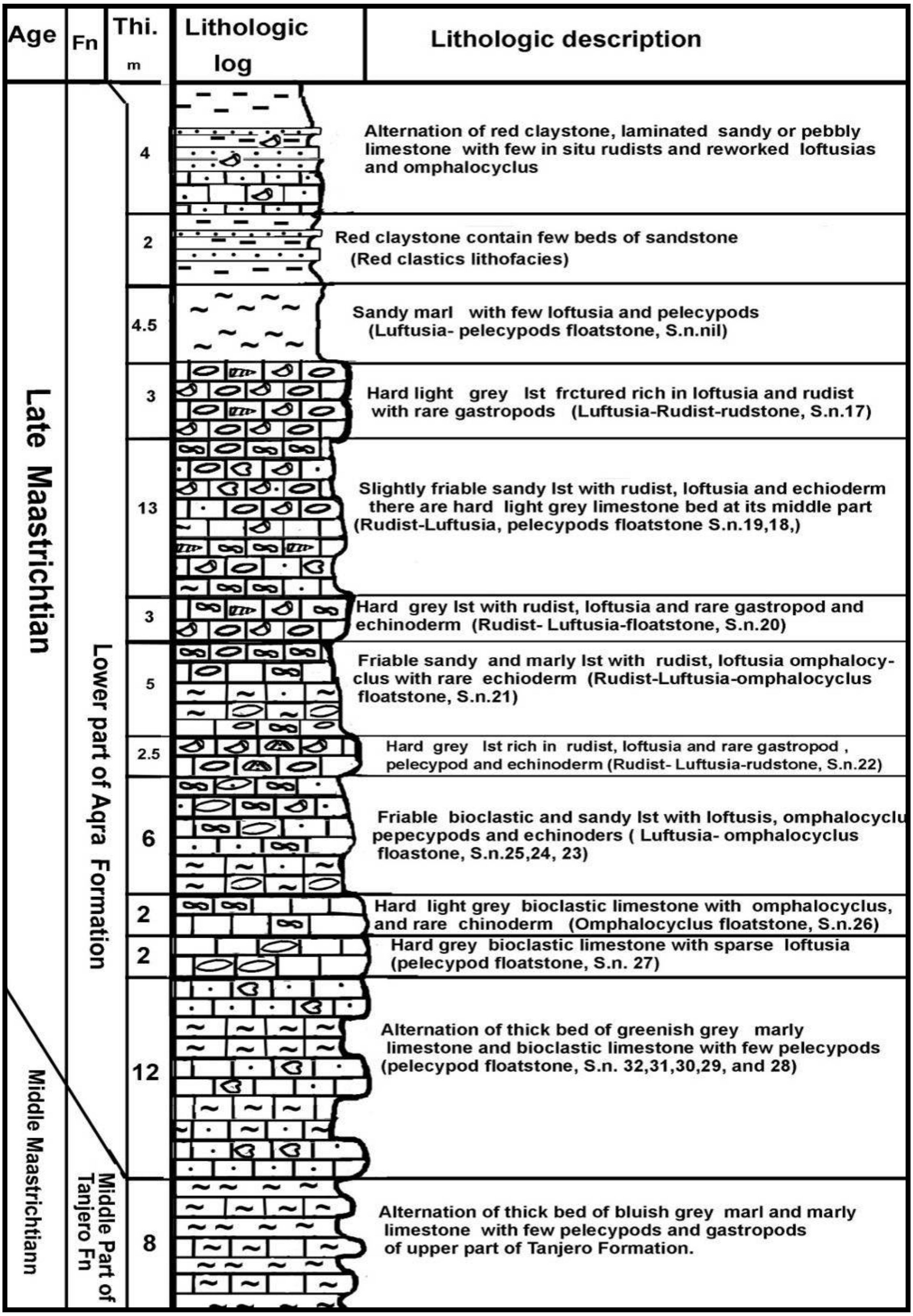

Fig.(2.23) Stratigraphic column of Lower part of Sura Qalat section (not to scale)

Chaptor Three

FACIES ANALYSIS

3.1 Preface:

Lithofacies and microfacies of Aqra Formation (Late Maastrichtian) are investigated in this study and the classification of Dunham (1962) for limestone is utilized. All the studied sections show low diversity fossils. All facies are containing more or less of three main types of allochems which are fossil skeleton, their bioclasts and lithoclasts in addition to some extraclasts. Therefore, we can assume that the facies have two origins or two factories; the first factory is biogenic factory for production of skeletons. The second factory is (physical factory) waves and currents which produce detrital (bioclasts) grains.

In addition to the classification of Dunham (1962), its modification by Embry and Klovan (1971) (Fig.3.1 and 3.5), and (Insalco,1998) are used too. This is because; the facies analysis of the formation will be more meaningful when they are used in micro and lithofacies identifications.

3.2 Fossil contents:

The rock beds of the studied sections of Aqra Formation are characterized mostly by high abundance of fossils and their bioclasts which constitute more than 70 percent of the rock mass of the Aqra Formation in the studied area. Therefore, the Aqra Formation consists of a biogenic and detrital limestones. These rocks are characterized by the existence of large benthic foraminifera (such as Lepidorbitoides, Orbitoides, Loftusia and Omphalocyclus spp) and macroorganisms like Pelecypod, Gastropod and Echinoderm and rare solitary corals.

Generally foraminiferas are used as index fossils for age determination because of short age, wide geographic distribution and their high abundance in the rocks, small size and most of the generas and species are well known.

3.3 litho and microfacies:

One of the main aims of this study is the investigation of facies analysis of Aqra Formation. Therefore, 100 thin sections are prepared from samples of the three selected sections (Kato, Kele and Suraqalat sections). The purpose of analyzing microfacies is to combine the results of the texture, structure, types of allochems and orthochems together with specific fossils content for inferring paleoenvironment, paleogeography and even tectonics.

Facies is a body or packet of sedimentary rock with features that distinguish from other facies. A facies is the product of deposition, and it may be characteristics of a particular environment or a particular depositional process (Tucker, 1991). Benthic foraminiferas are common in warm, shallow seas, living within and on the sediments and encrusting hard substrate. Most of the fossils and their bioclasts are so large that they are distinguishable by naked eyes (or hand lens) in outcrops or inn hand specimen. Therefore, both lithofacies and microfacies are utilized for reaching best result.

3.3.1 Rudstone microfacies:

According to Flugel (2004), rudstone is equivalent to packstone and grainstone which defined by him as grain supported carbonates rocks containing more than %10 grains larger than 2mm. Rudstone must be further characterized by compositional and textural criteria. Generation of rudstone needs erosion and transport. He farther added that erosion can be triggered by shallow water settings allowing destruction by storm.

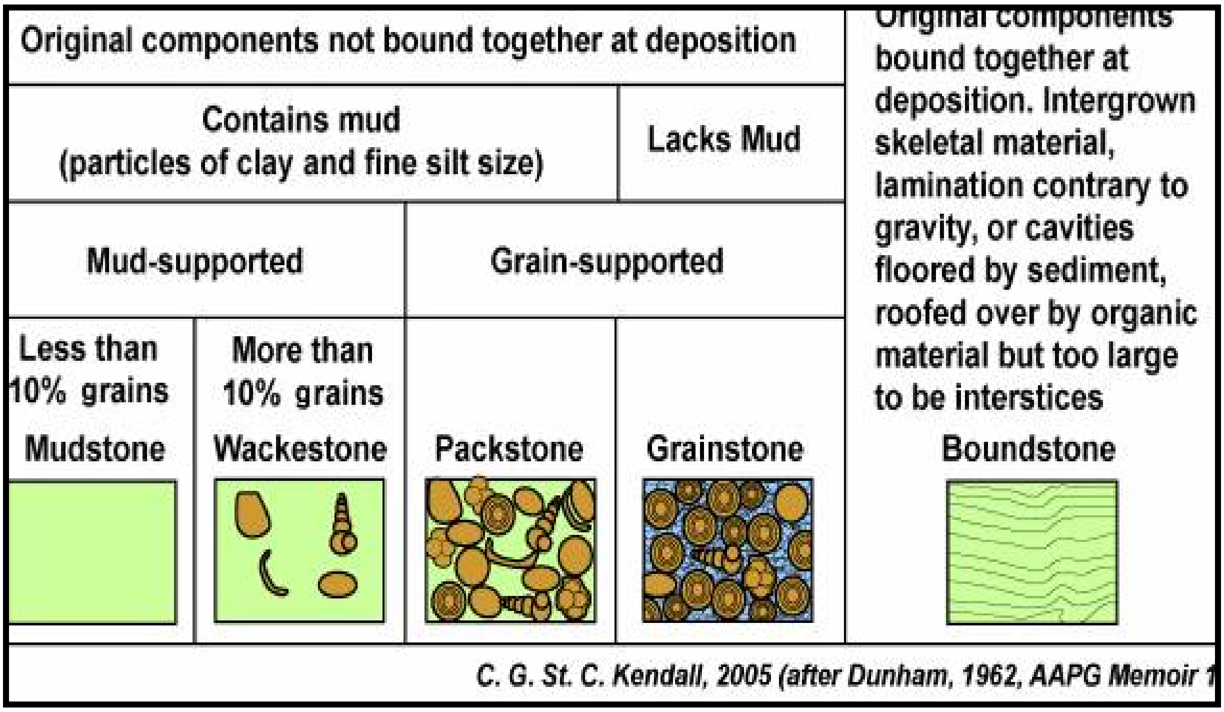

Fig.(3-1) Classification of carbonate rocks (Dunham, 1962)

This facies are introduced to Dunham's classification by Embry and Klovan, (1971) which consist of self-supporting large allochems (more than 2 mm in diameter) which are bounded by mudstone (micrite) (Fig. 3.1).

According to Wilson, (1975), this facies is deposited in forereef near reef flank environment where the strong wave and current action are prevalent. According to above authors, the allochems of this facies must be derived from the reef but many authors has included the non–reefal allochems in this facies such as Sadooni and Alsharhan, (2003) as they assigned the orbitolina bearing limestone as orbitolina rudstone. Kenter et al, (2005) found boundstone breccia in the fore reef area which is formed by gravity.

Fleury et al (1990) considered that on mounts of Valtou (Gavrovo zone) that Loftusia is in a conglomerate which comes in contact, by faults, with limestones probably of Cenomanian age, as well as with Paleocene breccias with Madrepores. The Loftusia shells are included in a Grainstone- rudstone facies along with debris of rudists, orbitoides sp. (large size, up to 16 mm), Lepidorbitoides sp. and other 798 benthic foraminifers.

Meriç (1965a) found abundant specimens of Loftusia in eastern Turkey, among which he determined L. anatolica n. sp., in conglomeratic limestones of Maastrichtian age. The Loftusia shells usually constitute elements of the conglomerate therefore can be considered as transported. The Lutetian unconformably overlies the Maastrichtian beds.

When the definition of Flugel (2004) is used, the occurrence of this facies is common especially in the lower part of the studied sections which consist of the large self-supported bioclasts (or reworked whole skeletons) of loftusia and omphalocyclus. These allochems are binded by fine grain matrix such as sand and silt sized carbonate grains in addition to lime mud. These facies underlined by erosional surface which are generated by strong wave and currents.

The clasts of this facies not derived from reef but most possibly derived from inner shelf by very strong wave during storm. In the lower part of the formation near Qishlagh village, this facies (Loftusia Rudstone) contain sporadicaly distributed rounded and sorted terrigenous gravels of cherts.

These facies include many subfacies such as:

1-*Ophalocyclus* bearing Rudstone.

2- *Loftusia* bearing Rudstone

3- *Rudist* bioclast bearing Rudstone

4- *Gastropods and pelecypods* bioclasts Rudstone.

The field evidences shows that the Loftusia bearing Rudstone is mostly reworked or transported from shallow environments to deeper ones by turbidity current making (turbidites) or transported by geostrophic current and deposited as tempestites. The evidences are:

1- Their beds are relatively thin 10cm- 0.5m and underlain by erosional surfaces.
2- The platy and elongated grains show imbrications (Fig.3.2and 3.3).
3- The test of the Loftusia are consist of agglutination of sand size lithoclasts (Fig. 3.4)

Under microscope, generally the rudstone is slightly different from hand specimen and can be called packstone as the large grains are too large to be seen in thin section. In some case the elongated grains (such as Loftusia) show parallel arrangement indicating southwest paleocurrent direction of transporting. They contain grains larger than 2m (Fig3.3) and constitute more than %40 of the all sections.

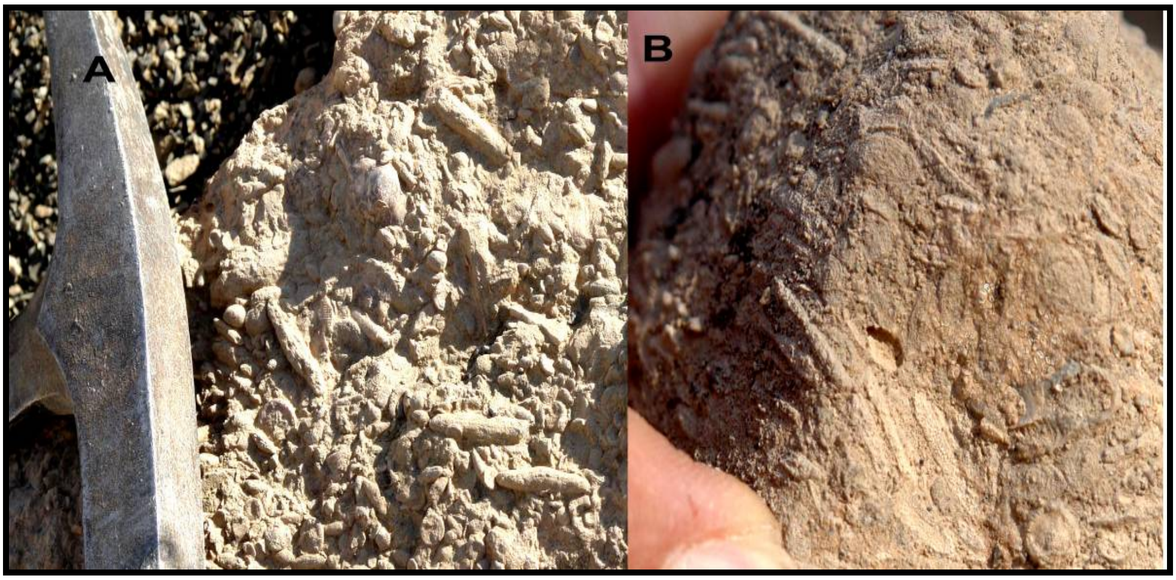

Fig.(3.2) **A)** *Ophalocyclus* and *Loftusia* bearing rudstone in the upper part of the Kele Section (sample no.15). The *Loftusia* shoes parallel arrangement.**B)** rudstone of the showing the imbrications of the *Ophalocyclus* large forams (sample no. 17).

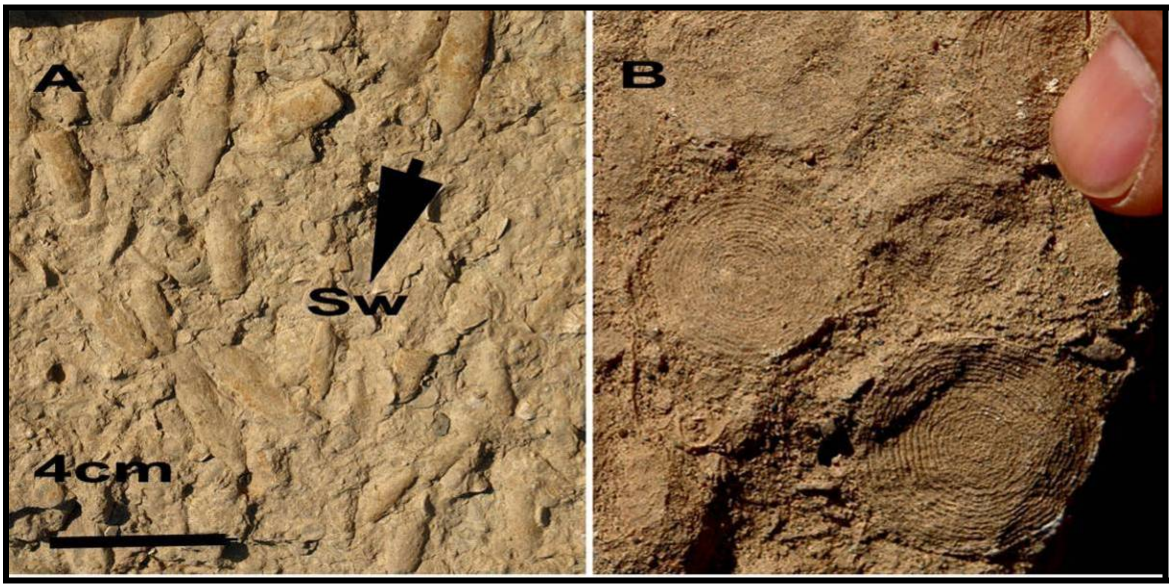

Fig.(3.3) **A)** *Loftusia* Rudstone in the Lower part of the Kato Section (sample no.18k). The matrix consists sand sized bioclasts, reworked *Orbitoids* and lithoclasts. The *Lofusias* show parallel arrangement and southwest paleocurrent direction. **B)** Cross section of *Luftusias* showing growth rings (sample no.27k).

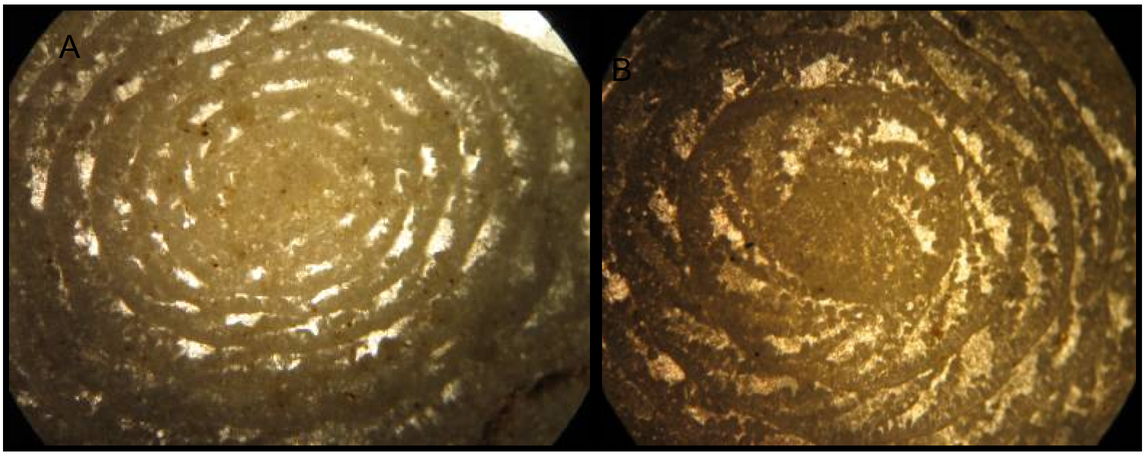

Fig.(3.4) two different species of *Loftusia* under polarized microscopes, showing agglutinated wall which is composed of sand size lithoclst grains. X10 (sample no.4).Lower part of Kato section

Allochthonous		Autochthonous		
Original components not bound organically at deposition		Original components bound organically at deposition		
>10%grains>2mm		By organisms that act as baffles	By organisms that encrust and bind	By organisms that build a rigid framework
Matrix supported	Supported by >2mm component			
Floatstone	Rudstone	Bafflestone	Bindstone	Framestone

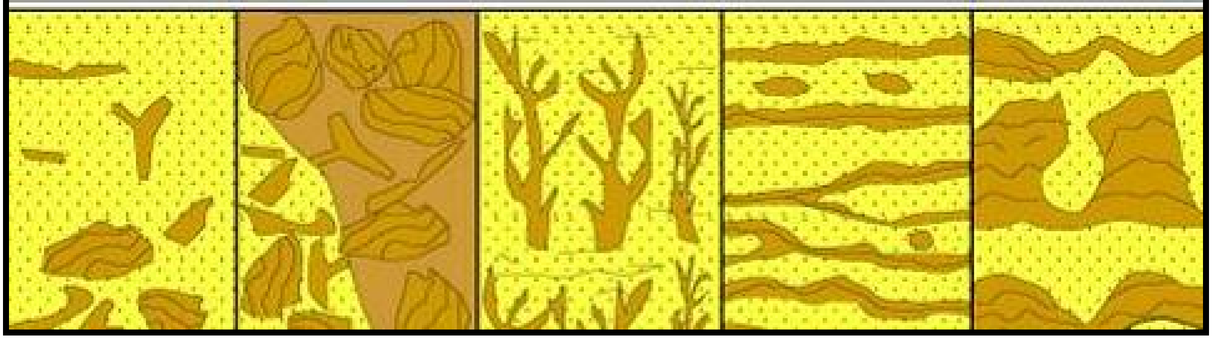

Fig (3.5) Classification of reefal limestone by Emery and Klovan (1971).

3.3.2- Bufflestone (Pillarstone) Microfacies:

This facies consist of stalk-shaped and branching fossils that trapped sediments during deposition by acting as baffles by slowing down water movement and allowing sediment to settle (Emery and Klovan, 1971). According to Flugel (2004) the features for identifying the Bafflestone is the presence of large number of insitu stalk-shaped fossils.

This facies is found by Pomar et al (2004) in the rocks of Upper Cretaceous platform in the Pyrenees, Spain. They called it “Dense-hippuritid pillarstone” which commonly consist of 1-6m thick continuous and extensive beds composed of densely stacked elevator slender-hippuritid pillarstone.

In the studied sections, this facies is found in both Kato and Kele section while it is not found in the Suraqlat section. It is composed of densely and vertically arrangement of long and thin elongate in situ rudist which similar to that which found by Polmar et al (2004). The rudist skeletons of this facies are consisting of elongate whole rudists each about 5-10cm long and 2-3 cm in diameters (Fig.3.6 and 3.7). Complete lateral extent of beds cannot be measured due to intermittent coverage of the outcrops but it exists in both Kele and Kato near the middle part of the sections.

Some of the slender *hippuritids* are vertical but commonly are inclined. The matrix mostly consists of wackestone to mud-dominated packstone. In some rudist buildups, this Lithofacies is mostly composed of horizontally lying slender *hippuritid* fragments, conforming float stone and Redstone textures.

Rudist are anomalous bivalves which developed massive sessile shells, often with two valves showing strong asymmetry (Dechaseeaux et al, 1969) and were adapted to filter feeding. Many forms show the strong development of the attached valve and the subsequent reduction of the free valve. In general forms, rudists resemble corals and it has been suggested that *rudist* displaced corals from reefs during Cretaceous (Kauffman and Shol, 1974: Johnson and Kauffman, 1996) in Mitchell, 1999). As mentioned above the rudist Bafflestone (Fig3.6), in the Aqra lens, is very similar to coral baffle stone that is found in the lower part of Qamchuqa Formation by Ameen (2008).

Fig.(3.6) Rrudist Bafflestone of the lower part of Aqra Formation(Lens) which is similar in form to the coral Bafflestone. Kele section, sample no.31.

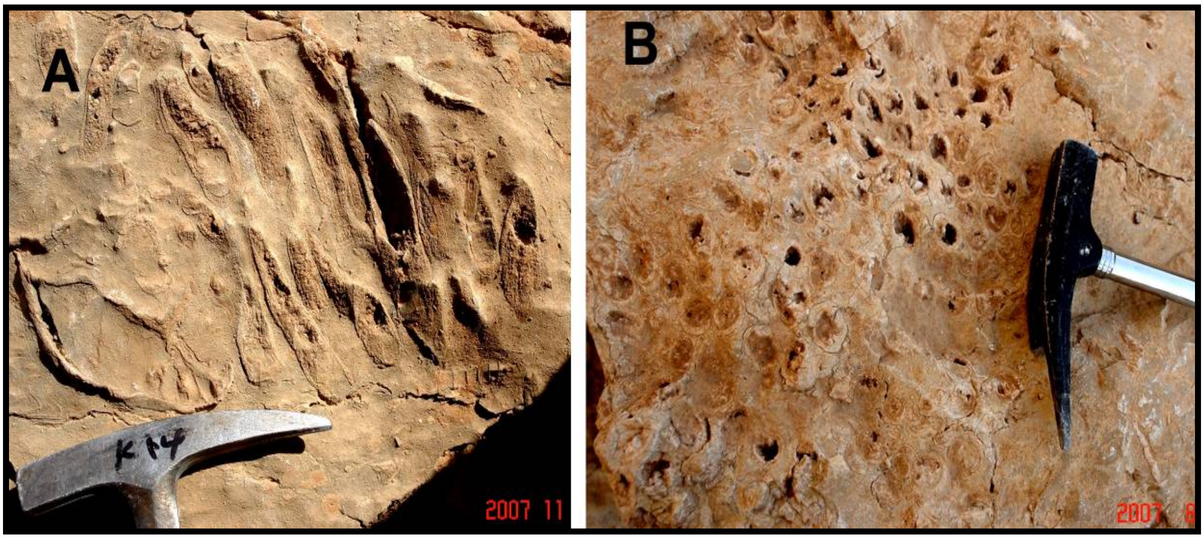

Fig.(3.7) **A)** Elongate rudist bufflestone showing longitudinal section in the middle part of the Keke and Kato sections (sample no. 14). **B)** Cross section of elongate rudist bufflestone (sample no. 33), Kele section.

3.3.3 Floatstone Microfacies:

Floatstone are matrix supported carbonate rocks yielding more than %10 grains larger than 2mm. This 2mm boundary creates difficulties in applying term to fossiliferous limestones or limestones with oncoids because the size of skeletal grains and oncoids can only reflect growth stages (Flugel, 2004). He added that the use of a strict terminology would put a gastropod limestone yielding adult snails into the floatstone category and limestones containing the same but juvenile snails into the wackstone category. He added further that floatstone and rudstone were originally proposed for reef carbonates and carbonate breccias. The matrix of floatstone does not necessarily correspond to micrite, but often exhibits fine-grained textures that must be described separately.

This facies is the most common one in the Aqra lens which has the matrix of fine grain carbonates and micrite. The matrix can be called wackstone or packstone, therefore the below facies can be named as floatsone-wackstone facies and for each one two photos are inserted in the text, one for hand specimen (floatstone) and other one for thin section (for wackstone or packstone), (Fig 3.8,3.9 and 3.10) This facies can be divided in to many different surfaces depending on the different contents like:

1-Omphalocyclus float stone.

2-*Loftusia* float stone

3-*Rudist* bioclasts float stone

4-*Gastropods* and *pelecypods* skeletons and bioclasts float stone

5- *Acteonella* float stone

6-*Echioderm* bearing float stone

All above facies exist in the all three sections which contain reworked whole or clasts of the above fossils. These facies are can be indentified in the field by eyes.

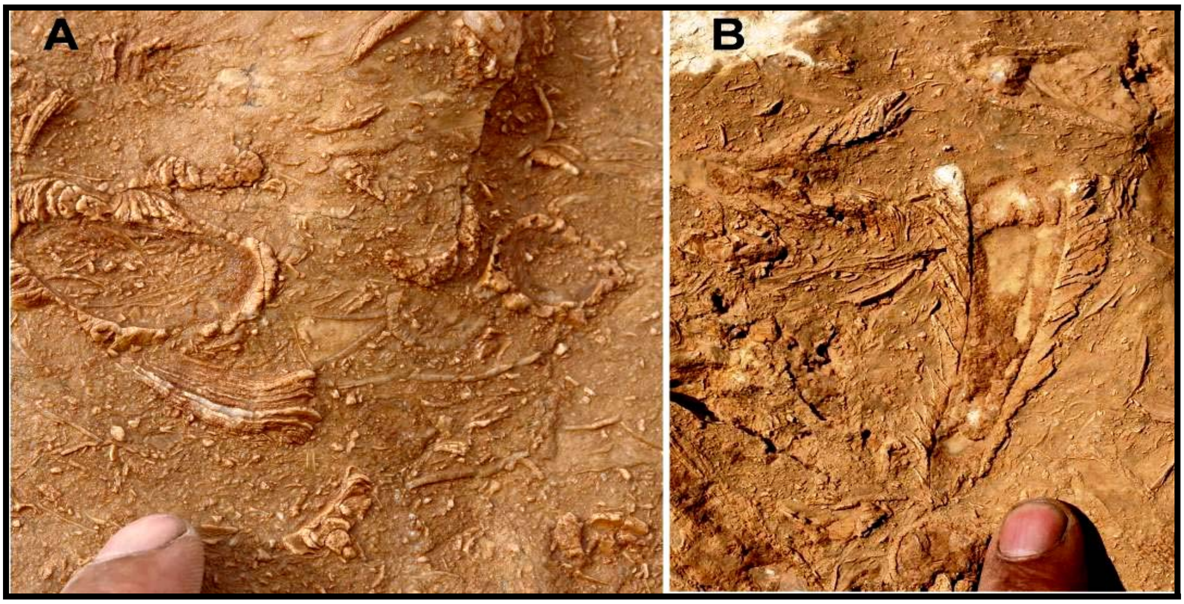

Fig.(3.8) **A)** Cross section of *Radiolitid rudists* with their bioclasts in the rudist floatstone-wackstone., middle part of Kato section, Sample no.13. **B)** Radiolitid rudists one of them in its life position while others are dislocated in floatstone. Kato section, sample No.14.

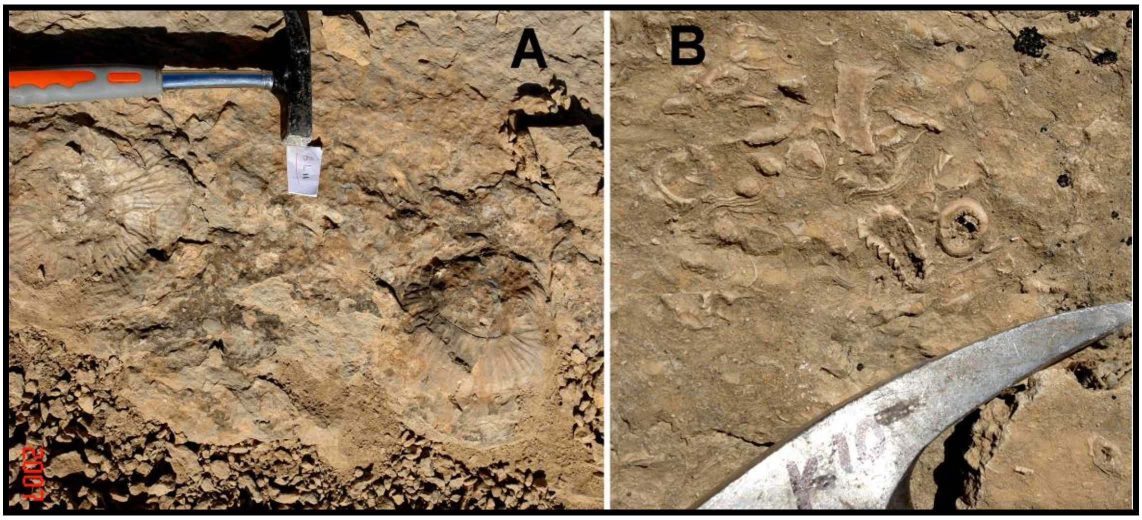

Fig.(3.9) **A)** Thick shelled *hippuritid* rudist floatstone-wackstone, Lower part of Kato section, Sample no.11. **B)** Thin shelled *radiolitid* rudist float stone. Kele section, sample No.10.

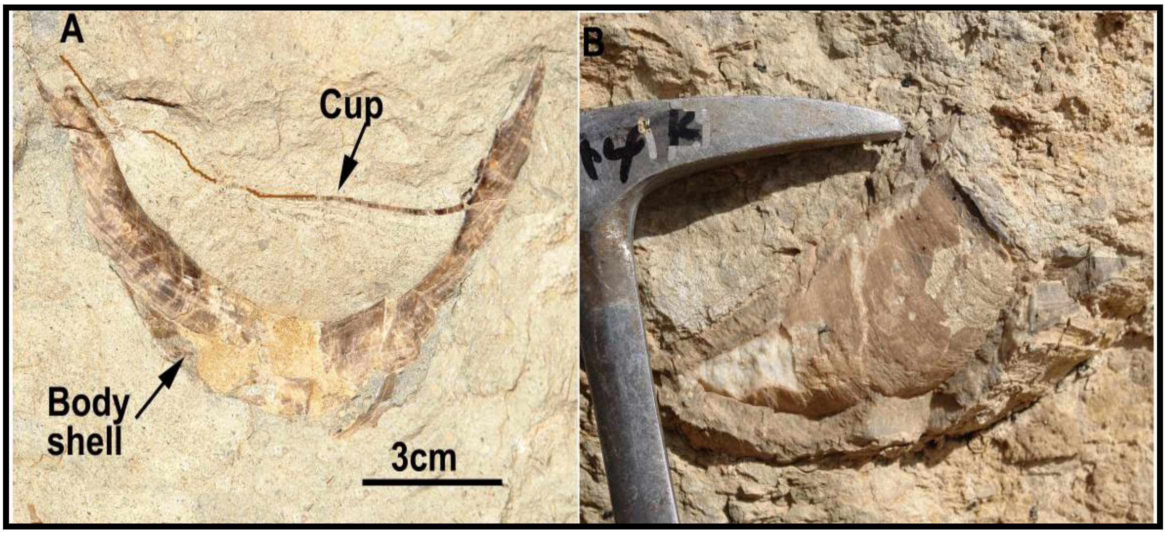

Fig.(3.10) **A)** Thick shelled hippuritid rudist in the floatstone, Lower part of Kele section, the upper valve (cup) can be seen which is dislocated (depressed) in its place toward inside the main body shell. Sample no.15. **B)** Thin shelled clinger radiolitid rudist in the floatstone. Kele section, sample No.14.

3.3.4-Mixstone microfacies:

The term "mixstone" is used by Insalaco (1998) in the descriptive classification of growth fabrics in the reef. Polmar et al (2004) stated that it is not dominated by one growth form and includes a variety of growth forms. In this study, this facies is common in all three sections. This is due to high energy and steep slope of the basin which facilated the mixing of different allochems from different environment in the basin. This facies is not indicative for certain environment except high energy one. The following subfacies are found in the sections:

Loftusia-rudist–Actineonella mixedstone.

*Omphalocyculas-Loftusia-Rudis*t mixtsone

3.3.5 Foraminifera-bioclast packstone microfacies:

This facies is one of the most important microfacies and it is the most common one in the thin sections. The ratio of the grains is more than %50 and they are self supporting. This facies is associated with sparselly distributed rudist and *Gastropods*. Toward south southeast, the Rudstone and floatstone, in the Kele and Kato sections, are changing to this facies as the case near Zardabe and Homaragh villages which appears as thick beds 30cm-4m). This facies contain reworked forams (mainly ortbioids) and bioclasts. The observing of the reworking is clear as the beds contain cross lamination and cross bedding near Zarda Bee. The large scale cross beddings are associated with boiturbation which may indicated the deposit of storm (tempestites). This is because tempestites are characterized by burrowing (Fig3.11, and 3.13) and hommucky cross stratification.The latter stratification can be seen in the figure (3.12). The *skolithos* trace fossil in this facies is about 15cm long which indicate rapid and high rate of deposition either by storm or turbidity currents.

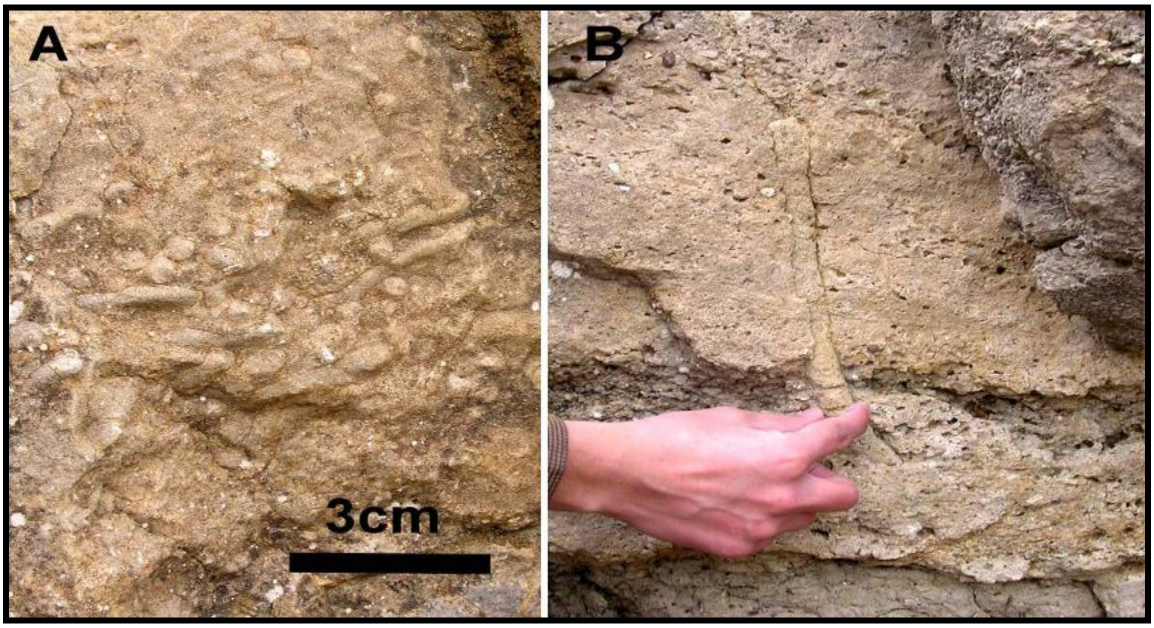

Fig.(3.11) Horizontal(**A**) and Vertical (**B**) burrows at southeast of Zarda Bee village in the foraminiferal bioclastic packstone

Fig.(3.12) Thick and cross bedded of bioclast grainstone at the southeast of Zarda Bee village.

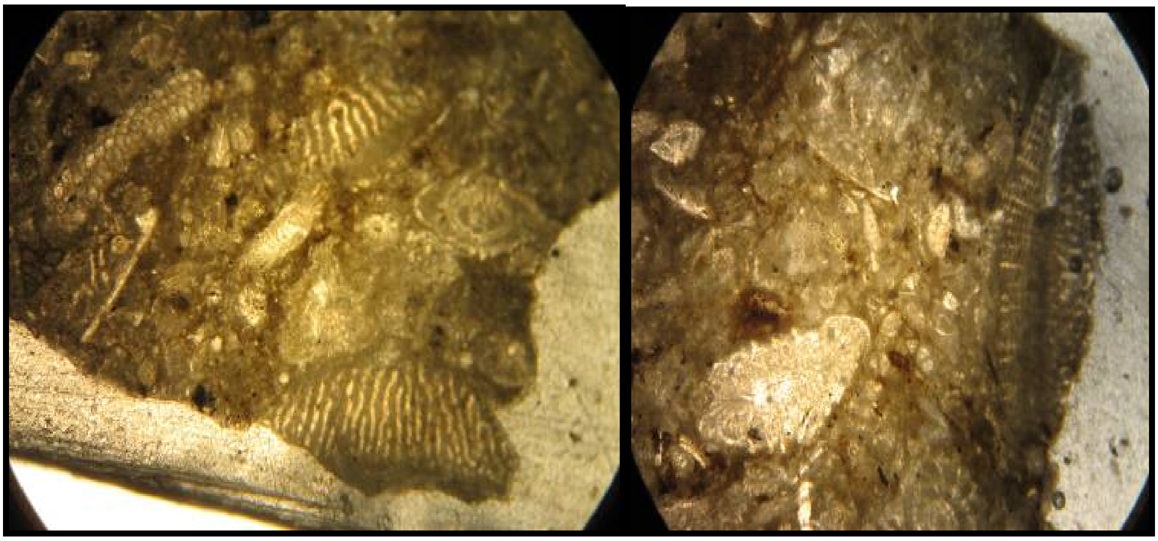

Fig.(3.13) Two Foraminiferal (Orbitoid) and bioclastic packstone in the upper part of the Suraqalat section, X20, N.L. s.n.7 and 8

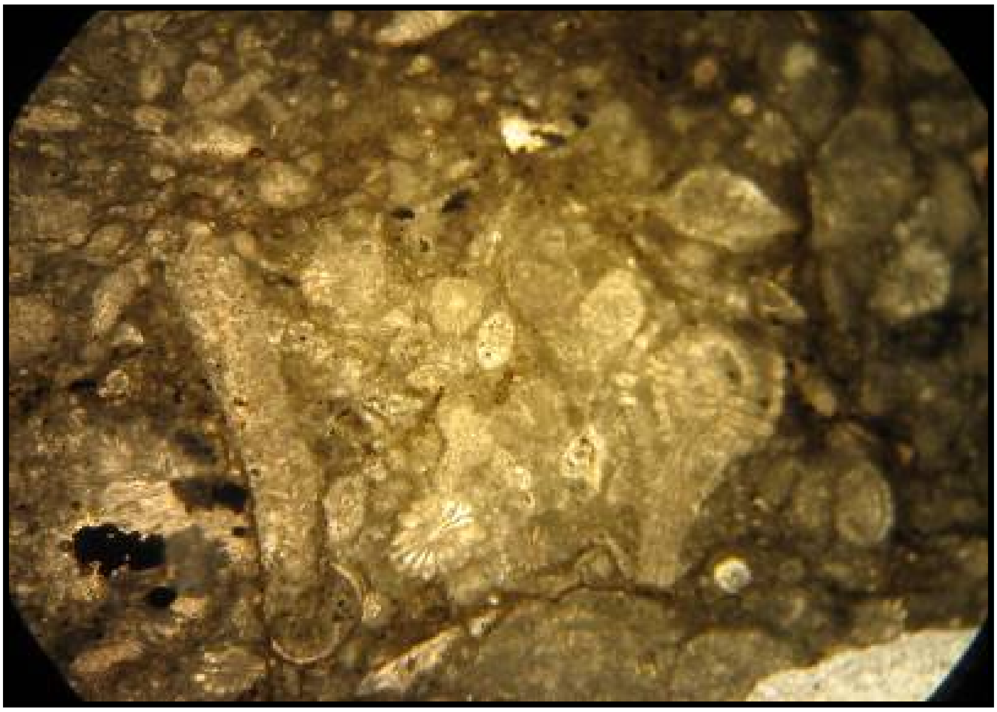

Fig.(3.14) *Orbitoid* packstone of Suraqalat section, s.no. 9)

3.3.6- Bioclastic grainstone microfacies:

Grainstone are grain-supported and mud –free carbonate rocks and consist of skeletal and non-skeletal carbonate grains. The absence of mud has various causes: deposition of grains in high-energy environments (e.g.in intertidal and shallow subtidal environments), rapid accumulation of grains allowing no coeval mud sedimentation (e.g. tubidites, deposition in current-controlled environment, winnowing of mud from previously deposited grain\mud mixtures. Grainstone are highly variable with regard to grain type, shape, size, and sorting (Flugel, 2004).

Grainstones are common rocks in platform and ramp carbonates. They are usually related to the locus of wave energy absorption such as shorelines, shoals or shelf break. Here, grainstones from thick accumulation at the outer shelf margins or in inner ramp setting. Bank-margin sands occur in tidal bar belts, tidal deltas, and marine sand belts, back-reef areas, on beaches and in subaerial dunes. Accumulation of grainstone can also originate below the wave sweep base owing to current effects (Tucker, 1991).

This facies distinguished by grain supporting and the groundmass is consisting of spary calcite with the ratio of micrite less than (%5) (Dunham, 1962). This facies is rare in the formation and it appears in Kele and Kato sections which consist of well sorted and rounded rudist and gastropods bioclasts. The grains are in the size of coarse sand. It contains both parallel and cross lamination. It is underlain by irregular (Hummocky) erosional surface fig (3.15).This rareness may be attributed to the rapid sedimentation in the basin of Maastrichtian due to high tectonic of the area. This rapid sedimentation deposited about 100m of carbonate during Late Maastrichtian.

Fig. (3.15) the erosional contact between bioclastic grainstone and underlying baffle stone in the lower part of Kele section

3.3.7- Lithoclast packstone microfacies:

Lithoclasts are equivalent to extraclasts, which their size varies from 0.3mm to several centimeters. According to Blatt et al (1980), lithoclast (or mudclasts) is used to imply a rock fragment derived from outside the basin of carbonate deposition by erosion and transportation. They added that, in terms of the hydraulics of transport and history, there is significant genetic difference between a mud crack flake or an eroded fragment of contemporary beach rock (both are intraclasts) and an older limestone pebble (lithoclasts).

Fossiliferous sedimentary rock, fragments that can be dated as significantly older than the host rock are lithoclasts while the implication of the term intraclast is the lithified particle and its disruption from its original setting and redeposition take place essentially contemporaneously with the sedimentation of the stratigraphic unit in which it is found.

According to the Blatt et al., (op. cit), the distinction becomes more difficult; when the limestone fragments are lacking internal evidence for their age. In general, lithoclasts are very uncommon in most carbonate rocks. Where a carbonate platform terminates landward against a sea cliff of older rocks, the eroded products of that cliff may contribute lithoclasts to the new sediment. Both intraclasts and lithoclasts have been termed lime clasts when the distinction between distant and local derivations cannot be made.

According to Tucker (1991), intraclasts are fragments of lithified or partly lithified sediments. A common type of intraclast in carbonate sediments is a micritic flake or chip derived from desiccation of tidal-flat muds or disruption by storms of partially lithified or cemented subtidal lime muds.

Aqra Formation, lithoclasts and intraclasts are common in all section especially Kele and Kato sections. The lithoclasts mostly contain some fossil structures and show more angularities than intraclasts, while intraclast are mostly rounded structures (Fig.3.16). They have darker color tone as compared to the lithoclasts. In Aqra Formation, this facies is generally badly sorted and occasionally contain unknown grain that are mostly elongated and has dark color (Fig.3.16B).

The lithoclast grainstone is found in thick and cross bedded limestone at the distal part of the basin near Mokaba and south of Sitak villages. In addition to lithoclasts, intraclasts are found too. They consist of rounded gravel sized white (as seen by naked eyes) clasts and occur in the lower part of the Kele section.

The occurrence of the intraclasts (rip up clasts) in the formation is due to high energy of the environment (Fig 3.17) which characterized by reworking of sediment and generation of several agent of erosion of preexisting semi-lithified sediment by turbidity, and storm generated current.

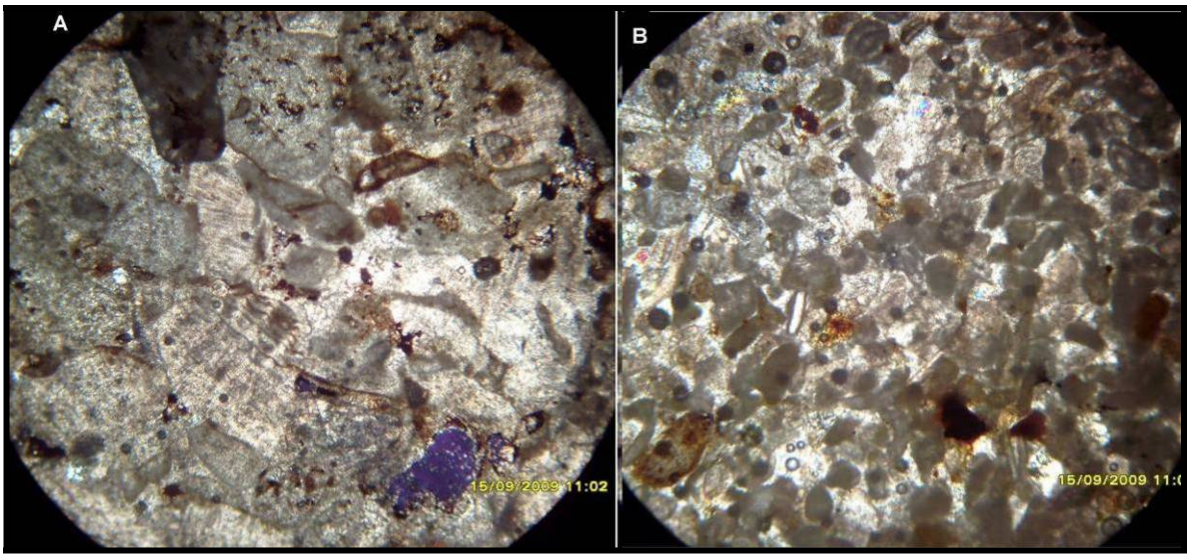

Fig (3.16) Lithoclastic grainstone in the thick and cross bedded limestone beds at 500m southeast of Zarda Bee village (X20, N.L.)

Fig (3.17) Intraclasts as rip up clasts in Aqra Fn. Found in the Kele section

3.3.8 -Terrigenus conglomerate Lithofacies:

This facies occur in the base of the formation as thick beds (30cm -1.5m) and in one case (as at the base of Kele section) it alternate with rudist float stone and with erosional contacts (Fig3.18). It consists of terrigenus rounded and sorted pebbles and cobbles of chert and siliceous limestone with siliceous cement materials in additional to sand or silt matrix in some sections.

This facies is very important for paleogeographic and environmental construction of the basin in which the formation is deposited (see chapter four, section 4.2). This conglomerate is studied in detail by Karim (2004) who called it Kato Conglomerate and in some place has about 500m of thickness. He assigned it as deposit of low stand fan delta. The important of this facies is attributed to the fact that this facies is acted as hard substrate for organic buildup in addition to preventing the influx of turbidity when acted as barrier against new stream invasion.

3.3.9-Red clastic Lithofacies:

This facies consists of red claystone, sandstone and conglomerate that is located at the top of the Aqra Formation. This facies is belong to Red Bed Series but here described because it alternate with biogenic or reworked fossiliferous limestone bed of the Aqra Formation as the case at the top of the Mokaba section. Another reason for the description is that this facies is very important for environmental and tectonic reconstruction of the basin of the Aqra Formation.

Barzinjy (2005) described, in detail, the tectonic, environment and sources of this facies. He attributed the color of these red clastics to the red siliceous and ferruginous mudstone or shale of Qulqula Radiolarite Formation. He assigned it as alluvial fan and combined this facies with Kolosh and Gercus Formations.

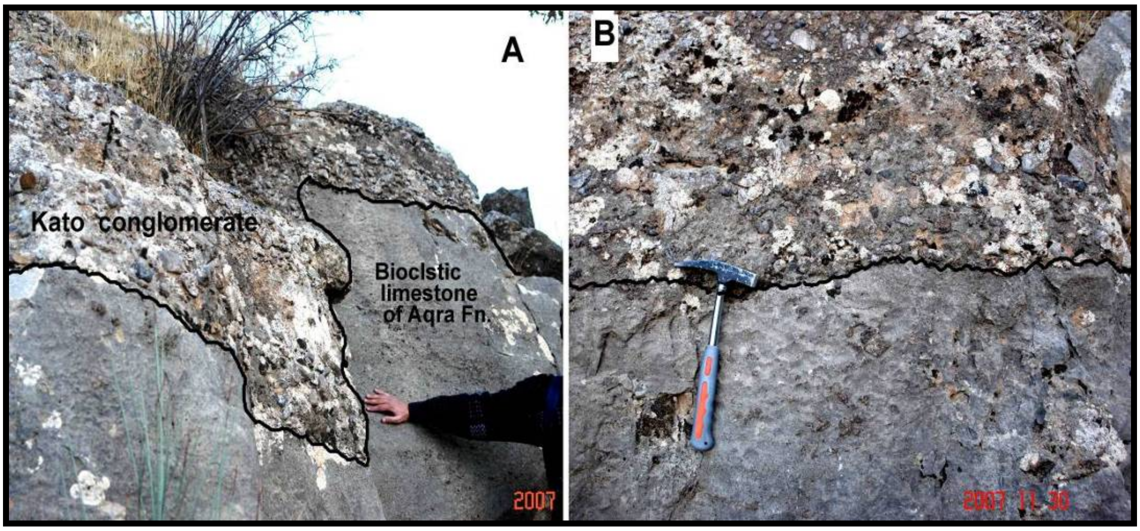

Fig.(3.18) **A** and **B**\ Terrigenous conglomerate lithofacies overlying the rudist Floatstone at the base of Kele section

3.3.10-Sandy marl lithofacies:

This facies consists of sandy or fossiliferous marl or marly limestone that is located at the base of the Aqra Formation. According to Karim (2004), this facies is belonging to middle part of Tanjero Formation. In the inner shelf the Aqra Formation is underlain by conglomerate while in the outer shelf it underlain by this facies. It is very clear in Zarda Bee and Mokaba area and contains rare Planktonic forams in addition to some thin limestone beds that contain *orbitoid* forams in addition to bioclasts. In some localities, the marly limestone beds contain sporadic echinoderm (Fig3.19), large gastropod and *pelecypods* such as Lower part of Suraqalat and southwest of Tagaran village. It is possible that this facies deposited in the outer shelf or upper slope.

Fig.(3.19) *Echinoderms* that are collected in the marly limestone of the lower part of Sura Qalat section.

3.4-Correlation:

The correlation of the different parts of the studied sections is important for environment and paleogeographic setting in addition to tectonic model of the basin. This can be done with the aid of the result of chapter two (lithology and stratigraphy) and three (facies analysis) in addition to implementation of the fieldwork data.

When the Lithology of the overlying and underlying formations are used, the correlation is easy, especially both contacts are gradational. This type of the contacts has the representative Lithology of elapsed time without non-deposition or removal by erosion. The first appearance of the red clastics of the Red Bed Series, at the top of the sections, is used to correlate the top of the sections. The disappearance of the biogenic or detrital limestone and appearance of calcareous shale or sandstone, at the base of the section, can be connected for the correlation of the base of the sections. The difficulty will arise when one want to correlate the middle part of the sections. This is because the Lithology of the different parts of the sections are similar. However, the laminated and cross bedded limestone (grainstone) at the lower part of the Kato and Kele sections can be used for the correlation of the strata inside the sections (Fig. 3.21). In the Suraqalat section, there is no laminate and cross bedded limestone (grainstone) due to deepness of this section as compared to other two sections. Another fact that make the section difficult to compare with other ones is that it show more signs of deformation such as faulting folding. Therefore, there is possibility of repetition of some beds. However, the equivalent of the laminated, cross bedded grainstone in the lower part of Kato section can be found in the Suraqalat section which consists of the litho and bioclast packstone near the middle part of the section.

According to Al-Ameri and Lawa (1986), the Aqra Formation, in the type locality, is mainly deposited on an island (Fig.3.20). Therefore, the correlation of the Formation in the type locality is very difficult due to the fact that no sign of island is seen in the studied area (Chuarta-Mawat area) during Maastrichtian. Another reason is that in the type area, the underlying and overlying formations are Bekhme and Kolosh formations respectively instead of the Tanjero Formation and Red Bed Series in the studied area. The only relation is that in both localities, the formation is developed on hard substrate. In the type locality it grown on the hard limestone of Bekhme formation while in Chuarta-Mawat area it grow mainly on conglomerate.

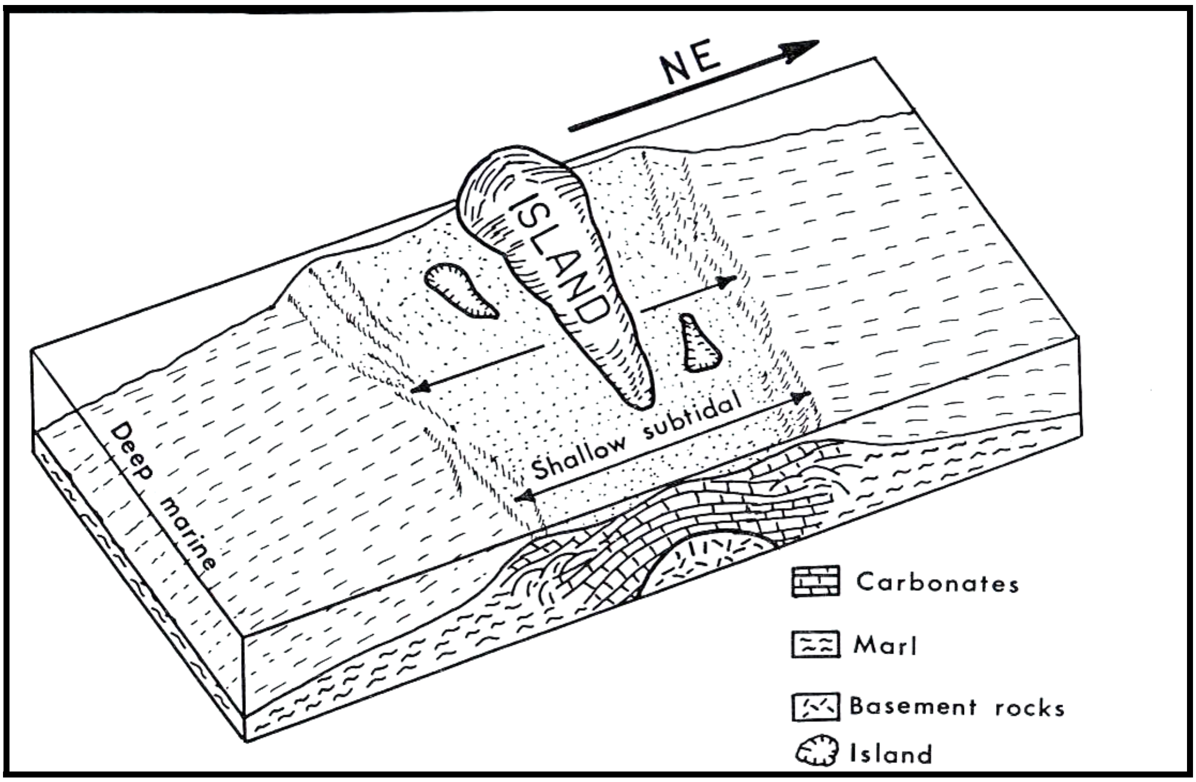

Fig.(3.20) Depositional environment of Aqra Formation, in the type locality, showing that the rudist bearing rocks deposited on island (rudistid island) during Maastrichtian (Al-Ameri and Lawa 1986)

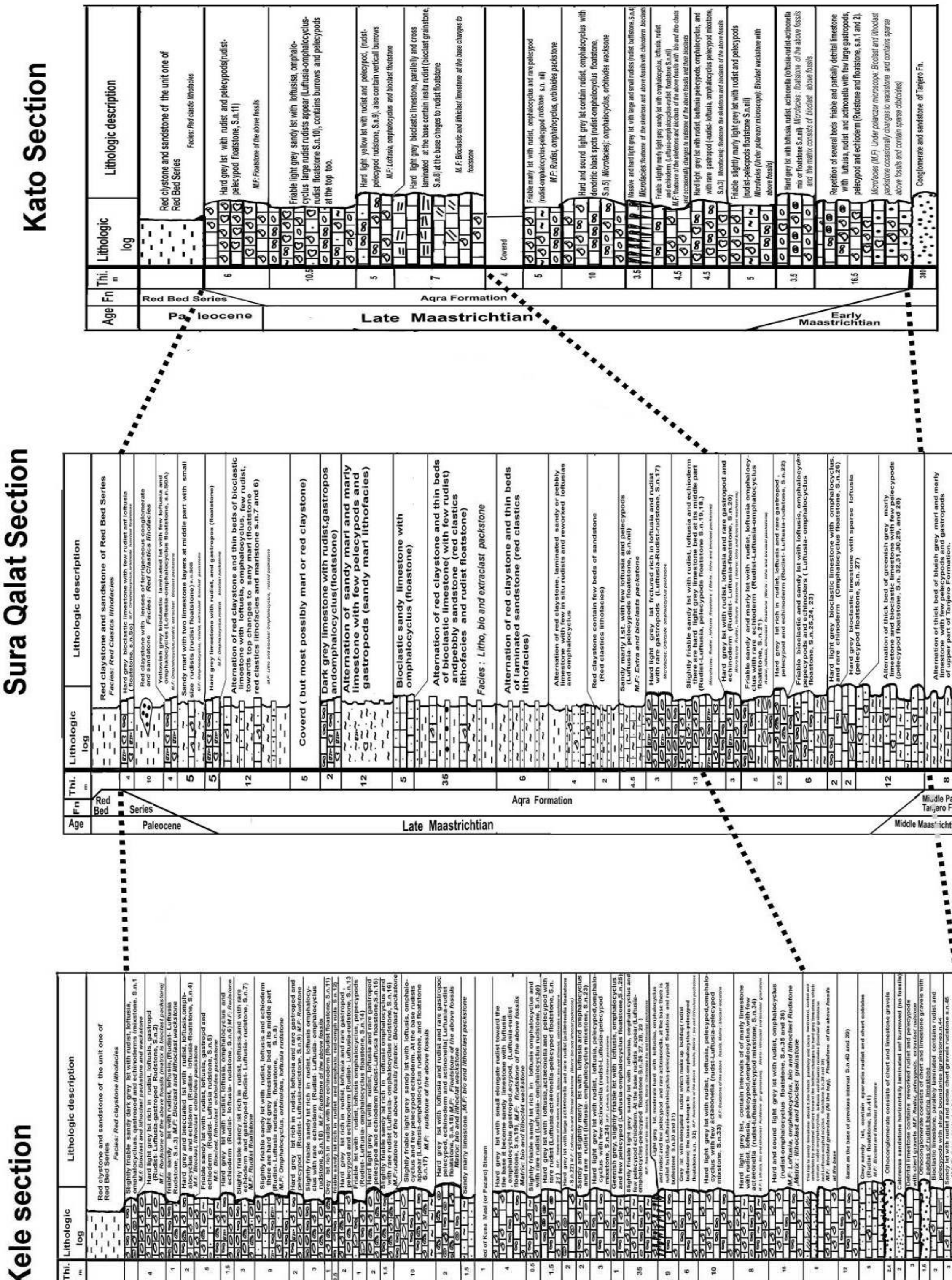

Fig.(3.21) correlation of the three studied sections in Chuarta-Mawat area

Chaptor Four

DEPOSITIONAL ENVIRONMENT AND TECTONICS

4.1- Preface:

There are two facts that make the present study important for the formation in the studied area. The first is that, it is the first detailed one for the formation in the Chwarta-Mawat area. The second one is that all previous ones are conducted on the distal area of the basin (outer shelf). Among the new papers that dealt with this formation in the distal areas are that of Lawa et el (1998) and Kubaysi (2008) which treated the lithology and fossil content in addition to age determination in the Mokaba and Zarda Bee sections.

The present study has taken three different sections which are previously not studied. Two of these sections (with the maximum thickness) are located in the proximal area of the basin (mid-shelf) and the other one in the distal area of the basin (with lessor thickness). Due to these facts, the present study have conducted detailed facies analysis and reconstructed both paleogeography and paleo-environment in manner to be realistic.

4.2- Depositional environment:

According to (Tucker, 1991), benthic foraminiferas are common in warm, shallow seas, living within and on the sediment and encrusting hard substrate. It is agreed that Aqra Formation in the type area is deposited in the reef and fore reef environment (Jassim and Goff, 2006). Henson (1950), recorded that in Aqra Formation in northern Iraq, the compact reefal rudistic limestones pass into shallow facies of the reefal margin with *Loftusia, Omphalocyclus*, and *Orbitoides.*

According to Karim (2004), the Aqra Formation (or Aqra lens), in the Chwarta area, is deposited during sea level rise (high stand systems tract). While he assigned the conglomerate and sandstone of the Tanjero Formation (below Aqra lens) as deposit of low stand systems tract in the shape of low stand fan delta.

He also mentioned that in Chwarta-Mawat area several large fans were deposited which consist of boulder and gravel conglomerate. The deposits of these fans are about 500m thick. He further added that this area was consisted of coastal area of a large foreland basin.

According to Liu (2006), during Middle to Late Maastrichtian eustatic sea-level fall, the open marine condition was restricted to the basin central areas. He mentioned that a prominent hiatus developed on the NW flank, and platform carbonates were deposited as late high stand systems set on the SE flank of the Mesopotamian Basin.

Sadooni (1996) claimed that shallow-marine carbonates were deposited in Central Iraq during the Late Campanian-Maastrichtian. These carbonates consist of foraminiferal-shoal and bryozoans-algal-rudist, bank deposits, separated by argillaceous, oligosteginal packstone and mudstones. The buildups are believed to have developed on block-faulted topographic highs, while marly limestones were deposited in the intervening basinal low areas.

According to Cameil, (2005) the upper beds of the Qahlah Formation at Jabal Huwayyah, United Arab Emerates, is composed of massive conglomerates with subordinate sandstones. The sandstones increase upward and contain clasts of red mudstone and chert. Overlying this lower sequence of conglomerate and sandstone a highly fossiliferous silty limestone beds containing most of the fauna found in the Qahlah dominated by rudists were interpreted by Smith et al. (1995) as having been deposited on stable shoals above active wave base. This stratigraphic relation between conglomerates (with sandstone) is similar to Aqra Formation in the studied area (Fig.4.1).

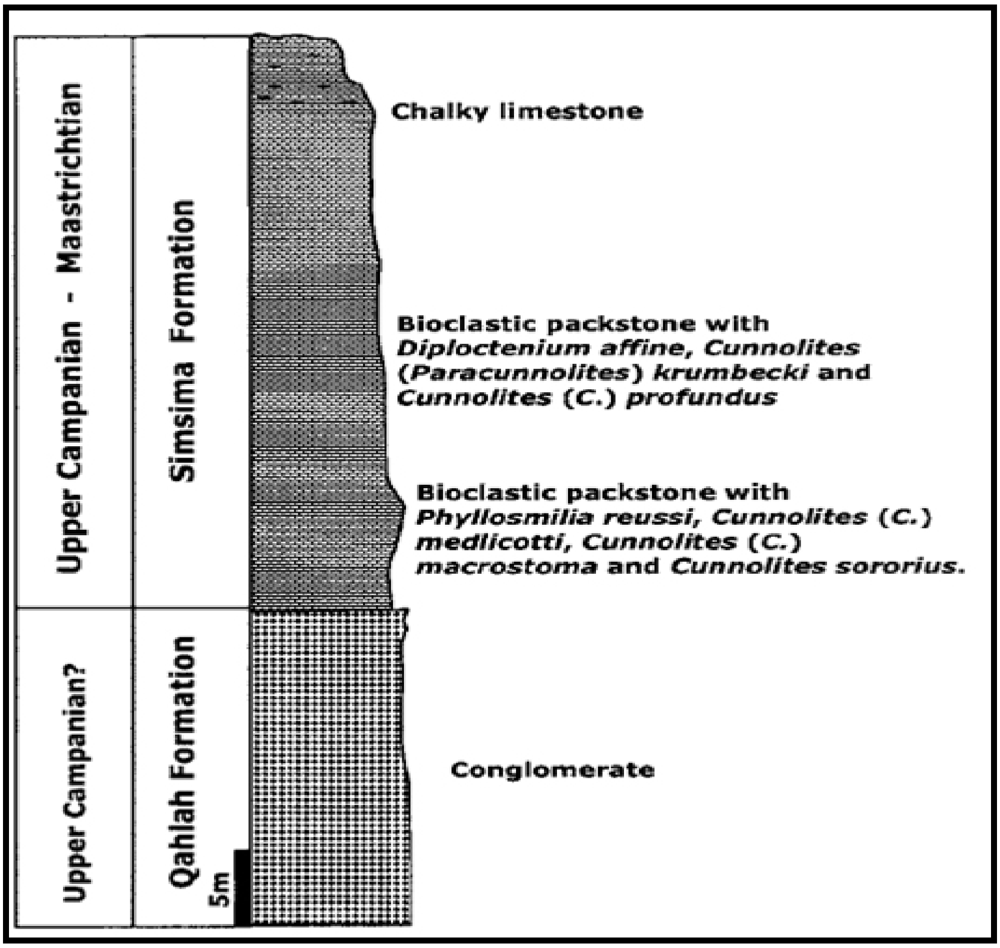

Fig.(4.1) stratigraphic relation between Qahlan(conglomerate) and Simsima Formations (biogenic limestone: packstone) of Jabal El Rawdah, Cameil, (2005). This relation is similar to relation between Tanjero and Aqra Formation in the studied area.

Although rudists are sometimes considered as characteristic 'reef-builders' of the Cretaceous, several important differences exist between typical coral-algal-hydrozoan reefs and rudist formations. Rudist formations are typically of low relief and form more or less tabular bodies. Bound, wave-resistant fabrics were uncommon, and elevator morphotypes were supported by sediment which accumulated during their vertical shell growth. Consequently, growth fabrics of rudist associations were constratal, in contrast to superstratal fabrics of modern coral reefs (Steuber and Loser,2000).

Alsharan et al. (2000) described these beds as representing a transgressive phase during the deposition of the formation. They attributed their deposition to an open shallow shelf environment, below wave base without or with very rare terrigenus influx. Their interpretation is based on the gradual upward decrease of algae and the gradual upward increase of plank tonic forams. The *hippuritid* thickets, at the top together with the shallow water echinoid *Codiopsis*, indicate near shore conditions. Shallow water carbonate shoals form the remainder of the succession (Smith et al., 1995).

Orbitoides usually occurs together with specimens of the genera *Omphalocyclus, Siderolites, Lepiorbitoides and Sulcoperculina.* Late Cretaceous *Orbitoides* is interpreted to be lived in deeper environments and in the Upper photic zone at the depths of about 40-80m. (Hottinger,1997). The environment is mostly interpreted as being open marine with some terrigenus input. The morphology (thick lenticular test, presence of lateral chambers) indicates a habitat in high energetic environments, which is supported by the presence of siderolites. The model of Al-Ameri and Lawa, (1986) in the type locality shows the Aqra Formation as isolated platform in the deep basin. This is appearing from their model (fig.1-13) and Aqra Formation is surrounded from all sides by deep basin as indicated by deposition of marl.

The above ideas are very important for new environmental and paleogeographic reconstruction of the Aqra Formation in the studied area. This is because these ideas give us pre- Aqra environment and the base (substrate) on which the Aqra reef or biogenic carbonates are began to grow.

According to Facies analysis and above ideas, the pre- Aqra environment was coastal area which was covered by gravels and boulders (Conglomerate lithofacies).

The pre-Aqra topography that is formed by these sediments was hilly-like coastal area that was shaped by fan delta (alluvial fan discharged into the sea) (Fig.4.2).

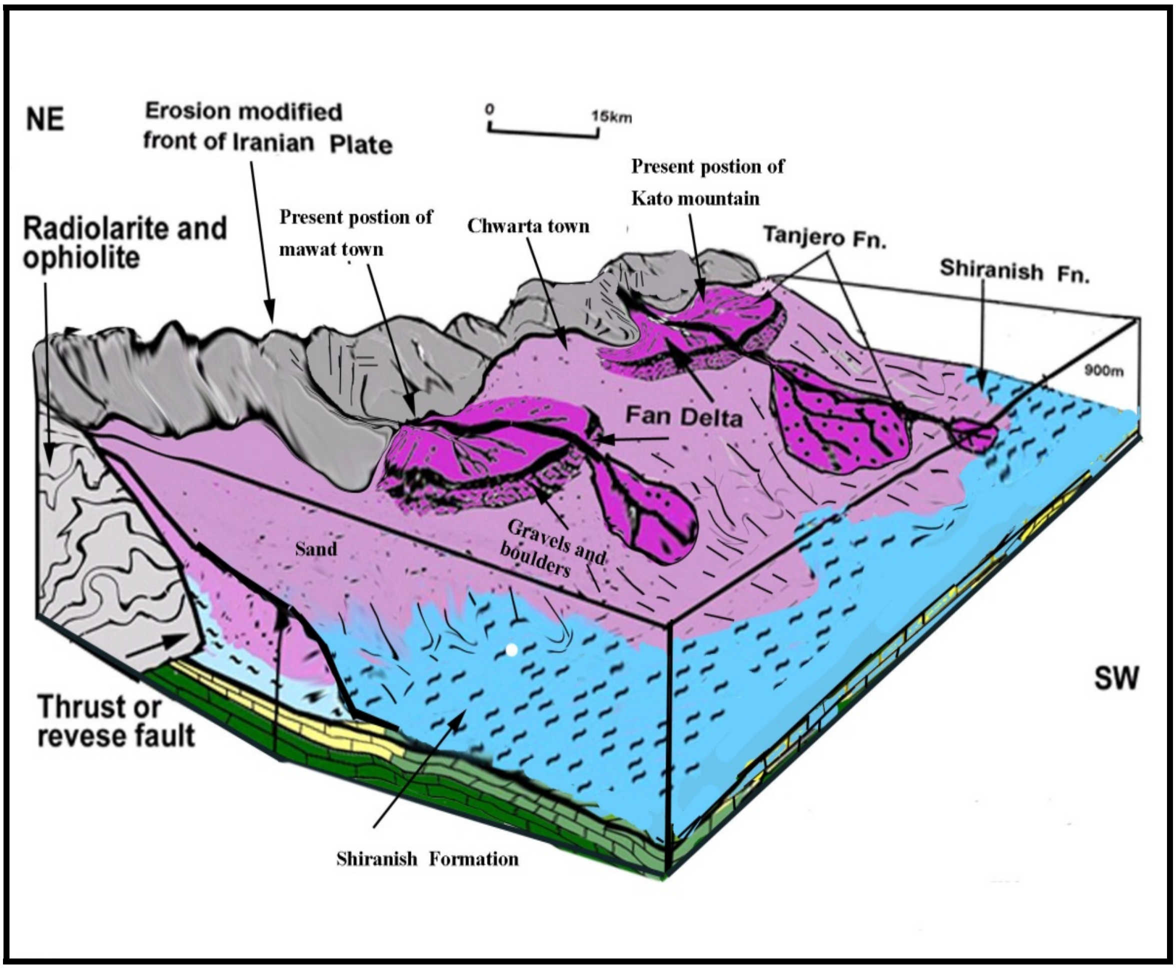

Fig.(4.2) A model for the basin of the Tanjero Formation (slightly before deposition Aqra Formation) shows the conglomerate is acted as substrate for deposition of carbonate of the formation (Modified from Karim, 2004).

The coastal area of the Lower Maastrichtian was subsided and more or less deepened (depend on the nearness to the coast). After this deepening, the deposition of the transgression system tract began and then followed by high stand system tracts (Karim and Surdashy, 2005c).

The sediments of the transgression system tract were marl (marl Lithofacies at the base of Suraqalat section) in the distal area and red claystone at the proximal area.
These sediments are not deposited or eroded during progradation of sea and the conglomerate remained clean for growth of biogenetic limestone.

Another effect of the Deepening (TST and HST) was ceases or decreased of the influx of the turbidity due to retreat of the coastal area toward source area (toward NE). This is forced the existed streams to lose their gradient and their power to transport the sediments.

When the alluvial fan is shaped due to very large flood, it deposits coarsest and most resistive sediments. This nature of sediments is other factor that stopped the turbidity from the source area due to resistance of the sediments of the alluvial fan (gravel and boulder). These coarse sediments has positive role in the diverting of the streams and putting turbidity away from previous routes. Therefore the next smaller flood takes other routes away from the previous place.

Therefore, the growth of the reefal and biogenic limestones was depended on the low stand fan sediments (accumulation of gravels and boulders) for substrate and for decreasing turbidly. This doesn’t means that there was no stream in the area of Chwarta-Mawat area. In the area many small and low energy streams were reaching the foreland basin and supplying the nutrients to the basin as evident from prolific growth of organisms and from sporadic quartz, igneous and chert grains that can be seen in several beds (in the mudstone facies). Near Zarda Bee village terrigenus sandstone beds and lenses are alternating with biogenic or reworked limestone ones.

The high rate of the sedimentation is clear from the morphology of the rudest (shape of the body on the substrate). Most of the rudist have the elevator shape which stands vertical to the substrate and the growth is normal to the bedding plains (Fig. 4.3 and 4.4). According to Steuber and Loser (2000) elevator rudist requires a certain amount of background sedimentation to stabilize vertical growth shell. They added that all *hippuritids* and most *radiolitids* rudist lived as elevator while clinger cannot survive in high sedimentation rate.

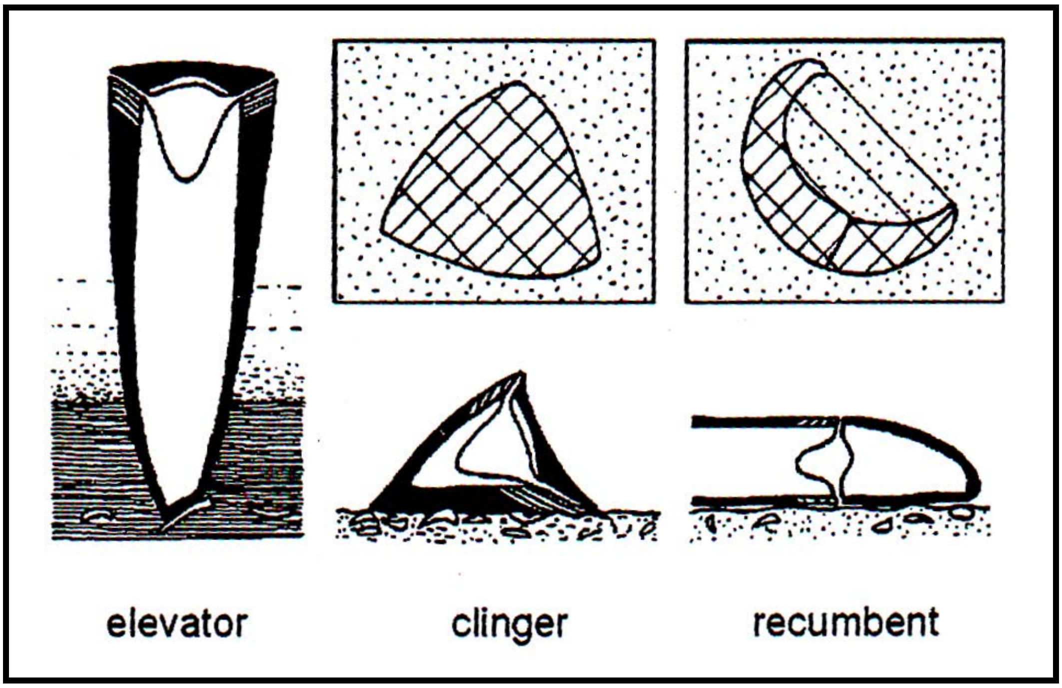

Fig.(4.3) type of *rudists* shape on the substrate (Steuber and Loser,2000).

Fig.(4.4) Elevator *rudists* in the lower part of Kele section (s.n.9)

The growth of the biogenetic limestone on hard substrate like conglomerate (Fig.4.1) is similar to the lower sequence of the Qahlah Formation at Jabal Huwayyah, Unite Arab Emerate as appear from the below paragraph by Cameil (2005).

According to Flugel (2004, p.530) the *Actaeonellid* gastropod are common in brackish-influenced Cretaceous sediments. Therefore, it is possible that the basin was influenced by fresh water influx. In the studied area several bed at the lower and upper part of the section contain terrigenus clastic sediment that are supplied to the basin by fresh water influx.

The roles of the coarse sediments are very clear from two field observations. The first is that where the thickness of the conglomerate is high the thickness of the Aqra Formation is high too as can be seen in the Kato and Kele sections with 100 and 80metter thickness. The second is that at the base of the both sections the conglomerate alternate with biogenic limestone as discussed in the conglomerate Lithofacies (see chapter two).

From discussion of all facies, it appears that the energy was high during the deposition and during whole span of the deposition of the formation, during upper Maastrichtian as evidence from mix stone. But it was higher in the lower part than upper part, which is clear from reworked *loftusia* and broken skeleton debris that can be seen in the lower part. Because of this, even the float stone of rudist and large pelecypod contain bioclasts and lithoclasts. The low occurrence of the grainstone is attributed to high rate of deposition.

The temperature can be known crudely from the grain association which is defined by Flugel (2004), as assemblage of dominating skeletal and non-skeletal grains that are coexist in certain basin or formation. When the classification of Ensiele (2000) about grain association and their environments are applied for the formation, in the studied area, the foramol is only association that fit the formation (Fig.4.5).

According to Flugel (2004) the framol (fra: Foraminifera and mol: mollusk) association is introduced for non-tropical carbonates that are consisting predominating of foraminifera and mollusks. This association is applicable because contain only foraminifera (*loftusia, omphalocyclus and orbitoids*) and mollusks (*pelecypod* including *rudists and gastropods*). In the formation, no coral (except very rare solitary *corals*), algae and *bryozoans* are found. Therefore, the environment is deposited in temperate of mid-latitude (30-34degres of latitude) (fig. 4.5).

According to Al-Ameri and Lawa (1986), the depositional location (paleogeographic location) of the Aqra Formation, at type locality, is situated at 0-10 degrees of latitude. This means that the formation was deposited in the equatorial environment and transported tectonically for about 3600km to the present position from Maastrichtian to present. But in present study Aqra Formation is deposited in 30-34degres of north latitude and not transported more than 1400km from Maastrichtian to present. This is because, today the Arabian Plate is moving north-east at rates now estimated from GPS measurements to be 25 mm/year for Oman or 15.7 mm/year for the southern Red Sea.

.

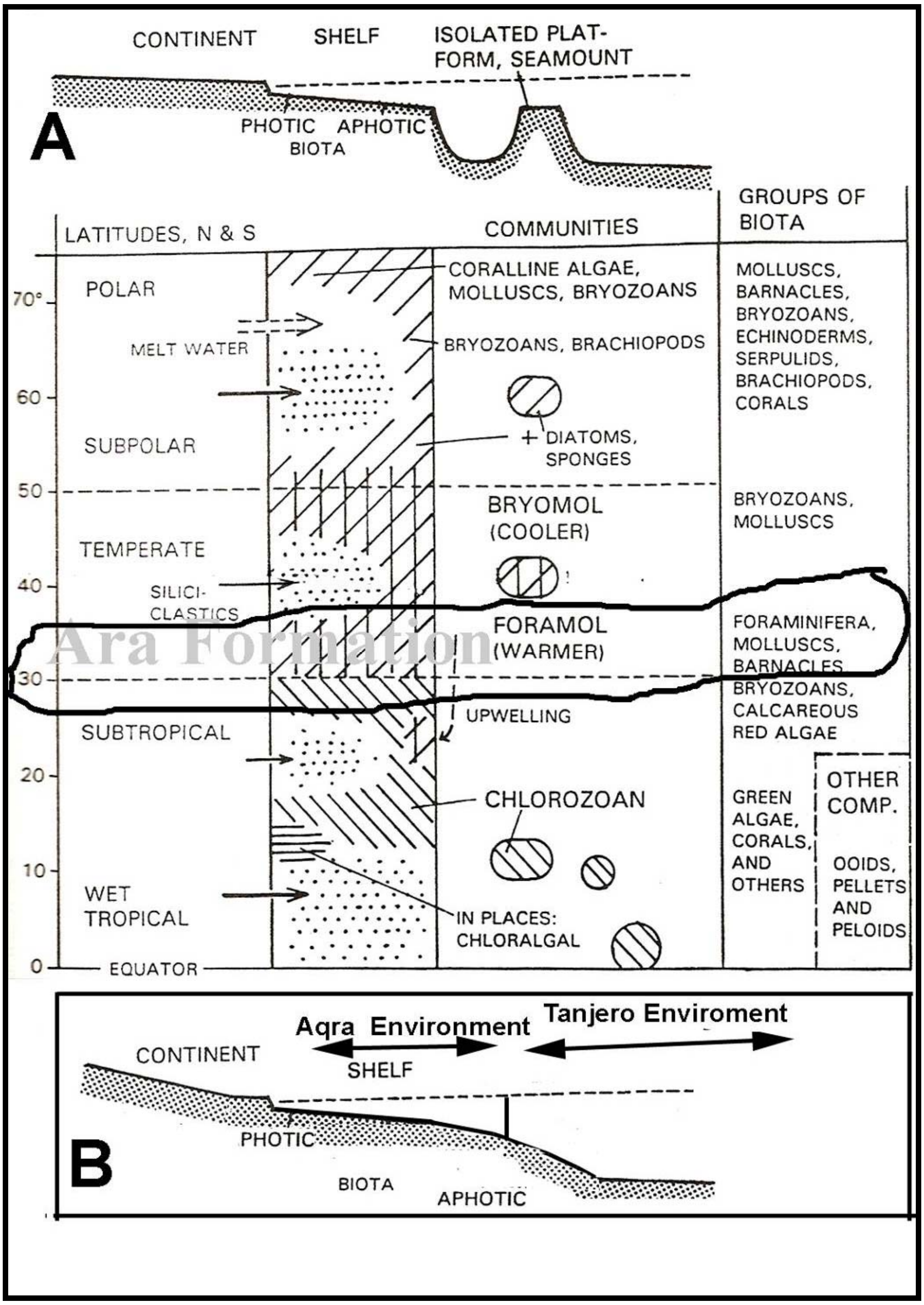

Fig.(4.5) **A)** Grain associations and their latitude in addition to temperature (Ensiele, 2000) on which the latitude of the Aqra Formation is indicated by solid black line.

B) Paleogeographic section showing environment of Aqra and Tanjero Formations in the studied area

4.3- Termination of the environment:

In the literature, the termination of the reefal limestone (or carbonate factory) on the platform is attributed to the drowning of carbonate which according to Schlager (1991), Kendall and Schlager (1981), the drowning may be resulted from decrease of nutrient supply and oxygenation and from increase of Salinity, predation and siliciclastic input.

According to (Tucker, 1991), drowned platforms are ones which is relatively rapid sea-level rise, so that deeper water facies are deposited over shallow water facies and many pelagic limestones were deposited in these situation. The platform drowning can be controlled by many factors, including rapid eustatic sea-level raise, crustal subsidence, ecological stress, water temperature, upwelling of cold deep water and the rate of sediment production and removal.

According to Catunenue (2006), the drowning represents the final stage in the evolution of a carbonate platform, prior to the return to a clastic dominated environment. Once the platform is drowned below the photic limit, filling of the available accommodation during subsequent high stand normal regression may only be achieved by means of siliciclastic progradation.

Most of the above ideas are not applicable for Aqra Formation in the studied area as the termination does not relate to drowning. But the citations of Mutt et al., (2005) and Catunenue (2006), about ecologic stress and siliciclastic progradation, are valid. This is because, field study of the contact with Red Bed Series shows gradational boundary which shows shallowing not deepening as required for drowning.

Due to tectonic uplift of the area, the siliciclastic progradation is increased and the carbonate deposits are ceased due to ecologic stress by influx of turbidity as red claystone and sandstone (red clastic Lithofacies) in addition to conglomerate. These clastics as Red Bed Series are studied by Al-Barzinjy (2005) who showed that conformably overly Tanjero Formation (including Aqra Lens).The turbidity decreased the oxygen and light penetration which prevent algae and bacterial growth that are necessary of rudist and foraminifera.

The problem of covering and termination of the Aqra Formation at the stuied area by Kolosh Formation is solved by the study of the Al-Barzinjy (2005) who concluded that Lower part (unit one and two) of Red Bed Series is equivalent to Kolosh Formation. Therefore, it is possible that in the type section, the basin is deepened and the processes of drowning are happened due to local subsidence below the photic limit.

Other possibility is that mentioned by Bellen et al. (1959) that Aqra Limestone Formation, in the type section, has an unconformable upper surface with Kolosh and Khurmala formations. In this case and for unconformable contact, Walther Law (cited in Blatt et al (1980) cannot be used and the environmental relation cannot be established.

The problem that arises against this tectonic discussion is the fact that in Chwarta-Mawat area, the basin of the Aqra Formation is uplifted while in the type section the formation is subsided or drowned. To minimize the effect of this problem, the author clarifies in the following two points.

The first is that according to Karim and Surdashy (2005a) the depositional axis(e.g.: proximal area), during Late Cretaceous, was deviated (diverted) more toward north as compared to trend of present anticlines. The diversion of depositional axis is clear along their elongation from Arabian Gulf to Turkish border. This axis is indicated by the above authors by connecting same lithology and thickness in certain time.

The depositional axis, was depended on the tectonic front (or deformational front) of Iranian Plate along its advance toward southwest during Late Cretaceous (Karim and Surdashy, 2005b, Ameen, 2008). Therefore, the type section was consisted of distal area and had the tectonic position of Sulaimani area where Kolosh Formation deposited due to subsidence.

The second is that Chwarta-Mawat area was consisted (during late Maastrichtian) of part of source area (or coastal area) therefore, the source area was uplifted while the basin was subsided. This type of relation between source area and the depositional basin is shown by Catunenue (2006) in the diagram which shows that the uplift (red or grey arrow) in the coastal area is associated with subsidence in the basin (black arrow), (Fig. 4.7)

4.4-Carbonate profile (or carbonate marine topography):

According to Read (1985) marine carbonate can deposit on several profiles such as ramps and rimmed shelves. The ramp can be homoclinal and distally steepened. In literature, Jassim and Goff (2006) and Bellen et al (1958), mentioned that the Aqra-Bekhme Formation has ramp profile or deposited on ramp topography. They added that this ramp contained reefal, fore reef and shoal limestones in type section.

A type of topography or profile that Aqra Formation had during deposition in the studied area is not exactly known and difficult. This is because, the outcrop is limited and only elongated along the depositional strike along the belt no more than 10km wide. Another factor of difficulty is that previously, this issue is not treated.

Karim (2004) studded the underlying Tanjero Formation and mentioned that it has shelf topography rather than ramp. He depended on the existence of the thick low stand wedge of sandstone (about 400m thick) at the area of Chaqchaq and Shadalla valley in addition to northern boundary of Piramagroon -Sharazoor plains. He supposed (and as cited in other literates) that this wedge is deposited on the slope. He further added that the shelf break is located to the northeast of this wedge at the present position Goizha, Azmir, Daban and Qarasard Mountain (or anticlines)

Another evidence is that he depended on the existence of incised valleys fill (Kato conglomerate) at the Mawat and Chuarta area, prove that this area northeast to these towns were forming the shelf during lower (former) HST and coastal area during upper (next) HST.

Another evidence for shelf-slope profile (as cited by above author) is the high thickness of the LST, which is in some place more than 500m. For this, Haq, (1991) and Emery and Myers (1996) mentioned that low stand wedge in ramp setting is relatively thin. He added that the shelf of the lower sequence is developed by high sedimentation (such as deposition of 500m conglomerate) on the front advancing of Iranian plate and coalesces of several coarse sediment low stand alluvial fans. The rapid deposit and burial of coarse sediment prevented part of them from reworking into deeper water, thus a clastic dominated platform (or fan delta front) is developed which was modified (flattened) by wave as shelf (Fig.4.6).

The result of the present study of the facies analysis showed that the profile is more or less changed to distally steepened ramp as compared to that of Tanjero Formation which was shelf as cited by Karim, (2004).

Before assignment of the profile, it is better to clarify the following facts:

1-No signs of lagoon are found such as pelletal limestone, mudstone, dolomite, stromatolite and miliolids.

2-The buildup facies such as algal frame stone is not fond and baffle stone constitute only less than 10 percent of the total thickness of the sections.

3-the presence of lenses or beds of terrigenus clastic sediments is the indicative of attached platform model (Fig.4.6) (depositional and paleogeographic model).

4-the deposition of about more than 400m of sandstone and conglomerate of Tanjero Formation in the basin may decreased sudden brake in paleo-slope and changed the shelf-slope profile to ramp.

5- The high tectonic during Tanjero Formation (as evidence from deposition of 500m of conglomerate or conglomerate Lithofacies) is more suitable for shelf-slope profile than ramp. This is because the huge thickness of sandstone and conglomerate is evidence of high gradient for shelf-slope profile not low gradient as required for ramp (according to Ahr, 1973, slope less than 1 degree).

6- The best case that can be compatible with Tanjero Formation and Aqra Formation is distally steeped ramps develop where earlier rimmed shelves undergo widespread drowning (transgressive and high stand system tract of Karim and Surdashy, 2005c, prior to deposition of Aqra Formation).He added that ramp also develop on rimmed shelves that are protruded by clastics (Tanjero Formation) prior to renewed carbonate deposition.

7-Abdelghany (2003) found *Loftusia morgani* near the base of the Simsima Formation in shallow-water facies. From this specimen, ophiolite particles have recovered within its agglutinated test. He mentioned that these particles were probably derived from the underlying ophiolite that supplied shallow-water clastics of the Qahlah Formation with grains. A similar conclusion was reached by Meric¸ et al. (2001), who found Middle–Upper Maastrichtian *Loftusia* species in Turkey with tiny ophiolitic rock particles adhering to their tests. They concluded that the shallow-water ophiolite platforms formed during Late Maastrichtian movements, which culminated in the closure of the Tethyan Ocean.

In the studied area and in all thin sections no ophiolite particles were observed in the shells of the Loftusia, but the tectonic setting of the studied area is slightly similar to that of Qahlah Formation (Oman). Carbonate ramps dominate much of today's modern carbonate shelves and were equally widespread in ancient systems. Models for carbonate ramp shelves have come from tropical settings in the Yucatan, Persian Gulf, west Florida Shelf, and subtropical to cool-water shelves surrounding the south and northwestern margins of Australia (Read, 1985).

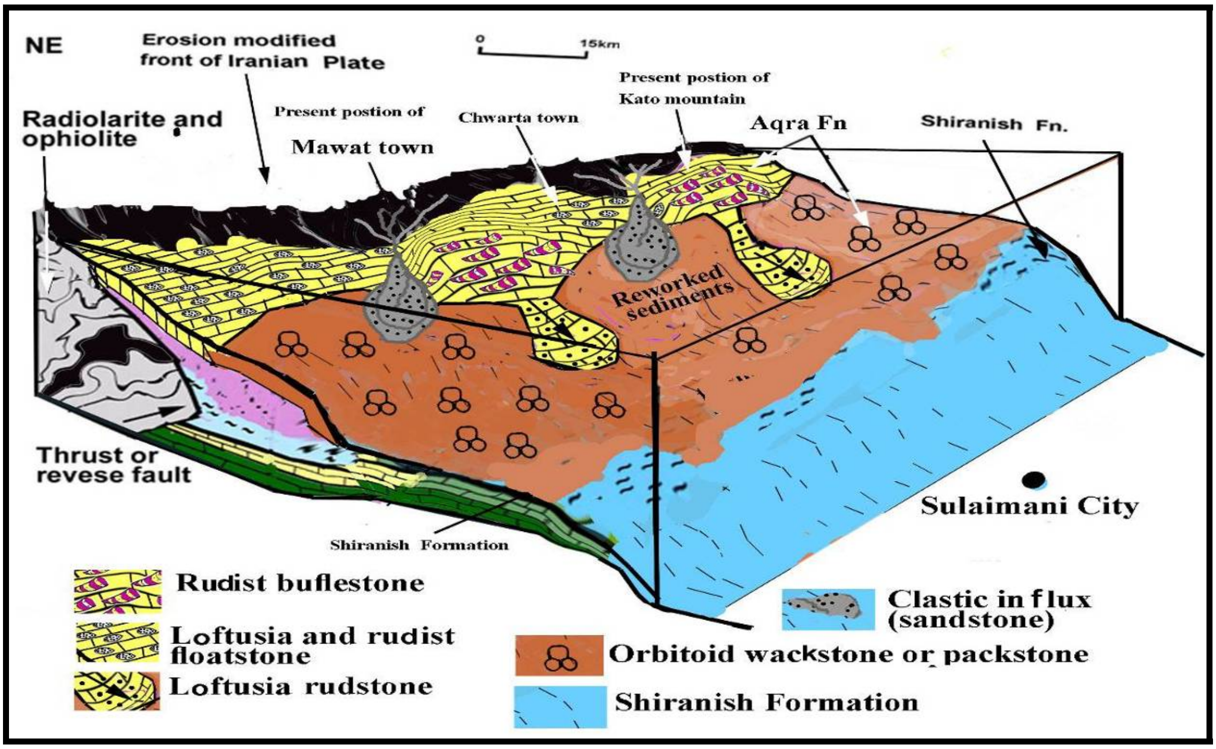

Fig. (4.6) A depositional and paleogeographic model (distally steepened ramp) for the basin of the Aqra Formation which shows that the maximum thickness of the Aqra Formation was deposited on the conglomerate of the Tanjero Formation (see fig. 4-2).

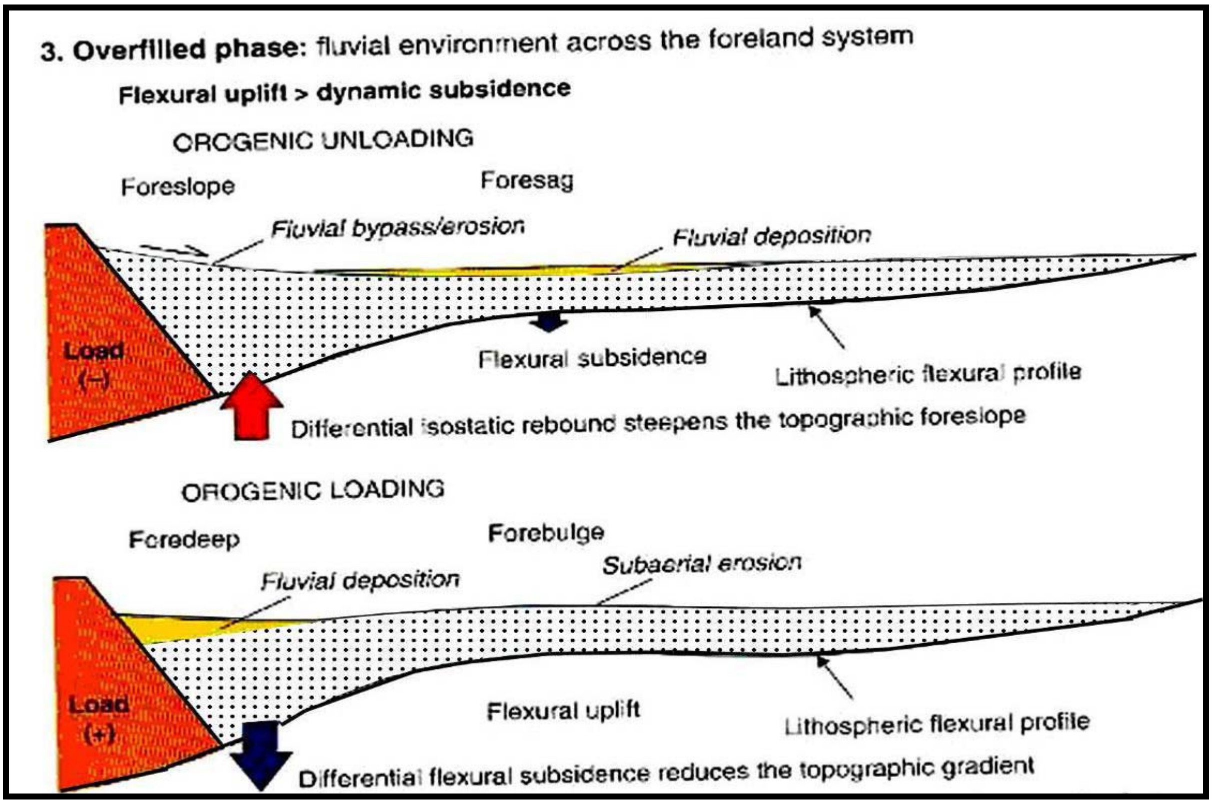

Fig.(4.7) Tectonic relation between source area and the depositional basin (Catunenue, 2006)

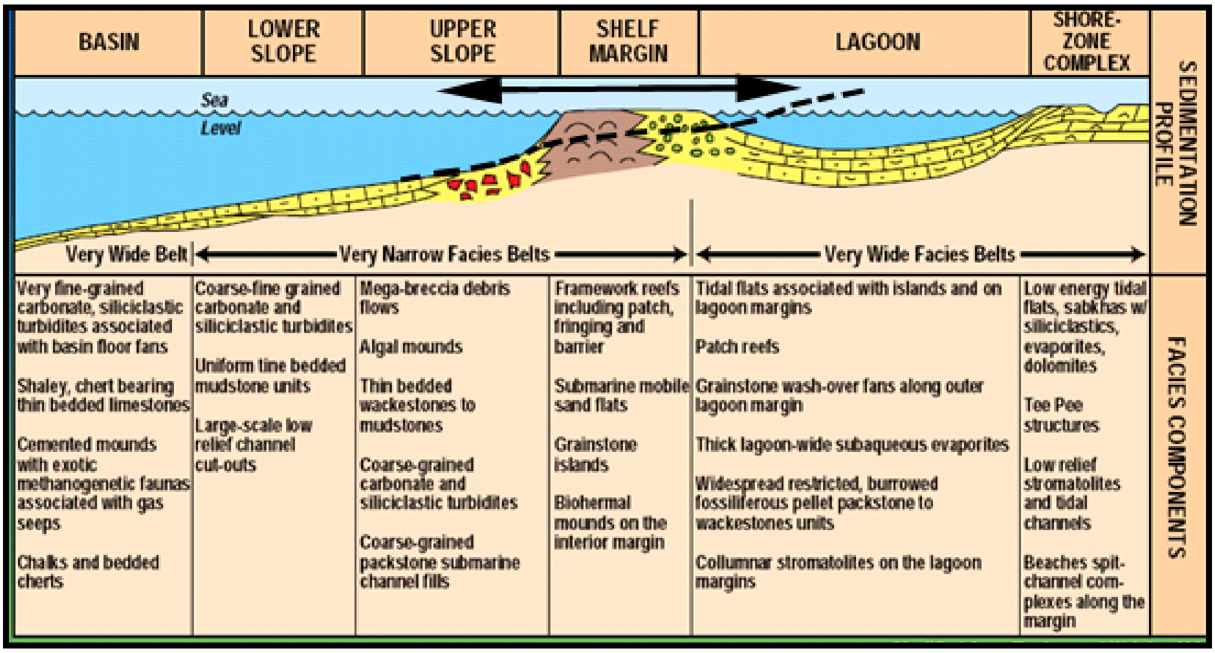

Fig (4.8) rimmed shelf topography and environment (After Tucker and Wright 1990) on which the environments of the Aqra Formation are indicated by the arrow. The dotted line is represent the paleogeographic cross section of the Aqra Formation in the studied area.

4.5-TECTONIC OF THE BASIN:

According to many authors and on a global scale, Maastrichtian was a period of widespread marine regression (Buday, 1980, Fischer & Germann, 1987; Haq et al., 1988, Jassim and Goff, 2006). The upward deepening transgression in the Oman Mountains is unusual and it seems that this transgression resulted from local subsidence at a rate exceeding the supply of sediments (Alsharhan and Nasir, 1996).

According to Karim and Ameen, (2008) after the deposition of Kometan Formation, the two continental parts of the Iranian and Arabian Plates were collided. Slightly before collision, the trench was filled with scraped off sediments (*radiolarites*) and ophiolites. These materials are uplifted and thrown onto the subsided continental part of the Arabian Plate.

The uplifted and over–thrown materials have formed positive land in the suture zone of the two plates. According to Karim (2004), Karim and Surdashy (2005b and 2006), due to this colliding, the studied area was transformed from passive margin to active Early Zagros Foreland Basin. According to these authors, Shiranish, Tanjero, Aqra, and Kolosh Formations are deposited in this foreland basin. They added that the collision changed the accretionary prism to source areas (organic belt) for Late Cretaceous sediments such as Shiranish and Tanjero Formations.

This collision is manifested by about 500m of gravel and boulder conglomerate (conglomerate Lithofacies) that can be seen at Chwarta, Mawat and Qandil areas. Field relations and vertical facies changes show that Aqra Formation is deposited on this conglomerate as reefal facies in the inner, mid and outer shelf as foramol association.

When the uplifts and relaxation phases of Ameen (2009) is considered that deposition of the Aqra Formation (in the studied area) occurred in the end of the relaxation phase of the Middle-Late Maastrichtian. According to this author, the uplift signal consists of very thick successions of the sandstone-shale's (flush facies) and conglomerates-red claystone (molasses facies) at basin plain and marginal areas (proximal area) of the foreland basin respectively. The representing Lithology of the relaxation phases consist of thick succession of marl (hemipelagite) and shale at the proximal area and distal part of the basin respectively (Fig.4.9).

The thickness of some of these above successions is more than four hundred meters thick. During Maastrichtian and Paleocene, the contrasts of the tectonic signals (sediments) are obvious and high but those of the post Paleocene are weak and not clear. He added that this attributed to concentration and release of stress along narrow strip near the Iraq-Iran Border while during post Paleocene time, the stress distributed and releases through wide and extended from Sanandij Serjan to the south of Sulaimani City. This is attributed to migration of the stress along low depth decollement thrusts toward southwest.

Karim and Surdashy (2005) concluded that Aqra Formation (or Aqra lens) is deposited during deepening (transgression and high stand system tracts). While conglomeratic Lithofacies is deposited during shallowing (low stand system tracts).These system tracts are equivalent to the relaxation and uplift of Ameen (2009). Numan (1997) in his study for the tectonic and paleogeographic position of Aqra Formation and Tanjero Formation assumed that Tanjero Formation (including Aqra Formation) is deposited in a trench before closure of the Neo-Tethys on the northeast sloping Continental Arabian margin (Fig. 4.10). Alavi (2004) discussed the ophiolite abduction (colliding of ophiolite with continental part of the Arabian Plate) but the stratigraphic position of Aqra Formation cannot be indicated on the models.

In the present study, the tectonic model is totally changed depending on the facies analysis and study of Karim, (2004) and Ameen (2008) and Taha, (2009) Fig. (4.11B). They assumed that it deposited on the southwestern sloping foreland basin .This foreland basin is bordered from northeast by source area which was supplying the basin with terrigenus sediment.

This influx was rapid and high during deposition of Tanjero Formation and was continuous during deposition of Aqra Formation. The effect of this influx was obvious in the distal area for the basin of Aqra Formation especially near Zarda Bee and Homaragh villages. Because of this clastic sediments, Karim (2004) named Aqra Formation, at distal area, as carbonate-siliciclastic succession. According to latter author, the constituents of this succession are alternation of biogenic limestone and calcareous shale with minor amount of sandstone and conglomerate. This influx is associated with nutrient influx too for organism growth.

The present model (Fig.4-6) is made use of the models of Bosence (2005) about genetic classification of carbonate platforms based on their basinal and tectonic settings in the Cenozoic. In these models (eight models), three of them is used for construction of the present model. The three models are more or less related to the tectonic and paleogeographic models of the studied area. The three models are:

1-Thrust-top platform (Fig. 4.12 A).

2- Delta-top platform (Fig. 4.12 B).

3-Forland margin platform (Fig. 4.12 C).

The first one (model A), is related to the studied area as this area is assigned zone of ophiolite abduction since the Late Cretaceous by Alavi (2004), Jassim and Goff (2006). The same abduction is suggested by Ibrahim (2009) (Fig.13).While according to Karim (2004) this area was zone of continental colliding of Iranian and Arabian plate which was occurred during Maastrichtian. So the studied area was affected by local tectonic front or thrust.

The second model (B), is one which has the closest relation to the studied area because Karim and Surdashy (2005c and 2005a) found several Low stand fans that are discharged into (or connected with) the basin of Tanjero Formation in the studied area. As discussed in the section of environment, at least part of the Aqra Formation is deposited on these fans which consisted of boulder and gravels.

The third (model C), is related to the studied area as this area is assigned as northeastern margin of Arabian platform (Buday,1980). Therefore, the present model (Fig.4.6) contains more or less some idea of the above models but the main dependent facts are obtained from facies analysis and field work. Arabian platform is ended during lower Maastrichtian and after generation of foreland basin,but local platform is developed in the studied area.In some places the arabian platform is not terminated but retreated south-west ward infront advancing clastic progradation of Tanjero Formation.

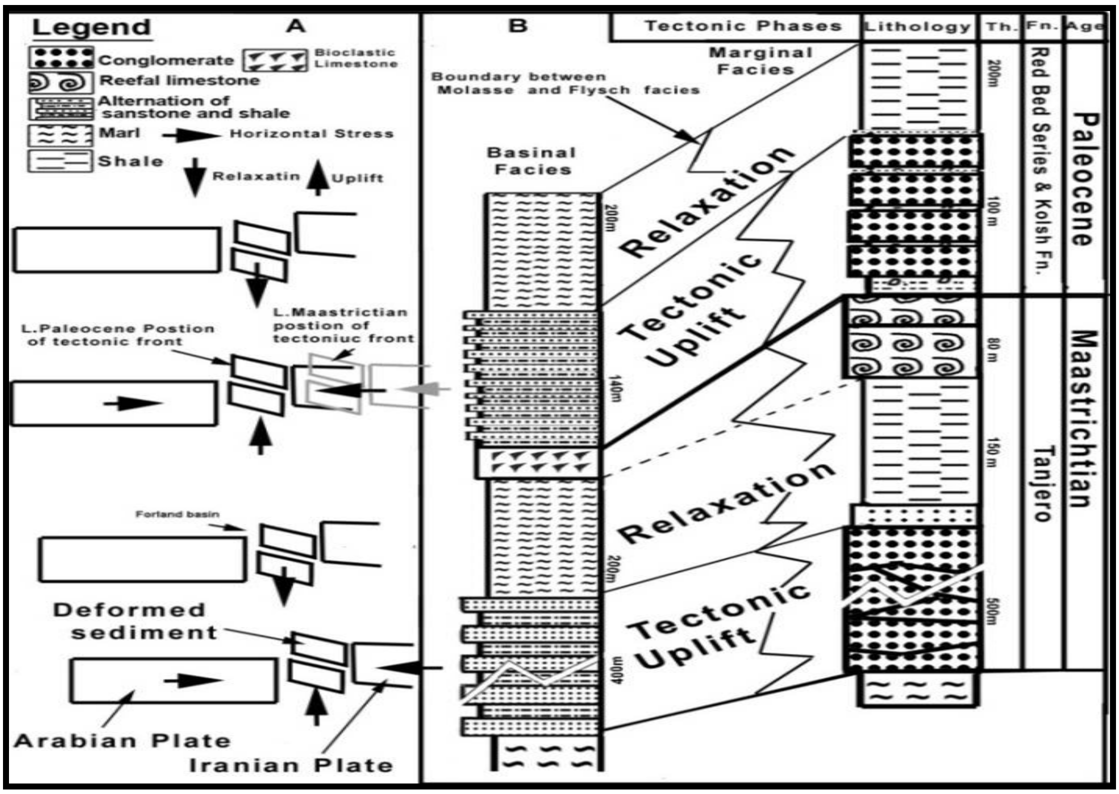

Fig.(4.9) The four tectonic phases of uplift and relaxation of Zagros Fold–Thrust belt during Maastrichtian and Paleocene with litho logical representation as shown by stratigraphic column the two ages of each phase (Ameen, 2009).

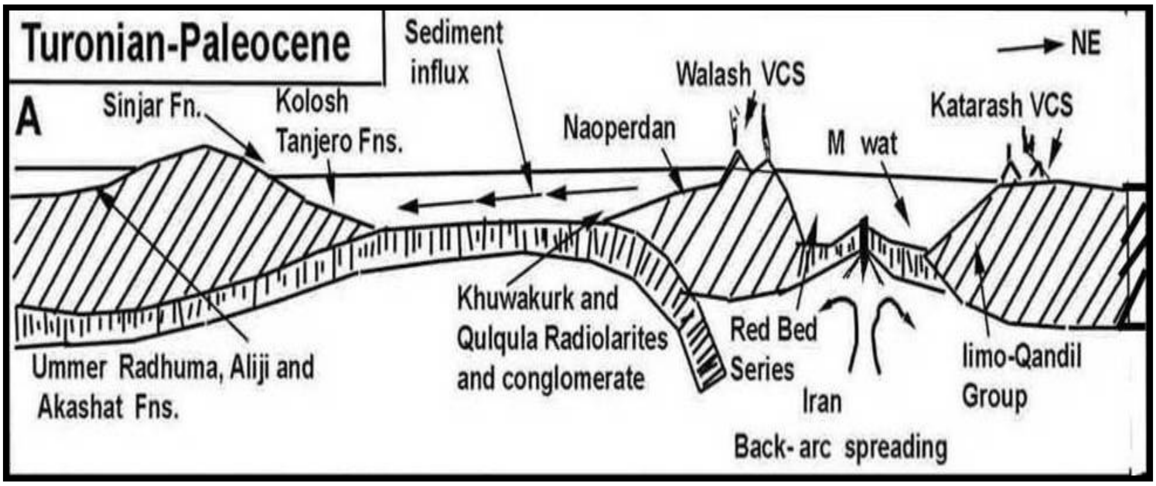

Fig. (4.10) The tectonic model of Numan (1997) in which the position of Tanjero Formation is indicated in a trench sloping toward northwest

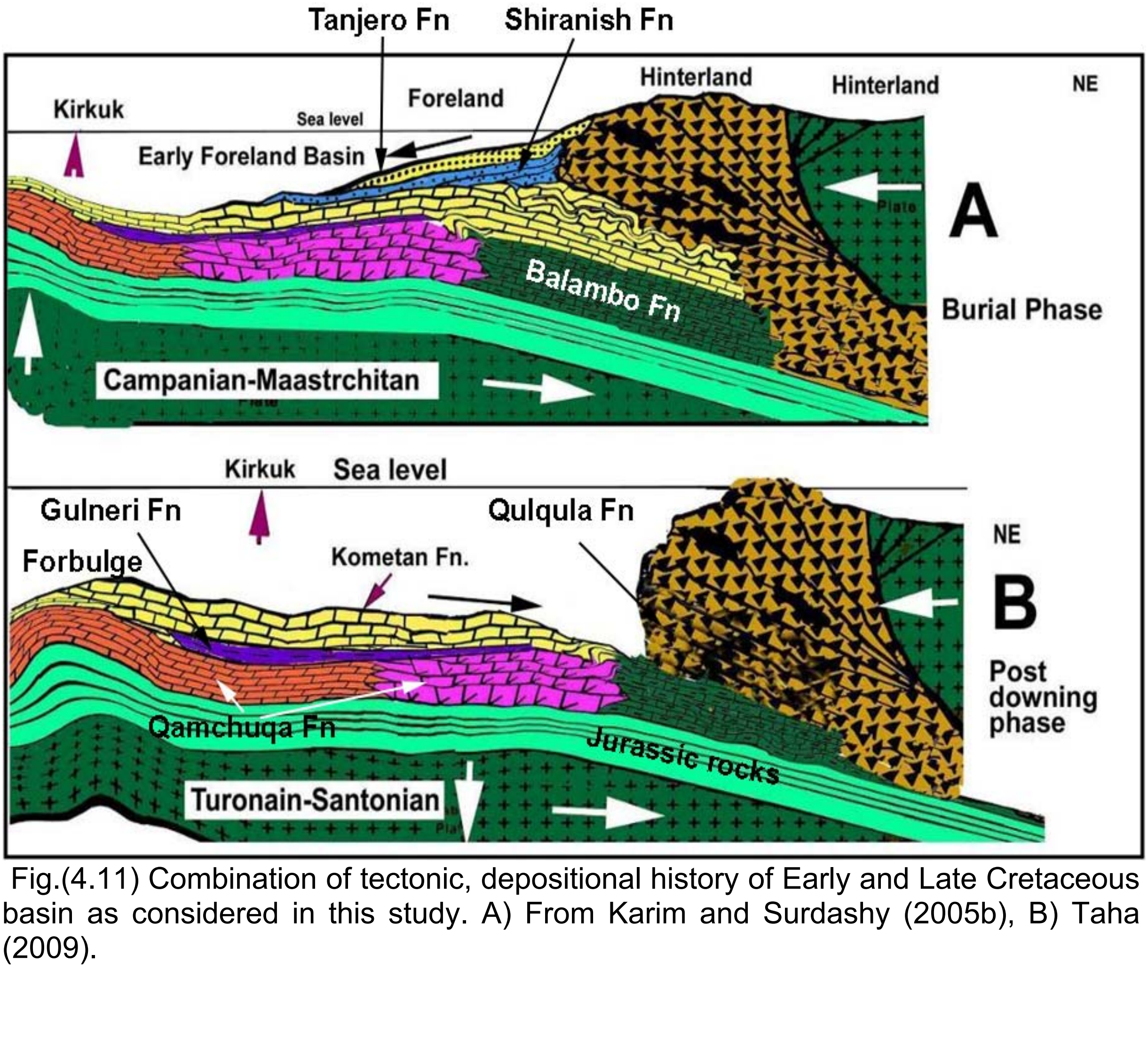

Fig.(4.11) Combination of tectonic, depositional history of Early and Late Cretaceous basin as considered in this study. A) From Karim and Surdashy (2005b), B) Taha (2009).

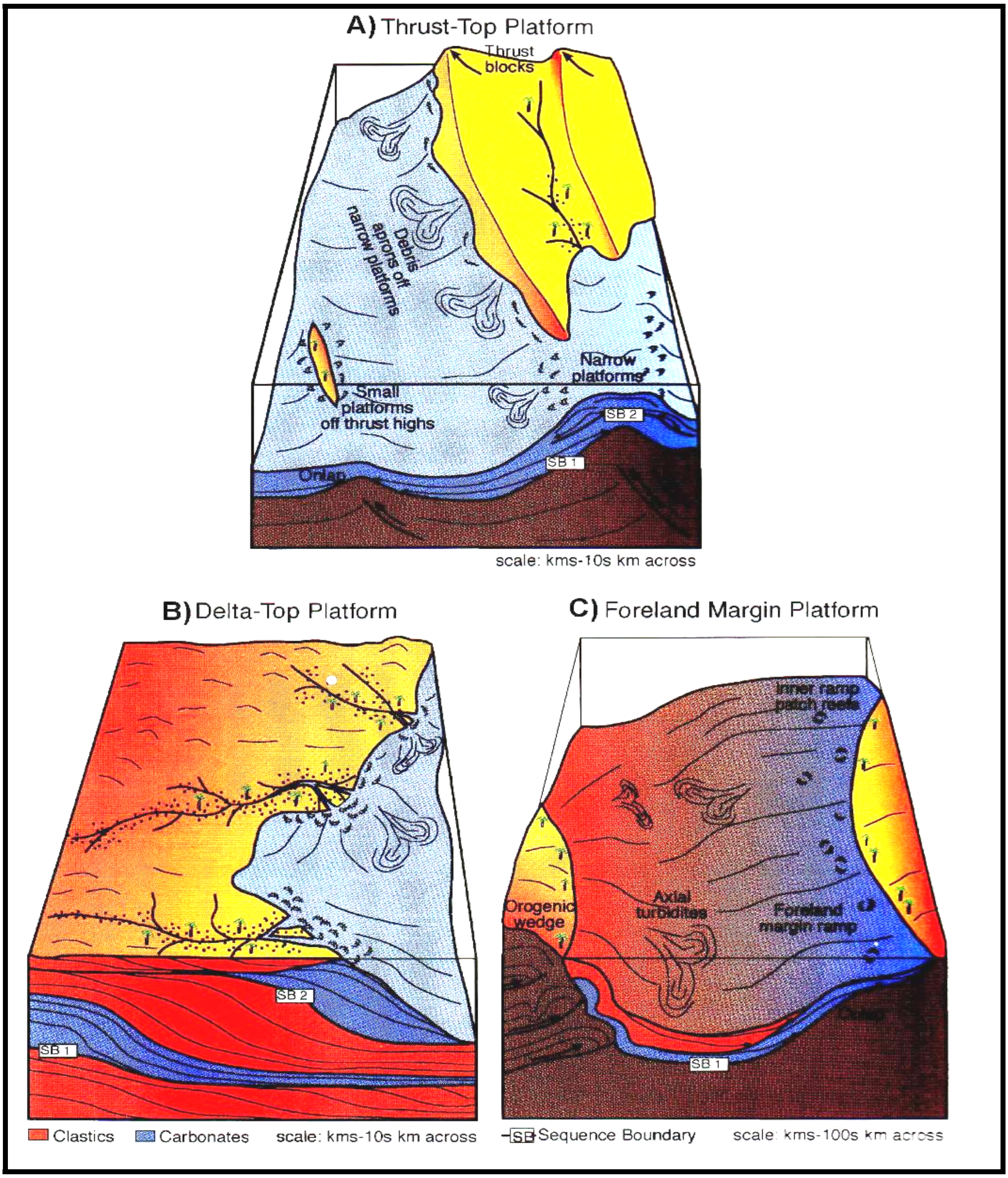

Fig.(4.12) Three models of Bosence (2005) about genetic classification of carbonate platforms based on their basinal and tectonic settings in the Cenozoic. From these models, a tectonical and depositional model of Aqra formation (in the studied areas) can be constructed.

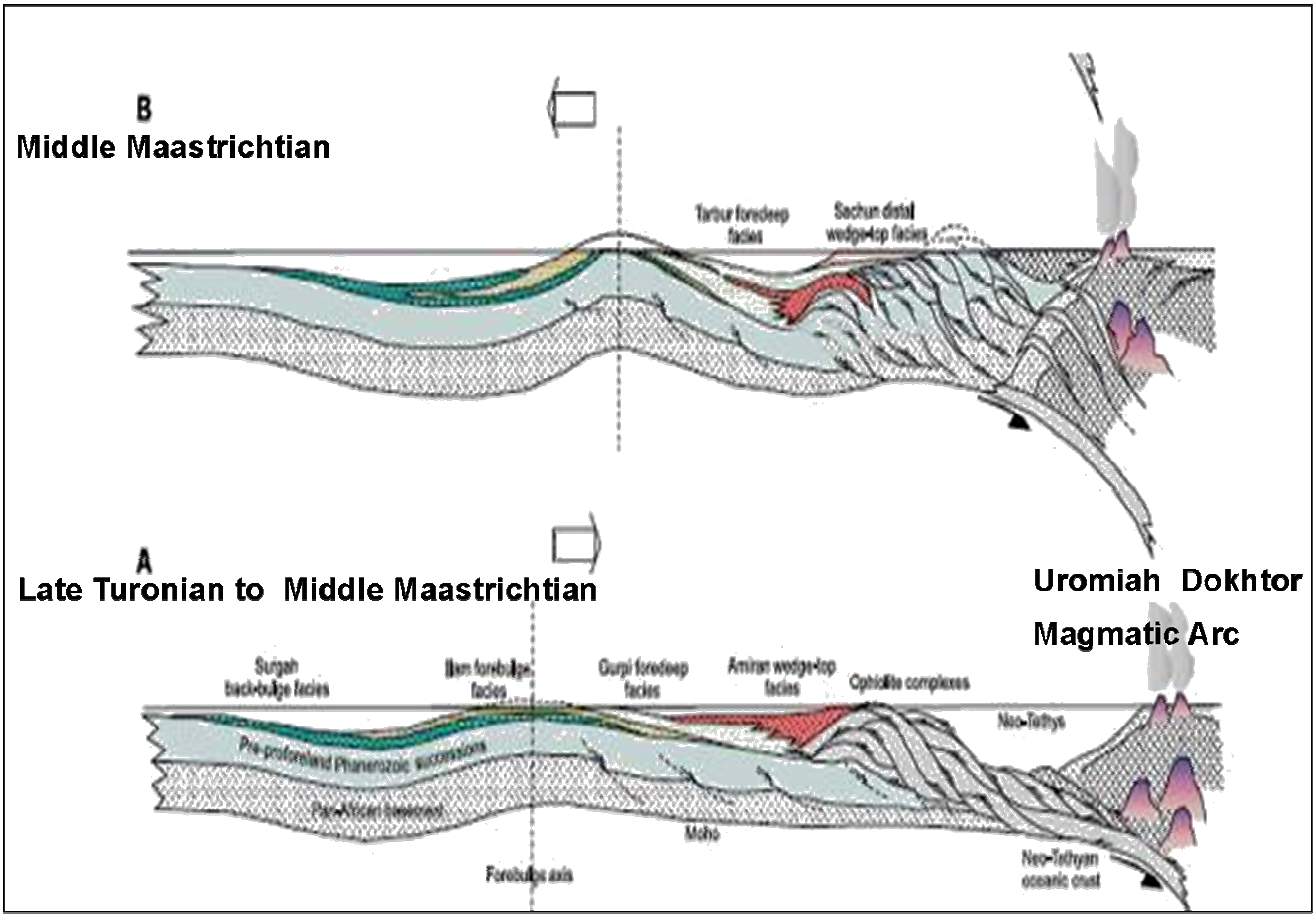

Fig. (4.13) ophiolite obduction on Arabian platform (colliding of Oceanic floor of Iranian plate with continental part of Arabian plate (Alavi, 2004).

4.6-Conclusions:

This study concluded the following:

1- Aqra Formation (Late Maastrichtian) in Chwarta-Mawat area mainly consists of Biogenic and detrital limestones which appear as thick well bedded or massive succession along both sides of the existed streams and gorges. The boundary with both underlying Tanjero Formation and overlying Red Bed Series are gradational and the contact is conformable.

2- The field study showed that the formation, in the studied area, is not connected with the Aqra Formation at type section and surrounded by Tanjero Formation from all sides.

3- The fossil content is rich, but with low diversity and belongs mainly to Foramol association which includes large forams (Loftusia, Omphalocyclus and Orbitoids) with mollusks (Gastropod and Pelecypods (including rudist) in addition to echinoderm and rare ammonites.

4-The lithology is mainly consisting of biogeneic and detrital limetones.

5- The main facies are floatstone, mixstone, Rudstone, grainstone, and bafflestone of the skeleton of one or more than one of the above fossils or their bioclasts.

6-The lithofacies such as terrigeneous conglomerate, marlstone and red clastic of Tanjero Formation and Red Bed Series are appeared very important for tectonic and environment reconstruction of the formation.

7-It is inferred that the highest thickness exists where the substrate is consisted of the thick conglomerate of the Tanjero Formation.

8-Most of these facies can be identified by eyes or hand lens due to large size of the fossils the matrix is consist mainly of sand or silt sized bioclasts with more or less micrite.

9- These facies are deposited in shallow and high energy platform (basin) of mid-latitude temperate climate with high rate of sedimentation. The basin was supplied intermittently by terrigenus clastics from source area which appear in some place as bed or lens of sandstone interbedded with the biogenic limestones. These clastics are supplied by many small and low energy streams which were reaching the foreland basin and supplying the nutrients to the basin.

10-The energy was higher in the lower part than upper part this is clear from reworked loftusia and broken skeleton debris that can be seen in the lower part.

11-The low occurrence of the grainstone is attributed to high rate of deposition in influx of terrigenous fine sediments.

12-The growth of the reefal and biogenic limestones were depended on the low stand fan sediments (accumulation of gravels and boulders) for substrate and for decreasing turbidly.

13-In the present study, the tectonic model is totally changed depending on the facies analysis. It assumed that it deposited on the southwestern sloping foreland basin. This foreland basin is bordered from northeast by source area which was supplying the basin with terrigenous sediment.

14-The Aqra Formation in the Chwarta-Mawat area cannot be correlated with type area in Dohuk Governorate due to high difference geological and stratigraphic setting of the both localities

References:

Abdelghany,O. 2003:Late Campanian–Maastrichtian foraminifera from the Simsima Formation on the western side of the Northern Oman Mountains. Cretaceous Research 24 (2003) 391–405

Abdelghany, O. 2003. Late Campanian–Maastrichtian foraminifera from the Simsima Formation on the western side of the Northern Oman Mountain sCretaceous Research 24 (2003) 391–405p.

Ahr, W. M.1973. The carbonate ramp-an alternative to the shelf model: Gulf Coast Association of Geological Societies transaction,V.23, p.221-225.

Al-Ameri, T. and Lawa, T.A.1986. Paleontological model and funal interaction within Aqra Limestone Formation \, North Iraq. Journal of Geological society of Iraq. Vol.19. No.3, pp.6-27.

Alavi, M., 2004. Regional stratigraphy of the Zagros Fold-Thrust Belt of Iran and its proforeland evolution. American Journal of Science, Vol.304, January, 2004, pp.1-20.

Al-Barzinjy, S. T. M., 2005. Stratigraphy and basin analysis of Red Bed Series from northeastern Iraq-Kurdistan Region. Unpublished Ph.D. thesis, University of Sulaimani University, 159p

Ali A. Abid and Kifah N. Al-Kubaysi.2009.Microfacies and Depositional environment of the Aqra Formation in Chwarta area, Sulaimaniyah Governorate, NE Iraq. Bulletin of Geology and Mining, Vol.5, No. 2.p.1-19.

Al-Kadhimi F., Sissakian V., and Duraid, 1996. Tectonic map of Iraq. GEOSURV , Baghdad.

Al-Kubaysi, K. N. 2008. Biostratigraphy of Aqra, Tanjero and Shiranishs Formation in Chwarta Area, Sulaimanyah Governorate, NE-Iraq. Iraqi Bulletin of Geology and Mining, Vol.4, No. 5.p.`-23

Al-Omari, F. S. and Sadiq, A., 1977. Geology of North Iraq (in Arabic). Mosul University Press, pp.197.

Alsharhan, A. & S.J. Nasir (1996) - Sedimentological and geochemical Al-Kadhimi F., Sissakian V., and Duraid, 1996. Tectonic map of Iraq. Geosurv Baghdad. Interpretation of a transgressive sequence: the Late Cretaceous Qahlah Formation in the western Oman Mountains, United Arab Emirates. *Sedimentary Geology*, 101: 227-242.

Ameen, B.M., 2008. Lithostratigraphy and Sedimentology of Qamchuqa Formation from Kurdistan Region, NE−Iraq. Unpublished *Ph*. D. Thesis. University Of Sulaimani, 147p.

Ameen, B.M., 2009. Lithologic signals of uplift and relaxation phases of Zagros Belt during Maastrichtian and Paleocene: Examples from Kurdistan Region, NE-Iraq GERMENA III, 2009, (in press).

Bellen, R. C. Van, Dunnington, H. V., Wetzel, R. and Morton, D., 1959.Lexique Stratigraphic International. Asie, Iraq vol.3c. 10a, 333p.

Bice , D.M.and Stewart, K.G.1990. The formation and Drowing of the isolated carbonate seamonts : tectonic and ecological controls in the northern apenning: Spec. Publs. Int. Ass. Sediment, 9,P.145-168
...

Blatt, H., Middleton, G., and Murray, R., 1980. Origin of Sedimentary Rocks. 2nd ed., Printice-Hall Inco., New Jersey, Engle Wood Cliffs.

Bosence, D., 2005. A genetic classification of carbonate platforms based on their basinal and tectonic settings in the Cenozoic. Sedimentary Geology,175, pp 49-72.

Bracier, M. D.1980. Micofossils, George Allen, London, 193p.

Buday, T. 1980. Regionsl Geology of Iraq: Vol. I, Stratigraphy:I.IM Kassab and S.Z. Jassim (Eds) D.G. Geol. Surv. Min.Invest.Pub. 445p.

Buday, T. and Jassim, S.Z. 1987. The Regional Geology of Iraq: Tectonic Magmatism, and Metamorphism. I.I. Kassab and M.J. Abbas (Eds), Baghdad. 445p. Edgell, Stewart H. 2006. *Arabian Deserts*. Dordrecht: Springer Verlag.

Cameil, M. 2005, Palaeoecological implications of Upper Cretaceous Solitary Corals, United Arab Emirates/Oman Borders. Revue de Paléobiologie, Genève (décembre 2005) 24 (2) : 515-532.

Cox, P. 1937. The genus Loftusia in southwestern Iran. Eclogae Geologicae Helvetiae, 30, 431-450.

Deschaseaux, C., Coogan, A. & Cox, L. 1969: Systematic descriptions; Hippuritoida–Hippuritacea.– In: Cox, L.R., Newell, N.D., Boyd, D.W., Branson, C.C.

Dunham, R. J., 1962. Classificati 101 arbonate rocks according to deposit-ional texture: in Ham, W. E. (ed.), Classification of rocks: a symposium, A. A. P.G, no. 1, pp. 108-121.
Dunnington, H. V., 1958. Generation, Migration and Dissipation of Oil in Northern Iraq. Arabian Gulf, Geology and Productivity. AAPG, Foreign Reprint Series No. 2. .

Einsele, G., 2000. Sedimentary Basin: Evolution, Facies and Sedimentary Budget. 2nd ed. Springer, 792p.

Embry A.F and Klovan J.E., 1972. A late Devonian reef tract on north-easternBanks Island ,N.W.T.: Bulletin of Canadian Petroleum Geology,V,19.P.730 -781.
, Casey, R., Chavan, A., Coogan, A.H., Dechaseaux (Eds.): Treatise On Inverte-65 Mansour: Diagenesis Of Upper Cretaceous Rudist Bivalves... Brate Paleontology, Part N, 3, Mollusca 6, Bivalvia. Geo-Logical Society Of America And University Of Kansas

Emery, D. and Myers, K. 1996. Sequence Stratigraphy. Blackwell Scientific Limited, 297p..

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

Fleury, J.J., Mavrikas, G. and Baudin, F. 1990. Paléobiogéographie du genre *Loftusia*, foraminifère du Crétacé terminal de la Téthys. *Bull. Soc. Géol. France*, (8), t. VI, n° 3, pp. 487-495.

Flugel ,E., 1982. Microfacies analysis of limestones, Springer Verlag, Berline, 633 p.

Flugel, E., 2004. Microfacies analysis of Carbonate rocks, Springer Verlag,Berline,976p.

***FULORIA*, R.C., *1976*.** Petroleum prospects analysis of southern Iraq, with particular reference to Yamama Formation INOC, Southern Petroleum Organization, **...**

Govindan, A. 2008. Paleobiogeography of Cretaceous and Tertiary Larger Foraminifera and Paleo-Seas. Proceedings of the International Symposia on Geoscience Resources and Environments of Asian Terranes (GREAT 2008), 4th IGCP 516,and 5th APSEG; November 24-26, 2008, Bangkok, Thailand.

Haq, B.U., J. Hardenbol and P.R. Vail (1988)-Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. *In:* Sea level changes, an integrated approach.*Society of Economic Paleontologists and Mineralogists*, Spec.Publ.,42:71-108.

Haq,B.U.,1991. Sequence Stratigraphy,sea level change and significance for deep sea.Spec.Publs.int.ass.Sediment,12.p.12-39.

Hottinger, L., 1977. Distribution of larger Peneroplidae, Borelis and Nummulitidae in the Gulf of Elat, Red Sea.Utrecht Micropaleontological Bullentins 15: 35 - 109.

The *2009 Ibrahim* Index1 includes new indicators more regularly updated, and therefore more immediately reflective of current reality.

Insalaco, E., 1998. The descriptive nomenclature and classification of growth fabrics in fossil scleractinian reef. Sediment. Geol. 1998,V.86 ,pp. 118-159.

Jassim, S.Z. and Goff, J.C.2006. Geology of Iraq. Published by Dolin, Prague and Moravian Museun, Berno. 341p.

Karim, K.H. 2004. Basin analysis of Tanjero Formation in Sulaimanyia area, NE-Iraq, Ph.D. thesis, University of Sulaimaniyai, 135 p.

Karim, K.H., 2005. Environment of Tanjero Formation as inferred from sedimentary structures in Sulaimanyia area, Kurdistan Region, NE-Iraq. KAJ.Vol.4, No.1.

Karim, K.H., and Surdashy, A. M. 2005a. Paleocurrent analysis of Upper Cretaceous Foreland basin a case study for Tanjero Formation in Sulaimanyia area, NE-Iraq, 2005, Iraqi Journal of Earth Science,Vol.5, No.pp.30-44.

Karim, K.H., and Surdashy, A.M . 2005c. Sequence Stratigraphy of Upper Cretaceous Tanjero Formation in : 103 anyia area, NE-Iraq, KAJ, Vol.4, No.1.

Karim, K, H, Surdashy, A.M. And Al-Barzinjy. 2007. Concurrent and lateral deposition of flysch and molasse in the foreland basin of Upper Cretaceous and Paleocene from NE-Iraq, Kurdistan Region. GERMENA IIP.757-769.

Karim, K. H., and Ameen, B. M. 2008. New sedimentologic and stratigraphic character-ristic of the upper boundary of Qamchuqa Formation (Early Cretaceous) in Northwest of Erbil Governorate, Kurdistan Region, NE/Iraq, Iraqi Geological Journal, Vol.4, No.2.

Kendall, C. G. St., Schlager, W., 1981. Carbonates and relative changes in sea level. Marine Geology, 44: 181-212.

Kenter J., A. M. Harris P, M, and Porta G.D. 2005. Steep microbial boundstonedominated platform margin-examples and implecations., Sedimentary Geology,178 ,pp.5-30.

***Kureshy*, A. A., *1969*, The Cretaceous larger foraminifera of Agra, Iraq**: Geol. Soc. Iraq Jour., v. 2, no. 1, p. 13-15. **Lawa,F.A.AL Karadakhi,A.I,Ismail,k.m.1998.**An interfingof the upper cretaceous rock from chwarta-mawat region (NE-Iraqi).Iraqi Geolo.Journal,vol.31 No.2.

Lawa,F.A.A. Karadakhi,A.I,Ismail,k.m.1983. Biostratigraphy of Aqra Limston.Formation in its type section. Unpubi.M.Sc.Thesis.Univ.of mosull.141p.

Lawa,F.A.AL Karadakhi,A.I,Ismail,k.m.1998. An interfingof the upper cretaceous rock from chwarta-mawat region (NE-Iraqi).Iraqi Geolo.Journal,vol.31 No.2.

Liu, C., Steinhauff, M., and Mitchell, J., (2006): Evolution of the Mesopotamian Basin (Iraq): Campanian to Neogene (abstract), Conference and Exhibition; 27-29 March, Manama, Bahrain.

Meriç, E. 1965a. Sur deux espèces de Loftusia et un nouveau genre, Asterosomalina. Rev. Micropal., vol. 8, no.1, pp. 45-52.

Meriç, E. 1965b. Etude géologique et paléontologique de la région entre Kahta et Memrut dag. Rev. Fac. Sci.

Meriç, E. 1967. Sur quelques Loftusiidae et Orbitoididae de la Turquie. Rev. Fac. Sci. Univ. Ist., série B, t. 32, n°
1-2, pp. 1-58, pl. 1-36.

Meric. E., and Mojab, F., 1977. World-Wide Geographical distribution of the species of the foraminfieral genus Loftusia. Istabul. Univ. fen. Fak. Mec. Seri B. 42(1-4): 143 – 155.
Meriç, E. 1979. Loftusia ketini (Foraminifère) nouvelle espèce du Maestrichtian. Revista Española de Micropaleontología
11, pp. 509–516.

Meriç, E. 1991. On the presence of Loftusia anatolica Meriç in the Maastrichtian sequence of Rava S. Maria
(Monts Lepini, Latium Centrale-Meridionale, Italy). Bulletin of the Technical University, Istabul 44, 97-102.

Meriç, E., and Avşar, N. 1992. Loftusia turcica Meriç and Avşar n. sp. from the Maastrichtian of eastern Turkey
(southeast Elazıg). Micropaleontology 38, pp. 303–309.

Mohammad Y. O. 2004. Petrology and geochemistry of serpentinite and associated rocks in Mawat and Penjwin areas, Kurdistan region, Northeastern Iraq. Unpublished M. Sc thesis, University of Sulaimani, Iraq

Numan, N.M.S. 1997. A plate tectonic senario for the Phanerozoic Succession in Iraq. Iraqi, Geol. Jour. Vol.30, No. 2, pp 85–110.

Pomar, L., Gili E., Obrador, A. and Ward, W.C., 2004. Facies architecture and high-resolution sequence stratigraphy of an Upper Cretaceous platform margin succession, southern central Pyrenees, Spin. Sedimentary Geology175, 2005, pp. 338-365

Read J. F., 1985. Carbonate platforms facies models. Am. assoc. pet. Geol. Bull.69, pp.1-21

Sadooni, F. N., 1993. Stratigraphic sequence, microfacies and petroleum prospectus of the Yamama Formation, Lower Cretaceous, southern Iraq. AAPG Bulletin, 77 (11): 1971-1988.

Sadooni, F. N., and A. Aqrawi, 2000, Cretaceous sequence stratigraphy and petroleum potential of the Mesopotamian basin, Iraq, in A. S. Alsharhan and B. Scot, eds.,Middle East models of Jurassic/Cretaceous carbonate systems: SEPM Special Publication 69, p. 315–334.

Sadooni, F. N and Alsharhan, A. S.. 2000. Stratigraphy, lithofacies distribution, and petroleum potential of the Triassic strata of the northern Arabian plate. AAPG Bulletin, v. 88, no. 4 (April 2004), pp. 515–538 515.

Sadooni, F. 2005. The nature and origin of Upper Cretaceous basin-margin rudist buildups of the Mesopotamian Basin, southern Iraq, with consideration of possible hydrocarbon stratigraphic entrapment". Cretaceous Research, 26: p. 21 **.**

Sartorio, D. and Venturini, S., (1988): Southern Tethys Biofacies, Agip Stratigraphic Department, 215p

Schafhauser et al**. (*****2003*****)** first described fabric and depositional environments of the Cardenas reefs and Baron

Schlager, W., Ginsburg, R. N., 1981. Bahama carbonate platforms-the deep and the past. Mar Geol.,1981, 44: pp.1-24.
3-224.

Schlager, W., 1991. Depositional bias and environmental change-important factors in sequence stratigraphy. Sedimentary G *Schafhauser et al*. (*2003*) first described fabric and depositional environments of the Cardenas reefs and Baron eology, 70: 109-130.

Schlager, W., 1991. Depositional basin and environmental change-important factors in sequence stratigraphy. Sedimentary Geology, 70: 109-130.Schlager, W., Ginsburg, R. N.,1981.Bahama carbonate platforms-the deep and the past.Mar Geol.,1981,44:pp.1-24.

Steuber**, T. (*****2002*****)** Plate tectonic control on the evolution of Cretaceous ...
www.pi.ac.ae/PI_ACA/pge/.../carb_strat_rud_Earth.php

Sissakian, V. K., 2000. Geological map of Iraq. Sheets No.1, Scale 1:1000000, State establishment of geological survey and mining. GEOSURV, Baghdad, Iraq.

Skelton**, *****1991*****),** and these flourished on more current-swept lime-sand substrates (eg in Apulia, Luperto Sinni & Masse, 1982; and on the Sligo margin .

Steuber, T. and Loser, H.2000. species richness and abundance pattern of Tethyan Cretaceous rudists (Mollusca: Hipputitacea) in the central-eastern Mediterranean and Middle East , analyzed from paleontological data base. Paleogeography, paleoclimatology. Paleoecolog , Vol.162. 75-104p.

Taha, Z.A.2008. Sedimentology of Late Cretaceous Formation from Kurdistan Region, NE−Iraq, Unpublished, M.Sc thesis, University of Suilaimani, pp.150.

Tucker, M. E., 1991. Sedimentary Petrology. Blackwell Science Publication Co.260p.

***Westphal*, H. & *Munnecke*, A. (*2003*):** Limestone-marl alternations - A warm-water phenomenon?- Geology, 31(3), 263-266. *Westphal*, H., Head, M. J. & *Munnecke*, **...**

Wilson, J.I., 1975. Carbonate Facies in Geological History. Springer-Verlag, Berlin, 471p.