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FACIES ANALYSIS OF THE UPPER CRETACEOUS – TERTIARY SUCCESSION IN SELECTED SECTIONS FROM NORTHERN IRAQ

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Key words: Facies analysis; Aqra-Bekhme; Shiranish; Tanjero; Kolosh; Iraq.

ABSTRACT

This paper includes petrographic and paleontological observations that are used to interpret the carbonate microfaces of the Aqra-Bekhme and Shiranish formations in terms of depositional environment. These formations show lateral facies variation in the Bekhme Gorge, Mukaba and Zarda Bee sections. An understanding of the facies change is presented in this study and used in the interpretation of paleogeographic setting during deposition of the Late Cretaceous formations in northern Iraq. For this purpose, a petrographic examination of about 300 thin sections allowed the recognition of a wide range of the microfacies, that are grouped into four environmentally indicative facies associations including: **1-** Back reef, **2-** Reef, **3-** Fore reef, and **4-** Deep marine. The back reef facies association of the Aqra-Bekhme Formation in the Bekhme Gorge section is characterized by mudstone-dominated microfacies that are rich in benthonic foraminifera. The reef facies association of the Formation consists of bioclastic packstone and grainsone. The fore reef facies association of the Aqra-Bekhme Formation includes bioclastic packstone-grainstone microfacies, rich in benthonic foraminifera. The mud-dominated deep marine microfacies occur in the middle parts of the The Aqra-Bekhma Formation at the Mukaba and Zarda Bee sections and is comprised of mudstone Similar facies are observed in the Shiranish Formation at the Bekhme Gorge section.

التحليل السحني للتتابع الطباقي للطباشيري الأعلى – الثلاثي في مقاطع مختارة من شمال العراق

سلام إسماعيل الدليمي و فاطمة طالب عبدالله

المستخلص

يتضمن التتابع الطباقي للعصر الطباشيري الاعلى – الثلاثي التكاوين الاتية: عقرة-بخمة، شيرانش، تانجيرو وكولوشالتي تنكشف في شمال وشمال شرق العراق، ضمن نطاق الطيات العالية في مقطع بخمة كورج في محافظة أربيل، وضمن نطاق الطيات المضطجعة في شمال شرق العراق في مقاطع موكبة وزردة بي في محافظة السليمانية. تم انجاز الفحوصات الصخارية لحوالي 300 شريحة من الصخر الكاربونيتية خلال هذه الدراسة. بالأعتماد على الوصف طبيعة ونوع المتحجرات والسحن الدقيقة الموجودة في الشرائح الصخرية تثبيت أربعة مجاميع سحنية وهي: الحيد الخلفي والحيد والحيد الامامي والبحر العميق. ان التتابع السحني لبيئة الحيد الخلفي لتكوين عقرة-بخمة في مقطع بخمة كورج يتميز بالسحنة الدقيقة mudstone والتي تكون غنية بالفورامنفيرا القاعية. التجمع السحني لبيئة الحيد للتكوين يتكون من مكسرات الاصداف packstone و grainsone. اما التتابع السحني لبيئة الحيد الامامي لتكوين عقرة-بخمة فيحتوي على السحنات

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الدقيقة لمكسرات الاصداف packstone-grainstone والتي تكون غنية بالفورامنفيرا القاعية. السحنة الدقيقة للبحر العميق الغنية بالطين تكون موجودة في الجزء الاوسط من تكوين عقرة-بخمة في مقاطع موكبة وزردة بي وتحتوي ايضا على سحن مشابهة لتكوين شيرانش في مقطع بخمة كورج.

INTRODUCTION

The Late Cretaceous – Tertiary succession includes: The Aqra-Bekhme Formation (Upper Campanian – Lower Maastrichtian), the Shiranish Formation (Upper Campanian – Maastrichtian), the Tanjero Formation (Upper Maastrichtian) and the Kolosh Formation (Paleocene – Lower Eocene). The Aqra-Bekhme and Shiranish formations are considered as carbonate successions that consist mainly of limestone (Bellen *et al.*, 1959). Whereas the Tanjero and Kolosh formations are considered clastic (flysch) units (Jassim and Goff, 2006). The exposures of these formations were studied in three locations (Figure 1, Table1), which are located in the High Folded Zone (HFZ), northern Iraq in the Bekhme Gorge section within the Erbil Governorate, and in the Imbricated Zone (IZ), northeastern Iraq in front of the Wadi Qala Juwalan in the Mukaba and Zarda Bee sections within the Sulaimania Governorate. The main objective of this work is to determine the facies associations within the studied formations in the selected areas.

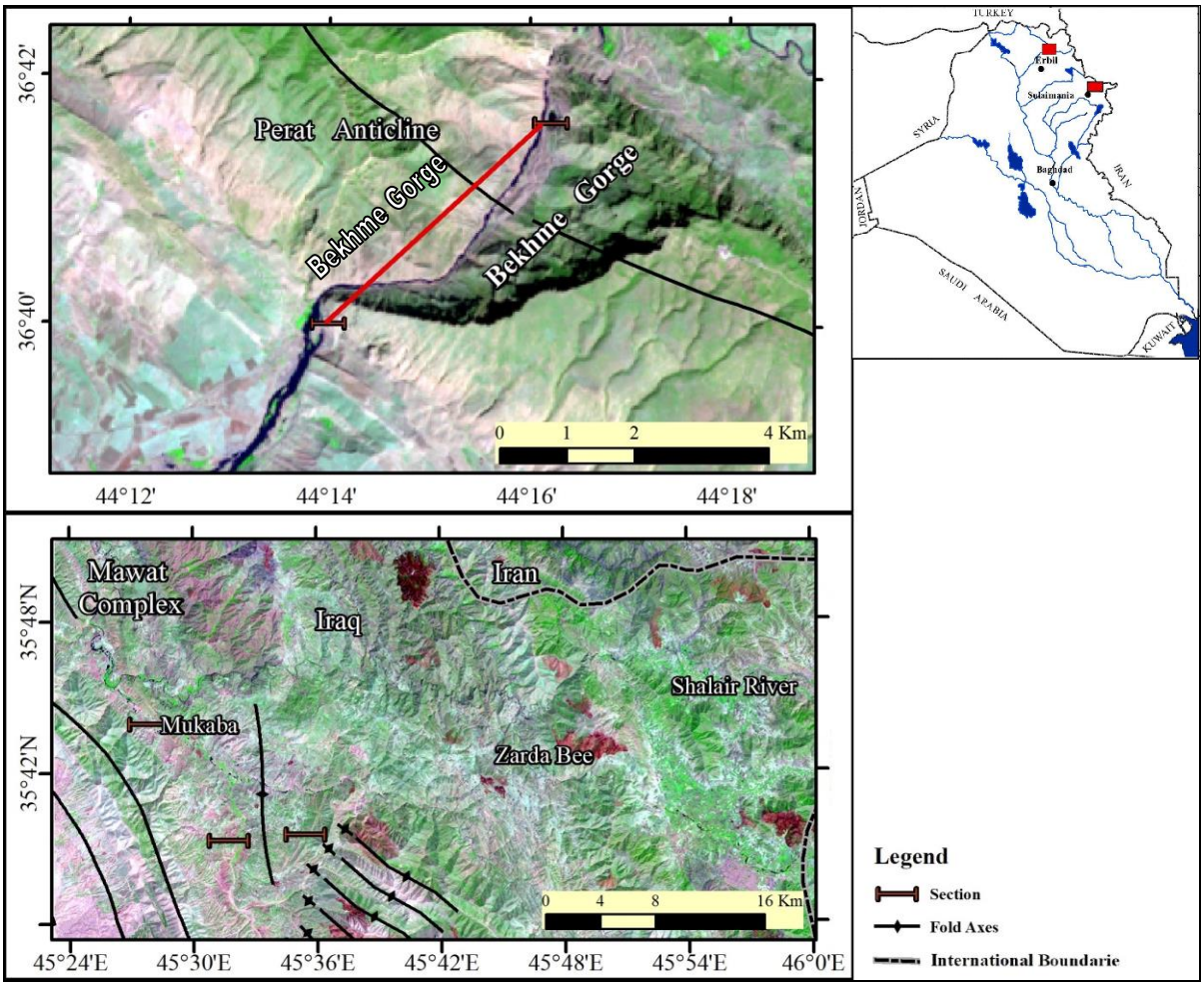

Fig.1: Location map and Landsat satellite image (USGS, 2013) showing the location of studied sections

Table 1: Geographic coordinate of the studied sections

Location	Section	Coordinate
Erbil	Behkme Gorge	E 44° 14' 00" – N 36° 40' 00" E 44° 16' 12" – N 36° 41' 38"
Sulaimania	Mukaba	E 45° 27' 48" – N 35° 43' 20"
	Zarda Bee	E 45° 32' 31" – N 35° 46' 39"

GEOLOGY OF THE STUDY AREA

The studied sections are located in the north and northeastern parts of Iraq (Figs.2 and 3), within the Erbil and Sulaimania governorates in the Behkme Gorge, Mukaba and Zarda Bee areas. The Zagros Fold Thrust Belt extends from southern Iran, which is part of the Alpine-Himalayan mountain chain, to southeastern Turkey (Alavi, 1994 and 2004). The trend of the folds in this zone is NW – SE. The Zagros Fold-Thrust Belt is considered as an active tectonic belt which represents the tectonic processes that occurred in the early stages of convergence zones (Hessami *et al*., 2001).

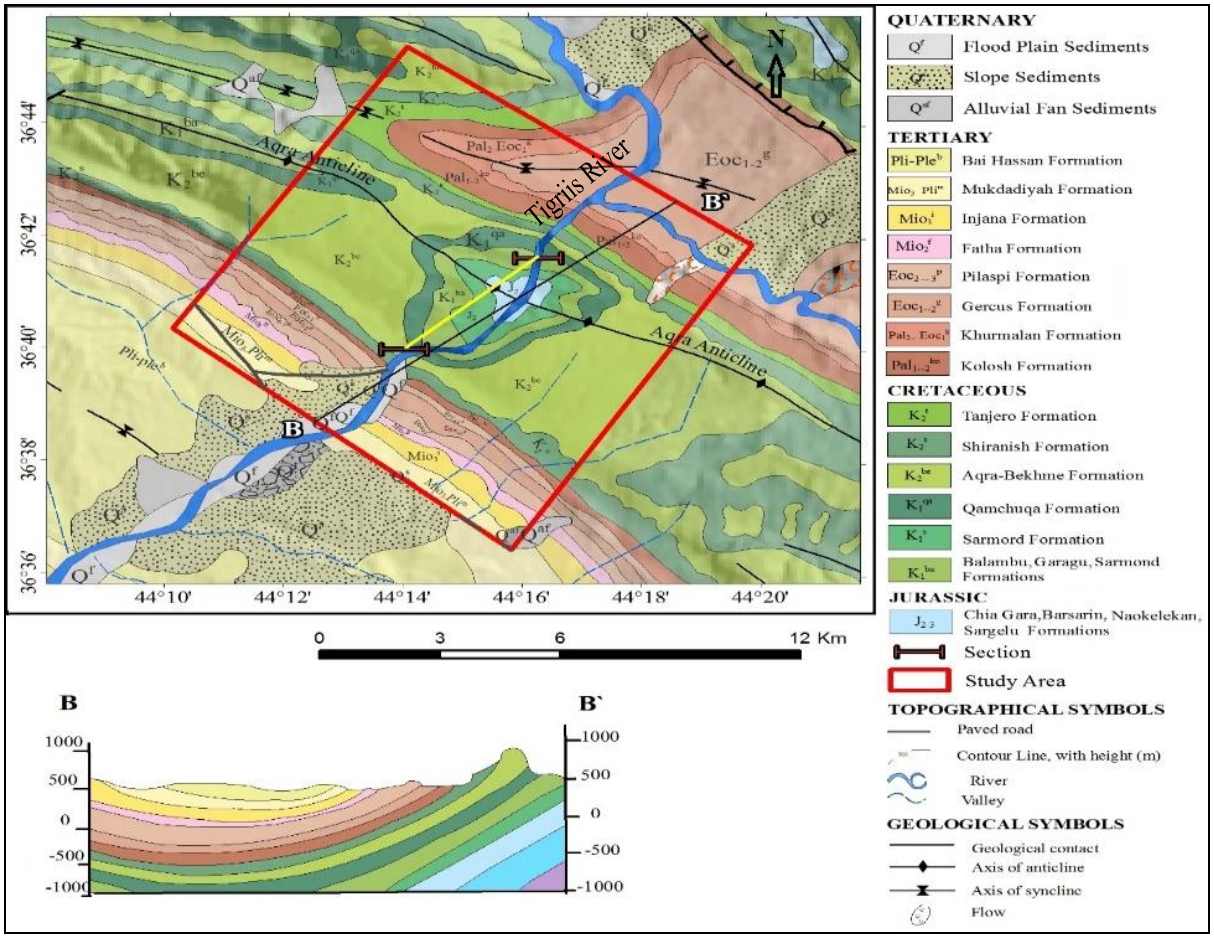

Fig.2: Geological Map and cross section of the studied area showing location of Bakhme Gorge outcrops (after Sissakian, 1997)

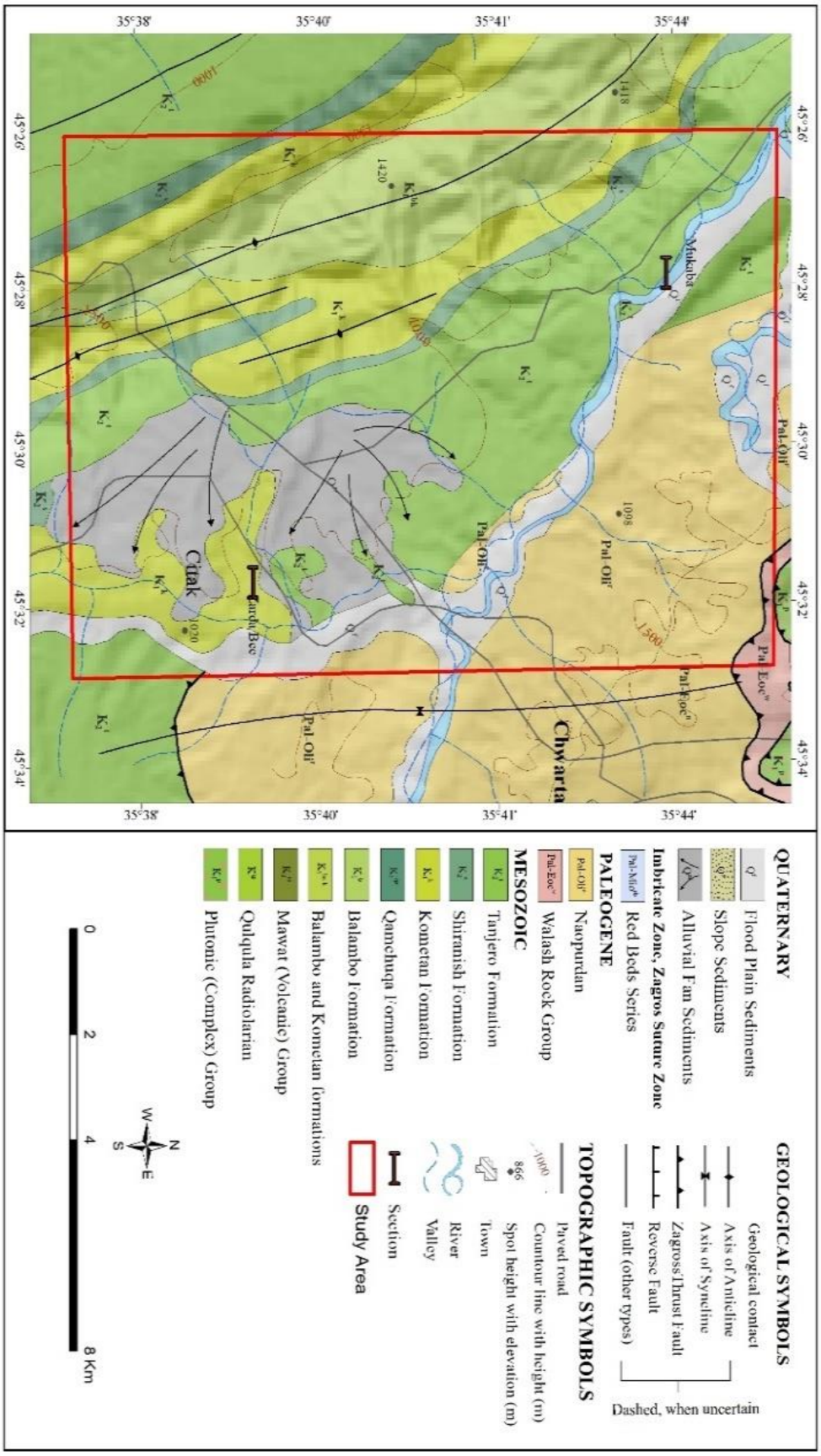

Fig.3: Geological map of the studied area showing location of the Zarda Bee and Mukaba sections (after Ma'ala, 2007)

During the Late Campanian – Early Maastrichtian, the paleotectonic setting of Iraq was effected by a plate motion which was changed from N to NE drift in the Late Campanian (Jassim and Goff, 2006), with a renewed compression occurred in the Paleogene (Paleocene – Early Eocene) (Aqrawi *et al*., 2010). The study area of both Erbil and Sulaimania underwent tectonic deformation that was inherited from the tectonic history of the Arabian Plate (Zebari *et al*., 2015). As a result of the collision between the Arabian and Iranian plates, the High Folded Zone was formed. This zone was intermediately uplifted in the Cretaceous and Paleogene, and strongly deformed in the Late Tertiary (Jassim and Goff, 2006). The general trends of the anticlines in the study area can be summarized as follows: In the High Folded Zone, N Iraq, within the Bekhme Gorge section in the Erbil region, the general trend of the anticlines is E – W, whereas in the Imbricate Zone of NE Iraq, within the Mukaba and Zarda Bee sections in the Sulaimania region, the anticlines have a general trend of NW – SE (Jassim and Goff, 2006; Al-Ma´amar, 2015).

PREVIOUS WORK

- Henson (1950) described the Aqra Formation as being one of the examples of reef in the Middle East. He considered the Aqra Formation to be a part of a giant reef that extends from the Aqra to Bekhme and their surrounding.
- Bolton (1958) described the Bekhme Formation in Ranya area, northeast Iraq and described it as a thick and massive beds containing various fossils forming fore-reef limestone, and shoal (reefal) limestone.
- Bellen *et al*. (1959) described briefly the distribution, age, lithology, fossils content, and stratigraphy of the Shiranish and Tanjero formations, and documented the fossils content in the Tanjero Formation as *Loftusia morgani*, *Omphalocyclus macropora*, *Siderolites calcitrapoides,* and *Globigerina cretacea*. They described the Aqra Formation as being built up of complex forereef carbonate rocks. The age of the Formation was determined by them as Maastrichtian.
- Chatton and Hart (1961) found it difficult to separate the Aqra Formation from the Bekhme Formation and they used the Aqra-Bekhme Formation term for the whole succession.
- Abdul Muniem and Said (1979) suggested that the Bekhme Formation rocks indicate facies of reef and shallow fore-reef environments depending on the presence of various species of planktonic and benthonic fossils.
- Sissakian and Youkhanna (1979) recognized reefal limestone consisting of rudist in the Bekhme Formation. They recognized three types of microfacies, and considered the sedimentary environment of the formation to be shallow marine, reef and fore-reef limestone.
- Buday (1980) used the term Aqra-Bekhme Formation for the Bekhme and/ or Aqra formations because of the difficulty of distinguishing between the two. He described the most representative foraminifera fossils of the Shiranish Formation that are recorded in the type locality including: *Globigerina cretacea*, *Bolivina incrassata*, *Nodosaria* sp. and *Textularia cretosa.*
- Lawa (1983) divided the Aqra Formation into nine microfacies units and determined the age of the formation to be Maastrichtian depending on the *Loftusia* species.
- Al-Omeri *et al*. (1989) divided the Aqra Formation into nine facies units, and suggested that the formation was deposited in there different environments of reef, fore-reef and back-reef. They determined the age of the formation as Maastrichtian.
- Bakkal *et al*. (1993) studied the biostratigraphy of the Shiranish Formation in the Hijran area, and determined the age as Middle – Late Maastrichtian by recognizing two

planktonic foraminiferal subzones of *Globotruncana, gansseri gansseri* and *Kassabiana falsocalcarata* subzones under the *Globotruncana contuse, stuartiformis* biozone.

- Al-Bazee (2003) described the foraminifera and ostracods species for the Upper Cretaceous-Lower Tertiary boundary in the Hujran – Erbil and Zawita – Duhok areas.
- Al-Mutwali and Al-Jubouri (2005) determined the age of the Shiranish Formation by Late Campanian – Late Maastrichtian based on the following biozones: *Globotruncana calcarata* (Late Campanian), *Globotruncanella havanensis-Roseta* fornicata Zone (Early Maastrichtian), *Globotruncana aegyptiaca* Zone (Early Maastrichtian), *Globotruncana gansseri* Zone (Late Maastrichtian).
- Al-Kubaysi (2006) studied the biostratigraphy and microfacies of the Aqra Formation in selected geological sections at Azmer anticline in the Chowarta locality (Sulaimania Governorate). She recognized 74 foraminiferal species, 36 of them are reported for the first time in Iraq.
- Sharbazheri (2010) estimated the duration of the unconformity gap at the lower part of the Tanjero Formation in the Chwarta area by about 1.23 my, represented by a 500 m thick succession of conglomerate and red claystone layers. He reported the following planktonic foraminiferal biostratigraphic zones from the base upward: *Globotruncana aegyptiaca* Interval Zone (CF8), *Gansserina gansseri* Interval Zone (CF7) *Racemiguembelina fructicosa* Interval Zone (CF4), *Pseudoguembelina hariaensis* Interval Zone (CF3) with missing zones of *Contusotruncana contusa* Interval zone (CF6) and *Pseudotextularia intermedia* Interval zone (CF5).
- Al-Dulaimi (2011) studied the Aqra Formation at two areas in North and North East Iraq. He described the formation as a thick succession of recrystallized, dolomitized and rudist-bearing limestone and occasionally sandy limestone.
- Lawa *et al*. (2017) considered that the Aqra reefal facies represents time of relative quiescence and shallowing within a mobile trough, whereas the flysch facies of the Tanjero Formation represents the unstable and evolution stage of the Kurdistan Foreland Basin.

MITHODOLOGY

Considering the lithological changes, 302 rock samples were collected from the Bekhme Gorge (Table 2), Mukaba and Zarda Bee sections. The laboratory work included the preparation of thin sections for each sample and their examination using the polarized microscope to differentiate various types of microfossils and microfacies. The petrographic constituents of the Aqra-Bekhme and Shiranish carbonates and the clastics of the Tanjero and Kolosh formations are examined using Dunham's (1962) classification for the carbonate depositional textures, and considering the results of previous workers (e.g. Bolton, 1958; Abdul Muniem and Said, 1979; Buday, 1980; Lawa, 1983; Al-Ameri and Lawa, 1986; Al-Omeri *et al*., 1989; Sharbazheri 2010; Lawa *et al*., 2017). The results of this study are compared with the models of standard microfacies and depositional environment belt of carbonates proposed by Wilson (1975) and Flugel (2004).

Table 2: Locations of the studied sections and number of samples of each formation

Locality	Section	Formation	Number of samples	
Erbil	Behkme Gorge	Kolosh	13	72
		Shiranish	28	
		Aqra – Bekhme	31	
Sulaimania	Mukaba	Aqra – Bekhme	38	112
		Tanjero	74	
	Zarda Bee	Aqra – Bekhme	55	123
		Tanjero	68	

RESULT AND DISCUSSION

- **Facies associations**

The definition of facies association is a group of facies genetically related to one another and have some environmental significance (Collinson, 1969). In this study, the description and observation of the fossils content and microfacies led to the determination of four facies associations as follows:

– **Back reef facies association:** The Back reef is defined as an extensive area protected by a barrier like central reef with changing, sometime restricted, water circulation (Zebari, 2010). This association is represented in the Aqra-Bekhme Formation in the Bekhme Gorge section (Figure 4). Its mainly comprised of dolomitic limestone. The main characteristics of the back reef environment in the studied samples are:

1. Bioclastic mudstone-wackestone microfacies, whichindicates a back reef (shelf lagoon) with open circulation and quiet water below normal wave base (Fig.5A). Perhaps patches of reef are developed within the open platform (shelf lagoon) (Flugel, 2004).
2. Low diversity of organisms with a rare abundance of boring organisms and detritus often rounded, restricted to certain areas. The peloids are often present as fecal pellets in protected areas (Flugel, 1982).
3. The presence of Miliolidae (Brasier, 1975) (Fig.5B).
4. The presence of *Orbitoides* sp., Miliolidae and Rotaliidae (Noel and Bronnimann, 1957 in Ali, 2010) (Fig.5C and D).

This facies association generally shows the mudstone-dominated interval with limestone and sandstone. Also it is characterized by the presence of benthonic foraminifera.

– **Reef facies association:** Reefs are carbonate bodies built up mainly by framework-building benthonic organisms, in which they are wave resistant structures form in shallow water on carbonate platforms. The reef and organic buildups commonly form where there is a break in slope on the sea floor, or landward of this break, within the slightly deeper water of platform interiors and epeiric setting. It forms commonly in a very narrow facies belt (Harris, 2009). The margin reef which occurs in the Aqra-Bekhme Formation at the Bekhme Gorge, Mukaba and Zarda Bee sections (Figs.6 and 7), consists of thick beds of dolomitic limestone and massive (structureless) dolomitic limestone. The microfacies are bioclastic packstone and grainstone. The organisms found in the reef facies are fragments of rudist, algae, gastropod and *Loftusia*. The main characteristics of the reef e facies can be summarized as follows:

1. The rudists are abundant in low-latitude; warm, shallow carbonate-dominated seas and represents the reef frame builders (Skelton and Gili, 1991 in Al-Dulaimi, 2011).
2. The reef environment represents the area of active growth of sessile framework building organisms (rudist, algae, corals,etc.). Wealth and great diversity of organisms characterize this facies with concentration of encrusting organisms and bioclastic micrite (Flugel, 1982) (Figs.5E and F).
3. The combination of limestone with rudist in original growth position contributes to the formation of mounds and buildups. The rudists are restricted in occurrence from open platforms to platform margins (Flugel, 2004).
4. The rudists are bizarrely shaped bivalves and represent the reef builders for most of the Cretaceous period (Ross and Skelton, 1993 in Al-Dulaimi, 2011).
5. In general, species of Orbitolinidae Family occur near reef and commonly in forereef facies (Douglass, 1960).
6. Boring organisms are very abundant, detritus between reef builders, peloids are present and bioturbations are common but laminations are absent (Flugel, 1982 and 2004).

– **Fore reef facies association:** The fore reef facies association in the Aqra-Bekhme Formation at the Bekhme Gorge (Mukaba and Zarda Bee sections) is composed of calcarenite limestone embedded with thick beds of dolomitic limestone. The microfacies include lime mudstone, wackestone and packstone. According to Schlager (2002), these facies zones represent the slope toward toe of slope environments. It represents the wind-facing side and reef flank beds against the open sea. It is characterized by abundant coarse, meters to centimeters sized reef debris. The main criteria that refer to the fore reef environment can be summarized as follows:

1. Presence of bioclastic packstone-grainstone that are rich in *Omphalocyclus macroporus*, *Orbitoides tissoti, Lepidorbitoides* sp., (Figs.5G and H), *Bolivina incrassata* and *Siderolites calcitrapoides* (Figs.8A and B). This indicates a high energy zone and strong water action in a typical reef-flank facies (Flugel, 2004), and fore reef environment (BouDagher and Fadel, 2008), with main occurrence of algae (Aqrawi *et al*., 2010).
2. Presence of packstone microfacies which contain bioclasts derived from reef-builders, reef-rudstone and reef-dwellers with large bioclasts-like rudist fragments indicates typical reef flank facies and fore reef slope in high energy zone (Flugel, 2004).
3. Presence of Rotaliidae, *Sulcoperculina* sp., *Lepidorbitoides* sp. and *Orbitoides* sp. indicates fore reef environment (Noel and Bronniman, 1957 in Ali, 2010 and Bou Dagher and Fadel, 2008).
4. Large foraminifera association such as *Orbitoides medius*, *Sulcoperculina* sp., *Orbitoides apiculates*, *Omphalocyclus macroporus* and *Lepidorbitoides* sp. are good indicators of fore reef environment (Henson, 1950).
5. Redeposition of shallow marine bioclasts (such as rudist fragments) with benthonic foraminifera (such as *Orbitoides* sp.) and planktonic foraminifera (such as *Globotruncana* sp.) is a good indicator for fore reef slope toward the open marine environment (Flugel, 2004).
6. *Loftusia* sp. is benthonic foraminifera of Maastrichtian age which reflects an outer shelf environment in front of the rudist reefs (Lekkas and Kemeridou, 2004 in Zebari, 2010).

– **Deep marine facies association:** The deep marine facies association consists of the skeletal lime mudstone to packstones. The skeletal grains consist mainly of planktonic foraminifera, such as: *Globotruncana* sp., *Heterohelix*, *Hedbergella*, and *Rogoglobigerina*, (Figs.8C, D and F) with few Rodiolaria (Fig.8G). The bioclasts are mostly fine and unidentifiable, and coarser bioclasts of rudist and few benthic foraminifera, such as *Loftusia*, *Orbitoides* and *Siderolites*, originate from the destruction of rudist belts by waves and currents. This association is found in the Aqra-Bekhme Formation in the middle parts of Mukaba and Zarda Bee sections. In the Bekhme Gorge section, the Shiranish Formation consists of mudstone, wackestone and packstone facies. This formation is considered to be deposited in a quiet open marine environment depending on the planktonic foraminifera: *Abathomphalus mayaroensis*, (Fig.8H). *Globigerinellides*, *Globotruncana*, *Globotruncanita*, and *Hedbergella* sp., Kolosh Formation is considered as a deep marine in the Bekhme Gorge section due to the presence planktonic foraminifera with *Rotalids* and other fossils fragments with the clastic contents which are fine sandstone, composed of fragments of various grain size of green-rock, chert and radiolarite (Bellen *et al*., 1959). Flysch sediments of the Tanjero Formation, in both the Mukaba and Zarda Bee sections represent a deep marine, due to the presence of transported foraminifera and their fragments, as well the domination of clastic sediments which are silty marls, siltstones, conglomerates and sandy or silty organic detrital limestone (Bellen *et al*., 1959).

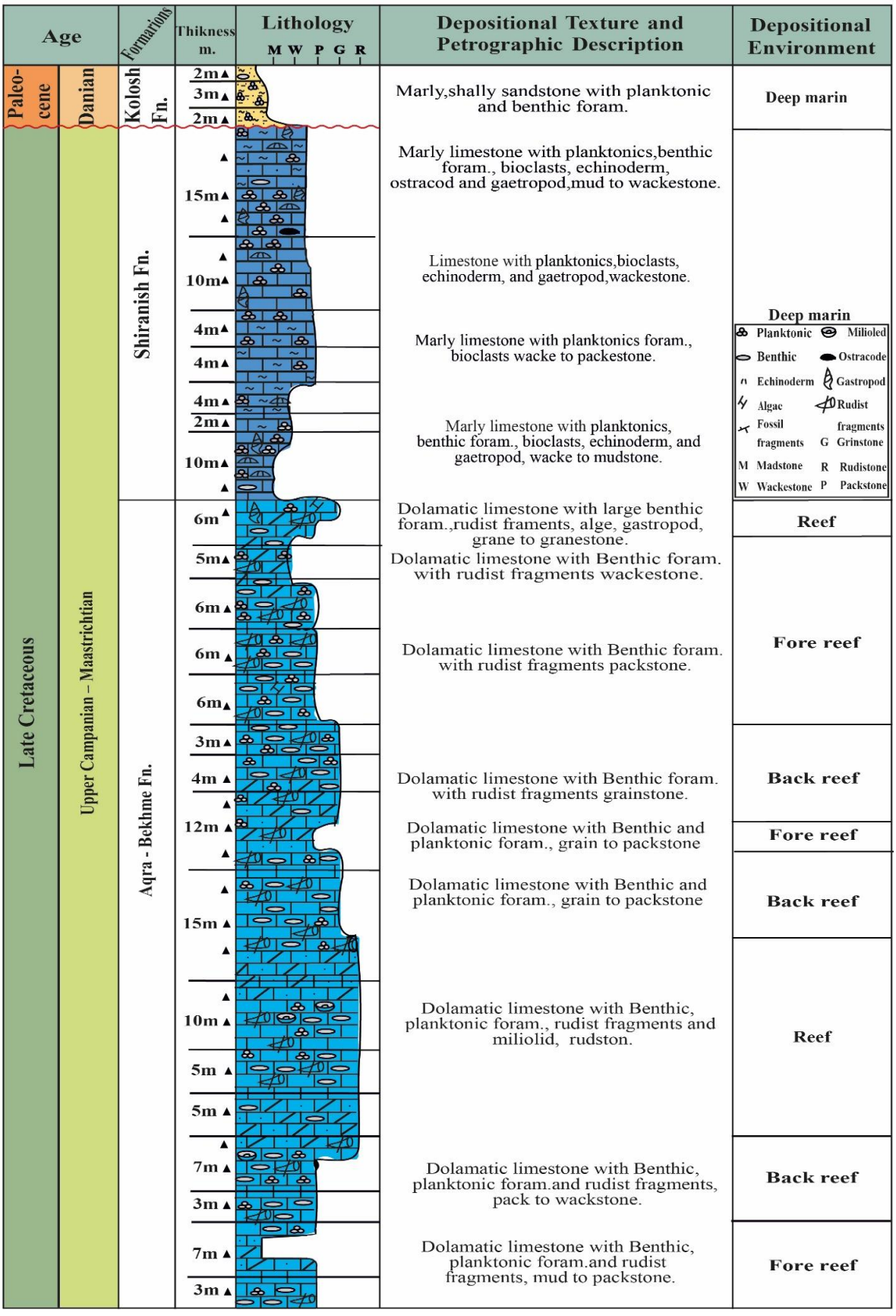

Fig.4: Facies association of the Bekhme Gorge section

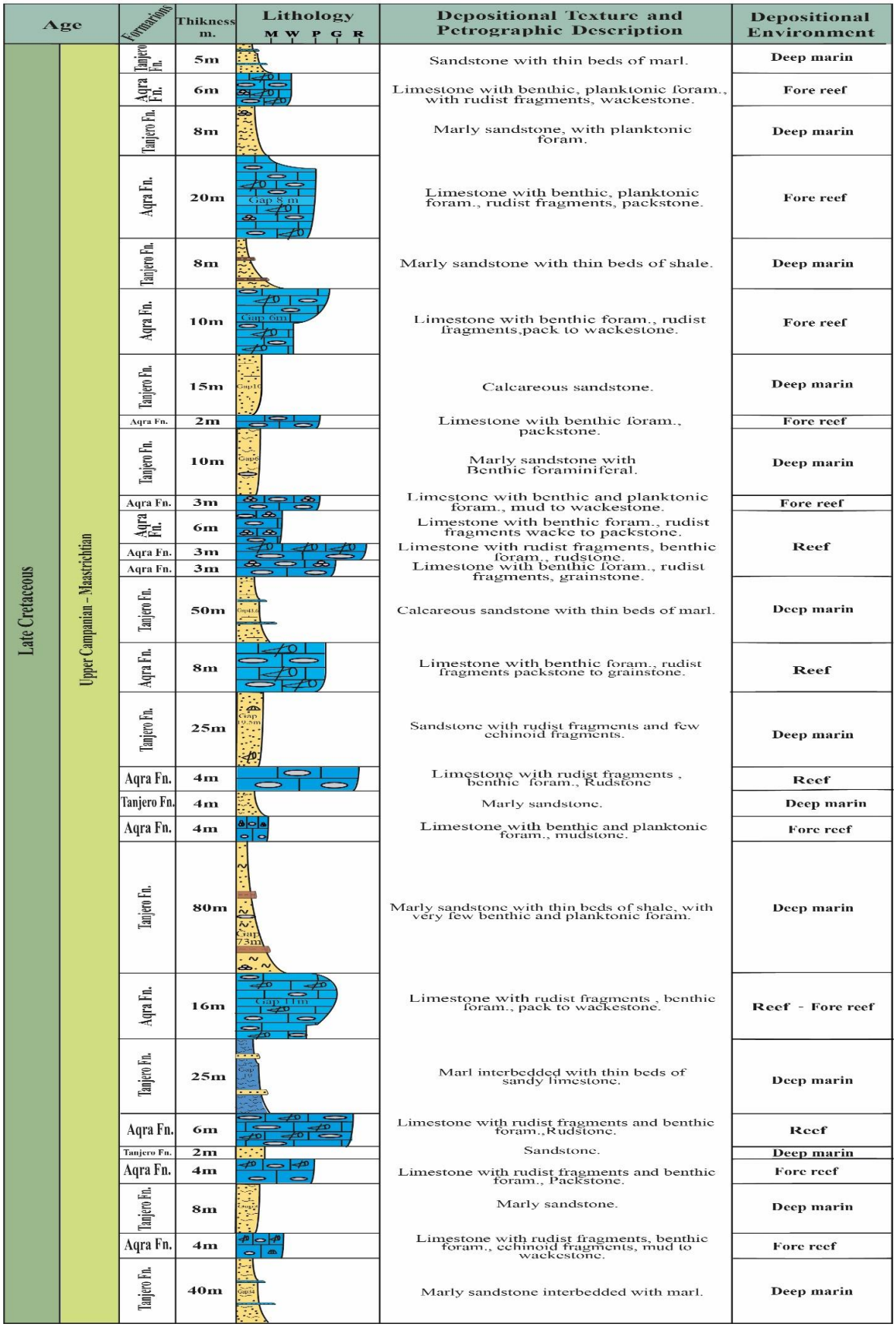

Fig.5: Facies association of the Mukaba section

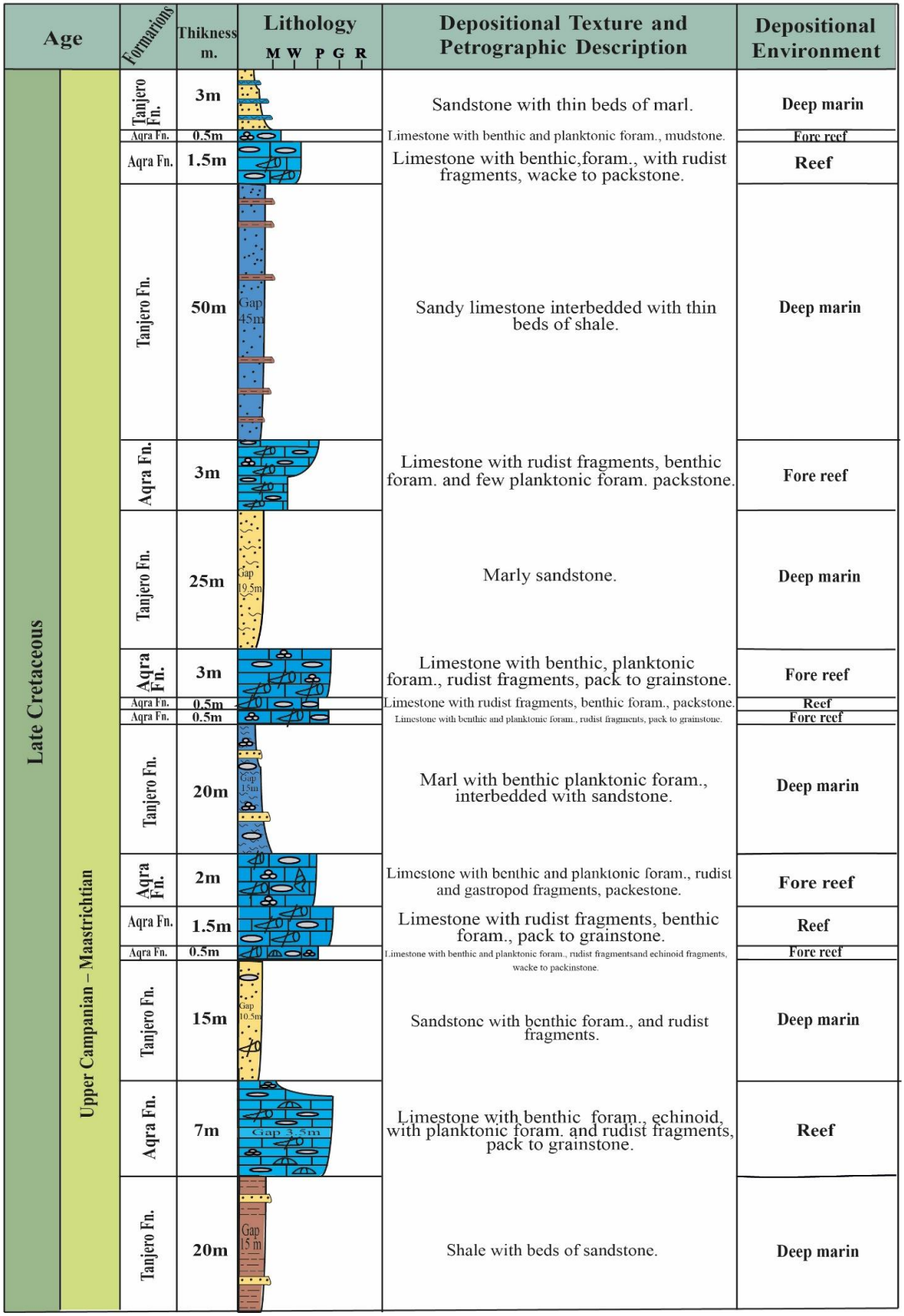

Fig.6: Facies association of the Zarda Bee section

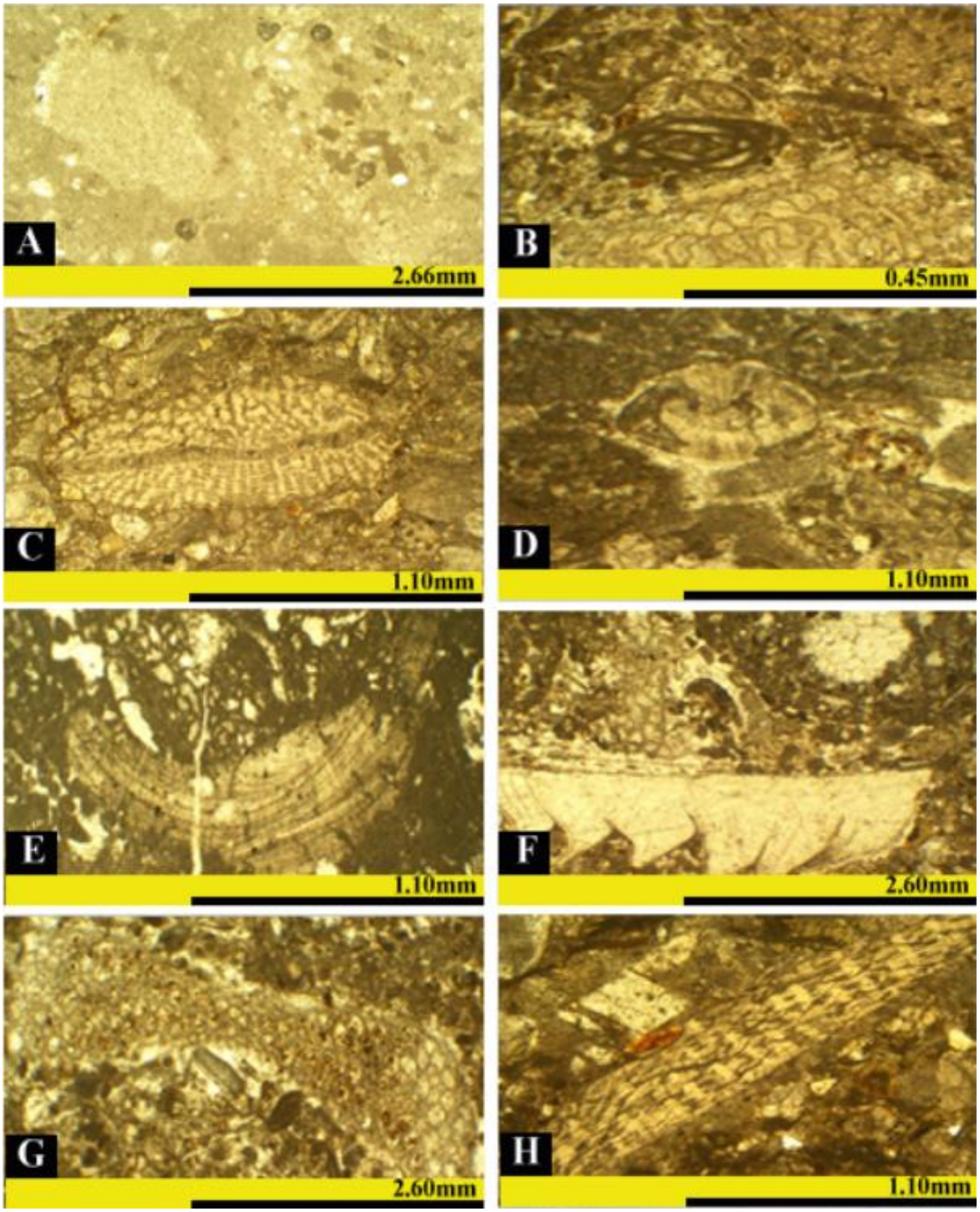
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Fig.7:

A. Bioclastic mudstone- wackstone microfacies, the Aqra-Bekhme Formation, the Bekhme Gorge section, sample No.27.

B. Bioclastic wackestone with Milliolid, *Omphalocyclus macroporus* and peloids, The Aqra-Bekhme Formation, the Bekhme Gorge section, sample No.30.

C. *Orbitoides* sp. in Bioclastic wackestone texture, the Aqra-Bekhme Formation, the Bekhme Gorge section, sample No. 37.

D. Bioclastic wackestone texture with Rotaliidae, the Aqra-Bekhme Formation, the Bekhme Gorge section, sample No.50.

E. Bioclastic packstone with rudist fragments, the Aqra-Bekhme Formation, the Bekhme Gorge section, sample No.42.

F. Bioclastic packstone with rudist fragments, pelloieds and *Loftosia* with algae and radiolarian chert, the Aqra-Bekhme Formation, the Mukaba section, sample No. M15.

G. Bioclastic packstone-grainstone with *Omphalocyclus macroporus*, the Aqra-Bekhme Formation, the Bekhme Gorge section, sample No. M9.

H. Bioclastic grainstone, with *Lepidorbitoides* sp., the Aqra-Bekhme Formation, the Zarda Bee section, sample No. Za3.

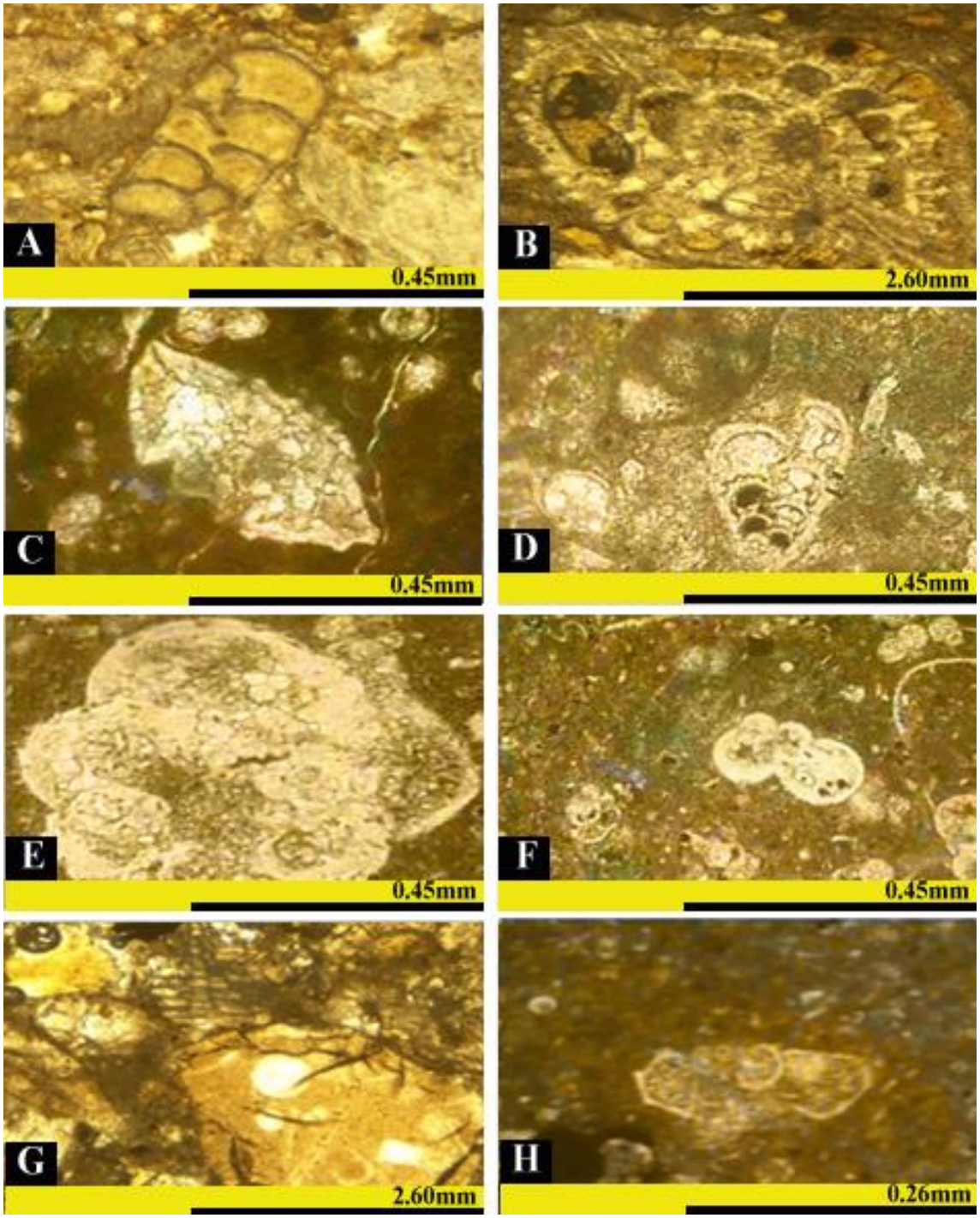
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Fig.8:

A. Bioclastic packstone-grainstone with *Bolivina incrassata,* the Aqra-Bekhme Formation, the Zarda Bee section, sample No. Z5.

B. Bioclastic packstone with *Siderolites calcitrapoides*, the Aqra-Bekhme Formation, the Mukaba section, sample No. M16.

C. Mudstone - packstone with *Globotruncana* sp., the Aqra-Bekhme Formation, the Mukaba section, sample No. M7.

D. Bioclastic mudstone with *Heterohelix*, the Aqra-Bekme Formation, the Mukaba section, sample No. M3.

E. Bioclastic mudstone-packstone with *Hedbergella* sp., the Aqra-Bekhme Formation, the Zarda Bee section, sample No. Z12.

F. Bioclastic packstone with *Rogoglobigerina*, the Aqra-Bekhme Formation, the Zarda Bee section, sample No. Z19.

G. Rodiolaria within chert fragments in packstone texture, the Aqra-Bekhme Formation, the Mukaba section, sample No. M6.

H. *Abathomphalus mayaroensis* Bolli; in planktonic mudstone to wackstone texture; the Shiranish Formation; Upper Campanian – Maastrichtian; the Bekhme Gorge section. Sample No.4

CONCLUSIONS

The facies analysis of the Aqra-Bekhme, Shiranish, Tanjero and Kolosh formations led to the recognition of four facies associations. The carbonate microfacies reflect the existence of reefal environment as indicated by the occurrence of reef and back reef facies association in the study area. However, the thickness variation in these facies succession indicate changes in the depositional conditions that were controlled by relative sea-level changes. This can be observed through the maximum and minimum thickness of reef facies association found in the Bekhme Gorge and Maukaba sections, respectively. In addition, the remarkable thickness increase in fore reef facies association at the Bekhme Gorge (115 m) compared to the Maukaba section (57 m) and Zarda Bee (15 m) sections indicates the difference in carbonate slope gradient, which is influenced by several factors such as sediment supply and slope morphology. The deep marine conditions prevailed in the study area as shown by the occurrence of thick successions of carbonate and clastic deep marine facies association of the Shiranish, Tanjero and Kolosh formations.

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