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AN INTERFINGERING OF THE UPPER CRETACEOUS ROCKS FROM CHWARTA – MAWAT REGION, NE IRAQ

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ABSTRACT

The Upper Cretaceous interfingering sequence of Chawrta – Mawat region have been described, and analyzed for their stratigraphy, and paleontology. These results are interrelated with respect to the characteristics of the depositional environment, the faunal variation and paleogeographic setting. The interfingering sequence is represented by the Tanjero Formation and Aqra Formation. This study points out a general variation trend both laterally and vertically from deep-flysch facies to reefal facies, that is from the margin of the carbonate platform to the central part of mobile trough through a transitional zone' between them. Several genera and species of macro and micro fauna are identified, from complete forms and thin sections. The giant Pelecypods (especially Rudist), gastropods with the echinoids, cephalopods, corals, brachiopods are the most common macrofossils, while the dominated large foraminifera are: *Loftusia, Omphalocyclus*, and *Orbitoides*. Micro and macro fauna testifies to the Middle and late Maastrichtian age. The *Loftusia minor – Loftuisa morgani* Zone, used as indictor for the Middle Maastrichtian age, while *Loftusia elongate – Lofusia persica* Zone, and mostly point to Late Maastrichtian. The Aqra/ Tanjero interfingering interval represents a ridge about 18 Km, in length and extends mostly NW – SE, forming a lentil body of variable thickness 0 – 225 m, within Kurdistan foreland basin. The variation from the flysch clastics is quite gradational laterally and vertically into Aqra reefal facies and most probably formed due to the presence of submerged highs within the rapidly subsiding trough basin, at the end of the Maastrichtian and termination of the paroxysmal phases of the Laramide orogeny.

التداخل الاصبعي بين طبقات الكريتاسى الأعلى فى منطقه جوارتا – ماوت، شمال شرق العراق

فاضل أحمد لاوه، أمانج ابراهيم القرداغى و خالد محمود اسماعيل

المستخلص

تتمثل طبقات الكريتاسى الأعلى فى منطقه جوارتا – ماوت بتداخل اصبعي بين تكوينى تانجرو وعقره في مقاطع سطحيه والتى تم نمذجتها ودراستها حقليا ومختبريا .اظهرت هذه الدراسه التغيرات العموديه والأفقيه للسحنات الفليشيه الى سحنات الحيديه ذلك من خلال العلاقات الطبقيه وأنواع السحنات الرسوبيه ونوعيه المتحجرات الكبيره والدقيقه منها ومدى ظهورها واختفائها والتى دلت على التغيرات فى البيئات الترسيبيه وعمق الحوض الترسيبي. ان ظهور وانتشار المتحجرات الكبيره وخصوصا الرودست وبطنيات القدم والمرجان وشوكيات الجلد وعضديات القدم وبأحجام كبيره وبمصاحبه الفورمينفيرا الكبيره ايضا (*Loftusia., Omphalocyclus*, and *Orbitoides*)، كلها اشارت الى التغير الكبير فى مستوى سطح البحر وتراجعه فى نهايه الماسترختى وحصول انقراض جماعى لمعظم انواع واجناس المتحجرات الكبيره والدقيقه على حدود االكريتاس والباليوسين. ولقد تم تحديد عمر التداخل كما يلى:

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The assemblages' zone of *Loftusia minor – Loftusia morgana*, indicate Middle Maastrichtian age, and *Loftusia elongates – Loftusia persica* zone Indicate Late Maastrichtian age.

INTRODUCTION

The Upper Cretaceous rocks of Kurdistan region (NE Iraq), are well expressed by three diagnostic facies and represented by the Shiranish Formation of open marine facies (Pre-flysch); Tanjero Formation is of flysch sediments, while the third is Aqra and Bekhma formations of reefal facies, (Bellen *et al*., 1959 and Abdel-Kareem, 1983). According to Buday (1980) the Late Cretaceous sedimentary cycle begins with a huge transgression, almost covers the whole Iraqi territories and terminated by another regression caused by the Laramide Orogeny around the Cretaceous/ Tertiary boundary. Sharland *et al*. (2001) included the studied units within the Tectonic Megasequence TMAP.9. The present work deals mainly with the facial changes from the flysch sediments to the reefal type, passing on the stratigraphic relationships between the Aqra and Tanjero formations, as well as their depositional environments at the Chwarta – Mawat area. The studied sections are located at the boundary between the Imbricated Zone and Zagros suture Zone, (Fig.1). The main structural unit in this region is represented by Azmer anticline, which is trend in the main zagros trend (NW – SE), and its carapace consist of the Early Cretaceous sequences (Fig.2). The northeastern flank of the Azmer anticline in the studied area has been intensively deformed, and occasionally sinks downward the Imbricated Zone, below the Swais Group (Paleogene-Red Bed Series) (Aziz *et al*., 2000 and Buday, 1980). This paper is based on field observations and samples collected from the interfingering intervals between Aqra and Tanjero formations, from two localities; Zarda Bee section, which is located about 13 Km, northeast of the Sulaimaniyah city, along the paved road between Sulaimaniyah and Chwarta towns (Figs.1 and 2). The second section is located along Maukaba gorge about 15 Km NE of the Chwarta town, (Figs.1 and 3).The variable deposits of Tanjero Formation are largely restricted to a deep trough-like depression, which was originated during Late Campanian – Maastrichtian times, Bellen *et al*. (1959) who also mentioned that during the widely expressed Tertiary/ Cretaceous break, the environmental controls on facies distribution were changed considerably. Al-Mehadi (1975) mentioned that reefal facies can be recognized in the upper part of Tanjero formation, in Chwarta – Mawat area. The first recorded Rudist in Aqra formation was determined by Khueen and Kummel, in 1937, then it was studied from other Cretaceous horizons by several authors since that time. Lawa (1983) studied in detail the microfacies of Aqra Formation, while Al-Ameri and Lawa (1986) proposed a Palaeoecological model for the Rudist reef for the type section of Aqra Formation. Al-Hadidi (1991) studied the macrofossils and paleoecology of Aqra limestone. Sharbazheri (2008) concluded that the boundary between the upper Cretaceous and Tertiary can be unconformable or conformable based on foraminiferal biostratigraphy. Al-Kubaysi (2008) studied microfacies and depositional environment of the Aqra Formation in Chwarta area. Sadiq (2009) also studied the microfacies of the Aqra Formation from Mawat area. Al-Dulaimai (2011) studied the Upper Cretaceous Rudist reef and associated microfossils of Aqra Formation. Lawa *et al*. (2013) clarifies the tectono-stratigraphy of the Upper Cretaceous sequences from Zagros fold thrust belts including the studied area. Al-Dulaimy and Al-Sheikhly (2015) recorded two new species of Rudist from Aqra Formation of Maastrichtian age.

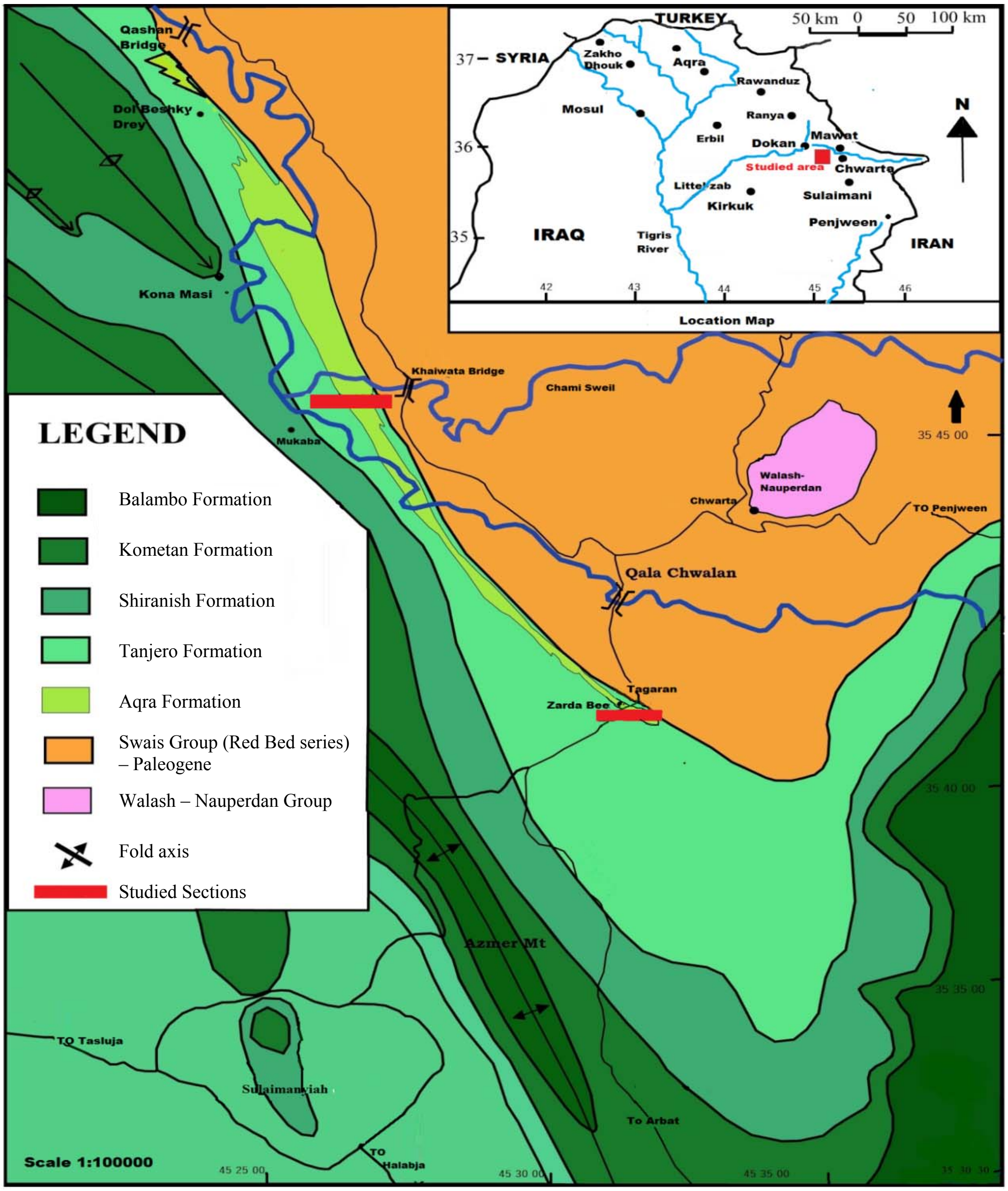

Fig.1: Geological map of the studied area, including both studied sections.
(Re-drawn after Aziz *et al*., 2000)

STRATIGRAPHY

The Cretaceous stratigraphic succession of the Azmar – Chwarta area, is as follows from top to bottom: **1)** Balambo Formation (Valanganian – Cenomanian). **2)** Kometan Formation (Turonian – L. Campanian). **3)** Shiranish Formation (U. Campanian – L. Maastrichtian). **4)** Tanjero Formation (L – M. Maastrichtian). **5)** Aqra – Tanjero interfingering (M – U. Maastrichtian), **6)** Swais Group (Paleogene), (Figs.2, 3 and 4). In the area under consideration, Aqra Formation occurs as a lentils body within (preferentially towards the top) Tanjero Formation, representing a prominent ridge about eighteen Km in length trending almost NW – SE, from nearby Zarda Bee to- Dole -Beishky Dray village (Figs.1 – 4).

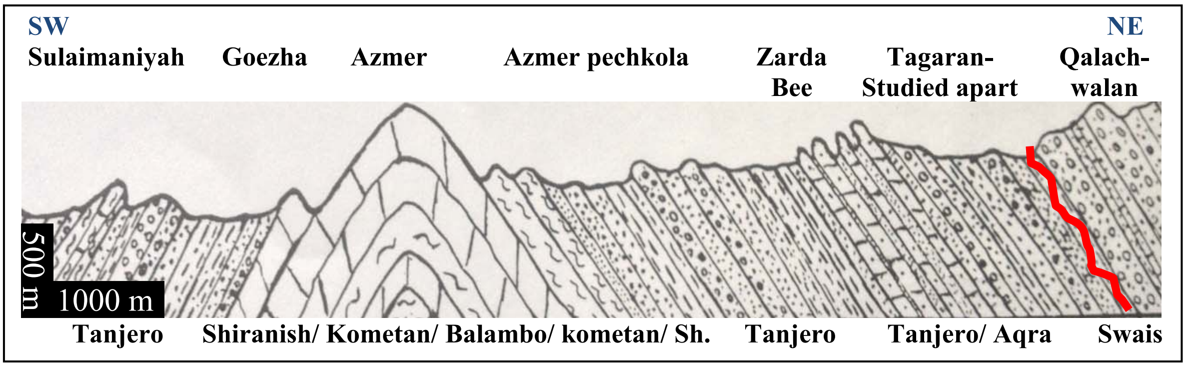

Fig.2: General geological section along Sulaimaniyah – Chwarta main road. (Oldest, Balambo fn., Kometan fn., Shiranish fn., Tanjero fn., Aqra fn., and Swais Group, Youngest)

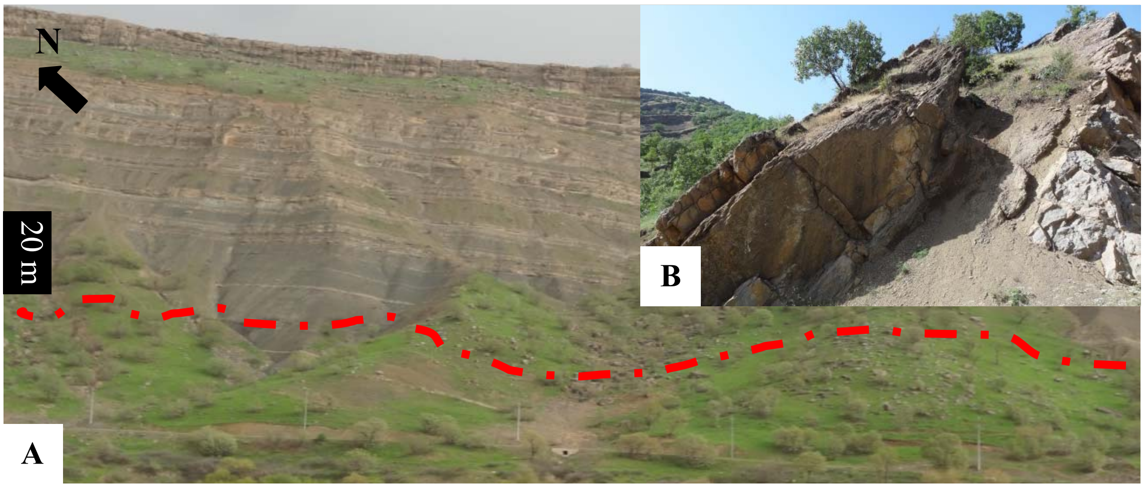

Fig.3: **A)** Transitional, gradational boundary between Tanjero and Aqra formations, Maukaba section, and **B)** Reefal carbonates predominated upwards

Fig.4: **A)** Swais Group – Continental red clastics overfills the foreland basin, **B)** Heterogeneous conglomerates with bitumen seeps within Swais Group

The lithostratigraphic changes from the flysch dominated facies of the Tanjero towards the carbonates dominated facies of the Aqra Formation almost of gradational, transitional, conformable nature, without any submarine or submarine erosional indications. Aziz *et al*.,

(2000) recorded Aqra reefal tongues in the upper part of Tanjero Formation. Stevanovitic *et al*. (2003) mapped the lenses of Aqra Formation in the studied area, and considered them as a good Aquifer. The carbonates beds in the upper part of Tanjero Formation increase both in thickness and in fossils content (especially large foraminifera and Rudist) (Figs.4 and 5).

- **Zarda – Bee Section**

In this section, the Tanjero Formation exceeds (1600 m) in thickness, underlies conformably the bluish marl of the Shiranish Formation and overlies the carbonates of Aqra Formation, which in turn overlies unconformably the molasses' sediments of the Swais Group (Figs.1 – 4). The interfingering between Tanjero and Aqra formations is about eighty five m thick, and occupies mostly the upper part of the Tanjero Formation. The Aqra Formation was originally described as a reef limestone complex with massive rudist, shoal reefs, detritus fore reef limestone, locally dolomitized, locally impregnated with bituminous material (Bellen *et al*., 1959). The studied Zarda Bee section is divided into two parts (Fig.5): The lower clastics predominated part about 41 m thick, consists of olive green siltstone, dark grey to grayish green shale interbedded with grayish-brown calcareous sandstone about (0.1 – 1.0 m) thick and occasionally pebbly, graded bedding, sole markings, *Skolithos* bioturbation and exfoliation are the most common sedimentary structures. Enormous echinoids, cephalopods, gastropods, corals, are common macrofossils and occasionally forms coquina bands. Consecutively within the clastics interval, thin organic sandy or silty limestone beds (0.1 – 0.4 m) are recognized. The upper part is characterized by alternation of thick sandstone beds and sandy limestone, about 40 m thick, and rich in giant pelecypods (*Graphyea, Glycymeris* and *Inocermaids*). They are alternated within the calcareous sandstone, siltstone and intraformational conglomerate (Fig.5). Relative to the lower part, the sandy limestone beds are thicker and reach 5 m. The pelecypods (Expect Rudist), gastropods, echinoids, brachiopods, are the most common macrofossils, while *Omphlaocyclus* spp., and *Orbitoides* spp., are present. The boundary between the Tanjero Formation and Swais Group are masked partially by Quaternary deposits. However, there are several conglomeratic deposits (multi-origin), between the Late Cretaceous and Early Paleogene indicating possibly an incised valley (Figs.5 and 6B).

- **Maukaba Section**

This section is located at Maukaba Gorge, along the intersection of Chami – Sewail with the ridge of the interfingering interval, about l Km south of Khaiwata Bridge (Figs.1 and 3). The thickness of the Tanjero Formation is about (1000 m), characterized by cyclic alternation of sandstone, siltstone, shale and marlstone, that is overlain conformably by the interfingering interval which is about one hundred and eighty m thick (Fig.5). The interfingering interval in Maukaba section can be subdivided lithologically into two main parts. The lower part (predominantly clastics), is about eighty two m thick, consisting of sandstone, shale, siltstone and occasionally conglomerate lenses, as well as, sandy detritus limestone and limestone. The gigantic rudist and enormous gastropods are frequent, in addition to the large foraminifera. The upper part of the interfingering interval is carbonate dominated sequence about ninety eight m thick, and consists of massive, fossiliferous limestone, locally dolomitized and impregnated with bitumen. The limestone beds are grey to grayish brown, tough, medium to coarse crystalline, occasionally sandy at the base of this part, mostly ridge or cliff forming (about 5 – 12 m) thick. The uppermost part of the inter-fingering interval shows decreasing of the limestone becoming more sandy. The interfingering interval overlies the Paleogene Swais Group. It's worthy to mention that the nature of the contact is slightly vague and a matter of controversy.

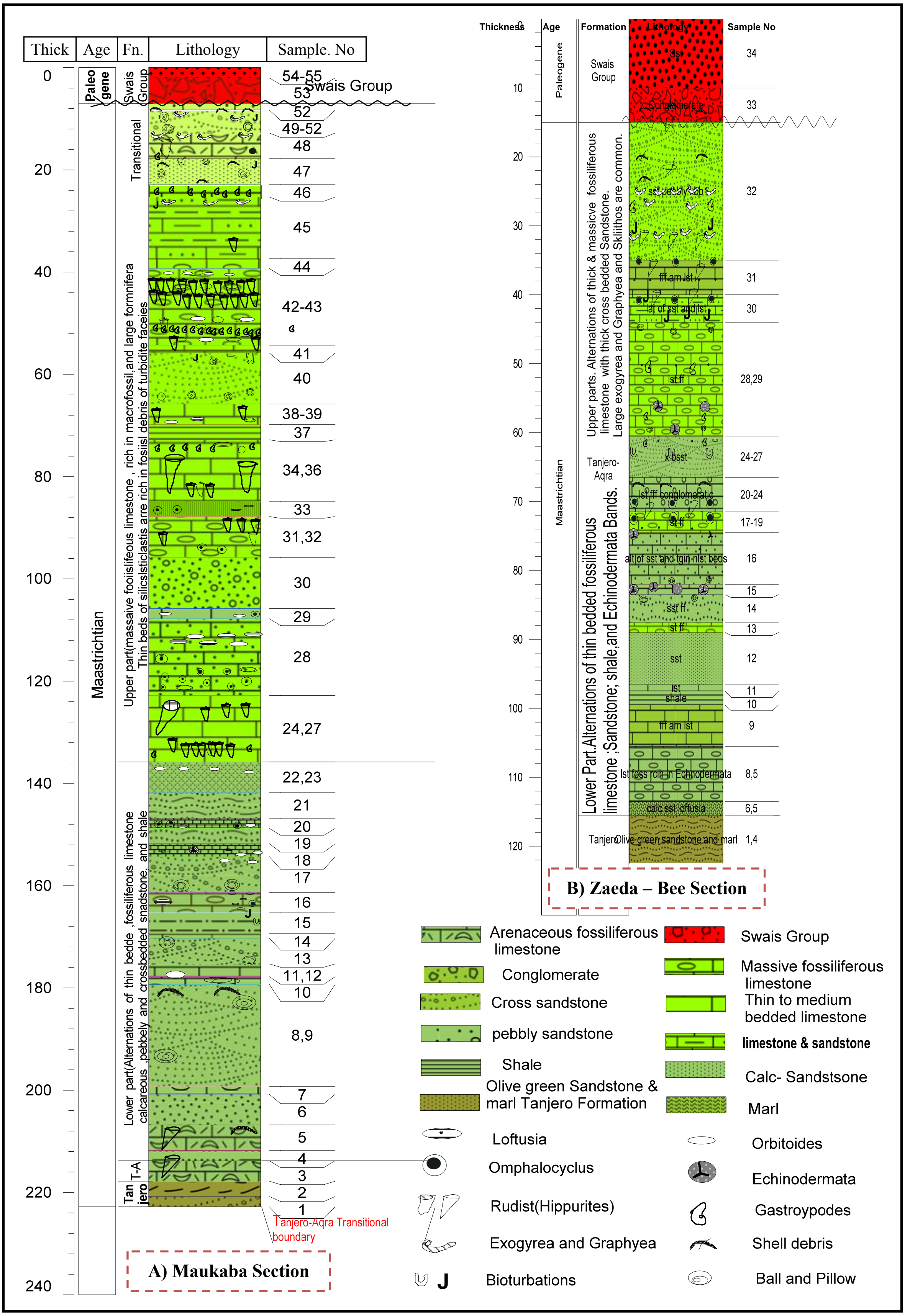

Fig.5: Stratigraphic column of, **A)** Maukaba section, **B)** Zarda Bee section

However, there is about thirty m thick sequence named as transitional zone, characterized by alternations of red clastics beds and thin detrital limestone, rich in reworked macro and microfossils (Fig.5). At Dol-beishkay Sheikh the interfingering interval reaches its maximum thickness (about 225 m), then it decreases towards the northeast, and disappears totally, at Qashan bridge, whereas Swais group unconformably overlies Tanjero Formation directly. Therefore, Aqra reefal facies forms a lentil body within the upper part of the Tanjero Formation.

▪ FOSSILS

The macro fauna present in the studied sections are very abundant, showing abnormally enormous size and extraordinary flourishment, relative to the underling and overlying lithostratigraphic units Table 1.

Table 1: Relative abundances of the dominated fossils in the studied sections

INTERFINGERING INTERVAL	ZARDA BEE SECTION		MAUKABA SECTION	
	L. PART	U. PART	L. PART	U. PART
RUDIST	R	R	C	A
OYSTER	R	A	R	C
GASTROPODS	A	A	A	A
CEPHALOPODS	A	-	R	R
ECHINOIDES	C	A	R	C
CORALS	C	R	R	C
L.FORAMINIFERA	C	A	A	A
PLK.FORAMINIFERA	R	A	A	C
R: Rare C: Common A: Abundant				

The giant pelecypods and gastropods are overall present and dominated the reefal part; nevertheless, brachiopods; echinoids, cephalopods and corals are also abundant at certain horizons (Fig.6D – M). Among them several genera of Rudist, are identified. Moreover, benthonic foraminifera, especially large forms are extremely abundant (Fig.7). The following genera and species are identified: Pelecypods: *Gervillia* sp., *Trigonia* sp., *Inoceramus* sp., *Pecton* sp., Rudist (Hippurites, Fig.6D, E, F, G and J): *Paleoiptyhus, Biradiolites*, *Barrettia*, *Durania*, *Antillocaprina*, *Eoradiolites*, *Hippurites* cf. *morgani* Douuville. Oyster: *Graphyaea vesicularis* Lamarck; *Exogyrea cancella*; *Exogyrea* spp.; *Glycemeris sp*.; Gastropods (Fig.6H): *Turbo* spp., *Clathratus Binkhort*, *Actenonella* spp.; *Turritella* spp.; *Merinea* spp., Cephalopods (Fig.6K): *Aturoidea* sp.; *Hamites* sp.; *Baculites* sp. Echinoids (Fig.6I): *Micostar* spp.; Corals (Fig.6L): *Cyclolites* spp.; Brachiopods. Large foraminifera (Fig.7A, G and L): *Loftusia elongate* Brady; *Loftusia morgani* Douville; *Loftusia persica* Brady; *Loftusia minor* Coxi; *Loftusia cox* Henson; *Omphalocyclus macroporus* (Lamarck); Omphalocyc*lus* sp., *Orbitoides media* (d' Archinc); *Orbitoides tissoti* Schlmnberger; *Lepidorbitoides socialis* (Leyrnerie), *Pseudorbitoides sp*., *Fissoelphidium operculiferm* Smout. (Fig.7H – L). Planktonic Foraminifera: *Globotruncana stuarti* (de lapparent); *Globotruncana arca* (Cushman); *Globotrunca stuartiform* Dalbiez; *Globotruncana* spp. *Pseudogumbelina* spp., *Heterohelix globosa* (Ehrenbarg); *Heterohelix striata* (Ehrenberg); *Rugoglobigerina rugosa* (Plummer). The common benthonic foraminifera are: *Bolivina incrassata* Wicher, *Bolovinoides draco*, *Gyrodina* sp., *Spiroplectammina* sp., *Quinquloculina* spp., and *Nodosaria* spp. In this work we considered that, Loftusia *minor – Loftuisa morgani* zone, as indictor of Middle Maastrichtian age, and *Loftusia elongate – Loftusia persic*a zone, as in dictator of late Maastrichtian age, for the studied sections.

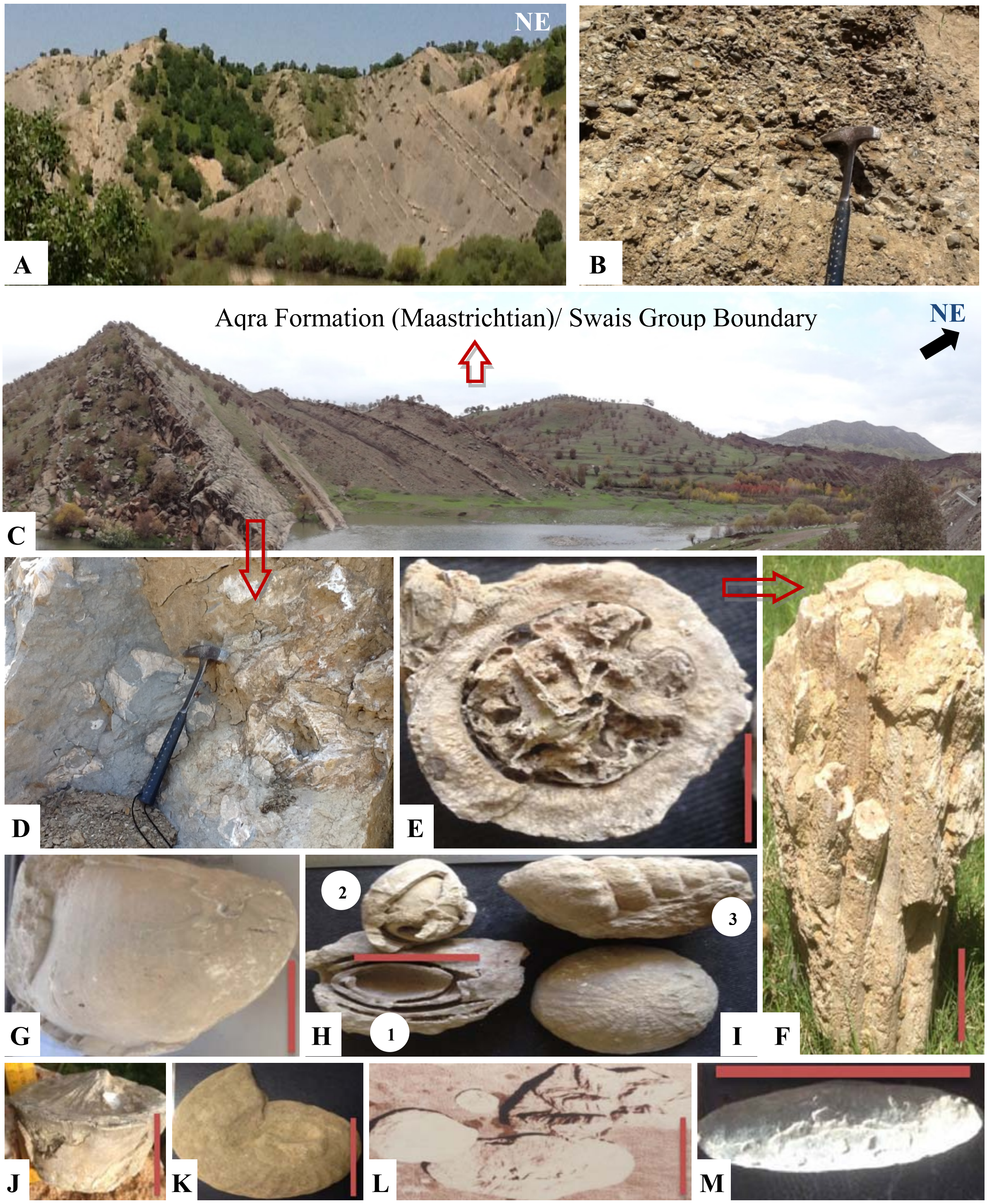

Fig.6: **A)** Lower part of Maukaba section. **B)** Conglomerate bed at the boundary between Interfingering interval and Swais Group (Zarda Bee section). **C)** Middle and upper part of Maukaba section. **D)** Reefal (Rudist) carbonates. **E** and **F)** Rudist Colony, *Eoradiolites* sp. **G)** *Durania* sp. (Rudist). **H1 and 2)** *Acteonella* spp., Maukaba section. **H3)** *Turritella* sp., **I)** Echinodermata, Zarda Bee section. **J)** *Glycemeris* sp., capped Rudist valve. **K)** *Ammonites* sp., Zarda Bee section **L)** Solitary Coral, *Cyclolite* sp., **M)** *Loftusia elongate*, Brady Maukaba section. (10 cm ▬▬)

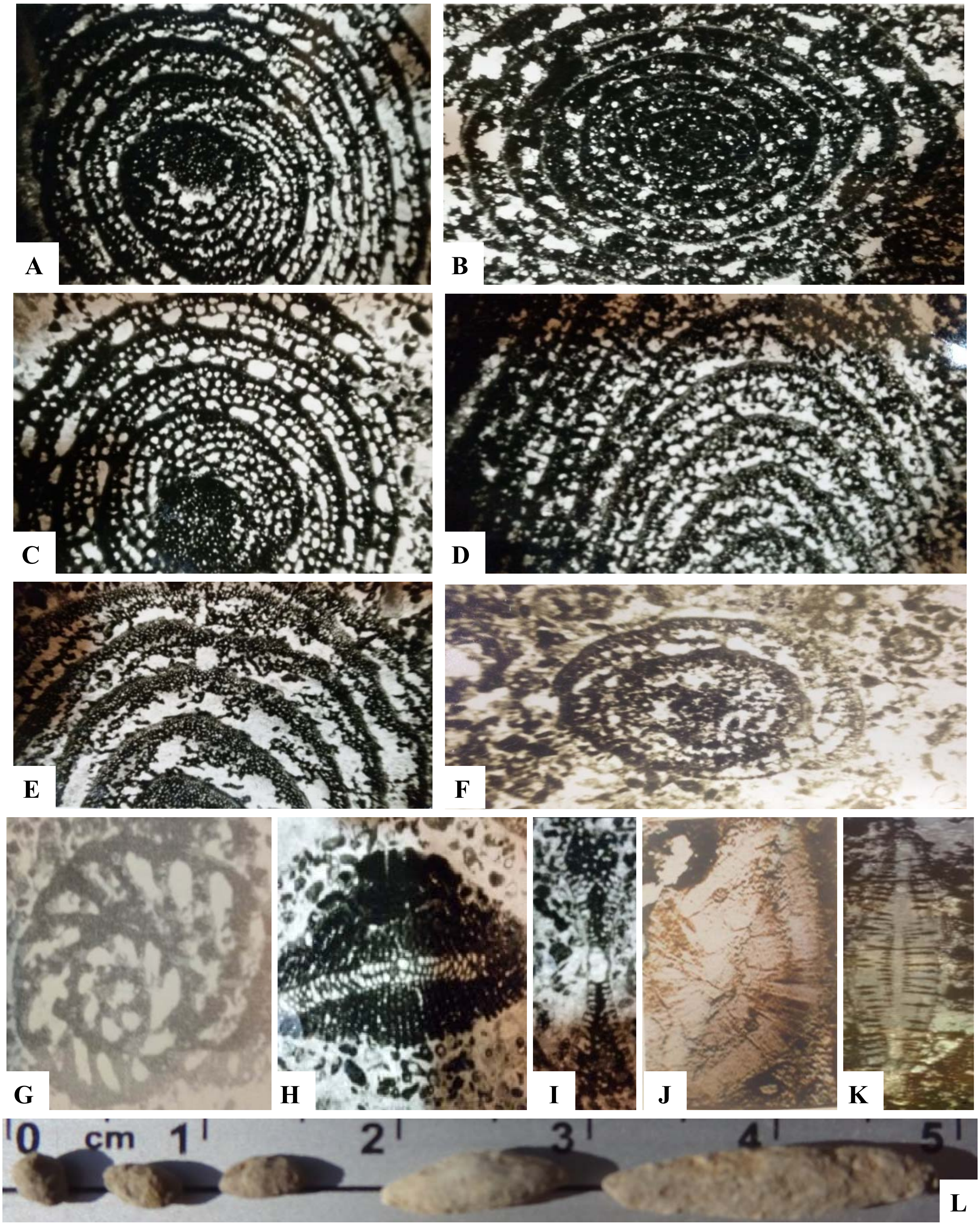

Fig.7: **A** and **B)** *Loftusia elongata* Coxi, equatorial view, X10. **C** and **D)** *Loftusia persica* Brady, equatorial and longitudinal view, X10. **E)** *Loftusia morgani* Douville, longitudinal view, X10. **F)** *Loftusia minor* Cox, equatorial view, X10. **G)** *Loftusia coxi* Henson, equatorial view, X10. **H)** *Orbiotoides media* (d' Archinc), X25. **I)** *Omphalocyclus macroporus* (Lamarck), X25. **J)** *Fissoelphidium operculiferm* Smout, X40. **K)** *Lepidorbitoides socialis* (Leymerie), X20. **L)** Complete form of *Lofusia minor*, *L. Coxi*, *L. morgani*, *L. elongate*, and *L. Persica* (all Figures from Maukaba section)

DEPOSITIONAL ENVIRONMENTS

The Tanjero Formation represents flysch sediment of deep; mobile rapidly sinking, trough trending NW – SE. Buday (1980); Abdel-Kireem (1986), and as deposits of Kurdistan foreland basin by Lawa *et al*. (2013). However, in the both studied sections and especially Maukaba, the thickness of the Tanjero Formation is relatively less than that of the type area, as well as other localities, which might reflect less subsidence of the trough, progressively replaced by Aqra reef facies. The marker beds (such as: Echinoids Band, Rudist Reef, and Large Foraminiferal Bands) are also consistent with the major facies changes, mostly indicates that both lithological changes and biostratigraphic markers are synchronous within the limestone successions of studied area. This may be a valuable tool for stratigraphic correlation across Kurdistan foreland basin, especially towards Aqra – Zakho Ranya ridge or towards Iranian border.

- **Zarda Bee Section**

The lower part of the interfingering interval is represented by the cyclical alternations of the sandstone, marl and argillaceous limestone. The planktonic foraminifera floated at the shallowest water depth of any Cretaceous planktonic genera. The benthonic foraminiferal assemblages (*Bolivina* spp., *Bolivinoides* spp., *Spiroplectammina* spp.) mostly reflect the outer shelf water depth. The recorded macro fauna from the upper parts (Cephalopods, Gastropods, Brachiopods and Pelecypods) indicates mostly sea bottom oscillation towards shelf water depth. The predominance of the organic detritus limestone, rich in heavy shelled *Graphyea* spp., *and Exogyrea* spp., are soft bottom dwellers close from basin shoreline. The planktonic foraminiferal assemblage shows diagnostic decreases both in genera and specimens. While benthonic foraminiferal assemblages are prevalent especially large type (*Loftusia* spp., *Omphlocyclus* spp., and *Orbitoides* spp.). The uppermost part of this section intercalated with red clastics influx and point to sub tidal sand channels that contorted and highly bioturbated by vertical *Skolithos* burrows, before the last major phase of the Late Cretaceous regression. The agglutinated *Loftusia* species are tolerate inhabited sandy substrates and they are deposit-feeder, usually built their shells from sand grains and small foraminiferal tests, mostly within shallow open reefal marine conditions.

- **Maukaba section**

The variation from clastics turbidites facies to reefal carbonates facies. The reefal framework is built of different variety of Hippurites (such as, *Durania*; *Hippurites*; *Barrettia*; *Plagesoptychus*), in addition to Gastropods (*Acteonella* spp.; *Turbo*), echinoids and subsidiary amount of corals. The faunal association point to water depth that doesn't exceed 50 m and almost forms carbonate island within a mobile and shallowing upward trough, (Figs.6 and 7).The decreasing of the planktonic/ benthonic foraminifera ratio, from Middle to Late Maastrichtian, is mostly associated by predominance of the large foraminifera. The evolution of the *Loftusia* from less than one millimeter in length to more than 120 mm (Figs.6M and 7L), possibly points to the shallowing upward successions. Simon *et al*. (2004) recognized the smaller rudist belonging to the genera *Bournonia* and *Biradiolites*, occurs in both the transgressive and highstand systems tracts. In the studied section site, it looks that they are mostly accumulated and flourished during the highstand system tract and relatively quiet tectonic conditions forming patchy reef bodies. Overall, the facial and fossil changes are penecontempornaceous with the turn over from under fill to over fill conditions in the foreland basin at the Cretaceous/ Tertiary boundary.

CONCLUSIONS

- The interfingering sequence between the Tanjero and Aqra formations in Chwarata – Mawat area within the imbricated zone consists a ridge about 18 Km in length and trends almost NW – SE, possibly represents the continuation of the Zakho – Aqra – Rawanduz – Ranya ridge of Aqra Formation.
- The Aqra reefal facies relatively represent a time of quiescence and shallowing within a mobile trough, whereas the flysch facies of the Tanjero Formation, represent the unstable and evolution stage of the Kurdistan foreland basin.
- The lower contacts of the Aqra Formation is quite gradational with the Tanjero Formation but its controversy and vagueness in upper contact with the Swais Group (Paleogene) indicate almost a major Cretaceous/ Tertiary boundary gap.
- Based on the large foraminiferal assemblages, the age of the interfingering interval is considered as Middle to Late Maastrichtian. The *Loftusia minor – Loftusia morgana* zone, is considered as age indicators for the Middle Maastrichtian, while *Loftusia elongate – Loftusia morgani* zone, as index for the Late Maastrichtian aged strata.
- The whole interfingering successions between Aqra and Tanjero formations in the studied area, almost point to the last regressive pulse in the Kurdistan Foreland basin, during Late Cretaceous.
- Both lithological changes and biostratigraphic markers are synchronous within the limestone successions of the studied area. This may be a valuable tool for stratigraphic correlation elsewhere in the uppermost part of the Cretaceous.

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