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Microfacies analysis and Paleoenvironment Interpretation of Upper Oligocene Azkand Formation in Western Iraq

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Abstract

This paper deals with the microfacies and paleoenvironment interpretation of the Azkand Formation at the high Euphrates river cliffs in north-western Iraq. In this study, the main components are dominated by the coexistence of large benthic hyaline perforated walls (Nummulitidae, Lepidocyclinidae, Amphisteginidae, Miogypsinidae, and Rotaliidae) and porcelaneous imperforate walls (Miliolidae, Peneroplidae, and Alveolinidae) with minor components of small benthic foraminifera. Other fossils are dominated by coralline algae, corals, bryozoans, mollusks, and shell fragments. These microbiota are considered beneficial in the biofacies analysis and recognition of paleoecology. On the basis of large benthic foraminiferal assemblages and microfacies features, eleven microfacies types have been recognized and interrelated. They indicate two depositional environments interpreted as shallow inner- to middle- ramp environments. The shallowest part in the studied section occurs in the photic zone which is characterized by the association of miliolids, peneroplids, and alveolinids. The middle ramp is classified into two shallow middle ramps characterized by dominant miogypsinis amphisteginids, and rotaliids, while the deeper middle-ramp setting is dominated by coralline algae along with nummulitids and lepidocyclinids.

Keywords: Azkand Formation, benthic foraminifera, paleoenvironment, ramp.

1. Introduction

The Azkand Formation represents the upper division of Kirkuk Group of the Iraqi Oligocene outcrop to north Iraq. Bellen, 1956 (in Bellen et al 1959) described the type section of Azkand Formation from the outcrops of Azkand cirque, three miles N-65°-E of the village of Azkand on the southern dome of the Qarah Chauq Dagh structure. The thickness of the formation is variable from one area to another. At the type area, it consists of 104m (Buday, 1980). Lithologically, it consists mainly of massive, dolomitic, and recrystallized limestone. The abundance of Heterostegina cf. assilinoides indicates a Late Oligocene age. The study area represents a fore slope facies of a marine platform (fore-reef) facies (Bellen et al., 1959). The outcrops are limited to Anah anticline, Muger Al-Dheeb vicinity and Wadi Houran (Sissakian, and Mohammed, 2007). In all other areas, they are exposed as small patches only in deep cut valleys, particularly speaking in wadi Khazgah Al-Sharje northwest of Anah town in western Iraq (Al-Twaijri, 2000).

The objective of this research is to interpret the depositional environments of the Azkand Formation in western Iraq, based upon the microfacies and faunal contents.

2. Geological Setting

The study area is located within the western desert of the upper Oligocene carbonate platform that developed along the southern Hadetha vicinity. Tectonically, it is represented as part of the stable shelf of the Arabian platform, which is characterized by the presence of block tectonics and the absence of tectonic folds (Buday and Jassim, 1987). The rocks of Oligocene in the Iraqi western desert have very limited extensions in the stable shelf either as outcrops or subsurface, located mainly within the Mesopotamian and low folded zones of the unstable shelf (Jassim and Karim, 1984). No Oligocene rocks are exposed in the southern desert due to the uplifting of the Salman zone and the Euphrates and Zubair subzones of the Mesopotamian zone in the Oligocene time (Jassim and Goff, 2006).

3. Study Area and Methods

This study is based on one outcrop section measured and sampled in the area located ten kilometers to the south of Hadetha Town, at the right bank of the Euphrates river Figure (1). A total of seventeen samples were collected and studied, more than thirty-five thin-sections were prepared and examined in the laboratory. In addition, two samples were taken directly above the boundary from the basal conglomerates for comparison, and the outcrops were sampled at one- meter intervals (Figure 2).

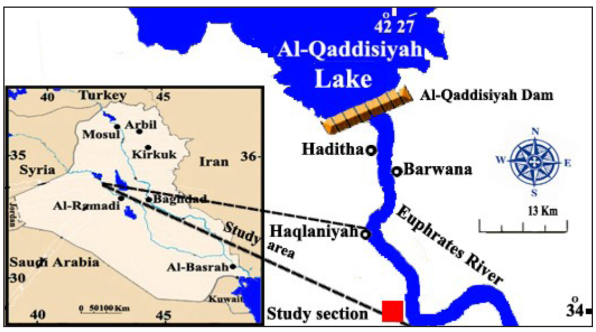

Figure 1. Location map of the study area.

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The lower contact of the Azkand Formation is unexposed, but covered by fluvial recent deposits, while the upper contact is always unconformable and is marked by a significant Savian break on the Oligocene/Miocene boundary, which is marked by basal conglomerates of the lower unit of the Euphrates Formation (Al-Ghreri et al., 2013).

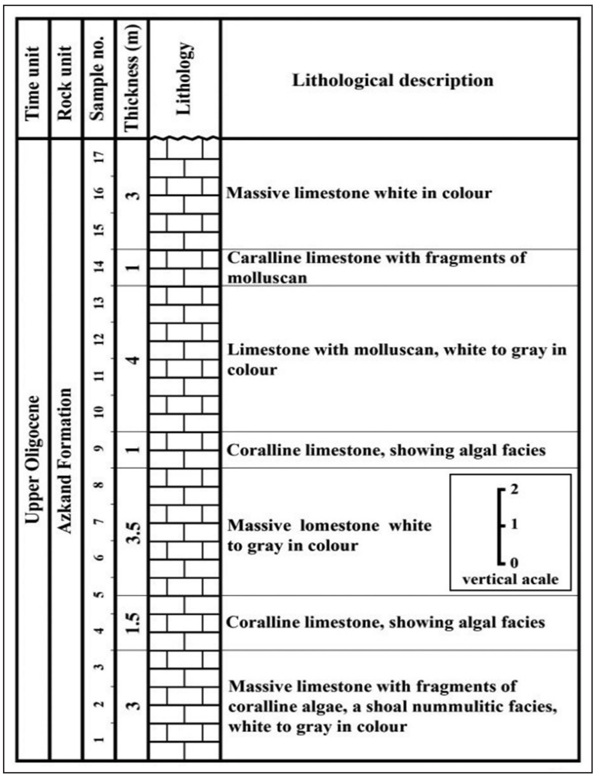

Figure 2. Lithological section of Azkand Formation in the study area.

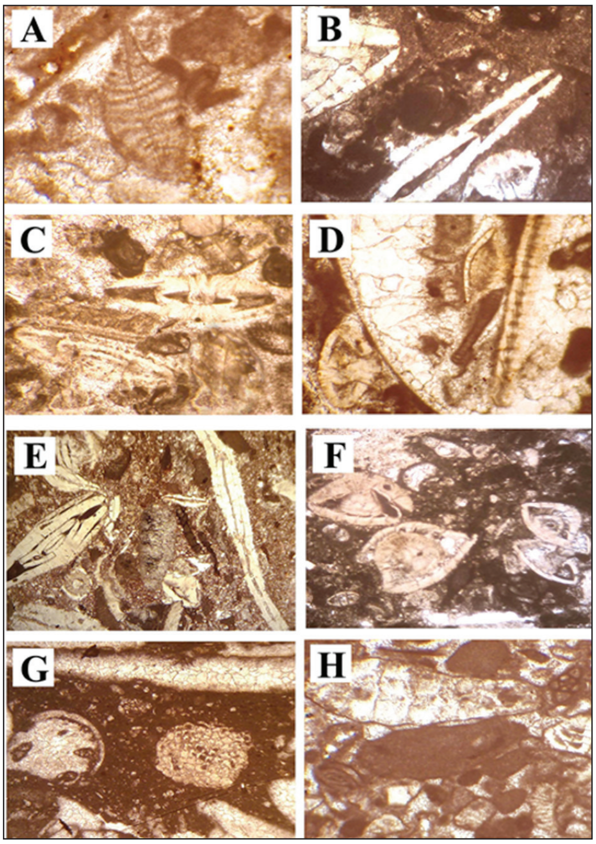

Figure 3. Microfacies types (MF) which recognized in the Azkand Formation:
A-MF1: Lepidocyclina nummulitidae wacke/packstone X25.
B, C-MF2: Nummulitidae wackestone to packstone. X25.
D, E-MF3: Heterostegina packstone, X30.
F-MF4: Amphistegina grainstone, X50.
G, H-MF5: Miogypsina corallinacean wackestone to packstone, X50.

4. Microfacies Analysis and Depositional Environments

Eleven different microfacies types could be distinguished in the Oligocene Azkand Formation by thin-section studies of the composition and structure which are described and illustrated here together with their environmental interpretation (Figures 3 and 4).

4.1 Microfacies 1: Lepidocyclina Nummulitidae wacke/ Packstone (MF1)(Figure 3-A)

Description: The major components of this microfacies are the small and ovate tests of the large benthic foraminifera, namely (Lepidocyclina spp., Rotaliaviennoti and Amphistegina sp.) with textures ranging from wackestone to packstone. Other biocontents include fragments of coralline red algae, bryozoans, and echinoids plate. They are one-meter thick and dominate the lower part of the studied section.

Interpretation: The presence of large benthic foraminifera (Lepidocyclina spp. and Rotalia sp.) indicates full marine environments within the euphotic zone, because symbiotic-bearing foraminifera are restricted to the euphotic zone, below the wave base (Corda and Brandano, 2003; Bassi et al., 2007; Hottinger, 1997; Romero et al., 2002).

The occurrence of the perforated foraminifera such as Lepidocyclinidae and Nummulitidae reflects deposition in the lower part of photic zone at the distal middle ramp (Hottinger, 1983).

4.2 Microfacies 2: Nummulitidae Wacke/Packstone (MF2) (Figures 3 B-C)

Description: This micrfacies consists of large and flat perforate foraminifera represented by the individuals of nummulitids such as (Nummulites sp., Operculina complanata and Heterostegina assilinoides) among the most common genera representing more than 60 %; they include Rotalia sp., miliolids sp., bryozoans, and fragments of red algae were presents. They dominate the lower part of the Azkand Formation.

Interpretation: The presence of large flat perforated tests (Nummulites sp., Operculina sp. and Heterostegina sp.) with coralline algae indicates deposition near a fair-water wave base on a proximal middle shelf (Corda and Brandano, 2003; Cosovic et al., 2004). Members of the genus Operculina only live in the warm waters of normal marine salinity, and show relatively high ecological tolerances compared to other biota (Langer and Hottinger, 2000). Operculina spp. are dominant foraminifera on deep reef fronts and inter-reef channels in Indonesia (Remena, 2006). They were also common in main reef, back-reef, patch reef, intra-reef, and deeper off-reef facies similar to those of the modern Indo-Pacific (Bosellini, 2006).

According to Hallock and Glenn (1986), the porcelaneous tests (mainly Heterostegina sp. and Amphistegina sp.) live in a tropical-subtropical environment over a wide bathymetric range, but are particularly frequent between depths of 40 and 70 m. Furthermore, they are most abundant in the mesophotic and oligophotic zones of subtropical seas, but thrive in tropical environments (Hottinger, 1983, 1997; Reiss and Hottinger, 1984). Such assemblage indicates that these deposits were formed in the distal part of the middle ramp well below the fair-weather wave base since there are no signs of wave hydraulic turbulence in these microfacies (Moghaddam et al., 2011).

4.3 Microfacies 3: Heterostegina Packstone (MF3) (Figures 3 D-E)

Description: This facies is composed of bioclasts of perforated foraminifera characterized by relatively diverse assemblage of Nummulitids such as (Heterostegina assilinoides, Heterostegina involuta, operculina sp., and Nummulites sp.,), with fragments of small foraminifera which are distributed irregularly among the large foraminifera. Coralline algae are also present. This microfacies is most prominent in the lower parts of the Azkand Formation, attaining a thickness of 1 m.

Interpretation: The presence of high diverse large perforated foraminifera nummulitids such as Heterostegina spp. and operculina sp., indicates deposition in the distal part of the middle ramp well below the fair-weather wave base (Beavinton and Racey, 2004). Nummulitidae protect themselves from ultraviolet light by producing very thick lamellated test walls or by occurring in relatively deeper waters. (Rasser et al., 2005).

The Oligocene nummulitid facies consists of Heterostegina, Operculina, Nummulites, and Spiroclypeus occuring in the middle-ramp deposits of the circum-Alpine area, northern Slovenia, and Malta (Nebelsick et al., 2005). Larger benthic foraminifers (Heterostegina, Amphistegina, Asterigerina) and calcareous red algae are the main components in the deeper ramp facies (Brandano et al., 2009). In general, Operculina, inhabit shallow-water soft substrates under the influence of a mixed siliciclastic carbonate environment (Reiss and Hottinger, 1984); whereas, Heterostegina occurs abundantly in calm-water environments being protected at shallow depths or in deeper parts of the sea down to 85 m (Geel, 2000). In the Oligo-Miocene, Heterostegina inhabited high energy forereef environments (BouDagher-Fadel and Wilson, 2000), of 20–30 m depth (Banner and Hodgkinson, 1991).

4. 4 Microfacies 4: Amphistegina Grainstone (MF4) (Figure 3-F)

Description: The main components of this facies are Amphistegina sp., Rotalia sp. and Heterostegina sp. with some minor components which include fragments of mollusca, echinoids plate and coralline algae fragments. This microfacies is dominant in the upper part of the Azkand Formation of (1) meter thick.

Interpretation: The interpretation of this microfacies is based on the abundance of large benthic perforates wall such as Amphistegina sp., Operculina sp.Rotalia sp. and Miogypsina sp. The association indicates shallow water environments photic zone of high-energy condition. The occurrence of Amphistegina sp. and Heterostegina sp. Indicate warm marine water with low to medium energy in photic zone and in the long range of depths between 40 and 70 m (Hallock and Gleen, 1986). Hallock et al. (1986) found in the study of the influence of environments on the test shape of Amphistegina sp. that the test shape varies with depth; they are robust and spherical in shallow environments, and thinner and flatter as depth increases. Finally, the dominant benthic foraminiferal genus is Amphistegina, which is considered a shallow water genus (McDougall et al., 1999).

4.5 Microfacies 5: Miogypsina corallinacean wacke/ packstone (MF5) (Figures 3 G-H)

Description: Miogypsinidae, coralline and Rotalids fragments are the dominant bioclasts with minor skeletal grains of echinoids plates and of mollusk red algae fragments. The depositional textures reflect poorly sorted wackestone; some other grains have been partially micritized. This microfacies dominates the upper part of the Azkand Formation with a thickness of 1 m.

Interpretation: This facies is dominated by a high diversity of benthic foraminifera mainly Miogypsinidae which are dominant in the lagoon and shallow subtidal depositional environments of the upper Oligocene-lower Miocene limestones (Flügel, 2004). This biota can contribute to coral-reef frameworks by successfully competing with coralline algae for space on hard substrates (Barattolo et al., 2007). Moreover, the abundance of Miogypsina spp. in rhodoliths decreases substantially with the increase of depth from 20 to 70 m (Minnery, 1990).

The occurrence of perforated-walled foraminifera such as Miogypsinidae with coralline red algae fragments, indicates deposition in the moderate to high-energy environment of an upper part of a carbonate shelf slope, at less than 50m of depth and in waters of normal salinity (Geel, 2000).

4.6 Microfacies 6: Coral Boundstone (MF6) (Figures 4 A-B)

Description: Coral has a wide distribution in the Azkand Formation, represented by two beds, at the middle and upper parts, usually capping most of the top section, with each bed ranging in thickness between 1 m and 1.5 m. It was formed by the growth of coral networks. The framework of this microfacies comprises in situ and unbroken coral. This is the most abundant type in the studied section, representing more than 50 %, and is composed mainly of corals. The associated fauna includes large benthic foraminifera such as miliolids and various types of calcareous coralline algae such as (Lithophyllum sp. and Lithothamnium sp.) echinoderms debris; rotaliida can rarely be seen.

Interpretation: Miliolids are common components in this facies indicating shallow-water, and low-energy environments in many modern and ancient examples of carbonate platforms (Reiss and Hottinger, 1984). Also, this facies is formed in patch reefs and represents the mid-ramp environment (Buxton and Bedley, 1989). According to Wilson (1975), and expanded by Flügel (2004), the allochems of this facies must have been derived from the reef.

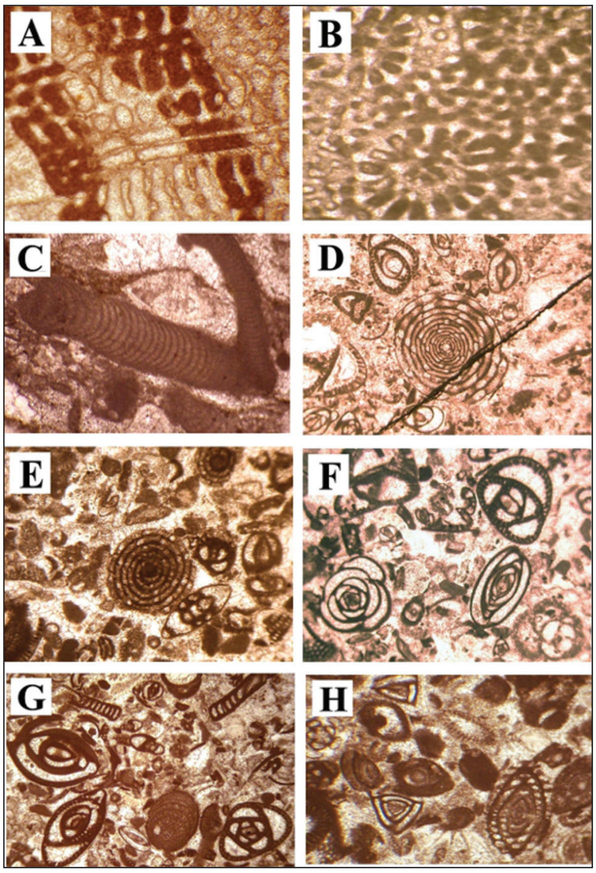

Figure 4. Microfacies types (MF) which recognized in theAzkand Formation:
A, B-MF6: Coral (boundstone) X25.
C-MF7: Articulated Coralline algae grainstone X 25.
D, E-MF8: Alveolinids miliolids packstone- grainstone X60.
F-MF9: Miliolids packstone – grainstone X 60.
G-MF10: Miliolids peneroplids grainstone X 60.
H-MF11: imperforate foraminifera packstone-grainstone X40.

4.7 Microfacies 7: Coralline algae grainstone (MF7) (Figure 4 C)

Description: in the Coralline Algae Grainstone, the articulated coralline algae are the most abundant constituents. Lithothamnion sp. and Mesophyllum sp. are the most conspicuous algae and Jania is rare. Large and small benthic foraminifera Amphistegina sp., Heterostegina sp., and bryozoans, echinoid and molluscan fragments are present. Small rhodoliths (Sporolithon sp., and Lithophyllum sp.) are locally common; they rarely include encrusting foraminifera such as Miogypsina. Sparry calcite is common.

Interpretation: Firstly, coralline red algae are used as a potential tool for paleoecology, paleoenvironment and paleobathymetry, builder of porous and permeable carbonate reservoir rocks for hydrocarbon and reefs rich in hydrocarbon (Kundal, 2011). Geographical ranges are controlled by water temperature, depth ranges, and light intensity (Johansen, 1981).

As for the abovementioned factors, this facies is widely distributed in tropical to polar normal marine waters, from intertidal depths to the base of the photic zone (Wray, 1977), at the depths of 20-80 m, but could be also present at the depths of 80-160 m depth (Flügel, 2004).

Articulated branching coralline algae are characterized by the dominance of crustose coralline thalli composed primarily of melobesioids (Lithothamnion sp. and Mesophyllum sp.), both genera grow most profusely in well-illuminated waters usually attached to hard substrates in low-energy conditions at depths of more than 50 m (Kishore et al., 2006). They are restricted to environments that are deeper inner- to mid-ramp ranging from 40 to 80 m depths at the upper photic zone (Misra et al., 2006). Similar associations have been recorded by Pomar et al. (2004) in the slope and outer ramp. In addition, to the Lithothamnion-dominated association typical for shallow warm-temperates to tropical environments, there is an association dominated by Mesophyllum characteristic of the lower photic zone in warm-temperate to tropical environments (Kroeger et al., 2006). Moreover, the occurrence of coralline algae with perforated walls such as (Amphistegina, Heterostegina) indicates that this facies was formed in the photic zone (Brandano et al., 2008).

4.8 Microfacies 8: Alveolinids miliolids packstone grainstone (MF8) (Figures 4 D-E)

Description: The main components of this microfacies are imperforated benthic foraminifera, namely alveolinids and miliolids, with less abundant of peneroplids. All other components are subordinate and are distributed irregularly among the facies. Some fragmentation of coralline algae, bivalves, and gastropods are present. This microfacies is observed in the lower part of the Azkand Formation with a thickness of 1.5 m.

Interpretation: This facies is characterized by abundant imperforate benthic foraminifera mainly Alveolinidae (Borelismelo spp.), miliolids such as (Austrotrillina howchin, Quinqueloculina sp.), and peneroplids (Peneroplis evolutus). Alveolinids are important faunal contributors to open-water sediments of the inner platform in shallow water or possibly hypersaline (Hottinger, 1997). According to (Murray, 1973) alveolinids, peneroplids, and miliolids are common in lagoons, shallow-water, and other quiet environments and are generally miliolids capable of tolerating higher salinities than other biota. However, all of this biota are very common in reef to backreef environments at normal marine salinities (Brasier, 1975; Hallock, 1984a; Reiss and Hottinger, 1984).

The occurrence of a large number of porcelaneous foraminifera suggests that the deposition took place in a shelf-lagoon setting, with very limited circulation and relatively hypersaline environments (Romero et al., 2002). A similar microfacies was reported from the shelf-lagoon environment of Asmari Formation, Iran (Brandano et al. 2008; Sadeghi et al. 2009; Vaziri-Moghaddam et al., 2006).

4.9 Microfacies 9: Miliolids packstone – grainstone (MF9) (Figure 4 F)

Description: This microfacies consists of predominant imperforate-walled foraminifera that include miliolids (Austrotrillina howchini, Austrotrillina sp., Spiroloculina sp., Quinqueloculina sp., and Triloculina sp.), with small miliolids, fragments of coralline red algae. Echinoid are present with debris of mollusks. The miliolids particles are heavily micritized, especially on their outer borders, and the spaces between grains are filled with sprite or micrite.

Interpretation: Porcelaneous foraminifera are regarded as the major components of this microfacies reported from open and restricted platform conditions (Hallok and Glenn, 1986). Miliolids are commonly present in back-reef-lagoon environments and the sheltered areas on the reef banks (Ghosh, 2002). The occurrence of porcelaneous such as miliolids (Austrotrillina spp.) preferentially live in waters of low turbulence, where abundant fine sediments occur and are characteristic of restricted lagoonal and/or relatively nutrient-rich back reef environments. (Brandano et al., 2008) and (Allahkarampour Dill et al., 2010) believed that the prevalence of porcelaneous foraminifera strongly suggests deposition in a protected inner-shelf lagoon- environment.

In general, the occurrence of imperforate foraminifera mainly Quinqueloculina sp. and Triloculina sp. indicates that deposition took place in a restricted shelf lagoon environment. Furthermore, whole porcelaneous foraminifera often dominate near-shore environments in water depths of less than 50 m, and can live in environments with extreme temperatures and salinity (Murray, 1973; Flügel, 2004).

4.10 Microfacies 10: Miliolidspeneroplids grainstone (MF10) (Figure 4-G)

Description: The main components of this microfacies are large benthic imperforate foraminifera, characterized by a relatively diverse assemblage of imperforate walls; examples include (Austrotrillina howchini, Austrotrillina, asmariensis, Peneroplis evolutus, Quinqueloculina, Dendritina, and Spirolina, in addition to coralline algae (Lithophyllum sp.), echinoderm plates and bryozoan fragments. This microfacies dominates the lower-middle parts of the Azkand Formation attaining a thickness of 2 m.

Interpretation: Generally, porcelaneous foraminifera are abundant where $CaCO_3$ availability is high and the water is warm and hypersaline (Ghosh, 2002). In this facies, the coexistence of foraminifera with porcelaneous walls such as (miliolids and peneroplids), indicates environments with very limited circulation and relatively hypersaline conditions (Amirshahkarami et al, 2007; Hallock and Glenn, 1986). Moreover, the larger porcelaneous foraminifera (such as Peneroplis and Archaias), hosting dinoflagellate, rhodophycean and chlorophycean endosymbionts dominate the upper photic zone (Romero et al., 2002).

The association of the large number of porcelaneous imperforate foraminiferal tests such as Austrotrillina, Peneroplis, Dendritina, and other miliolids, indicates that this assemblage is described in association with the inner-ramp environment (Brandano et al., 2008; Flügel, 1982, 2004; Vaziri-Moghaddam et al., 2006; Wilson, 1975).

4.11 Microfacies 11: Imperforate foraminifera packstone-grainstone (MF11) (Fig.4-H)

Description: The main components of this microfacies are larger benthic foraminifera with imperforate walls, such as Triloculina tricarinata, Triloculina trigonula, Archaias hensoni, Dendritina rangi, Austrotrillina howchini, Quinqueloculina sp., Peneroplis and miliolids. Coralline algae, corals, bryozoans; molluscan shells' fragments are also present. The minor components are small benthic foraminifera. This microfacies dominates the lower-middle parts of the Azkand Formation with a thickness of 2 m.

Interpretation: Large foraminifers with imperforate walls dominate the near-shore environments at water depths between 0 and 50m, and can live in environments with extreme temperatures and salinity (Murray, 1991; Flügel, 2004). Miliolids often dominate the modern reefs in normal oceanic salinities in addition to metahaline environments such as Shark Bay, Western Australia (Hallock and Glenn, 1985; James et al., 1999).

Porcelaneous foraminifera such as miliolids (Triloculina spp. and Quinqueloculina spp.) are common throughout the Azkand Formation. Triloculina spp. are often found in association with Quinqueloculina spp. in the Mediterranean Sea, the Caribbean Sea, and Western Australia (Murray, 1991). Benthic foraminifera such as Quinqueloculina spp. generally live on protected sedimentary subenvironments, and are commonly associated with sea grass beds and sandy and muddy substrates in waters at depths of less than 12 m (Murray, 1973, 1991; Betzler et al., 1997). They also live on reefal sediments and are among the most abundant foraminifera on the modern Great Barrier Reef, Australia (Uthicke et al., 2010). Furthermore, porcelaneous foraminifera mainly (Peneroplis and Archaias) live in recent tropical and subtropical shallow-water environments, hosting dinoflagellate, rhodophycean and chlorophycean endosymbionts (Lee, 1990). Due to the presence of epiphytic foraminifera, this microfacies could have originated in sea-grass-dominated environments (Brandano et al., 2008).

5. Microfacies Association and Depositional Model

The distribution of larger benthic foraminiferal assemblages are excellent indicators used as valuable tools to reconstruct palaeoenvironmental models in warm, shallow marine environments, especially in monotonous carbonate platform successions (Geel, 2000). In this study, two main environmental gradients can be identified in the Azkand formation. These include inner-ramp and middle-ramp environments. A general depositional scheme is provided in (Figure 5).

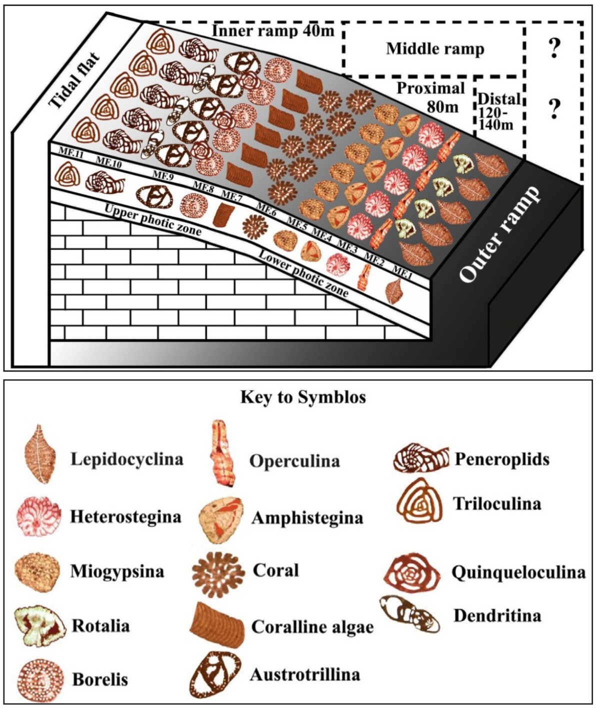

Figure 5. Depositional model for the carbonate platform of the Azkand Formation.

5.1 Inner- Ramp Environments

The most common microfacies of the inner ramp environment is the imperforate foraminifera types such as Peneroplis sp., Austrotrillina sp., Dendritina sp., Archaias sp., Borelis sp., Meandropsina sp., and miliolids. Other components include coralline algea and coral fragments dominating the restricted shallow sub-tidal environments or restricted lagoon environments (Hallock and Glenn, 1986; Geel 2000; Romero, 2006).

The occurrence of the large porcellaneous foraminifera type such as Archaias sp., Peneroplis sp., Borelis sp. Meandropsina sp. Dendritina sp. and miliolids indicates tropical and subtropical shallow-water environments (Lee, 1990), in the upper part of the upper photic zone (Brandano et al., 2008). The common association of coralline algea and coral fragments with miliolids and Austrotrillina sp. indicates the very shallow water at upper part of the upper photic zone in the inner-ramp environment.

5.2 Middle- RampEnvironment

This setting is represented by an assemblage of larger perforate foraminifera such as nummulitids (Operculina complanata, Heterostegina assilinoides and Heterostegina sp.), Lepidocyclinids (Nephrolepidina sp. and Eulepidina sp.), Asterigenids (Amphistegina sp.) and Miogypsinoid (Miogypsinoides complanata and Miogypsina sp.). Furthermore, the most common smaller foraminiferal fauna are Rotalia, corallinacea red algae, and scattered coral fragments.

The abundant occurrence of perforate foraminifera (such as Operculina sp. and Lepidocyclina sp.) and Rotalia sp. along with red algae places the oligophotic zone in the middle- ramp setting (Bassi et al., 2007; Brandano et al., 2008). Generally, the upper part of the lower photic zone is dominated by perforate hyaline foraminifera such as (Operculina sp., Heterostegina sp. Amphistegina sp. and Miogypsina sp.) with red algae association places the middle ramp in an oligophotic zone (Brandano et al. 2008; Corda and Brandano, 2003) to mesophotic zone (Hottinger, 1997).

Furthermore, Operculina complanata was found in the lower parts of the photic zone and in quiet settings away from the effect of waves (Beavington-Penney and Racey, 2004; Hohenegger et al., 2000). This species seems to tolerate a high amount of terrigenous sediments that reduce the light intensity (Bassi et al., 2007).

In this study, the middle-ramp setting can be divided into two parts, namely the proximal middle-ramp facies dominated by coralline algea with (Operculina sp., Heterostegina sp., Amphistegina sp., Miogypsina sp. and Rotaliasp.) and the distal middle- ramp facies which is characterized by dominant coralline algae with Nummulites sp. and Lepidocyclina sp.

6. Conclusions

The paleoenvironmental recognition of the Azkand Formation in Western Iraq based on the biofacies analysis suggests two major depositional settings. These depositional environments are the inner- and the middle-ramp environments. In the inner-ramp setting, the most abundant microfacies are wackestone-packstone with an imperforate wall. Examples include Peneroplis sp., Austrotrillina sp., Dendritina sp., Archaias sp., Borelis sp., Meandropsina sp., and miliolids which indicate the low-energy upper photic zone, and the shallow shelf lagoon depositional environment.

The middle-ramp setting is generally dominated by bioclast packstone-grainstone with perforate walls, and can be divided into (A) shallow part of the middle-ramp environment (proximal middle-ramp) characterized by the occurrence of large foraminifera with perforate walls such as Operculina sp., Heterostegina sp., Amphistegina sp., Rotalia sp., and Miogypsina sp., and (B) a deeper middle-ramp setting (distal middle-ramp), dominated by large perforated foraminifera such as, Nummulites sp. and Lepidocyclina sp. along with fragments of corallina.

References

Al-Ghreri, M.F., Al-gibouri, A.S., and Al-Ahmed, A.A. (2014). Facies architecture and sequence development of the Euphrates formation in western Iraq. Arabian Journal of Geosciences. 7: 2679-2687.

Allahkarampour, D., Seyrafian, A., and Vaziri-Moghaddam, H (2010). The Asmari Formation, north of the Gachsaran (Dill anticline, southwest Iran): facies analysis, depositional environments and sequence stratigraphy. Carbonates and Evaporites. 25(2): 145-160.

Al-Twaijri, F.S.S. (2000). Sequence Stragraphic Analysis of the Oligocene Succession in Western Iraq. M. Sc. Thesis, Baghdad University, 166p.

Amirshahkarami, M., Vaziri-Moghaddam, H., and Taheri, A. (2007). Sedimentary facies and sequence stratigraphy of the Asmari Formation at Chaman_Bolbol (Zagros Basin Iran). J. Asian Earth Sci., 29: 947-959.

Banner, F.T., and Hodgkinson, R.L. (1991). A revision of the foraminiferal subfamily Heterostegininae. Revista Espanola de Micropaleontologia 23: 101–140.

Barattolo, F., Bassi, D., and Romero, R. (2007). Upper Eocene larger foraminiferal-coralline algal facies from the Klokova Mountain (south continental Greece) Facies 53: 361-375.

Bassi, D., Hottinger, L., and Nebelsick, H. (2007). Larger Foraminifera from the Upper Oligocene of the Venetian area, northeast Italy: Paleontology 5(4): 845-868.

Beavingtone – Penney, S.J., and Racey, A. (2004). Ecology of extant nummulitids and other larger benthic foraminifera. Applications in Paleoenvironmental analysis: Earth Science Review 67(3-4): 219-265.

Bosellini, F.R. (2006). Biotic changes and their control on Oligo-Miocene reefs: a case study from the Apulia Platform margin (southern Italy): Palaeogeography, Palaeoclimatology, Palaeoecology, 241: 393-409.

BouDagher-Fadel, M.K., and Wilson M.E. (2000). A revision of some large foraminifera from the miocene of East Kalimantan. Micropaleontology, 46: 153-165.

Brandano, M., Frezza, V., Tomassetti, L. and Cuffaro M. (2008). Heterozoan carbonates in oligotrophic tropical waters: The attard member of the Lower coralline limestone Formation (Upper Oligocene, Malta). Palaeogeography, Palaeoclimatology, Palaeoecology, 272: 1-10.

Brasier, D. (1975). Ecology of Recent sediment-dwelling and phyla foraminifera from lagoons of Barbuda, West Indies: Journal of Foraminiferal Research, 5: 42-62.

Buday, T. (1980). The Regional Geology of Iraq. Stratigraphy and Paleogeography, edit. by Kassab, I. and Jassim, S.Z., GEOSURV, Baghdad, 1: 445.

Buday, T., and Jassim, S.Z. (1987). The Regional Geology of Iraq. Tectonism, Magmatism and Metamorphism, GEOSURV, Baghdad, Iraq, 2: 352.

Buxton, M.W.N., and Pedley, H.M. (1989). Short Paper: A standardized model for Tethyan Tertiary carbonate ramps: Journal Geological. Society, London 146: 746-748.

Corda, L., and Brandano, M. (2003). A photic zone carbonate production on a Miocene ramp Central Apennines, Italy. Sedimentary Geology, 61: 55–70.

Cosovic, V., Drobne, K., and Moro, A. (2004). Paleoenvironmental model for Eocene foraminiferal limestones of the Adriatic carbonate platform (Istrian Peninsula). Facies. 50: 61-75

Flügel, E. (1982). Microfacies analysis of limestones. Translated by K. Christenson. Springer, Berlin 633 p.

Flügel, E. (2004). Microfacies of carbonate rocks. Analysis interpretation and application. Springer, Berlin, 976 p.

Ghosh, A.K. (2002). Cenozoic coralline algal assemblage from southwestern Kutch and its importance in palaeoenvironments and palaeobathymetry. Current Science 83 (2): 153-158.

Hallock, P., and Glenn, E.C. (1985). Numerical analysis of foraminiferal assemblages: a tool for recognizing depositional facies in Lower Miocene reef complexes: Journal of Paleontology, 59: 1382-1394.

Hallock, P., and Glenn, E. C. (1986). Larger foraminifera: A tool for Paleoenvironmental analysis of Cenozoic carbonate depositional facies: Palaios, 1: 55–64.

Hallock, P., Forward, L.B., Hansen, H.J. (1986). Environmental influence of test shape in Amphistegina. Journal of Foraminiferal Research, 16: 224–231.

Hottinger, L. (1983). Processes determining the distribution of larger foraminifera in space and time: Utrecht Micropaleontology 30: 239–253.

Hottinger, L. (1997). Shallow benthic foraminiferal assemblages as signals for depth of their deposition and their limitations. Bulletin Society Geology France, 168(4): 491–505.

James, N.P., Collins, L.B., Bone, Y., and Hallock, P. (1999). Subtropical carbonates in a temperate realm: modern sediments on the southwest Australian shelf: Journal of Sedimentary Research, 69: 1297-1321.

Jassim, S.Z., and Goff, J. (2006). Geology of Iraq. Dolin and Moravian Museum, Prague. 341p.

Johansen H.W. 1981. Coralline Algae, a First Synthesis: Boca Raton, CRC Press 239 p.

Kishore, S., Misra, P.K., Jauhri, A.K., and Singh, S.K. (2006). Paleocene coralline algae from the Cauvery Basin South India. Journal of Geological Society. India, 68 (11): 789-796.

Kroeger, K. F., Reuter, M., and Brachert, T.C. (2006). Palaeoenvironmental reconstruction based on non-geniculate coralline red algal assemblages in Miocene limestone of central Crete. Facies, 52: 381–409.

Kundal, P. (2011). Generic Distinguishing Characteristics and Stratigraphic Ranges of Fossil Corallines: Journal geological society, India, 78: 571-586.

Lee, J.J. (1990). Fine structure of rodophycean profyridium purpureum insitu in Peneroplis pertusus and P. asicularis. Journal of Foraminiferal Research. 20:162-169.

McDougall, K.A., Poore, R.Z. and Matti, J.C. (1999). Age and paleoenvironment of the Mediterranean. Sedimentology, 51: 627-651.

Minnery, G.A. (1990). Crustose coralline algae from the Flower Garden banks, northwestern Gulf of Mexico: controls on distribution and growth morphology: Journal of Sedimentary Petrology. 60: 992-1007.

Misra, P.K., Jauhri, A.K., Singh, S.K., and Kishore, S. (2006). Coralline algae from the Fulra Limestone (Middle Eocene) of Kachchh, Gujarat, W. India. Journal. Geological. Society, 67(4): 495-502.

Murray, J.W. (1973). Distribution and Ecology of Living Benthic Foraminiferids: Palaeogeography, Palaeoclimatology, Palaeoecology 179: 43-56.

Murray, J.W. (1991). Ecology and Palaeoecology of Benthic Foraminifera: Essex, Longman Scientific and Technical 397p.

Nebelsick, J.H., Rasswer, M., and Bassi, D. (2005). Facies dynamic in Eocene to Oligocene Circumalpine carbonates. Facies, 51: 197–216.

Pomar, L., Brandano, M., and Westphal, H. (2004). Environmental factors influencing skeletal grain sediment associations: a critical review of Miocene examples from the western Mediterranean: Sedimentology, 51: 627-651.

Rasser, M.W., Scheibner, C., and Mutti, M. (2005). A paleoenvironmental standard section for Lower Ilerdian tropical carbonate factories (Pyrenees, Spain; Corbieres, France). Facies, 51: 217–232.

Reiss, Z., and Hottinger, L. (1984). The Gulf of Aqaba: Ecological Micropaleontology: Berlin, Springer - Verlag, 354 p.

Remero, W. (2006). Habitat variables determining the occurrence of large benthic foraminifera in the Berau area (East Kalimantan, Indonesia): Coral Reefs, 25: 351-359.

Romero, J., Caus, E., and Rossel, J. (2002). A model for the palaeoenvironmental distribution of larger foraminifera based on late Eocene deposits on the margin of the Pyrenean Basin (SE Spain): Palaeogeography, Palaeo climatology, Palaeoecology, 197:3-56.

Sadeghi, R., Vaziri-Moghaddam, H., and Taheri, A. (2009). Biostratigraphy and paleoecology of the Oligo-Miocene succession in Fars and Khuzestan areas (Zagros Basin, SW Iran). Hist Biol. http:// www.informaworld.com/smpp/title *content=t713717695.

Sissakian, V.K., and Mohammed, B.S. (2007). Geology of Iraqi Western Desert. Iraqi Bulletin of Geology and Mining. Special Issue, 51–124.

Uthicke, S., Thompson, A., and Schaffelke, B. (2010). Effectiveness of benthic foraminiferal and coral assemblages as water quality indicators on inshore reefs of the Great Barrier Reef: Coral Reefs, 29: 209-225.

Van-Bellen, R.C., Dunnington, H.V., Wetzel, R., and Morton, D.M. (1959). Lexique Stratigraphique International. Asie, Fascicule 10 a, Iraq, Centre National De La Recherche Scientifique, Paris, 333 p.

Vaziri-Moghaddam, H., Kimiagari, M., and Taheri, A. (2006). Depositional environment and sequence stratigraphy of the Oligo–Miocene Asmari Formation is SW Iran. Facies, 52:41–51.

Wilson, J.L. (1975). Carbonate facies in geologic history: Berlin, Heidelberg, New York, Springer 471 p.