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Biostratigraphy, microfacies and sedimentary environment of the Jahrum Formation in Chaharmahal Bakhtiari province, West of Iran

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Abstract

In this research, the biostratigraphy, microfacies, and depositional environment of carbonate sediments of the Jahrum Formation will be investigated based on microscopic textures and the distribution of benthic foraminifera. The Jahrum Formation was measured from Kuh-e-Hamze Ali in the Chaharmahal Bakhtiari province (Zagros Basin, Iran). The biostratigraphic analysis of this formation has led to the detection of three biozones in this area. These biozones consist of *Somalina* subzone, *Nummulites–Alveolina* assemblage subzone, and *Nummulites fabianii- Nummulites striatus* assemblage subzone which assigned to Middle and Late Eocene. The *Nummulites fabianii- Nummulites striatus* assemblage subzone is represented for the first time in the studied area. Nine microfacies are identified based on their fossil content (mainly foraminifera) and sedimentary textures. They consist of Dolostone, Mudstone with quartz, Bioclast- miliolids wackestone/packstone, *Praerhapydionina* -miliolid wackestone, *Alveolina* -*Nummulites-Orbitolites* wackestone/packstone, Bioclast–miliolid-*Rotalia* wackestone/packstone, Bioclast-lump packstone/grainstone, Interaclast-bioclast-*Alveolina* wackestone/grainstone, and Bioclast-*Nummulites* wackestone/packstone. These facies were deposited in four major depositional environments from a tidal flat, lagoon, shoal, and open marine environmental settings. The depositional environment of the Jahrum Formation is interpreted as a carbonate ramp.

Keywords: *Biostratigraphy; Microfacies; Jahrum Formation; Eocene; West of Iran.*

1. Introduction

Jahrum Formation consists of limestone, dolomitic limestone, and dolomite. The lower contact of Jahrum Formation with Pabdeh Formation is transitional and upper contact with Asmari Formation is mostly with disconformity not erosional. The Zagros Mountains of Iran are divided into three principal tectonic units (Stocklin 1968). It is divided into three zones included the Zagros fold-thrust zone, the imbricated zone, and the Urumieh–Dokhtar magmatic zone (Alavi 2004). The Jahrum Formation has been deposited on the carbonate platform of the Zagros Mountains and is composed of light-colored and shallow marine limestone (Ziegler 2001). In most places of the Zagros Basin, included Lorestan, Khuzestan, and some parts of the Coastal Fars and Interior Fars provinces the Jahrum Formation lies conformably on the deeper facies of the Pabdeh Formation (Paleocene–Oligocene). The upper contact of the Jahrum Formation with the Asmari Formation is marked by an unconformity in most places (Fig 1).

A review of the literature indicates that many studies have been done on the Jahrum Formation of the Dezful Embayment because of oil field spreading. The biostratigraphy of Jahrum Formation has been studied by James and Wynd (1965), Rahaghi (1980), Kalantari (1986), Hottinger (2007), Changaei et al. (2023) and Babazadeh and Cluzel (2022, 2023). Sedimentology, depositional environments, and sequence stratigraphy of this formation have been studied by Seyrafian (2000); Parastoo (2002); Vaziri-Moghaddam et al. (2002); Nadjafi et al. (2004); Taheri et al. (2008); Moallemi (2010); Khatibi Mehr and Adabi (2013); Moallemi et al. (2014).

Based on benthic foraminifera, the Jahrum Formation is assigned to Middle-Late Eocene in the study area while the previous researchers were attributed this formation to Late Paleocene to Eocene or Middle Eocene (James and Wynd 1965; Seyrafian 1998; Vaziri Moghadam et al. 2002; Taheri et al. 2008; Jehangir Khan et al. 2021). The late Eocene age is mentioned for the first time in this region. Based on the distribution of benthic foraminiferal associations and sedimentary features, the main microfacies are deposited in a shallow carbonate platform setting. The distribution of microfacies represents a more or less deepening trend from tidal flat facies to fore-shoal facies in the inner and middle carbonate ramp environments. The aims of the study are 1- to describe the main microfacies and their distribution over the carbonate platform, 2- to represent the new stratigraphic level based on the benthonic foraminiferal assemblages, and 3- to reconstruct the paleoenvironment of the carbonate platform.

2. Materials and methods

The studied section is located at 50 km south Shahrekord City with geographical coordinates of 31°55'67"N and 50°56'27"E (Fig 2).

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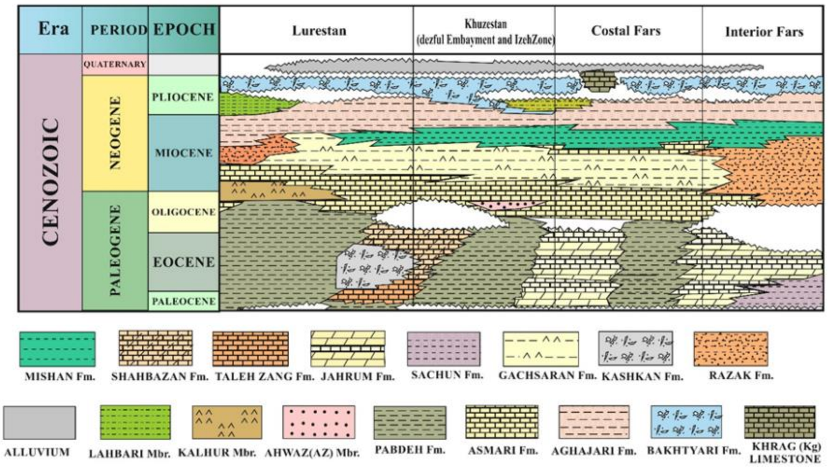

Fig 1. Correlation chart showing the stratigraphic position of the Jahrum Formation within the Cenozoic rocks of the west to southwest Iran (modified from Motiei 2001).

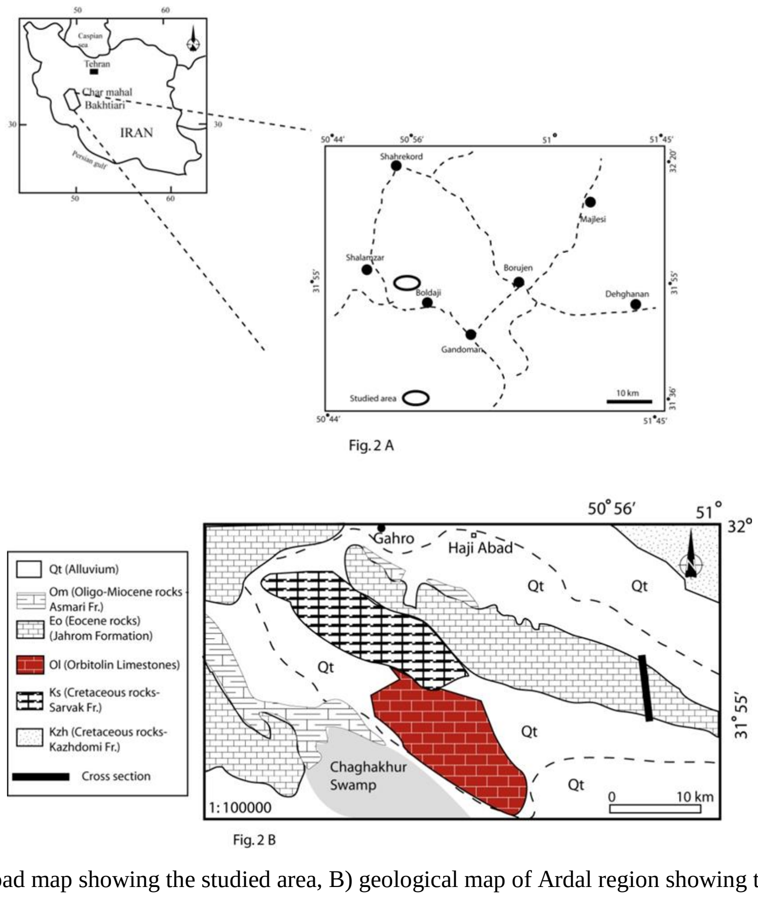

Fig 2: A) Schematic road map showing the studied area, B) geological map of Ardal region showing the stratigraphic section

The generic names of the benthic foraminifera taxa are based on the foraminiferal classifications of Rahaghi (1983), Loeblich and Tappan (1988), and Hottinger (2007) Ghasem Shirazi et al. (2014a). Microfacies types were classified according to the facies texture of Dunham (1962) and Embry and Klovan (1971). The definition of the elements of carbonate facies based on petrographical studies (grain size, grain composition, and fossil content) is established by Buxton and Pedley (1989) and Flügel (2004).

3. Biostratigraphy

The first foraminiferal biozonations are established by James and Wynd (1965) for the Jahrum Formation in the Zagros region. According to studied microfauna (Fig 3), several benthic foraminifers are identified and arranged in three foraminiferal biozones (Fig 4). These biozones consist of *Somalina* subzone, *Nummulites–Alveolina* assemblage subzone, and *Nummulites fabianii-Nummulites striatus* assemblage subzone.

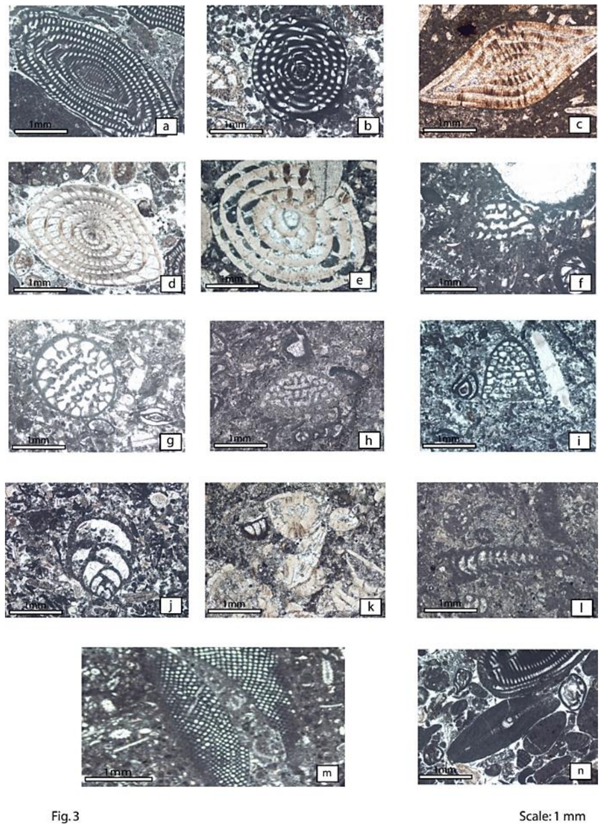

Fig 3. Photographs of selected benthic foraminifera in thin sections of Jahrum Formation. a: *Alveolina* sp., Subaxial section, X40, b: *Alveolina* (*Glomalveolina*) sp., Transverse section, X40, c: *Nummulites* cf. *striatus*, Axial section, X40, d: *Nummulites* cf. *laevigatus*, Subaxial section, X40, e: *Nummulites* cf. *fabianii*, Subaxial section, X40, f: *Coskinolina* sp., Axial section, X40, g: *Barattolites* sp., Transverse section, X40, h: *Coskinolina* cf. *perpera*, Subaxial section, X40, i: conical agglutinated form., Oblique section, X40, j: textularid form, Axial section, X40, k: *Asterigerina* cf. *rotula*., Axial section, X80, l: *Praerhapydionina* sp., Oblique section, X40, m: *Orbitolites* cf. *complanatus*, Oblique section, X40, n: *Somalina* cf. *stefaninii*, Axial section, X40. Scale= 1 mm.

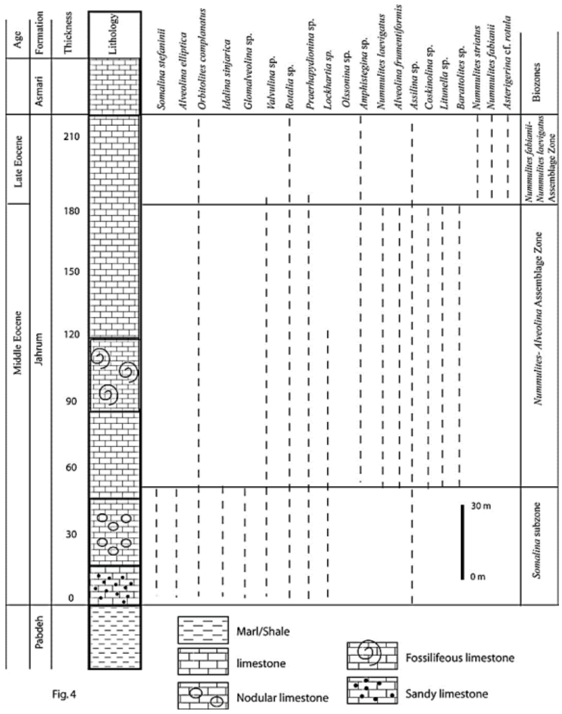

Fig 4. Biostratigraphy of the Jahrum Formation at the study area.

4. Microfacies analysis

Based on lithology, sedimentary characteristics, textures, associated benthic foraminifera, the nine microfacies were recognized in the Jahrum Formation. These are grouped into four main facies associations, which are from shallowest to deepest: tidal flat, lagoon, shoal, and fore-shoal (open marine) (Fig 5).

4.1 Tidal flat facies group

The rare fauna is represented in the littoral zone of the tidal flat setting.

MF1: Dolomitic limestone (Dolostone) (Fig 5a)

This facies represents a finely crystalline and homogeneous texture. The dolomite grains are small and rhomboidal in shape. Vuggy porosities are also present in dolostone. It is impossible to identify fossil fragments such as miliolids and small bivalves due to the recrystallization of dolomites (Wanas 2008; Beigi et al. 2017).

Interpretation:

Dolomitization is a diagenetic process in sedimentary environments. The dolomitic limestone occurs in a tidal flat (supratidal to intertidal) environment with low energy conditions (Wilson and Evans 2002; Al-Saad 2005; Wilmsen et al. 2010). This facies is equivalent to the RMF22 (supratidal-intertidal facies) of Flügel (2010).

MF2: Mudstone with quartz (Fig 5b)

This facies is composed of dense lime mudstones. It consists of light gray argillaceous micritic limestone that contains rare small miliolids, rare rotalids, and small bivalves. In some samples, the quartz is less abundant and considered a subordinate element.

The quartz probably reflects a reworking process and is produced by a river flow. This facies occurs in various environments from tidal flat to lagoonal settings.

Interpretation:

The small miliolids and small rotaliids are widespread in the littoral zone of the tidal flat setting. They represent an oligotypic community of epifaunal benthos and indicate a low-energy depositional setting (Zamagni et al. 2008).

4.2 Lagoon facies group

MF3: Bioclast- miliolids wackestone/packstone (Fig 5c)

The dominant lithofacies within MF3 is fine-grained wackestone to packstone, in which the micritic matrix is occasionally partially recrystallized. The texture varies from wackestone to packstone. This microfacies is characterized by the abundance of small miliolids such as *Quinqueloculina*, *Biloculina*, and *Triloculina*. The miliolids comprise 40 to 50% of total bioclasts. Other components such as *Valvulina*, *Textularia*, *Coskinolina*. may vary from 20 to 30%. The bioclasts (echinoderm and bivalve fragments) are less than miliolids and their proportion may contribute up to 20% of total allochems.

Interpretation:

The presence of mud matrix in this microfacies indicates a low to moderate energy environment. On the other hand, the presence of miliolids suggests a restricted environment with low energy. The restricted condition is also suggested by the rare to absent normal marine biota. The conical agglutinated foraminifera (*Coskinolina*) prefer to occupy the soft muddy substrate just below the tidal level and its occurrence implies the nutrient-rich lagoonal environments (Geel 2000, Vecchio and Hottinger 2007). The low diversity of bioclastics and high abundance of miliolids reveal that this facies is deposited in the shallow water of a restricted lagoon environment (inner ramp). Thus, this microfacies represents the shallowest upper part of the photic zone with very light and high translucent.

MF4: *Praerhapydionina* -miliolids wackestone (Fig 5d)

The matrix is a fine-grained micrite. Almost 50 % of the total biota contents is made up of miliolids, predominantly *Quinqueloculina*. A well-preserved *Praerhapydionina* was identified. The echinoderm fragments and small hyaline foraminifers such as Rotalia are less common (up to 20%). Hence, this facies is characterized by the miliolids-dominated assemblage.

Interpretation:

According to Flugel (2004) and Zamagni et al. (2008), the miliolids are lived in the shallowest waters with limited rotation and represent an oligotypic community. They occur in the lagoon environment.

The presence of the conical porcellaneous foraminifera such as *Praerhapydionina* indicates a tropical carbonate platform within the upper part of the photic zone (Reiss and Hottinger 1984; Hohenegger et al. 2000). This type of taxon is known as an indicator of restricted lagoonal in the inner ramp and proximal part of the middle ramp (Nebelsick et al. 2005, Barattolo et al. 2007). Then the small miliolids dominated assemblages along with conical porcellaneous foraminifera occur on the soft muddy substrate in a low-energy and widespread to the shallow subtidal setting.

MF5: *Alveolina* -*Nummulites*- *Orbitolites* wackestone/packstone (Figs. 5e and 5f)

This facies is represented by wackestone to packstone textures. It consists of foraminifera (55–60%), peloids (10–20%), and bioclasts such as echinoid, gastropod, and bivalve fragments (5–10%). The foraminifers are predominantly composed of *Orbitolites*, *Nummulites*, and *Alveolina*. This assemblage shows an equal abundance in the micrite texture. Other components such as echinoid and bivalve fragments, miliolids, and *Rotalia* are rare. This facies is characterized by an inhomogeneous assemblage of small lenticular *Nummulites, Alveolina, Rotalia,* and small miliolids.

Interpretation:

Alveolina is an important element in the Eocene deposits which occurred in the protected and inner ramp setting. The *Orbitolites* occurs in the shallowest parts of carbonate platforms or carbonate ramp (inner ramp) (Hottinger 1977; Rasser et al. 2005). The *Alveolina* is found slightly deeper than the *Orbitolites* in the shallow water environment. The occurrence of robust and ovate *Nummulites* suggests a shallow open marine environment with minimal increase in nutrients (Hohenegger 1999; Beavington-Penney; Racey 2004). The co-occurrence of hyaline and porcellaneous foraminifera represents an open shelf platform or low relief with the connection between the front and behind relief. This suggests that no effective barrier existed (Romero et al. 2002; Rasser et al. 2005). Hence this association reflects an offshore transport of *Alveolina* and *Orbitolites* facies into the Nummulites facies.

MF6: Bioclast – miliolids - *Rotalia* wackestone / packstone (Fig 5g)

This facies is predominantly composed of benthic foraminifera such as Rotalia, miliolids, and bioclasts. The *Rotalia* and miliolids consist of 40-50% and 20-30% of total foraminiferal fauna respectively. Other components are subordinate elements in this facies as they compose peloids and bioclasts (15 to 20%). The bioclasts include the fragmented benthic foraminifera (*Valvulina, Textularia*), echinoids, and bivalves. The texture varies from wackestone to packstone.

Interpretation:

The association of small rotalids with agglutinated foraminifera (*Valvulina, Textularia*) indicates lagoon and open marine environments in fine-grained wackestone/packstone (Geel 2000; Zamagni et al. 2008; Ghasem Shirazi et al. 2014b). The small rotalids are common in the lime mud and terrigenous mud deposits of inner neritic facies but rarely found in clean carbonate facies (Ferrer et al. 1973; Luterbacher 1984; Babazadeh 2008). The small rotalids are found in the clean carbonate facies in the studied area. The co-occurrence of small rotalids and agglutinated foraminifera reflects an open marine connection in a shallow environment. Therefore, this association occurs in an open lagoon setting and extends to behind of shoal settings in the offshore environment (Flugel 2004).

4.3 Shoal facies group

MF7: Bioclast -lump packstone/grainstone (Figs 5i and 5j)

The lumps (mud pebbles) are probably formed by reworking weakly consolidated lime mud. The lumps and bioclasts (up to 70%) are the most common constituents of this facies. The other subordinate components (up to 10-15%) are rarely present, and consist of bivalve, echinoderm, and gastropod fragments are rare. The allochems are medium sorted, fine to medium sand size, and vary from sub-angular to round. This facies indicates high-energy shoals (back-shoal) and formed at the inner-mid ramp transition.

Interpretation:

In the grainstone facies type, the micrite is washed and removed from the environment that is interpreted as the results of a high-energy environment. Usually, rounded bioclasts are forming bioclastic shoals and are generally found in more energetic environments than Alveolina (Rasser et al. 2005). Therefore, the presence of sparry calcite, low abundance of micrite, and rounded foraminiferal fauna suggest a high-energy shoal environment above the fair-weather wave base (Flugel 2010; Khatibi Mehr and Adabi 2013).

MF8:Interaclast-Bioclast-*Alveolina* packstone/grainstone (Fig 5h)

The *Alveolina* and bioclasts (up to 50%) are in equal abundance and are bounded by a micritic matrix. The intraclasts occur in various sizes (2mm – 5mm) and frequencies (20 to 30%). The other components such as miliolids, *Orbitolites*, and peloids are present and counted to 20%. Based on the presence of both micritic texture and calcite cement, this facies can change from wackestone to grainstone. The presence of intraclasts and sparry cement reflects an alternation of intermediate to high-energy conditions. Therefore, this microfacies was deposited under moderate to high energy conditions in the subtidal zone of a shallow marine platform landward of the shelf margin shoal.

Interpretation:

The intraclasts indicate a hard substrate and are redeposited in a shallow water environment under the agitation of the water. Also, the presence of intraclasts along with the abundant bioclast and low percent of micrite display that the sedimentation took place in the subtidal zone of shallow waters with high energy (Rasser et al. 2005). The subtidal origin is supported by the lack of subaerial exposure and evaporative components. This facies occurs in an open lagoon with a high-energy environment.

4.4 Open marine facies group (fore-shoal)

MF9: Bioclast-*Nummulites* wackestone/packstone (Figs 5k and 5l)

This microfacies is predominantly composed of *Nummulites* (up to 50%) and bioclasts (up to 30%). Almost 10-20 % of the other biota contents are assigned to bivalves and peloids. The bioclasts of the facies include predominantly *Operculina, Assilina*. with subordinate *Rotalia*. Most of the forms are well preserved with only minor fragmentation. The facies is characterized by wackestone and packstone alternation of equal thickness.

Interpretation: The presence of *Nummulites* along with *Operculina* and the absent normal lagoon biota indicates that the sedimentation took place deeper than previous facies. The presence of small lenticular and thick *Nummulites* indicates more light and food. Therefore, they relatively prefer shallow water in the inner to middle ramp setting whereas, larger flattened nummulitids are adapted to less light and food at deeper parts of the ramp (middle or outer ramp settings) (Hallock 1985; Geel 2000; Beavington-Penney and Racey 2004). The presence of oriented foraminifera indicates their short displacement in front of the shoal.

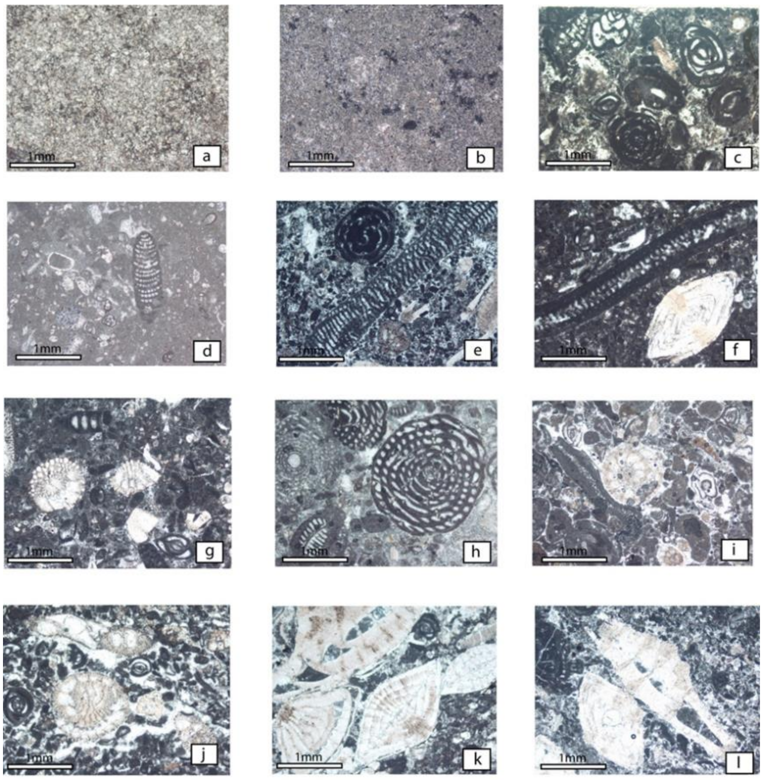

Fig. 5 Scale: 1 mm

Fig 5. Photomicrograph of microfacies of the Jahrum Formation. a: Dolomitic limestone (Dolostone), b: Mudstone with quartz, c: *Praerhapydionina*-miliolid wackestone, d & e: *Alveolina-Nummulites-Orbitolites* wackestone/packstone f: *Praerhapydionina*-miliolids wackestone, g: Bioclast–miliolid-Rotalia wackestone/packstone, h: Intraclast-bioclast-*Alveolina* packstone/grainstone, I and J: Bioclast-lump packstone-grainstone, k and l: Bioclast-*Nummulites* wackestone/packstone. Scale = 1 mm.

5-Discussion

The depositional environments of the Eocene can be similar to those found in many modern carbonate depositional settings. By the way, the Persian Gulf seems to be the best modern analogous for elicitation of ancient water depths, because it includes many similarities with the Zagros foreland basin during the Eocene.

Hence, the sedimentological and paleontological studies indicate that a ramp-type carbonate platform sedimentary model can be fully applied to these ancient carbonate deposits (Read 1982; Tucker 1985; Tucker and Wright 1990).

Ahr (1973) stated that the sedimentary model of the ramp setting represents an inclined platform where it can extend from shallow water platform to deep marine environment (basin) without specific interruption in the slope. According to Burchette and Wright (1992), the ramp is subdivided into three environments based on wave-base.

The inner ramp is the part of the ramp environment that extends from the shoreline to the fair-weather-wave-base, the middle ramp begins from fair-weather wave-base (fwwb) to normal storm-wave-base with sediment reworking by storms and the outer ramp occurs below-normal storm wave base down to the basin plain.

The distribution of the benthic foraminifera can be controlled by the paleoenvironmental conditions such as temperature, nutrient, salinity, water depth, and environmental energy in the shallow carbonate platform (Hottinger 1997, Hohenegger 1999 and 2000).

The Jahrum Formation represents the different types of benthic foraminifera of the Eocene stratigraphy in the Zagros region. The most important benthic foraminifera consist of *Somalina* cf. *stefaninii*, *Orbitolites* cf. *complanatus*, *Alveolina* sp., Nummulites cf. *laevigatus*, *Nummulites* cf. *striatus*, *Nummulites* cf. *fabianii*, *Asterigerina* cf. *rotula*, *Praerhapydionina* sp., *Assilina* sp., *Alveolina* sp., *Glomalveolina* sp., *Coskinolina* sp., *Opeculina* sp., *Rotalia* sp., *Valvulina* sp, and miliolids. Three biozones are distinguished based on the distribution of benthic foraminifera (Fig 6).

The first two biozones, *Somalina* subzone, and *Nummulites-Alveolina* assemblage subzone, are ranged Middle Eocene and correlated with Wynd's biozones (1965) in the Zagros region while the third biozone, *Nummulites fabianii- Nummulites striatus* assemblage subzone, is introduced and attributed to Late Eocene for the first time.

Formation	Age	Wynd (1965)	In this study
Jahrum Formation	L Eocene (Probably)	*Chapmanina-Pellatispira-Baculogypsinoides* Assemblage Zone (Zone 53)	*Nummulites fabianii- Nummulites striatus* Assemblage Subzone
	M. Eocene (Probably)	*Nummulites-Alveolina* Assemblage Subzone (51)	*Nummulites-Alveolina* Assemblage Subzone
		Dictyoconus-Coskinolina- Orbitolites complanatus Assemblage Subzone (50)	
		Linderina Subzone (49)	
		Somalina Subzone (48)	*Somalina* Subzone
	Early Eocene	*Opertorbitolites* Zone (44)	
	Paleocene	*Miscellanea- Kathina* Assemblage Zone Zone 43	

Fig 6. Correlation chart of foraminiferal biozones between Wynd's biozones (1965) and studied area

Based on the specifications of microfacies, four carbonate sedimentary environments, including tidal flats, lagoon, shoal, and fore-shoal have been distinguished. The tidal flat zone is demonstrated by two microfacies: Dolomitic limestone (dolostone) and Mudstone with quartz. The Dolomitic limestone with rare faunal elements occurs in restricted environments of the inner ramp. The dolomitization is related to hypersaline water of a tidal flat. The Mudstone consists of small miliolids, small rotaliids, and shells of bivalves which represent an oligotypic community of epifaunal benthos (Zamagni et al. 2008). The quartz is less abundant and probably derived by river currents. The succession of dolomitic limestone and Mudstone with quartz is usually formed in the low energy domain in the littoral zone of the tidal flat. The lagoon zone is indicated by four microfacies: Bioclast- miliolids wackestone-packstone, *Praerhapydionina* -miliolid wackestone, *Alveolina* - *Nummulites*- *Orbitolites* wackestone-packstone, and Bioclast–miliolids-*Rotalia* wackestone-packstone. The differentiation between four microfacies is based on the proportion of particular foraminiferal taxa and sedimentary texture. The small miliolids as a representative of oligotypic fauna, indicate a warm and shallow water environment and occurred in the restricted lagoon with extreme salinity and nutrient-enriched conditions. The small rotalids (*Rotalia*) prefer soft and fine-grained substrate and occur in the lagoon and open marine environments (Geel 2000; Zamagni et al. 2008).

Hence, the small foraminifera (miliolids and *Rotalia*) are considered as r-strategic biota and represented the rapid growth and short generation times. They are widely distributed from the inner ramp setting. The bioclasts such as gastropods and bivalves occur in shallow water environments above fair-weather wave base which indicate lagoonal conditions with moderate water circulation (Scheibner et al. 2007). The *Orbitolites* and *Alveolina* represent tropical shallow water and find in protected shelf from the lagoon to more inner part of the middle ramp setting. The *Orbitolites* occur in the shallower environment than *Alveolina* in the carbonate platforms (Hottinger 1973, 1977, Rasser et al. 2005). In addition, the presence of *Orbitolites* indicates an increase in light intensity in a shallow water environment. The nummulitids prefer the wide range of environments in the carbonate platform while the alveolinids consider as the typical lagoonal fauna. The co-occurrence of *Alveolina* and *Nummulites* represents a transitional position between the inner and mid ramp environments (Hohenegger et al. 1999). It represents the semi-restricted lagoonal conditions with moderate water circulation. Thus, the lagoonal microfacies indicate the low-energy conditions in the restricted intertidal to the subtidal environment of the inner ramp (Geel 2000; Rasser et al. 2005). This interpretation was supported by the presence of porcellaneous foraminifera, carbonate mud, and the absence of high-energy structures. The shoal area is revealed by two microfacies: Bioclast-lump packstone-grainstone and Interaclast-bioclast-*Alveolina* packstone-grainstone. The shoal facies consist of hyaline and porcellaneous foraminifera in a grainstone and packstone texture. They are generally characterized by the high abundance of rounded bioclasts, mud pebbles, sparry calcite cement, and the rare or lack of mud texture. All of these characters indicate a high-energy environment in the middle ramp. The back-shoal is characterized by the presence of miliolids, alveolinids, and orbitolitids while the fore-shoal (towards the open marine) is assigned to the presence of perforated and imperforated foraminifera. The fore-shoal area (towards the open marine) is characterized by one microfacies: Bioclast-*Nummulites* wackestone-packstone. The small, robust, lenticular, and thick lamellar *Nummulites* along with alveolinids indicate shallower part of the shallow water and occur at the restricted lagoon of inner ramp environments, whereas the large, flattened, elongate, and thin lamellar *Nummulites* together with *Assilina* and *Operculina* dominate the deeper parts of the ramp and occur at the seaward side of shoals of middle ramp (Fig 7).

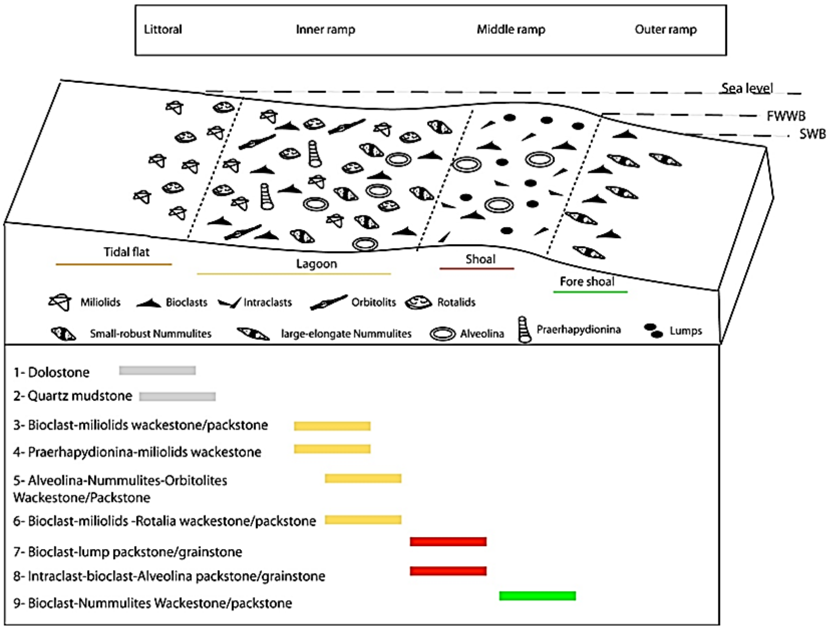

Fig 7. Depositional model of the Jahrum Formation at the study area.

6. Conclusions

The Jahrum Formation consists of a thick sedimentary succession of shallow-water carbonate in the study area. Four major environments, tidal flat, lagoon, shoal, and open marine, are recognized in the Eocene Jahrum Formation. Based on the distribution of foraminiferal taxa and sedimentary features, nine microfacies are identified.

The microfacies represent a more or less deepening trend from tidal flat facies to fore-shoal facies in the inner and middle carbonate ramp setting. The tidal flat is represented by MF1 and MF2 which formed under low-energy conditions. The inner ramp environment is identified by the microfacies MF3- MFT6 which consisted of abundant small and large benthic foraminifera (miliolids, alveolinids, etc) in the lagoonal setting. Both foraminiferas in the recognized facies indicate deposition within the photic zone. Two microfacies (MF7 and MF8) are represented in the shoal area. They are considered by the presence of rounded bioclasts, mud pebbles (lump), and sparry calcite cement which are characterized by high energy conditions. The middle ramp environment is recorded by the MF9, where the taxon of *Nummulites* is associated with *Assilina* and *Operculina*.

The benthic foraminifers are abundant biogenic components of the shallow-water carbonate succession in the Jahrum Formation. The small benthic foraminifera such as miliolids and rotalids as well as large benthic foraminifera such as *Alveolina* sp., *Orbitolites* sp., *Nummulites* sp., *Operculina* sp., etc. are found in the studied area. They are arranged in three assemblage zones during the Middle and Late Eocene.

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