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Lithostratigraphy, Microfacies Investigation and Paleoenvironmental Reconstruction of the Jahrum Formation in the West and North of the Bandar Abbass Area, South Iran

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ABSTRACT

The Jahrum Formation is one of the most important reservoirs in the Zagros Basin and the Persian Gulf. In this research, the Jahrum Formation in west and northwest Bandar Abbass has been investigated. The thickness of this formation in the studied area in Anguru Section is about 278m. Based on the paleontological studies, 104m thick of the Jahrum deposits is related to Middle Eocene and 174m to late Eocene. The lower contact of this formation with the Pabdeh Formation is gradational and the upper contact with the Asmari Formation is paraconformable. The Jahrum Formation in the studied section is lithologically consists of fossiliferous limestone and medium to thick bedded beige to gray dolomitic limestone. Based on the field and petrographic studies in the Jahrum Formation 6 types of microfacies and 6 subfacies have been identified. These microfacies have been deposited in 3 standard facies belt, including lagoon, Nummulites bank and open marine environment. These microfacies have been deposited in a distally steepened ramp.

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INTRODUCTION

The limestone of the Jahrum Formation consists one of the reservoir intervals in the Zagros basin in Iran. In order to study the Jahrum Formation a surface section of Anguru of this formation in the Zagros Basin has been selected. Anguru Section in Tange Keshar is located in the folded Zagros Belt and follows its characteristics. The Zagros Basin with 1800km long is located in the middle parts of the Alp-Himalaya orogenic belt, and with a thick bound with northwest-southeast trend is start form Turkey and continued to Hormoz Straight in Iran. This mountain range is northeast is bounded with Taurus at west and Persian Gulf in south-southwest. In the Zagros Basin one of the area in which the Jahrum Formation is widely exposed is northwest and west of Bandar Abbass. Since the limestones of the Jahrum Formation are resistant against weathering, they formed highlands in the Zagros folded belt and the outer layer of different anticlines. Although Jahrum Formation is more resistant against weathering in compare with the Asmari one. It is noteworthy to say that climate has an important role in forming the geomorphology of the outer layers of the formation.

Review of the literature revealed that integrated studies (lithostratigraphy, biostratigraphy, depositional environment and sequence stratigraphy of the Jahrum Formation have not been carried out in the Bandar Abbass Area. The lack of data makes the correlation of this area to other parts of the Zagros area impossible. So, in this investigation, the Jahrum Formation in the Anguru Section in Bandar Abbass Area has been studied as a point of view of microfacies, depositional environments, and biozonation based on the foraminifera. The results have been used for reconstruction and analysis of the depositional environments.

MATERIAL AND METHODS

After the field study in the Bandar Abbass area, the Anguru Section has been selected. About 200 samples have been selected for thin section preparation. Thin sections were stained with alizarin red-s for differentiation of calcite and dolomite following Dickson [8]. Based on the types and percentage of the allochems, texture, fossil contents and size of the fossils, 6 types of microfacies and 6subfacies have been identified. For limestone

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analysis, Dunham classification [8]. and for microfacies classification Flügel standard facies belt [6]. Buxton and Pedley classification [3]. for depositional environment have been used. and. Based on these data a sedimentolgoical and petrographical log has been prepared. Finally a 3D depositional model has been proposed for the Jahrum Formation.

Geological Setting:

The selected section of Anguru is located in the Zagros basin. Anguru section (27° 16' N and 55° 50' E) is located in west of Bandar Abbass City, south Iran, Eastern part of the Zagros area (Fig. 1). The Anguru Anticline with 45km long and 12km wide is located in the west-northwest of Bandar Abbass and is 55km far from Bandar Abbass (16' and 27° N and 55° and 50' E. Based on the field studies

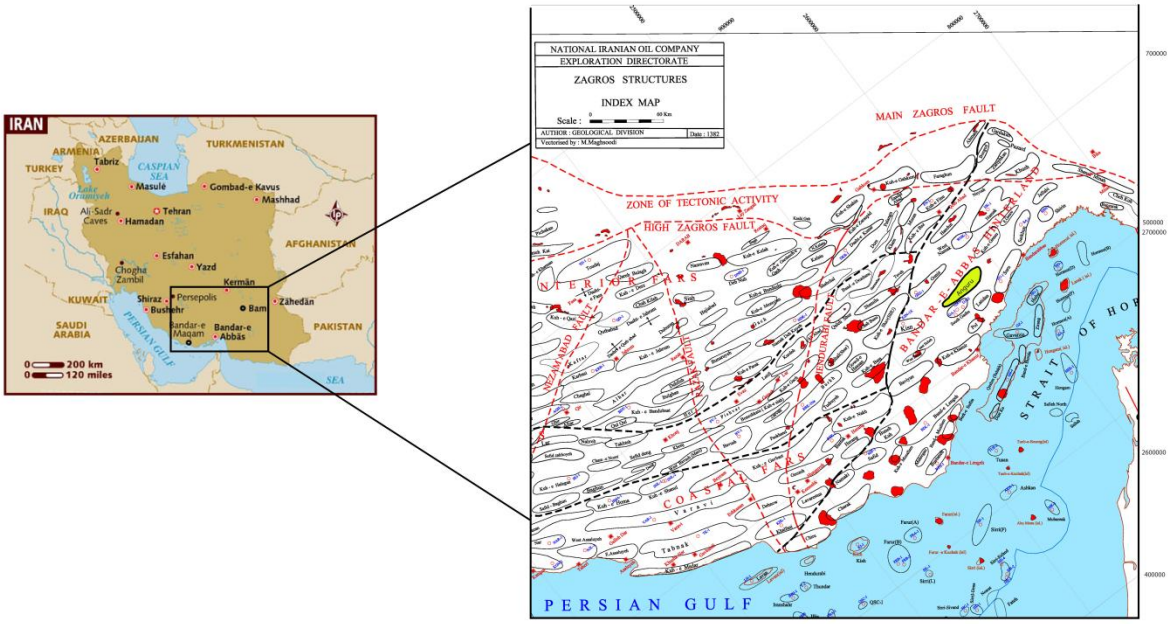


Fig. 1: location map of the studied area in Zagros Basin and Coastal Fars.

Literature Review:

Review of literature indicates that many studies have been done on the Jahrum Formation of the Dezful Embayment because of oil field spreading. The Jahrum formation biostratigraphically has been studied by James, and Wynd, [8]. Rahaghi, [15]. Kalantari, [9]. Sadegholvad, and Faghih, [7]. Hottinger and Khosrotehrani *et al.*, [2]. sedimentology, depositional environments and sequence stratigraphy of this formation have been studied by Seyrafian, Vaziri-Moghaddam *et al.*, [13]. Nadjafi *et al.*, [12]. Taheri *et al.*, [18]. Parastoo, Khatibimehr and Moallemi, These studies indicated that the Jahrum Formation has been deposited in a shallow marine carbonate ramp. Based on the benthic foraminifera the age of the Dammam Formation (equivalent to Jahrum Formation) is Priabonian (Boukhari *et al.* These studies revealed that the Jahrum Formation of the Bandar Abbass area has not been studied integrately.

Lithostratigraphy:

The Jahrum Formation is 278m thick, which is paleontologically identified that 104m is related to the age of Middle Eocene and 174m to Late Eocene. During the field trips, 280 samples have been selected of the studied interval. The stratigraphic column of the Jahrum Formation in the Anguru Section is presented in the figure 2.

The lower contact of the Jahrum Formation with the Pabdeh Formation is gradational (Fig. 3a). The Pabdeh Formation consists of pelagic microfacies and planktonic fauna. The Jahrum Formation in this section lithologically consists of fossiliferous limestone and beige to gray medium to thick layered dolomitic limestone. The base of the Jahrum Formation consists of argillaceous limestone and medium bedded dolomitic limestone with abundant benthonic (*Operculina* spp.) and planctonic foraminifera and with echinoid debris, bivalve and bryozoans. In the middle part of the formation in spite of *Operculina* spp. large benthic foraminifera like *Nummulites* sp., *Assilina* sp., and *Discocyclina* sp along with bivalve and echinoid debris are present (Fig. 3a). The upper part of the Jahrum Formation consists of thick bedded fossiliferous limestone of shallow marine water and lagoonal environment like Dacycladacea, Gastropoda and Bivalve (Oyster), along with benthonic

foraminifera like *Orbitolites complanatus* ،*Nummulites* sp. cf. *N. striatus* ، *Nummulites* sp. cf. *N. fabbianii* ، *Alveolina* spp .*Baculogypsinoides* sp. (Fig. 3d).

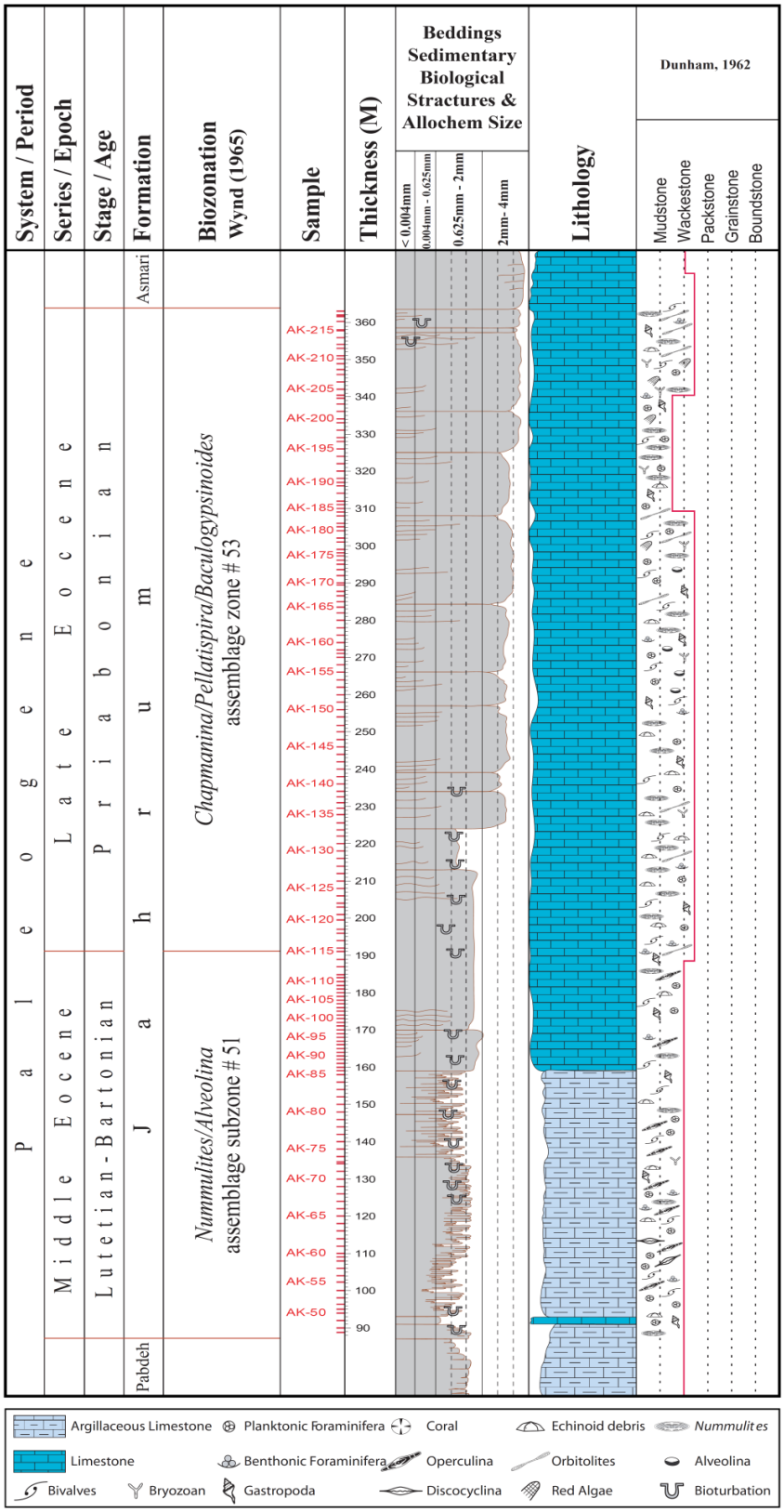


Fig. 2: Stratigaphic column of the Asmari Formtion in the Anguru Section in Tange Keshar.

The Jahrum Formation is widely exposed in the studied area and because of high resistance against withering, forms the cliffs especially in Tange Keshar. High- karstification and well-developed joint formation

caused to form a good hydrocarbon reservoir. Based on paleontological studies the lower contacts of the Jahrum Formation with the Asmari Formation is paraconformable (Fig. 3d).

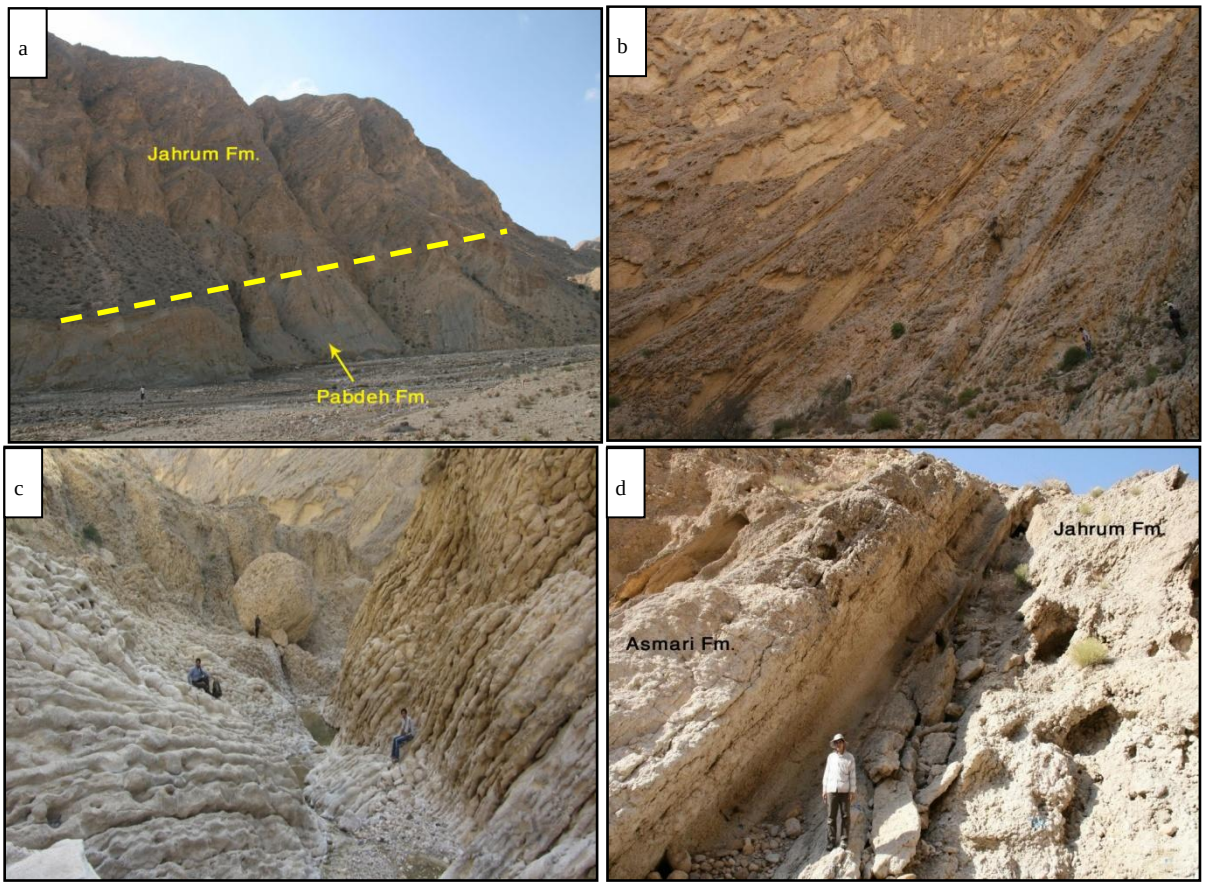


Fig. 3: A. the lower contact of the Asmari Formation with the Pabdeh Formation in the south flank of the Anguru Section (west ward look). b. the outcrop view of nodular limestone with abundant benthonic foraminifera in the lower part of the Jahrum Formation in the Anguru Section. c. the outcrop view of medium to thich-bedded limestone in the middle part of the Jahrum Formation in the south flank of the Anguru Section (west ward view). d. the upper contact of the Jahrum Formation and Asmari Formation in the south flank of the Anguru Section (west ward view).

Microfacies Association:

Based on the field studies and petrographic investigation of the Jahrum Formation 6 types of microfacies have been identified. These microfacies have been deposited in the lagoon and open marine environments. These microfacies have been described subsequently.

Lagoon Microfacies (JA):

Lagoon microfacies have been developed in the middle to upper parts of the Jahrum Formation. This facies belt is observed with the texture of grain-supported texture, especially packstone.

JA1: Benthic foraminifera bioclast pelloidal packstone:

This microfacies is characterized with grain-supported texture with abundant and variable porcelaneous bioclasts. Foraminifera are including *Textularia* spp., *Quinqueloculina* spp., *Elphidium* spp., *Nummulites* sp., *Triloculina trigonula*, *Spiroloculina* spp., *Pyrgo* spp., *Spirolina* spp., *Bigenerina* sp., *Triloculina* sp., *Nummulites* sp. cf. *N. fabbianii*, *Orbitolites complanatus*, *Orbtolites* sp., *Penarchaias* sp. cf. *P. glynnjonesi*, *Triloculina tricarinata*. Nonforaminifera microfossils are *Lithophyllum* sp., *Lithothamnium* sp. *Lithoporella* sp., Bryozoan, Echinoid and bivalve debris. The amount of pelloid varies between 15-40%. Besides pelloid, wide variety of lagoonal microfaun (Miliolid, micritized red algae) and open marine microfauna (*Nummulites*, Echinoid debris) are present in this microfacies.

This microfacies is observed in the upper parts of the Jahrum Formation in Anguru Section. mixing of the porcelaneous and hyaline test of marine fauna indicates that the lagoon is attached with the open marine

environment (Fig. 4a).in this microfacies a subfacies has been identified, namely *Nummulites /Orbitolites* bioclast pelloidal packstone. The main allochems of this microfacies is pelloid**,** *Orbtolites* sp., *Orbitolites complanatus*, *Nummulites* sp. cf. *N. fabbianii, and Nummulites* sp.. the other bioclasts are *Textularia* spp., *Quinqueloculina* spp., *Elphidium* spp., *Triloculina trigonula*, *Pyrgo* spp., *Russella* spp., *Spirolina* spp., *Bigenerina* sp., *Triloculina* sp., *Rhabdorites malatyaensis*, *Rhabdorites* sp., *Penarchaias* sp. cf. *P. glynnjonesi*, *Neotaberina neaniconica* n. gen. n. sp., *Alveolina* spp., *Praerhapydionina delicata*, *Asterigerina rotula*, *Lithophyllum* sp., Bryozoan debris, Bivalve debris.

This microfacies is grain-supported and well sorted. Presence of micrite indicates that this microfacies has been deposited in low energy environment of lagoon. The comprises bioclast of this subfacies such as porcelaneous benthonic foraminifera and pelloid is indicate the deposition in shallow marine. Stratigraphic position are also indicate the deposition in the lagoon (Fig. 4b). dolomitization is one of diagenetic feature has been affected on this microfacies. the amount of dolomite is between 5 to 25%. Dolomitization is fabric destructive and obliterated the precursor fabric of the allochems. This microfacies is observed in the middle part of the Jahrum Formation of the Anguru Section.

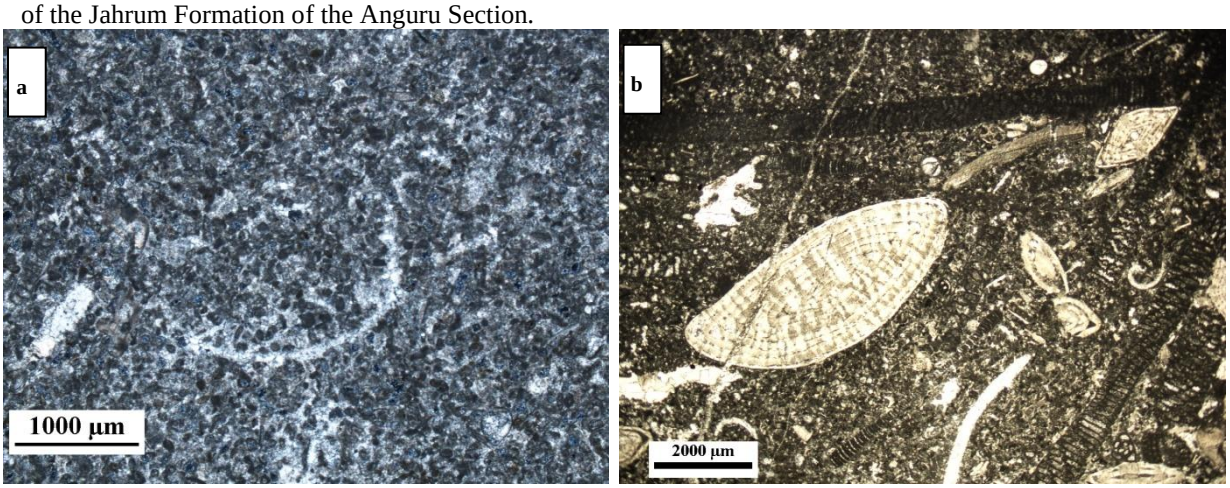


Fig. 4: Photomicrographs of the lagoon microfacies. a. Benthic foraminifer bioclast pelloidal packstone, PPL. b. *Nummulites* /*Orbitolites* bioclast pelloidal packstone, PPL.

Interpretation:

Abundant pelloid along with *Orbitolites* and Miliolids and with a lower amount *Nummulites and* mud-supported facies, proposed the deposition in the lagoonal environments. Based on the Buxton and Pedley, it is equivalent to RMF-20 of Flügel facies belt No. 2. The condition of this environment is shallow, with medium to low energy and presence in the photic zone below the fair-weather wave base. The lagoon is well connected to open marine environments and is temperature and salinity of this environment is close to the open marine.

JA2: Pelloidal benthic foraminifera packstone to grainstone:

This microfacies is characterized with grain-supported texture. The main allochems of this microfacies are pelloid and porcelanous benthic foraminifera including *Quinqueloculina* spp., *Elphidium* spp., *Orbitolites* sp. *Praerhapydionina delicate*, *Textularia* spp., *Neorhipidionina spiralis*, *Rhabdorites malatyaensis* and nonforaminiferal fossils like bivalve debris, red algae (*Lithothamnium* sp. .*Lithophyllum* sp.). The AJ2 is present in the upper parts of the Jahrum Formation in the Anguru Section. Bioturbation and micritization are the main diagenetic features affected on this microfacies. About 3-5% sand sized quartz grains are scattered in the matrix (Figure 5a and b).

Interpretation:

This microfacies is equivalent to RMF-20 of Flügel and facies No. 2 (Buxton and Pedley, 1989). Abundant porcelanous foraminifera along with the existence of detrital quartz grains indicate the deposition in the shallow, medium to low energy environment of the lagoon. Wide variety of euryhaline macrofauna reveals that the lagoon is attached to open marine by tidal channel. This lagoon environment is characterized by shallow, medium to low energy and presence in the photic zone below the fair-weather wave base.

Open marine Facies Association:

4 microfacies have been identified in the open marine facies belt. These microfacies have been described below.

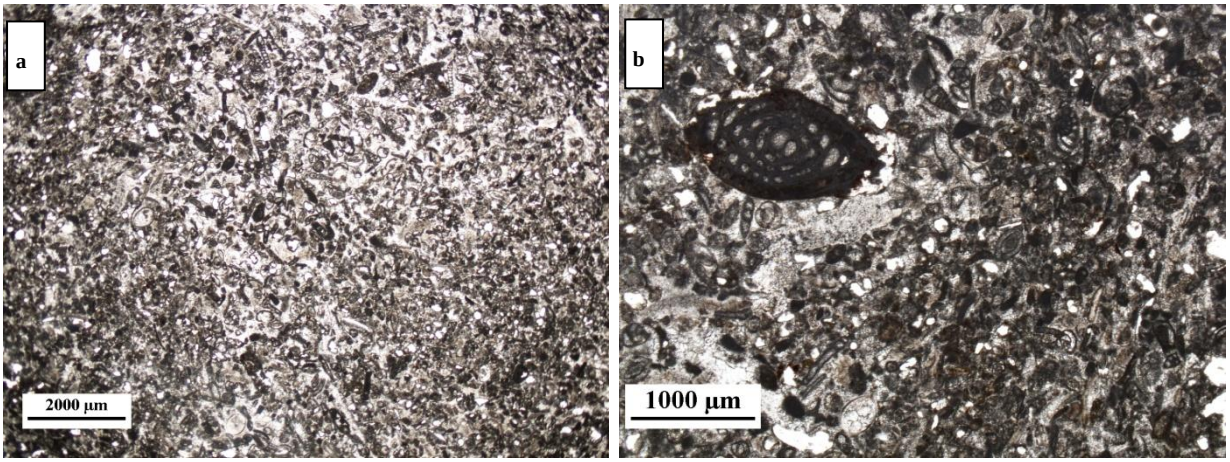


Fig. 5: a and b- Pelloidal benthic foraminifer packstone to grainstone.

JB1: Nummulites wackestone to packstone:

Nummulites are the main allochems of this microfacies. In outcrop view, large *Nummulites* with the size of about 20mm is observable (Figure 6). Size and form of the *Nummulites is* function of depositional environment. The elongate *Nummulites* is related to the offshore deeper water environment and shows the increase in the accommodation space (Jorry, 2004*). Nummulites* are the major constituents of the Paleogene deposits especially in Middle Eocene. The size of them is about 160mm (Rasser *et al*., 205). Pelloid up to 45% is also observed. According to Hottinger (1983), *Nummulites* indicates the deeper parts of the basin. Large and abundant allochems in the micrite indicates that the energy is low and only occasionally is storm. So the *Nummulites* microfacies has been deposited below Fair weather wave base. Based on the predominant allochems and texture 3 subfacies have been identified in this microfacies:

1). *Nummulites* packstone to wackestone (Fig. 7a)
2) Peloid *Nummulites* packstone (Fig. 7b and c)
3) Nummulites bioclast pelloidal packstone (Fig. 7d)

Fig. 6: The outcrop view of microfacies JB1: *Nummulites* wackestone to packstone.

Interpretation:

A large *Nummulites* Belt in the northern and southern parts of the Tethys ocean in the carbonate Eocene is observed (Figure 8). Presence of micrite and high degree of fragmentation indicates the inversion texture and reveal that a low energy environment is occasionally is affected by storm waves. Waves energy is high enough to break the allochems, but not high enough to remove the micrite. Large size of *Nummulites*, Autochthonous *Nummulites*, well sorting in *Nummulites* test and grain-supported texture suggest that this facies is deposited in *Nummulites* Bank. This facies is formed in the mid ramp below wave base. Such a *Nummulites* Bank is reported in shallow marine environment of Eocene of Tethys Ocean. Distribution and formation of this facies caused to form bioclast and *Nummulites* Band in the mid ramp part of the platform. It is noteworthy to say that orientation of *Nummulites* is an indication of paleocurrent.

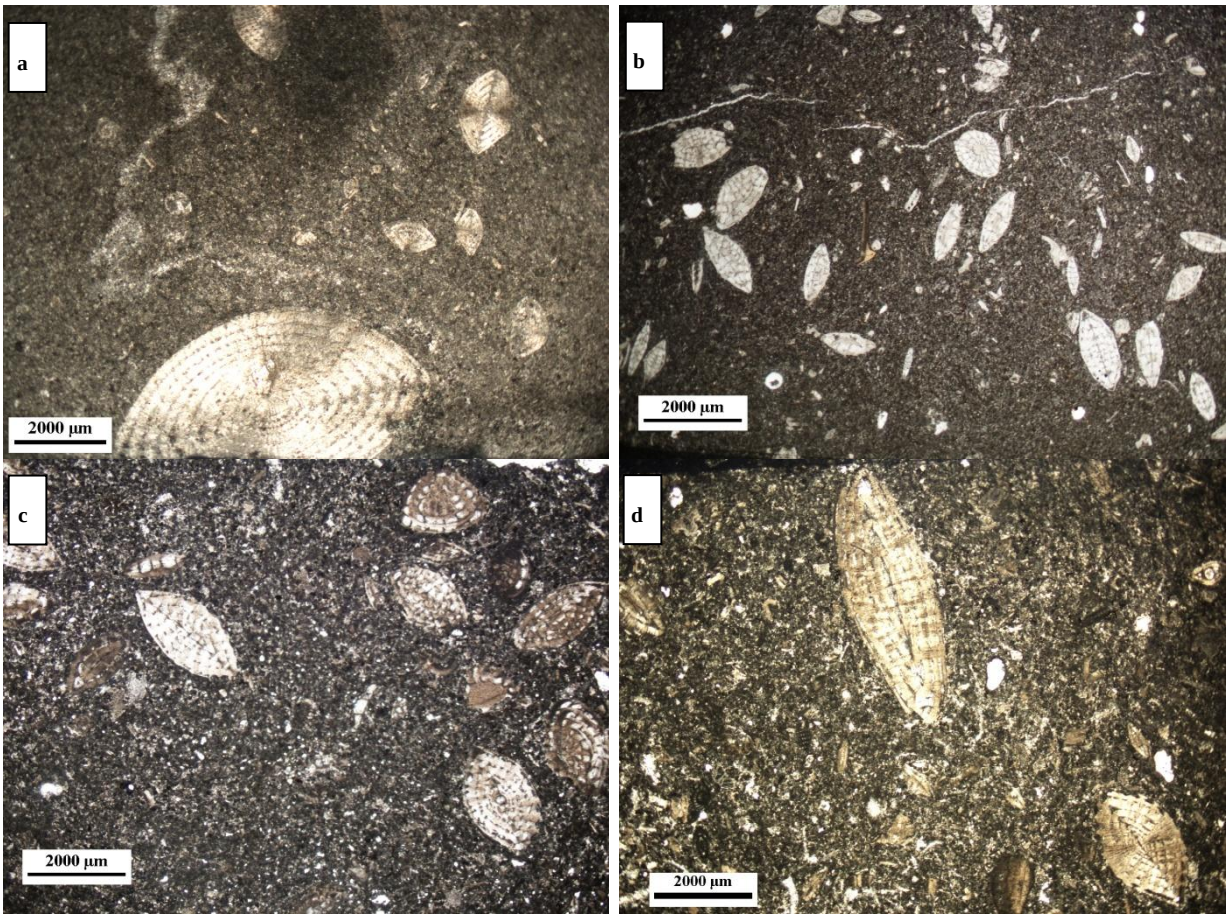


Fig.7: a- Photomicrograph of Nummulites Bank. a. *Nummulites* wackestone. b and c Peloid *Nummulites* packstone. d. *Nummulites* bioclast pelloidal packstone.

According to Racey, [14] *Nummulites* along with *Assilina, Discocyclina and Alveolina* have been occurred in the mid ramp. Based on Bassy presence of *Nummulites* along with *Assilina* proposed the deposition in the mid and proximal outer ramp. Based on the foraminifera depositonal environement of the *Nummulites* varies from mid to outer ramp, so *Nummulites* along with *Discocyclina and Operculina* is related to outer ramp and without them is related to mid ramp. The major distribution of this microfacies is related to mid ramp of the Eocene in the Zagros Basin. The same microfacies is introduced by Khatibimehr and Moallemi and Sadeqi *et al*. in middle ramp. This microfacies is equivalent to RMF-13 and above fair-weather and Buxton and Pedley, is equivalent to facies belt No. 5 related to mid ramp.

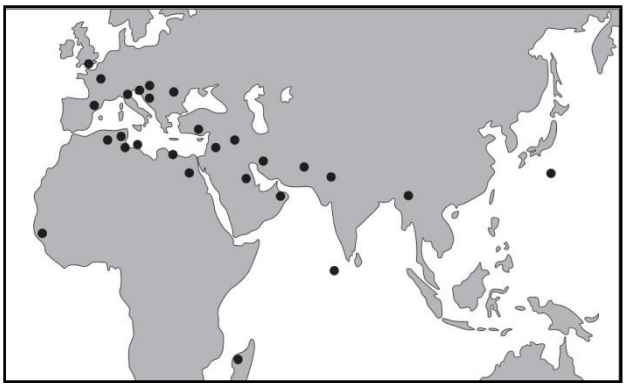


Fig. 8: Geographic distribution of *Nummulites carbonate of Eocene (after* Racey *et al*.,*).*

JC1: Planktonic foraminifer Discocyclina/ Nummulites/ Operculina pelloidal wackestone to packstone:

The texture of JC1 varies from wackestone to packstone. This microfacies consist of *Discocyclina, Nummulites and Operculina* and with a lower amount planktonic foraminifera like *Globigerina* spp., *Globigerina yeguaensi*s. Large, planar *Discocyclina* indicates the deposition in nearly deep marine (Geel, 2000). Bioturbation and burrowing is common (Fig. 9a and b). Based on the bioclasts and texture 2 subfacies have been identified including:

1) *Nummulites*/ *Discocyclina* wackestone to packstone (Fig. 9c)
2) *Nummulites*/ *Assilina* packstone (Fig. 9d)

Dolomitization is a common diagenetic process in this facies. This facies is an observant of deeper water in west-northwest of Bandar Abbass in the Eocene.

Interpretation:

Association of *Discocyclina* and *Nummulites* indicates the deposition in the fore reef facies with the depth of about 50-80m (Vaziri-Moghaddam *et al*., 2002). Based on the Racey, (2001) elongate Nummulites and Discocyclina is related to nearly deep water and thick lenticular Nummulites is related to shallow parts (mid ramp). This microfacies is equivalent to RMF-3 of Flügel (2010) and facies belt No.5 of Buxton and Pedley (1989) and formed in the outer ramp.

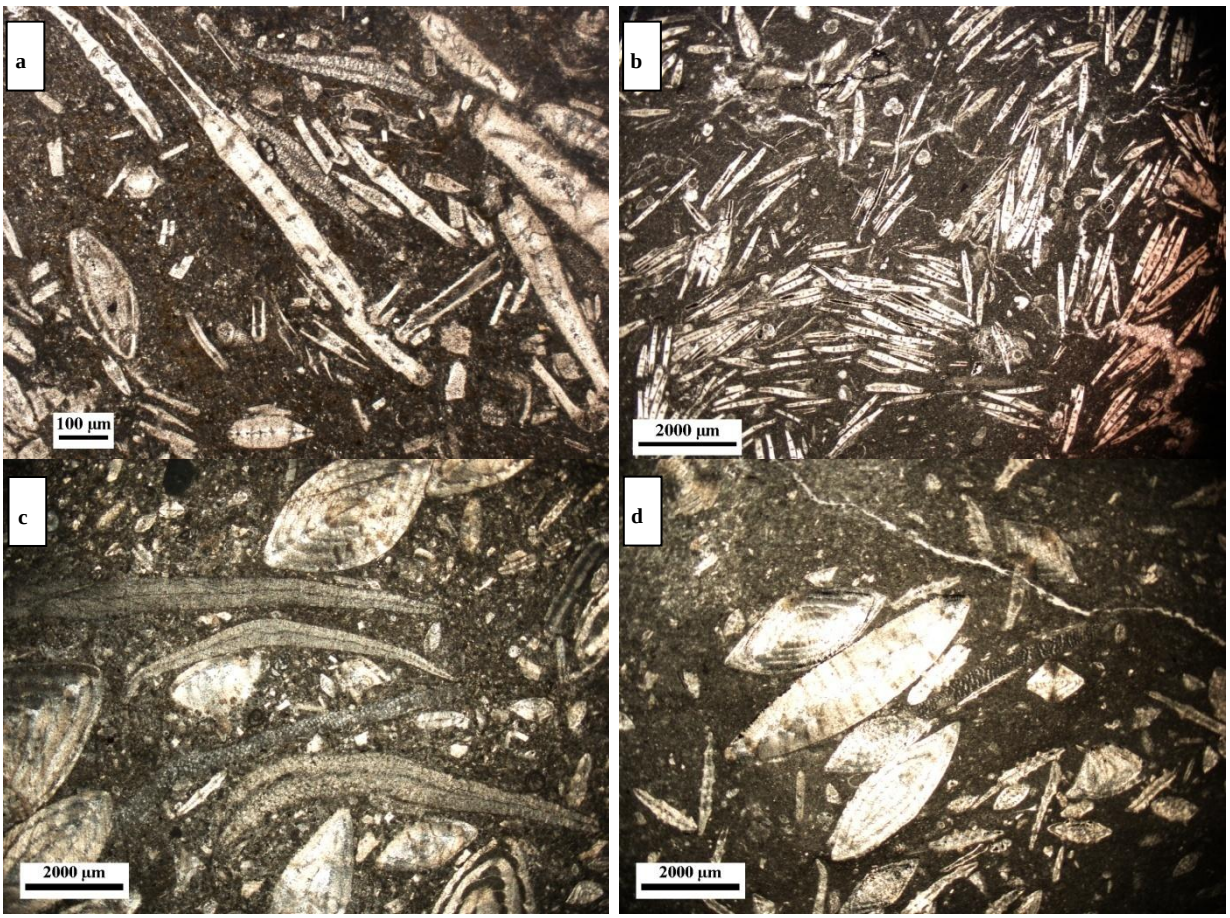


Fig. 9: photomicrograph of open marine microfacies. a and b- Planktonic foraminifera *Discocyclina*/ *Nummulites*/ *Operculina* pelloidal wackestone to packstone, PPL. c. *Nummulites*/ *Discocyclina* packstone, PPL. d. *Nummulites*/ *Assilina* packstone, XPL.

JC2: Operculina/(small) Nummulites pelloidal packstone:

The main allochems of this microfacies are benthonic foraminifera and *Nummulites.* Other fossils are *Textularia* spp., *Planorbulina* spp., *Quinqueloculina* spp., *Elphidium* spp., *Bolivina* sp., *Triloculina trigonula*, *Spiroloculina* spp., *Pyrgo* spp., *Nummulites* sp.cf *N. Globules*, *Cibicides* sp., *Assilina* sp., *Assilina* sp.cf. *A. spira*, *Spirolina* spp., *Bigenerina* sp., *Triloculina* sp., *Globorotalia* spp., *Valvulina* spp. and Bryozoan and Echinoid debris. Bioturbation and burrowing are common. Pelloid is subordinate allochems (Fig. 10 a and b). Based on the present fauna this microfacies is related to open marine environment. This microfacies is observed in the lower part of the Anguru Section.

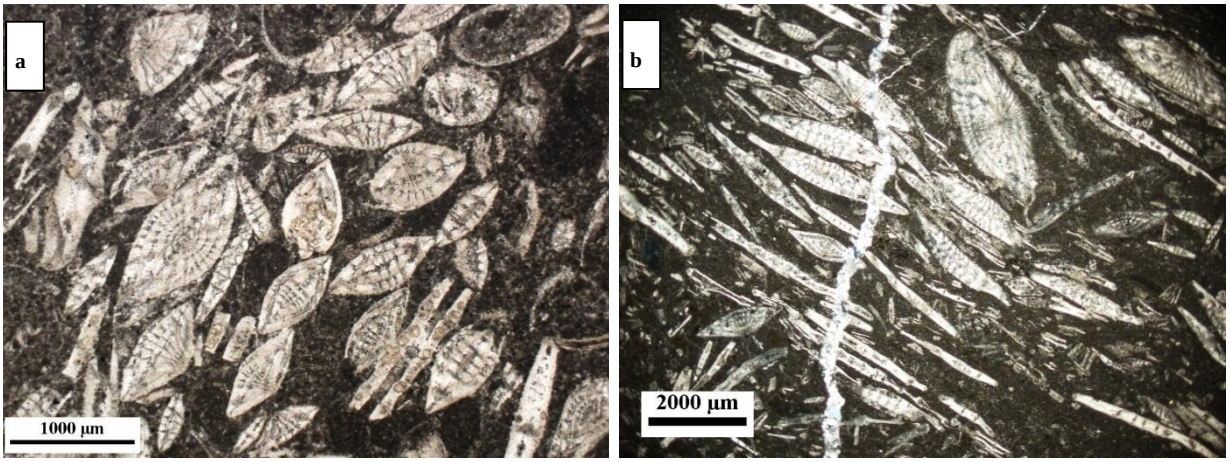


Fig. 10: a and b- Photomicrograph of *Operculina*/(small) *Nummulites* pelloidal packstone, PPL.

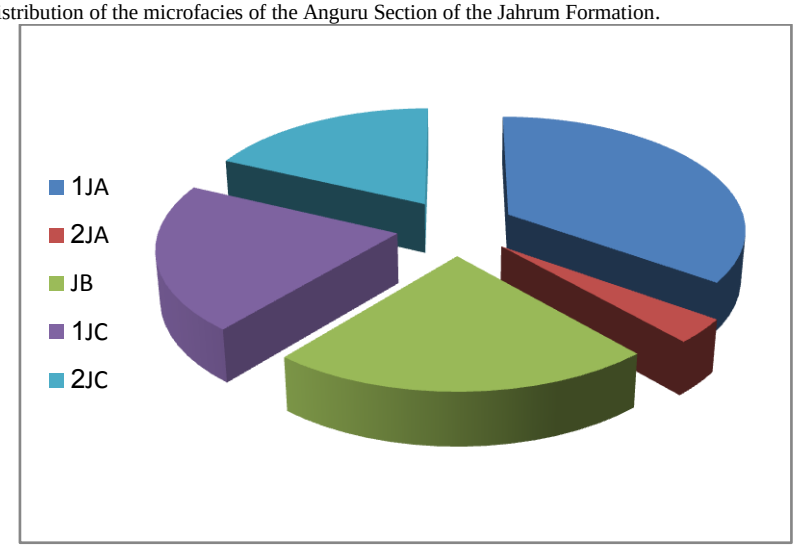
Introduction:

The assemblage of *Operculina* and *Nummulites* indicates the deposition in the deep water condition (Moallemi and Khatibimehr, 2010). The difference in this microfacies with JC1 is in the lack of *Discocyclina* and presence of *Operculina*. This microfacies is equivalent to facies belt No. 5 of Buxton and Pedley (1989) and was deposited in the outer ramp.

Frequency Distribution of Microfacies:

The identified microfacies in the Jahrum Formation in the Anguru Section have been summarized in table 1. Petrographic analysis of thin sections revealed that the microfacies of the lagoon environment are more abundant than other facies belt. Open marine and *Nummulites* bank facies belt come next regarding their abundance.

Table 1: Frequency distribution of the microfacies of the Anguru Section of the Jahrum Formation.



Depositional Environment:

Based on the field study and by the use of the lateral and vertical change of microfacies and based on the Walter's law, the Jahrum Formation has been deposited in 6 microfacies association. The comparison of this microfacies with the standard facies belt of Flügel (2010) and Buxton and Pedley, (1989) the Jahrum Formation has been deposited in the distally steepen ramp. Gradual change of microfacies, the lack of main barrier reef and turbidite deposit in the inner parts of the platform, and the presence of redeposited sediment in the distal part of the platform suggested the distally steepened ramp environment. Generally 6 types of microfacies have been identified which have been deposited in the inner and mid parts of the platform.

The evidence like wide variety of lagoonal bioclast (e.g. Miliolids), porcelanous test benthonic foraminifera (e.g. *Coskinolina*, *Dictioconus* and Valvulinid) and pelloid and intraclast along with marine fauna (Echinoids), sorting and grain –supported texture proposed the deposition of JA1 and JA2 in the shallow open lagoon environment of the inner ramp. The presence of abundant *Nummulites* with distinct orientation in JB1, large size

and autochthonous *of Nummulites*, well sorted Nummulites tests, and grain supported texture indicate the deposition in the *Nummulites* Bank in the mid part of the ramp, below faiweather wave base. Such *Nummulites* banks have highly been reported in shallow marine deposits of Eocene (Racey, 2001). Paleocurrent reconstruction can be done by the consideration of *Nummulites* orientation.

The open marine environment starts with *Nummulites* bank. By increasing depth *Operculina* and then *Discocyclina* appears. Deepening of the water is indicated by the presence of the majority of planctonic foraminifera and with a lower amount *Operculina* and small *Nummulites* (JC1 and JC2). The 3D schematic block diagram of the Jahrum Formation is presented in figure 11.

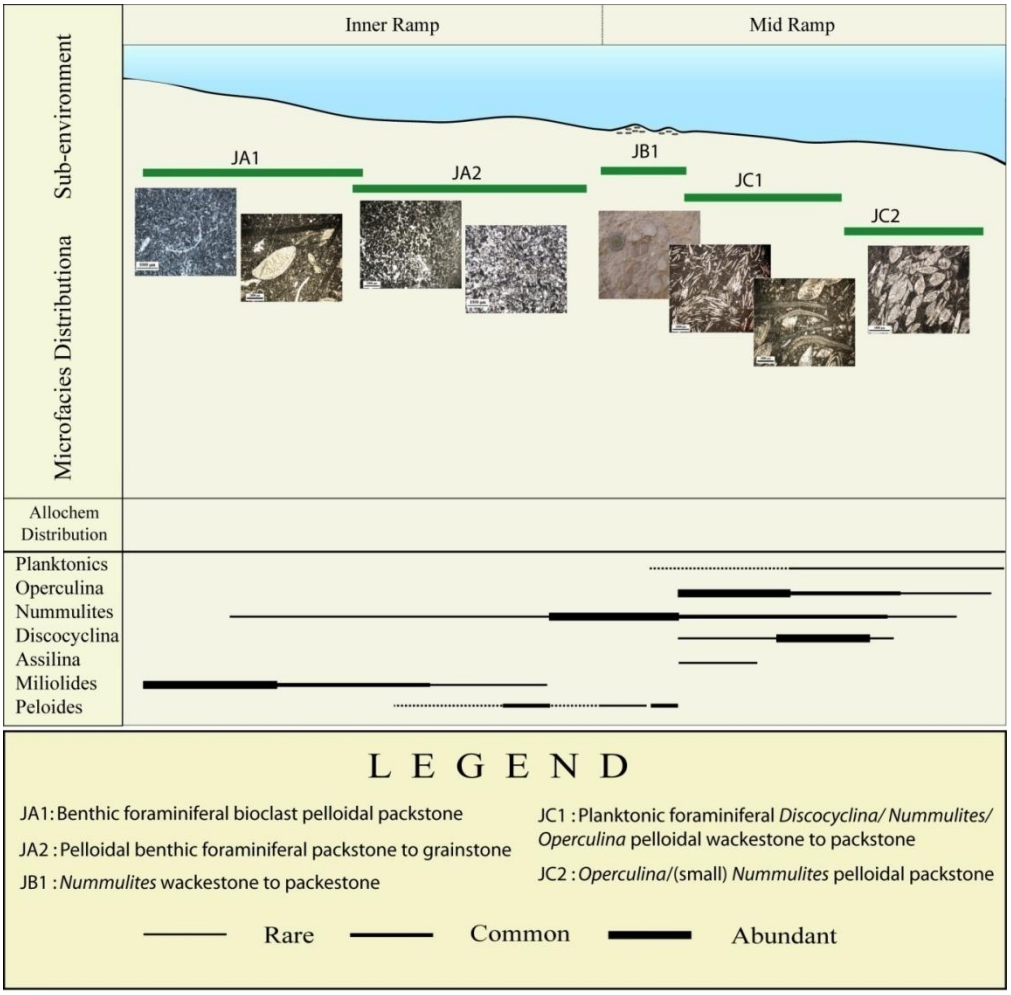


Fig. 11: Schematic block diagram of the Jahrum Formation in Anguru Section of Tange Keshar.

Table 1: the identified microfacies of the Jahrum Formation in the Anguru section of the Bandar Abbass Area.

0.1	Facies Code	Facies Name	Subfacies	Depositional Environment		Facies Frequency of the Anguru Section
JA	JA1	Benthic foraminifera bioclast pelloidal packstone	*Nummulites* /*Orbitolites* bioclast pelloidal packstone	Lagoon	Inner Ramp	Abundance
	JA2	Pelloidal benthic foraminifera packstone to grainstone	-			Abundance
JB	JB1	*Nummulites* wackestone to packstone	*Nummulites* packstone to wackestone	*Nummulite* Bank/shoal	Inner to Mid Raap	Common
			Peloid *Nummulites* packstone			Common
			Nummulites bioclast pelloidal packstone			Abundance
JC	JC1	Planktonic foraminiferal *Discocyclina/ Nummulites/ Operculina* pelloidal wackestone to packstone	*Nummulites/ Discocyclina* wackestone to packstone	Open marine	Mid Ramp	Abundance
			Nummulites/ Assilina packstone			Common
	JC2	*Operculina/*(small) *Nummulites* pelloidal packstone	-			Abundance

Conclusion:

- Based on the field study and petrographic investigation of the Jahrum Formation in the Anguru Section the following can be concluded.
- In the Anguru Section, the lower contact of the Jahrum Formation with the Pabdeh Formation is gradational and the upper contact with the Asmari Formation is paraconformable and is characterized with a paleosol horizon.
- The thickness of this formation in the studied section is about 278 m and lithologically consists of limestone and dolomite. Based on the paleontological studies the age of the Jahrum Formation is Middle Eocene (Lutetian to Bartonian) to Late Eocene (Priabonian).
- 3 faces belt have been identified including lagoon (JA), *Nummulites* Bank (JB) and open marine (JC).
- Gradual change of microfacies, the lack of main barrier reef and turbidite deposit in the inner parts of the platform, and the presence of redeposited sediment in the distal part of the platform suggested the distally steepened ramp environment.
- The identified microfacies in the Jahrum Formation in the Anguru Section have been summarized in table 1. Petrographic analysis of thin sections revealed that the microfacies of the lagoon environment is more abundant than other facies belt. Open marine and *Nummulites* Bank facies belt come next regarding their abundance.

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