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Facies Analysis and Depositional Environment of the Rus and Jil Formations (l- Eocene) in Najaf and Samawa Areas, Southern Iraq

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Abstract
This research deals with study of facies and depositional environment of the lower Eocene Rus and Jil Formations at Najaf and Samawa Governorates, Southern Iraq. Two major lithofacies are recognized in the studied sections, namely carbonate and evaporite lithofacies. The carbonate lithofacies is divided into five microfacies whereas the evaporite lithofacies is divided into three Sublithofacies.From facies analysis the Rus and Jil Formations, in the study area, represent deposition in a shallow carbonate rimmed platform. The Rus Formation consists of two shallowing upward successions each of them represents peritidal environment, i.e., beginning with subtidal followed by intertidal and culminated with supratidal setting. The Jil Formation consists of two shallowing upwards successions representing shelf to peritidal environments. The Jil Formation grades from open marine to sabkha, i.e., beginning open marine followed by shoal, subtidal, intertidal and culminates with supratidal setting. The abundance of evaporites indicates that the climate during their depositions is arid to semi-arid.
Keywords: Facies, depositional environment, Rus Formation, Jil Formation, Sabkha.

1. Introduction

The Rus Formation was first defined by Bramkamp in 1946 (Bellen et al., 1959) from the type section on the SE flank of the Darnmam dome in E Saudi Arabia and a supplementary section was chosen later by Owen and Nasr in (1958) in the Zubair well no.3 at the Mesopotamian Zone of southern Iraq. The formation is well defined in a very restricted area in Iraq in the southern Salman and Mesopotamian Zones especially between the transversal Kut-Dezful and AL Batin faults. Outcrops along the Saudi-Iraq border lack anhydrite (due to dissolution). The Jil Formation corresponds to beds previously assigned to the Dammam Formation (the Wagsa, Sharaf, Schbicha Members and the lower chalky part of Huweimi beds introduced by Huber and Ramsden (1944-1945, in Bellen et al., 1959)

The Middle Palaeocene-Eocene Megasequence AP l0 was deposited during a period of renewed subduction and volcanic arc activity associated with final closure of the Neo-Tethys. This led to uplift along the NE margin of the Arabian Plate with the formation of ridges and basins, generally of NW-SE trend in N and Central Iraq and E- W trend in W Iraq. Significant lateral facies changes occurred across these tectonic features. Uplift of the E margin of the Arabian Plate during the Early Palaeocene explains the absence of the Danian from most of the High Folded Zone and the Foothill Zone (Jassim & Goff 2006).

Ditmar and the Iraqi-Soviet Team (1971) recognized an important regional unconformity at the base of the middle Eocene. However this unconformity is here recognized as a sequence boundary; the megasequence boundary is placed in the latest Eocene following Sharland et al. (2001). The Middle Palaeocene-Eocene Megasequence (AP 10) is divided into two sequences: The Palaeocene-early Eocene and middle-late Eocene sequences.

The Jil Formation was first informally introduced through unpublished reports of the Iraq Geological Survey. Tamar-Agha (1982) first introduced the sequence under the name Salman Formation and then changed to Jil Formation, Al-Mubarak and Amin (1983), introduced the sequence under the name Jil Member and finally Jassim and co-workers (1984), suggested the succession to be called Jil Formation Jassim and others 1984. There are only few studies on these formations so far. Al-Hashimi (1973) studied the sedimentary facies and depositional environments of the Eocene Dammam and Rus Formations. The depositional environments and different litho-and-biofacies of the Eocene (Dammam and Rus Formations) are discussed and illustrated on five facies maps. The nummulites limestone facies (sub-littoral) changes laterally towards south and south-eastern area into an anhydrite (lagoon or "sabhka") facies during the lower Eocene.

Tamar –Agha (1983) revealed that Rus –Jil Formations were deposited during early Eocene time (Rus –Jil Formation) in southern Iraq indicating semi-barred restricted marine platform lagoon (dominance of supersaline conditions) in subtropical regions. Nummulitic shoals acted as a barrier between the main sea and the lagoons.

Al-Jubouri (2003) studied the sequence stratigraphic analysis of the Paleocene –Eocene succession western and southern Iraq. According to the study, the lower Eocene of the south is represented by the Rus Formation which is along the shoreline of a shallow homoclinal ramp setting, whereas the evaporites and mudstones of Rus Formation are mainly deposited in quiet lagoon of high salinity and high evaporation rates in warm and arid climate.

The main aim of this work is to study the facies of Rus and Jil Formations in Samawa and Najaf southern Iraq, in order to interpret the depositional environment through facies analysis.

2. Methodology

The study area is located in south of Iraq (Samawa and Najaf Governorates).

Table 1. The location of drilling wells, depth and number of samples.

Wells	Governorate	location		Drilling (depth m)	Number of samples
		Latitude	longitude		
B.H.8 Samawa	Samawa	45° 06′ 15″	30° 29′ 16″	45	25
B.H. 13 Samawa	Samawa	44° 49′ 30.9″	3o° 46′ 35.3″	50.6	20
B.H.22 Nasiriya	Samawa	45° 28′ 48″	30° 48′ 42″	48	11
B.H.23 Najaf	Najaf	44° 11′ 53.4″	31° 46′ 32.4″	100	14

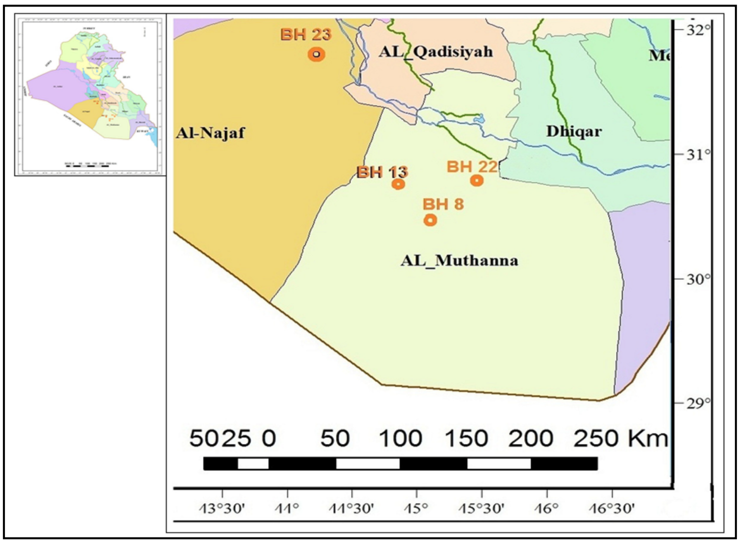

Figure 1. Location map of the study area

Four fully-cored boreholes drilled by the Iraq Geological Survey in Samawa and Najaf located in the southern part of Iraq. These wells are namely, Samawa 8, Samawa13, Nasiria 22 and Najaf 23 (Fig. 1). These wells are selected on the bases of their completeness of the formations, thickness, location and distance between them. The cores are described in the field according to the variations in lithology, color, hardness, texture, fossils content, sedimentary structure and nature of contacts. After the description of strata they are divided later into facies.

The laboratory work involves making thin sections (about 75 thin sections) prepared in the workshop of the Department of Earth Science, in College of Science / University of Baghdad. Carbonate thin sections are stained with Alizarin red S. The thin sections are studied under petrographic microscope.

3. Facies

Two major lithofacies are recognized in the studied sections, namely carbonate lithofacies and evaporite lithofacies.

3.1 Carbonate lithofacies

The Jil Formation is dominated by greyish brown, brownish grey and yellowish grey, thick bedded and dolomitic limestones to dolomite. At the base, the carbonate is bioturbited (boring filled with another sediment) followed by organodetrital carbonate (mostly gastropods and bivalves) then followed by carbonates almost devoid of fossils with impregnation of hydrocarbon and finally overlain by solution breccia. The middle part of Jil Formation consists of alternation of carbonate and thin beds of gypsum. The overlying beds are bioturbated carbonate and carbonate contains bioclast and fenestral porosity. At the upper of Jil Formation it consists of organodetrital and bioturbated carbonate with a lot of cavities at several levels. Above these layer marly carbonate and calcarenite (bioclastic) overlain by marly carbonate, fossiliferous carbonate (biomolds of most probably nummulite) and carbonate contains nodular gypsum. At the upper contact the carbonate is bioturbated, friable and contains vug porosity and biomolds with impregnation of hydrocarbon (Fig. 2).

The carbonate lithofacies in the Rus Formation are subordinate. They are pale brown, greyish brown and pale grey, thin bedded, dolomitic limestone and dolomite. At the base of the Rus Formation, it consists of laminated carbonate demonstrated by bioturbation to carbonates contains algal mat followed by birds eye and flaser bedding. In the upper beds the carbonates comprise wisps of evaporites. In the upper part it consists of chalky and marly carbonate add to flaser bedding carbonate and fenestral carbonate near to the contact with Dammam Formation (Figs3, 4 and 5).

Five microfacies are recognized in the studied sections. These microfacies are described here according to two of the most widely used schemes, i. e., Dunham's textural classifications (1962) and Folk's (1959, 1962) terminology. Both classifications subdivide limestone primarily on the basis of matrix content. The carbonate microfacies of Rus and Jil Formation can be summarized in

3.1.1 Dolomitic lime mudstone microfacies:

This microfacies consists of less than 10% of grains floating in dolomitic lime mud. The groundmass consists mainly of micrite (dolomitic mudstone) and few phosphatic fragments. The micrite is affected by neomorphism and dolomitization processes (partially or wholly). Some horizons contain bioclasts and/or bioturbated.

This submicrofacies is equivalent to SMF 23 of Wilson (1975 in Flugel 2010). Flugel 2010 named such facies unlaminated, homogeneous, unfossiliferous, pure micrite (homogeneous, non-fossiliferous micrite).

This microfacies occurs at lower part the succession in of well B.H.13 and the upper part succession in B.H.22. This microfacies is also present at the upper part of the succession in well B.H.23. It contains sometime gypsum nodules at times (Plate 1a).

3.1.2 Foraminifera fossiliferous wackestone to packstone microfacies:

This microfacies contains more than 40% benthic foraminifers such as miliolids and biomolds sometimes filled with authigenic gypsum, few phosphatic fragment and pyrite. The groundmass consists of either micrite or microsparite the latter results from neomorphic, partially and in sometime wholly dolomitized and dolomite rhombs contain zoning.

This microfacies is equivalent to SMF18 of Flugel (2010). He named such facies grainstone/packstone with abundant foraminifera or algae. The main feature of this SMF Type is the high abundance of benthic foraminifera and/or calcareous green algae. Other grains are peloids, cortoids and composite grains. Common textures are grainstones and packstones. Sediments of SMF 18 occur as bars and channels, and in sand shoals heaped up by tidal currents in shallow lagoons and bays (restricted platform, FZ 8) and in shelf lagoons with open circulation (FZ 7).

This microfacies occurs at the upper and lower part of the succession in well B.H.8 associated with birds' eye structure. It is also found it in the lower part of well B.H.13 (Plate1b). In well B.H.23 is microfacies containing moldic porosity of benthonic foraminifera like Textularia in the lower part of this well and Nummulites at the upper part of this well in addition to another biomolds of fossils. This microfacies contains in some part pelecypod and gastropod. The whole components are embedded in micrite, partially recrystallize to microspar and partially or wholly dolomitized with few phosphatic fragments in the lower part.

3.1.3 Peloidal wackestone microfacies:

This microfacies consists of peloids, about 30%, and few biomolds. The biomolds are sometime filled by authigenic gypsum and/or phosphatic fragment. This microfacies is occasionally found with evaporite in wispy shape. The groundmass contains micrite matrix partially or wholly dolomitized.

Peloidal wackestone microfacies is equivalent to SMF 16 of Wilson (1975). He named such facies pelsparite or peloidal grainstone. In Flugel (2010) SMF 16 named non- laminated peloidal grainstone/packstone is characterized by tiny, equal-sized peloids associated with benthic foraminifera, ostracods and/or calcispheresis. This microfacies is common in shallow platform interiors comprising protected shallow-marine environments with moderate water circulation (FZ 8) and in inner ramp settings, and may also occur in evaporitic arid platform interiors (FZ 9A). Peloidal wackestone microfacies occurs at the lower and upper part of well B.H.22 and in the lower part of well B.H.13. In well B.H.23 this microfacies occurs at the middle part the succession about one metre (Plate 1c).

3.1.4 Fossiliferous and intraclastic wackestone

This microfacies consists of intraclast, peloids, few biomolds and fenestral porosity which are filled with authigenic gypsum. The groundmass contains micrite matrix partially dolomitized.

Fossiliferous and intraclastic microfacies is equivalent to SMF 21 of Flugel (2010), which he named fenestral packstone and bindstone. SMF 21 was originally defined by Wilson (1975) a ‘spongiostrome mudstone fabric’ with algal tufts. Relicts of porostromate algae or calcimicrobes may be preserved or not eaten from animals. More useful criteria in distinguishing this microfacies are fenestral fabrics typically developed in FZ 8 and FZ 9A. .

This microfacies is about 40cm at the middle part of the succession in well B.H.22 and thickness about 150cm at the upper part of well B.H.13. At the lower part of well B.H.23 this microfacies containing gastropods biomolds and it is not filled with gypsum. The thickness of this beds about 50cm (Plate1d).

3.1.5 Algal bindstone microfacies:

In the present study, the bindstone microfacies consists of laminated algal mat in micrite matrix. Some of the samples contain lamina or remains of lamina of algal mat most probably because eaten by animals, with few phosphatic fragment and authigenic pyrite. Micrite matrix is partially dolomitized. Some samples contain evaporites nodules displacing the algal lamina.

This microfacies is equivalent to SMF 20, i. e., Laminated stromatolitic bindstones/mudstones of Flugel (2010). Its occurrence is very common in the intertidal zone, but also in supratidal and shallow subtidal zones. Open platforms (subtidal, FZ 7), tidal zones of restricted lagoons (FZ 8) and arid coasts (FZ 9A, supratidal). This microfacies is found at the lower part of the Rus Formation in well B.H.8 at two levels. The first one at the base thickness about 70cm underlying it laminated carbonate demonstrated by bioturbation thickness 130cm in carbonate rock and another one above it with anhydrite nodules displaced the algal laminated thickness about 50cm. Also this microfacies found it in well B.H.22 at the middle part thickness about 50cm with anhydrite nodules (Plate 1e, 1f).

3.2 Evaporites lithofacies

The evaporites lithofacies is the most conspicuous and characteristic of the Rus Formation. It is white, grey, brown, and light green beds. Nodules and nodular structures are the most dominant feature of these sediments. The nodules are sub-spherical irregular or even cylindrical (elongated) in shape. In general the nodules show compound wispy to wispy structure and chicken-wire texture, whereas the cylindrical nodules are commonly arranged parallel to the bedding plane. The evaporite nodules are mostly surrounded by wisp of carbonate film showing mosaic form or without prominent boundary revealing a structureless type (Plate 2a-d). Even the laminated gypsum is formed of coalescing nodules, except few laminated structure seen in the lower part of well B.H.22 (Plate 2e and 2f). In the studied wells a lot of veins of satin-spar gypsum are present (Plate 2g) whereas the selenite gypsum is present in the Jil Formation only (plate 2h) (Fig.6). This lithofacies comprises about more than half of the Rus Formation in the studied sections. Thickness of the evaporite lithofacies ranges from 18 m in well B.H.13 to 37 m in well B.H.8 m and 42 m in well B.H.22. The evaporite nodules are of replacive and displacive nature, though the former is more common. In the present study it is believed that this lithofacies represents supersaline state as the progressive desiccation of the lagoon continued. The incoming influx of water was in equilibrium with the evaporated water to form such thick evaporite beds.

Schreiber et al. (1976 in Walker, 1984) (Fig. 7) recognizes three main environmental settings for subaqueous evaporites. These settings are identified on the basis of sediment characteristics. They are believed to reflect the depth at which deposition occur. Criteria used Schreiber et al. (1976 in Walker, 1984) include:

1-Structure indicative of wave and current activity, identifying an intertidal and shallow subtidal environment. 2- Algal structure (in the absence of wave and current – induced structures) which are believed to identify a deeper environment but one that still resides with the photic zone. 3- Widespread evenly-laminated sediment (rhythmites) that luck of evidence of current and algal activity (perhaps associated with gravity-displaced sediments), and characterize the deep, subphotic environment.

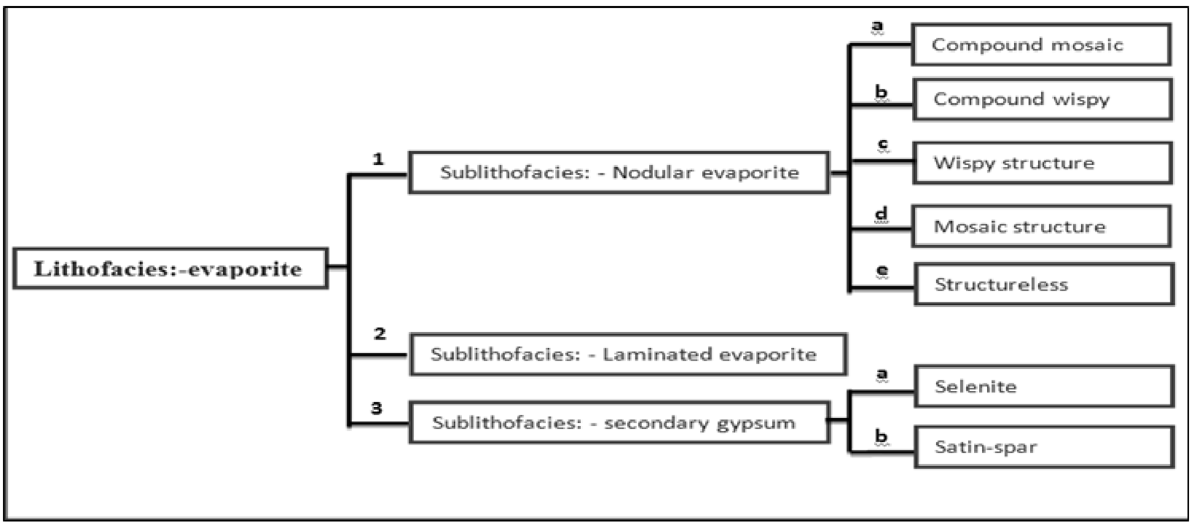

Figure 6. Evaporites lithofacies in the study area

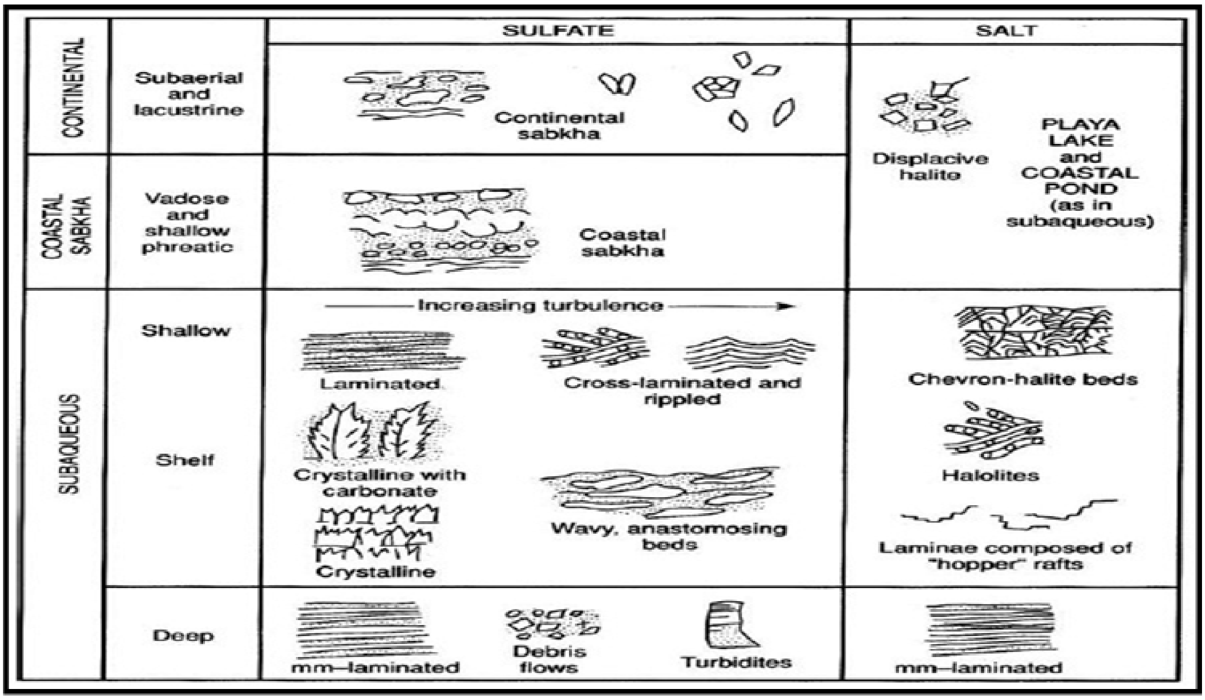

Figure 7: -Summary of physical environments of evaporites deposition and the main facies present (modified from Schreiber et al. 1976 in Walker, 1984).

4. Depositional Environment

Generally, facies distribution of the Rus and Jil Formations in the previous study are as follows: Al-Hashimi, 1974 (in Tamar-Agha et al., 1997) stated that "during the Lower Eocene regressive phase prevailed in south and southwestern Iraq , and thus, the sublittoral nummulitic facies of the Lower Ypresian (Wagsa Beds) was replaced by a littoral , miliolid-mollusca facies during upper Ypresian (Shabicha beds).

Facies analysis carried out by Tamar-Agha 1983 revealed that the early Eocene time (Rus-Jil Formations) in the Iraqi Southern Desert (in Umm El-Hashim KH/2) indicate deposition in a semi-bared restricted marine platform lagoon (dominance of supersaline conditions) in subtropical regions. Nummulitic shoals acted as a barrier between the main sea and the lagoons.

According to Tamar-Agha, 1997, the Jil Formation represents an asymmetric upward shoaling shelf cycle (shelf mud-sabkha cycle) which commences with a shoal and changes upwards to quite subtidal deposits of inner shelf lagoon (restricted marine) and culminated by the development of intertidal and supratidal sabkha.

According to Al-Mubarak and Amin, 1983, the depositional environment of the Jil Formation is quiet marine, with depth not more than 100m and represents the tropical –subtropical shoal facies. Depended on the isopach map of the Rus Formation (Fig. 8) (adapted after Al-Siddiki, 1973) the Rus formation represented semi closed shape looks like lagoon.

In the present study, facies distribution of the Rus and Jil Formations in the study area represents deposition on a shallow carbonate rimmed platforms. In Nichols (2009) rimmed carbonate shelves are shallow platforms marked at their outer edges (margins) by a pronounced break in slope into deeper water. They have a nearly continuous rim or barrier along the platform edge. Because the Rus Formation deposited in hypersaline water and high thickness of evaporites beds need to barrier make restricted platform. In the Jil Formation nummulitic shoals represented barrier.

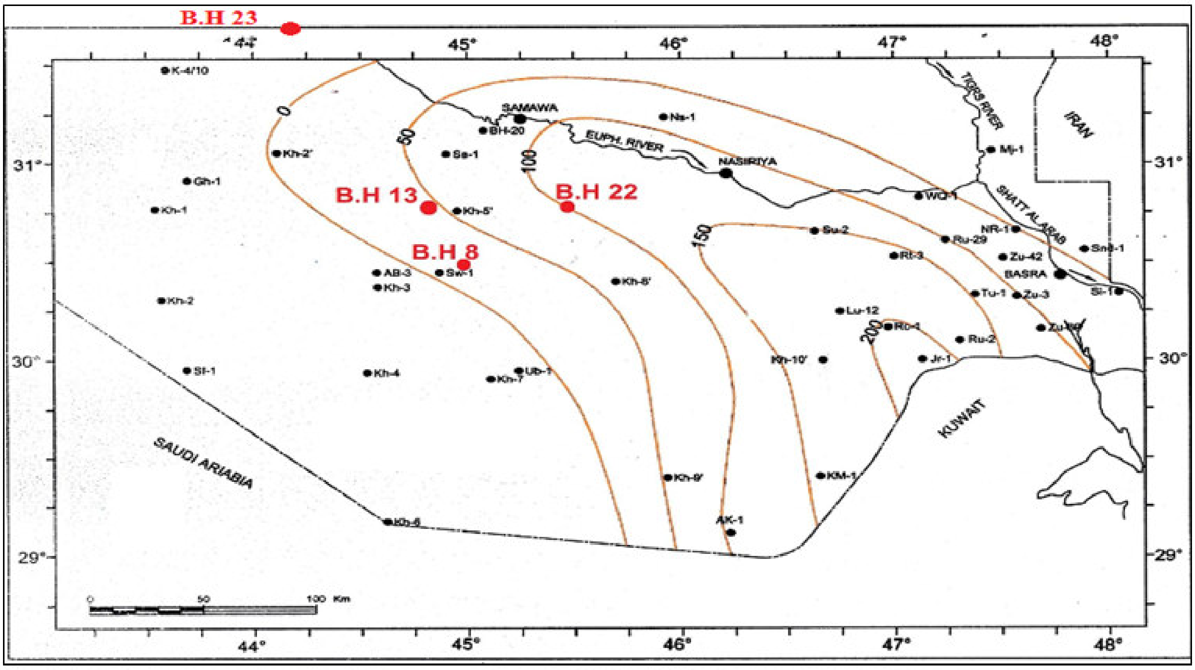

Figure 8. Isopach map of the Rus Formation (adapted after Al-Siddiki, 1973)

The sedimentary environment of the Rus Formation is concluded depending on the description of texture and type carbonate grains considering to the standard microfacies classification suggested by Wilson (1975) and its latest modification adopted by Flugel (2010). The Rus Formation located in Facies Zone 8 that characterized by bioclastic wackestones, lithoclastic and bioclastic sands, pelleted carbonate mudstones, stromatolites, interbeds of shale or silt; deposited in shallow water on inner platform where water circulation may be restricted and Facies Zone 9 that characterized nodular dolomites and anhydrites (on platforms where evaporative conditions exist); stromatolites; siliciclastic muds or silts; deposited in intertidal to supratidal zone.

The Rus Formation consists of two shallowing upwards successions each of them representing peritidal environment, i.e., beginning with subtidal, intertidal and supratidal setting figures (5, 6 and 7). The Jil Formation can be summarized as two shallowing upwards successions representing gradation from open marine to sabkha, i.e., beginning open marine, shoal, subtidal, intertidal and supratidal setting figure (8). The clay minerals are referring to arid to semi-arid climate.

According to the Schreiber's model et al. (1976 in Walker, 1984) that he proposed for physical environments of evaporites, deposition of Rus Formation contains structure indicative of wave and current activity represented by flaser bedding, identifying an intertidal and shallow subtidal environment. The Rus Formation contains also algal structure (in the absence of wave and current – induced structures) that represents deeper environment but that still resides with the photic zone. The Rus Formation contains occasionally birds eye structure and fenestral porosity that indicated intertidal and supratidal environment. Depending on Schreiber model of evaporites facies the Rus Formation represents coastal sabkha and subaqueous shallow and shelf environment.

5. Conclusion

-The facies distribution of the Rus and Jil Formations in the study area represents deposition on a shallow carbonate rimmed platforms.

-The Rus Formation consists of two shallowing upwards successions each of them representing peritidal environment, i.e., beginning with subtidal, intertidal and supratidal setting. The Jil Formation can be summarized as two shallowing upwards successions representing gradation from open marine to sabkha, i.e., beginning open marine, shoal, subtidal, intertidal and supratidal setting. The clay minerals are referring to arid to semi-arid climate.

-The evaporites facies of the Rus Formation represents coastal sabkha and subaqueous shallow and shelf environment.

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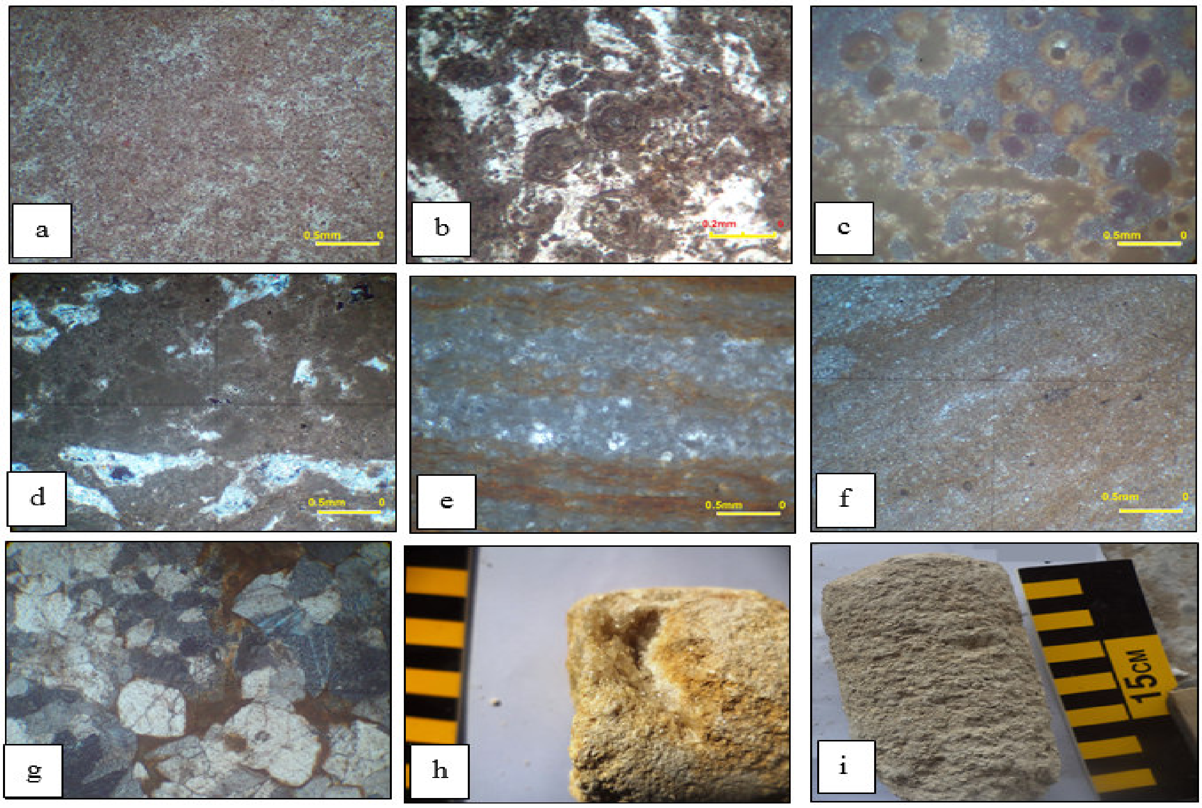


Plate 1. Carbonate microfiches and lithofacies in the study area.

(a) Dolomitic lime mudstone from the Rus Formation at B.H.8 (depth147m) (PPL.4X). (b) Miliolid fossiliferous wackestone to packstone from the Rus Formation at B.H.8 (depth145m) (XPL.10X). (c) Peloidal wackestone from the Rus Formation at B.H.22 (depth101m) (XPL. 4X). (d) Fossiliferous and intraclastic wackestone from the Rus Formation atB.H.22 (depth118m) (XPL.4X). (e) Algal bindstone from the Rus Formation at B.H.8 (depth146m) (XPL.4X). (f) Algal bindstone from the Jil Formation at B.H.23 (depth224.5m) (XPL.4X). (g) Calcarenite from the upper part of the Rus Formation at B.H.13 (depth 95m). h) Calcarenite from the upper part of the Rus Formation at B.H.13 (depth 95m). (i) Calcarenite from the middle part of the Jil Formation at B.H.23 (depth 175.5m)

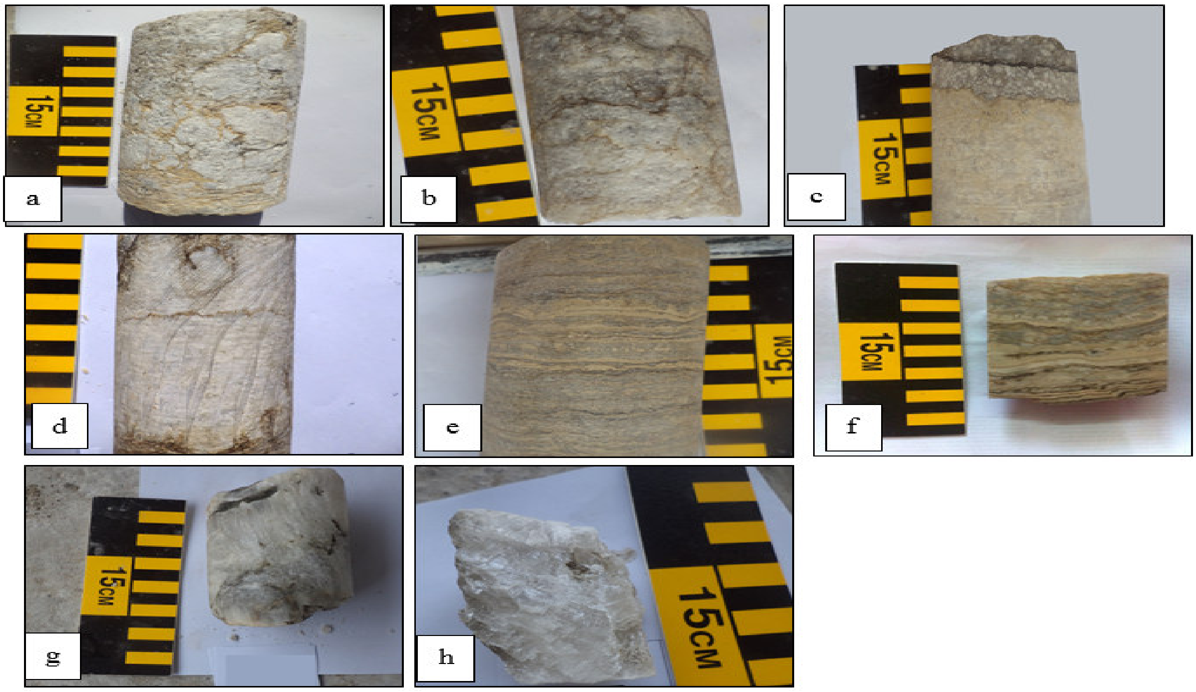
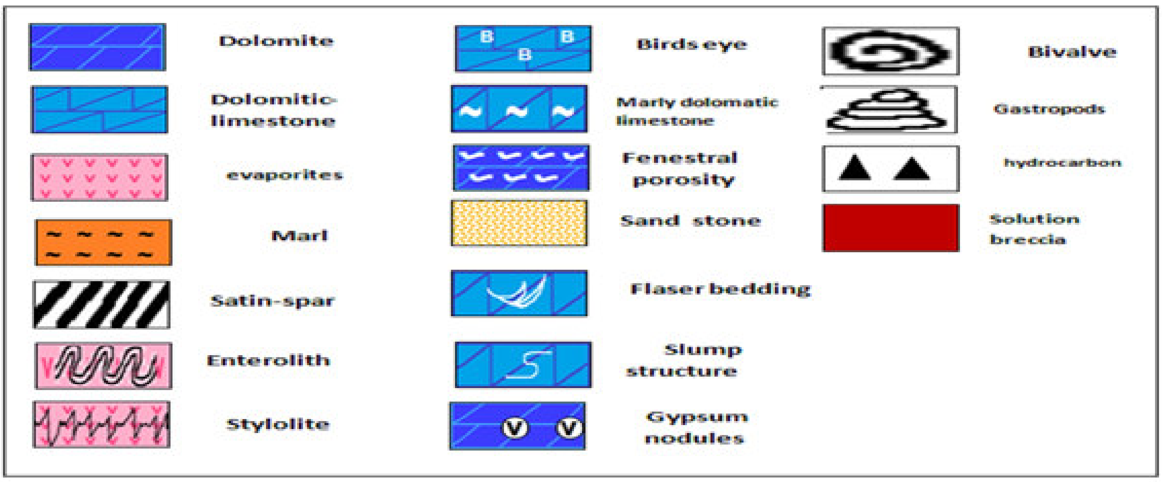


Plate 2. Evaporites lithofacies in the study area.

(a) Compound wispy structure from Rus Formation at B.H.13 (depth 109 m). (b) Wispy structure from Rus Formation at B.H.22 (depth 102 m). (c) Mosaic structure from Rus Formation at B.H.22 (depth 122.5 m). (d) Structureless from Rus Formation at B.H.13 at (depth 110.8 m). (e) Laminated gypsum with dolomite from the Rus Formation at B.H.22 (depth 141m). (f) Laminated of evaporite nodules with carbonates lamina at B.H.13 (depth 116 m). (g) Vein of satin-spar gypsum from the Rus Formation at B.H.8 (depth 121m). (h) Selenite crystal of gypsum atB.H.23 (depth 151m).

Legend



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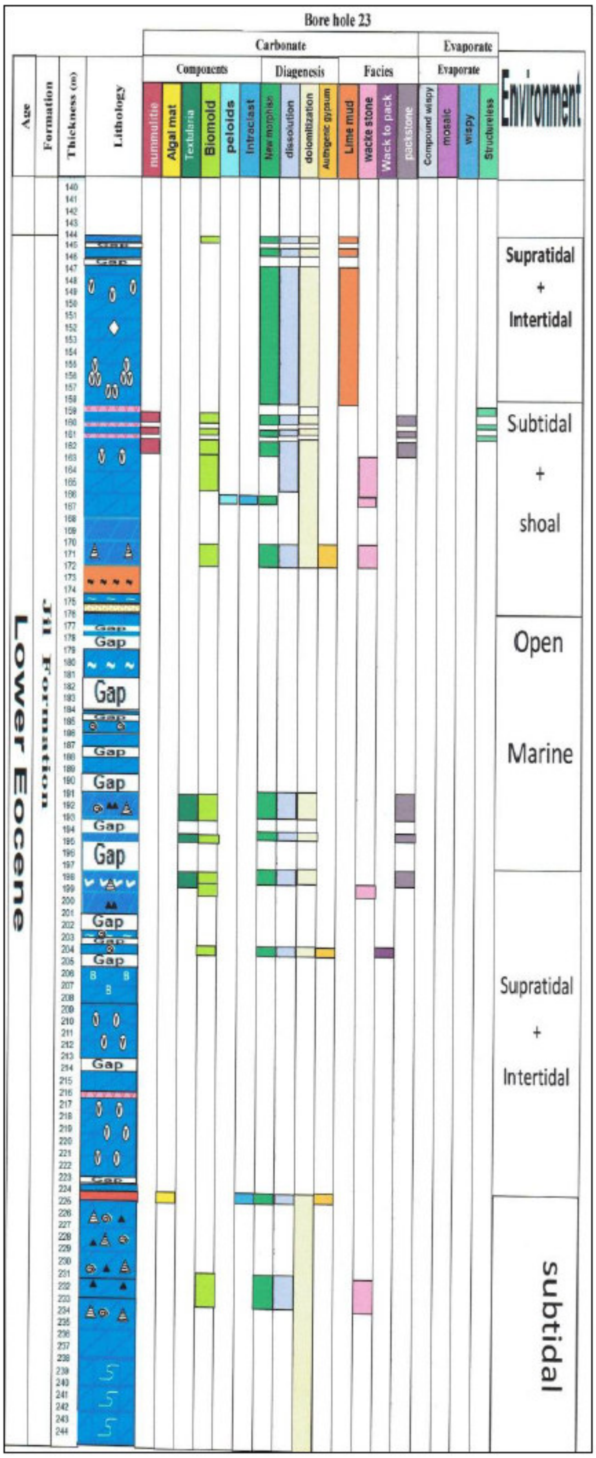

Figure 2. Bore hole 23 in Najaf area

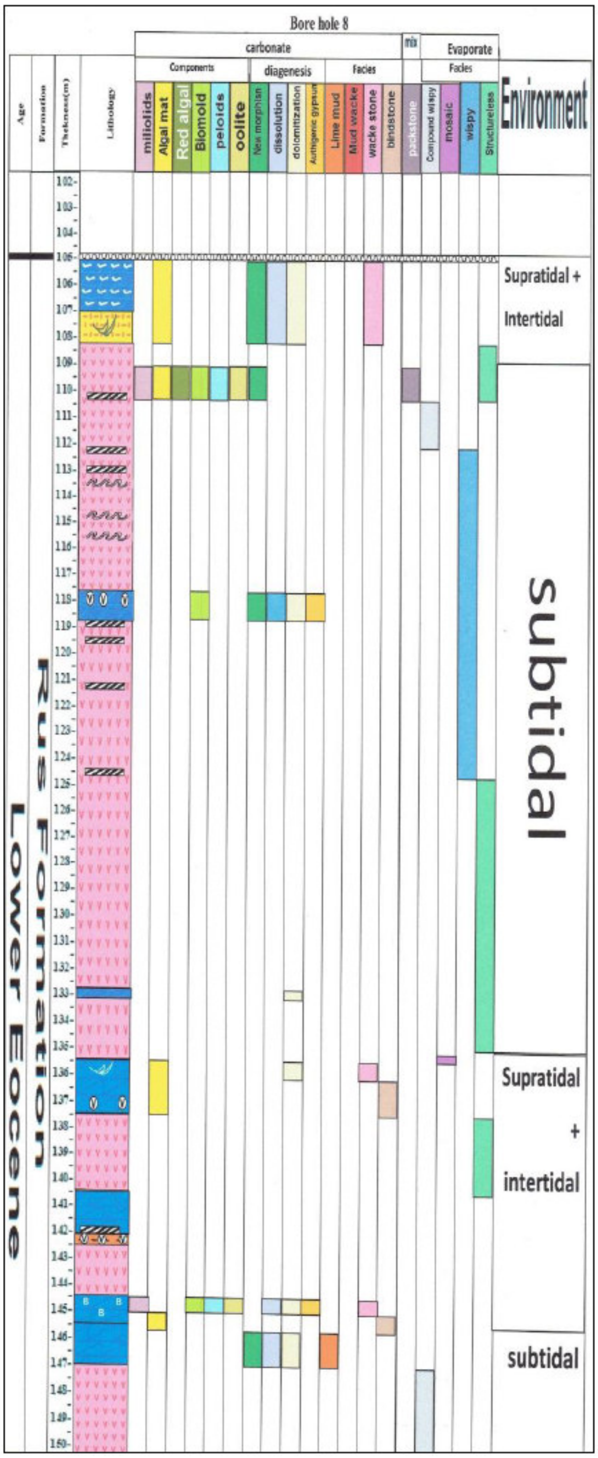

Figure 3. Bore hole 8 in Samawa area

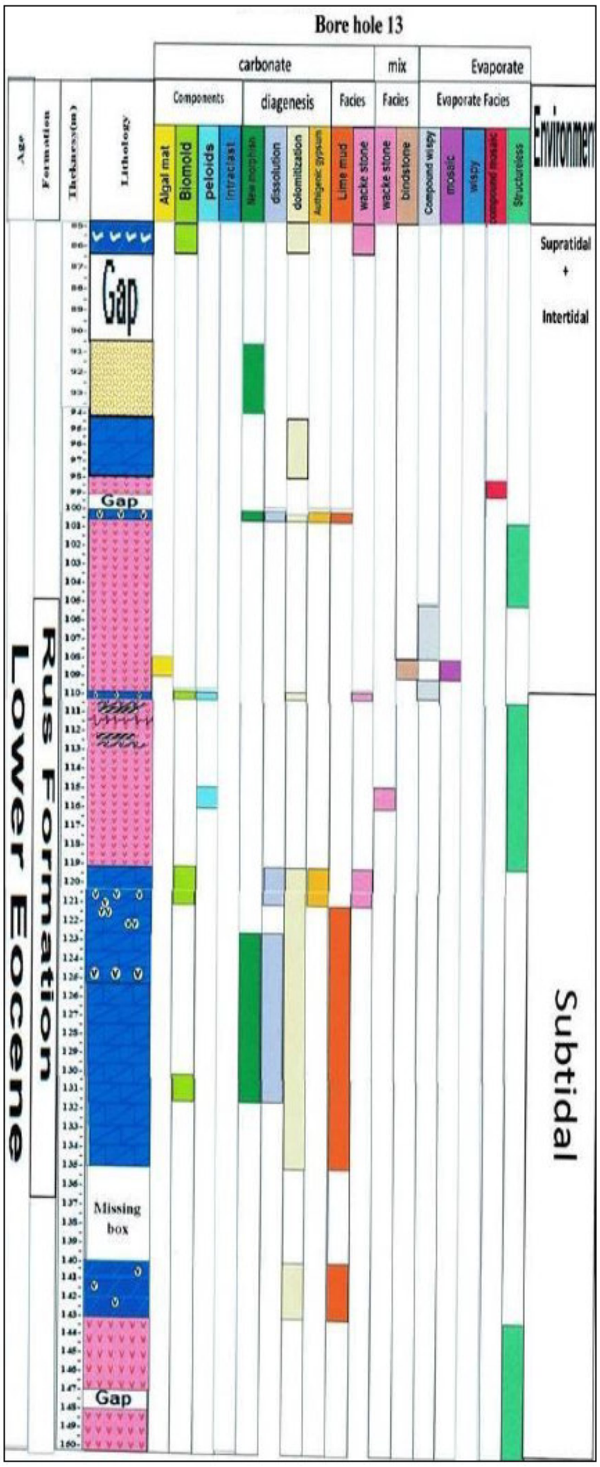

Figure 4. Bore hole 13 in Samawa area

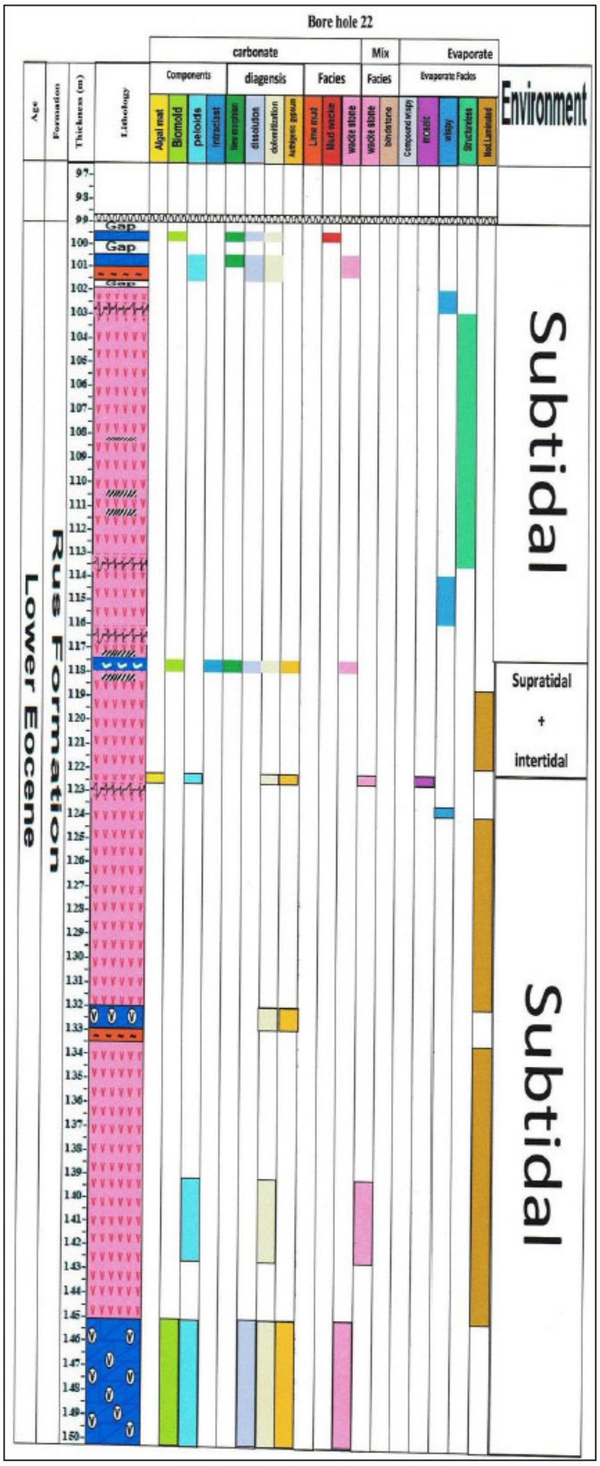

Figure 5. Bore hole 22 in Samawa area