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Microfacies and Paleoenvironment of Jaddala Formation in Selected Wells in Kirkuk and Jambour Fields in Northeastern Iraq

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ABSTRACT

The microfacies are identified within the Jaddala Formation in wells (Ja_40, K_243, and K_411) in northeastern Iraq and from the petrographic study. it is found that most of the skeletal grains consist of planktonic forams such as (*Globigerina*, *Globorotalia*, *Acarinina*, and *Subbotina*). Benthonic foraminifera is low, while non-skeletal granules are limited to quartz and phosphate grains, and the groundmass is mainly brown to light micrite. The lithology is affected by diagenetic processes such as compaction, cementation, dissolution, recrystallization, and authigenic minerals such as pyrite. Based on the petrographic study, the microfacies are divided into three main microfacies identified as Lime Mudstone Microfacies (LMJ), Lim Wackstone Microfacies (LWJ) and Lime Packstone Microfacies (LPJ) which are divided into two Submicrofacies Planktonic Foraminiferal Lime Packstone Submicrofacies (LPJ1) and Bioclastic Lime Packstone Submicrofacies (LPJ2). The depositional environment of the formation is determined depending on the Microfacies content of the fossil's planktonic foraminifera and benthonic foraminifera as well as its comparison with the standard microfacies. Three main environments for the sedimentation of the Jaddala Formation are distinguished depending on the classification of the environments set (toe_ of_ slope, deep shelf, and deep sea). This difference in environments is caused by a difference in the topography of the sedimentary basin.

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السحنات الدقيقة والبيئة القديمة لتكوين جدالة في آبار مختارة في حقلي كركوك وجمبور في شمال شرقي العراق

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الملخص

تم التعرف على السحنات الدقيقة ضمن تكوين جدالة في الآبار (Ja_40، K_243, K_411) في شمال شرقي العراق ومن الدراسة البتروغرافية وجد أن معظم الحبيبات الهيكلية تتكون من الفورامنيفيرا الطافية مثل (Globigerina, Globorotalia, Acarinina and Subbotina) والقليل من الفورامنيفرا القاعية، في حين أن الحبيبات غير الهيكلية تقتصر على حبيبات الكوارتز والفوسفات، وتتكون ارضية السحنة بشكل أساسي من المكرايت البني إلى الفاتح. تتأثر السحنات بالعديد من العمليات التحويرية منها الانضغاط والسمنتة والاذابة وإعادة التبلور ، والمعادن موضعية المنشأ منها البايريت. اعتمادا على الدراسة البتروغرافية تم تقسيم السحنات الدقيقة الى ثلاث سحنات رئيسة (Lime Mudstone Microfacies (LMJ), Lime Wackstone Microfacies (LWJ) and Lime Packstone Microfacies (LPJ) which were divided into two Submicrofacies Planktonic Foraminiferal Lime Packstone Submicrofacies (LPJ1) and Bioclastic Lime Packstone Submicrofacies (LPJ2)). تم تحديد البيئة الترسيبية للتكوين اعتمادًا على السحنات الدقيقة ومحتواها من متحجرات الفورامنيفرا الطافية والقاعية ومقارنتها مع السحنات القياسية. وبذلك تم تمييز ثلاث بيئات رئيسة لترسيب تكوين جدالة بالاعتماد على تصنيف البيئات، وهذه البيئات مقدمة المنحدر والرصيف والبحر العميق (Toe_ of_ Slope, Deep Shelf and Deep Sea). هذا الاختلاف في البيئات ناتج عن اختلاف في طبوغرافيا الحوض الرسوبي.

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Introduction

The first who described the Jaddla Formation is Henson (1940; in Bellen et al., 1959) in his typical section near the village of Jaddala in Mount Sinjar in the Foothill Zone that includes (350 m) lime clastic, chalky lime, and marl with sometimes thin tongues forming shallow lime. In the study of Al-Sultan (2018) on the sedimentary site of the Jaddala Formation in the oil fields of Kirkuk and Bai Hassan, the formation was deposited within three environments: the deep shelf, toe-of-slope, and deep sea. In the study carried out by Majeed et al. (2012), to investigate the microfacies and environmental analysis of the Jaddala Formation for selected wells in northern Iraq, he concluded that the sequencing of the Jaddala Formation may resulted from deposition within three environmental areas: the deep shelf, toe_ of_ slope and the deep sea. Al-Mutwaly and Al-Rubai (2021) proved in their research on the geological history, archaeological, and microfaciess stratigraphic of the Eocene-Oligocene boundary in the Sinjar area, northwestern Iraq, that the Jaddala Formation consisting of marl and marly limestone sequences representing the deep marine environment. They also revealed the effect of diagenetic processes such as compaction, cementation, dissolution, recrystallization, and authigenic minerals on the conclusion of sedimentary environments as they were produced from three main environments: toe-of-slope, deep shelf, and deep sea. The lower boundary contact of the formation is a surface of unconformity with the Aaliji Formation and the upper contact is also a surface of unconformity with Eocene deposits (Jassim and Goff, 2006).

In the current study, three wells are selected from the Jambur (Ja_40) and Kirkuk (K_243 and K_411) oil fields with a total of (284) thin sections (slides) from the Geology Department of the North Oil Company (Table 1). The study area is located within the foothill zone located in the Butmah_Chemchemal Subzone of the unstable shelf of Iraq in the dome of Baba from the Kirkuk field and the fold of Jambur (Figure 1).

Table 1: location, samples' number, wells, and formation thickness.

Jaddala Formation				Geographical Coordinate	Well
Number slide	Thickness	Lower limit	Upper limit		
134	170m	2035	1865m	N:35 14 19, E:44 25 51	Ja_40
98	112m	857m	745m	N:35 29 35, E:44 23 05	K_243
52	80m	640	560	N:35 31 05, E:44 20 41	K_411

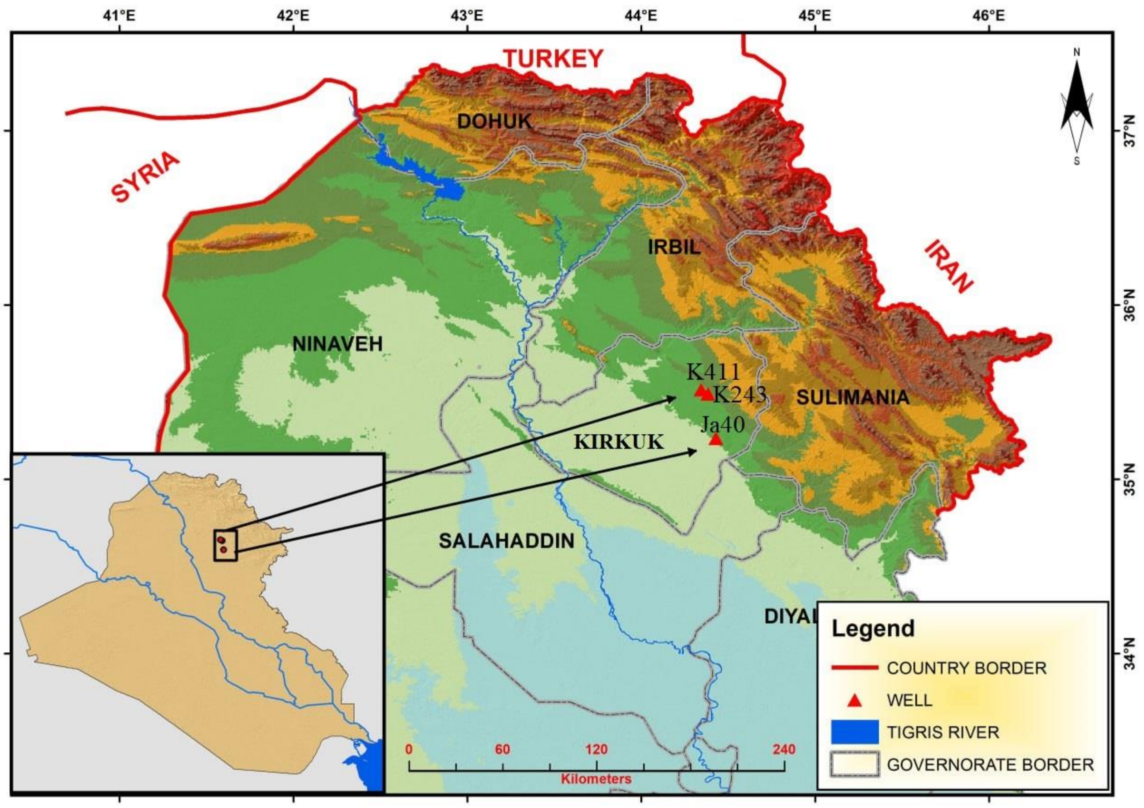

Fig.1. locations of the study wells in the Jumbur and Kirkuk oil fields (ARC GIS 10.8)

Aim of study

The present study aims to identify the skeletal and non-skeletal components and diagenetic processes of the Jaddala Formation, as well as to determine the main and sub-microfacies to determine the depositional environment and draw the sedimentary model.

Materials and Methods

Three wells were selected from the oil fields of Jumbour and Kirkuk. 284 thin section slides prepared by the company have been examined under the microscope to determine the skeletal and non-skeletal components and diagenetic processes, including the conclusion of microfacies, as well as reviewing the final reports of the North Oil Company for these wells, maps of the structural and well loges and studying them in detail.

Result and Discussions

Petrography

284 thin sections from the studied wells have been studied petrographically. The fossils are divided into skeletal and non-skeletal components, and planktonic foraminifera constituting more than 90% of the skeletal components represented by the genera (*Globigerina, Globorotalia, Acarinina, and Subbotina*) (Plate 1/A) and a very small percentage of benthonic foraminifera (Plate 1/B) and bioclastic (Plate 1/C). The non-skeletal components are granules of quartz and phosphate (Plate 1/D). The groundmass consists of the matrix in which the granules of micrite are buried. It is composed of fine-crystallized crystals ranging in size between (1-4) microns of calcite and aragonite (Folk, 1959). It is of pale or opaque color to black, depending on the concentration of organic or clay materials, and it may be of primary origin or formed by the effect of diagenetic processes (Plate 1/E). The third component is cement, which is a chemical deposit of calcium carbonate from solutions deposited inside the voids in the sediment, which is called micro-spar in the case of fine-sized granules distinguished by their euhedral or subhedral-shapes of 5-20 microns in size resulting from the recrystallization of the micrite (Plate 1/F), but if the lime crystals are rough and greater than 10 microns, it is called sparite and they are brightly colored under the microscope. The cementation process that occurs in most of the available spaces gives carbon deposits stability and strength (Boggs, 2006) as well as authigenic minerals such as pyrite (Plate 2/D) and compression (Plate 2/E).

Microfacies

Carbonate rocks are divided into three main different microfacies according to Dunham's classification (Dunham, 1962) that are divided into secondary sub-microfacies through the petrographic study depending on the rock contents of skeletal grains and non-skeletal grains relative to the ground as shown in figures (2, 3, 4) that illustrate the distribution of skeletal and non-skeletal grains, diagenetic processes, types of microfacies and porosity.

1- Lime Mudstone Microfacies (LMJ): This microfacies is found in all wells of the study, where it is located in the upper part of the formation and the percentage of skeletal grains is less than (10%) of the components, representing planktonic foraminifera spherical chambers such as (*Globigerina* and *Globorotalia*) with the presence of some benthonic foraminifera in addition to the bioclastic (Plate 2/F) and consist of quartz mineral, and the granules that have been mentioned in this microfacies is buried with a groundmass of fine and sometimes recrystallized probes and from the micrite. The diagenetic processes in this microfacies are weak such as compaction and recrystallization, where most of the skeletal components appear as patches of spar scattered in the groundmass, and this microfacies is equivalent to the standard facies (SMF-3) deposited within the (FZ-1) band representing the deep-sea environment (Wilson, 1975 and Flugel, 2004).

2- Lime Wackstone Microfacies (LWJ): This microfacies is observed in the middle part of the formation in the wells of the study and its percentage is limited as it does not exceed (10 m) in the best, and it contains mainly the planktonic foraminifera and a little of the benthonic foraminifera with bioclastic. The proportion of skeletal granules does not exceed (20 m) of the total components. The granules, which are similar to what is in the previous microfacies, are buried with a groundmass of the soft spar. They are recrystallized and sometimes pelletal, which is sometimes characterized by containing some clay materials (Argillaceous materials) (Plate 2/A). This microfacies is affected by diagenetic processes, the most important and obvious is the process of mechanical compaction, where the directivity and elongation are observed in the skeletal grains, in addition to the secondary calcite, micrite, pyrite, and sometimes silica fill the cavities of some planktonic fossils are found. These microfacies are equivalent to the standard microfacies (SMF-8) and deposited within the facies zone (FZ-2), which represents the environment of the deep shelf (Wilson, 1975; Flugel, 2004).

3- Lime Packstone Microfacies (LPJ): This microfacies is located at the bottom of the Jaddala Formation in the wells of the study that include the formation. It is identified following the classification of Dunham (1962) as adopted in the study. The percentage of skeletal grains is more than (40-60%) of the total skeletal components of planktonic foraminifera by genera (*Globigerina, Globorotalia, Acarinina,* and *Subbotina*). These microfacies are divided into two Sub-microfacies:

A- Planktonic Foraminiferal Lime Packstone Submicrofacies (LPJ1)

This microfacies is located at the lower part of the Jaddala Formation in all study wells, where the percentage of skeletal grains reaches (60%) of the total components of the microfacies and contains a high abundance of planktonic foraminifera, which constitutes approximately (85%) of the total granules with some benthonic foraminifera and bioclastic (late (2/B). This facie is affected by diagenetic processes, the most important of which are mechanical and chemical compression, and cement is one of the main factors affecting this microfacies, in addition to the fact that pyrite, glauconite, and phosphate granules fill some shell chambers. These microfacies are equivalent to the standard microfacies (SMF-2) and deposited within the FZ-2 facies zone, which represents the deep shelf environment (Wilson, 1975; Flugel, 2004).

B- Bioclastic Lime Packstone Submicrofacies (LPJ2)

This microfacies is characterized by containing a high percentage of bioclastic, more than (50%) of the total granules, which is associated with a limited percentage of planktonic foraminifera (*Globigerina* and *Globorotalia*) and the forms of benthonic foraminifera are few in this microfacies (Plate 2/C). This microfacies is located in the lower part of the composition of the Jaddala Formation on the boundary with the Aaliji Formation with a thickness of (5m). These granules are buried with a groundmass of brown to dark brown micrite. These microfacies are affected by diagenetic processes such as cementation, dissolution, and recrystallization, as well as authigenic minerals such as pyrite and glauconite. These microfacies are equivalent to the standard microfacies (SMF-2) and deposited within the FZ-3 facies zone representing the open sea environment (Wilson, 1975; Flugel, 2004).

Depositional Environment:

The Jaddala Formation (Middle Eocene) in the study wells consists of sequences of marly limestone and limestone and major environments have been identified depending on the classification of environments set by (Flugel, 2004). The distinguished three main microfacies and two sub-microfacies according to their abundance, starting with the shall lime mudstone microfacies (LMJ), which represents the most widespread facies in the Jaddala Formation in all wells, followed by lime packstone microfacies (LPJ), which is divided into two sub-microfacies, planktonic foraminiferal lime packstone sub-microfacies (LPJ1) and bioclastic lime packstone sub-microfacies (LPJ2), and lime wackstone microfacies (LWJ) is less prevalent and limited in distribution. Through these microfacies and the life assemblages, it is possible to identify three types of environments in which the formation is deposited: toe_ of_ slope environment that consists of a lime packstone microfacies (LPJ) rich in planktonic foraminifera, debris of benthonic foraminifera, and a few Echinodermata, and this environment is located within the deep zone according to Wilson (1975; modified by Flugel, 2004). The second environment is the environment of the deep shelf, which consists of the lime packstone microfacies (LPJ) and the lime wackstone microfacies (LWJ), which is characterized by containing soft materials such as micrite, silica deposits, calcareous materials, planktonic foraminiferal shell residues, and other organism remains indicating sedimentation in a deep environment due to the predominance of planktonic foraminifera and the small amount of benthonic foraminifera such as containing genera (*Globigerina* and *Globorotalia*). The presence of pyrite, glauconite, and phosphate are all indications of deep and calm pelvic conditions. The third environment is the deep-sea environment, which represents lime mudstone microfacies (LMJ) containing the planktonic foraminifera, which exists in deep and trenched environments caused by the presence of faults as a result of the movement of plates and the presence of planktonic in abundance, silica granules and radiolaria shells all indicate a deep environment. This difference in environments is caused by a difference in the topography of the sedimentary basin. Through the abundance of genera (*Acarinina* and *Subbotina*) and the absence of the genera (*Morozovella*), the climatic conditions that prevailed during the deposition of the Jaddala Formation were subtropical to temperate (Premoli Silva and Borrsman, 1988) (Fig. 5).

Conclusions

The study reveals the following results:

1_ The abundance of planktonic foraminifera on the rest of the skeletal components represented by genera (*Globigerina*, *Globorotalia*, *Acarinina*, and *Subbotina*), less benthonic foraminifera and less bioclastic.

2_ Based on the petrographic study, the formation is divided into three main microfacies (mudstone, wackestone, and packstone) and two sub-microfacies:

A_ Planktonic foraminiferal lime packstone sub-microfacies (LPJ1)

B_ Bioclastic lime wackestone sub-microfacies (LPJ2)

3_ Depending on the microfacies and their fossil content, the environments that precipitated the Jaddala Formation are divided into three environmental zones (toe-of-slope, deep shelf, and deep sea).

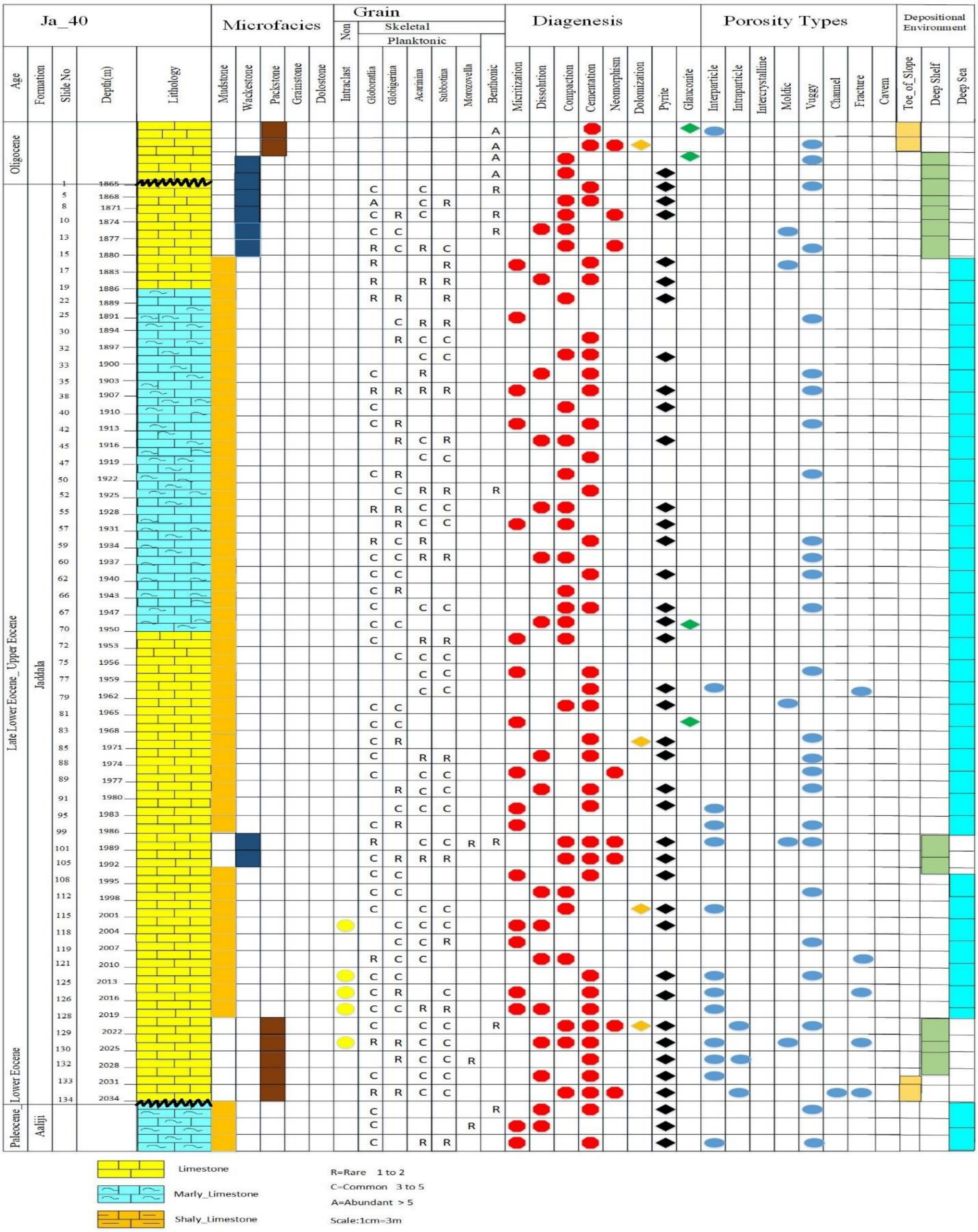

Fig. 2. Distribution microfacies and depositional environment of Jaddala Formation in a Well (Ja_40)

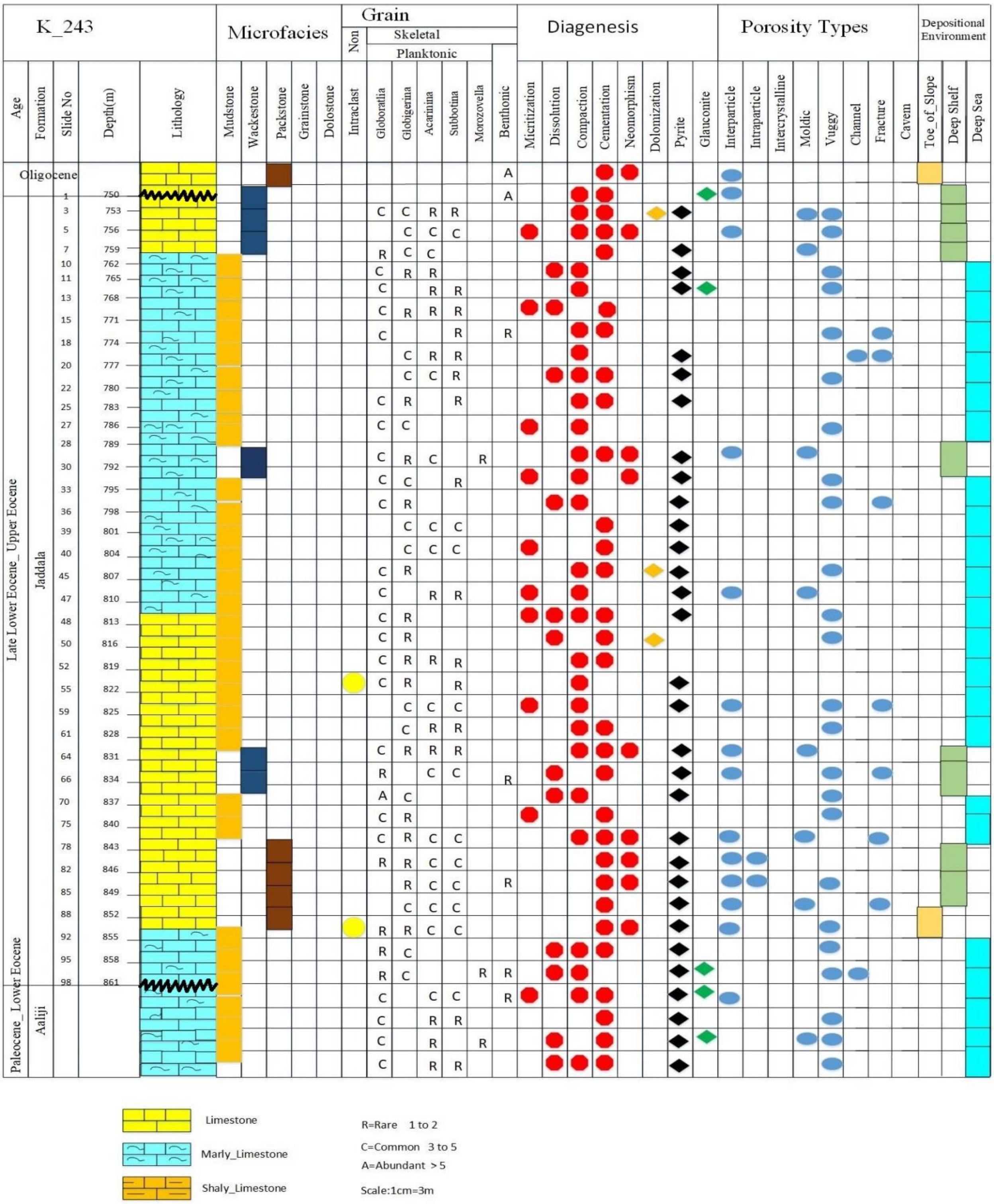

Fig. 3. Distribution microfacies and depositional environment of Jaddala Formation in a Well (K_243)

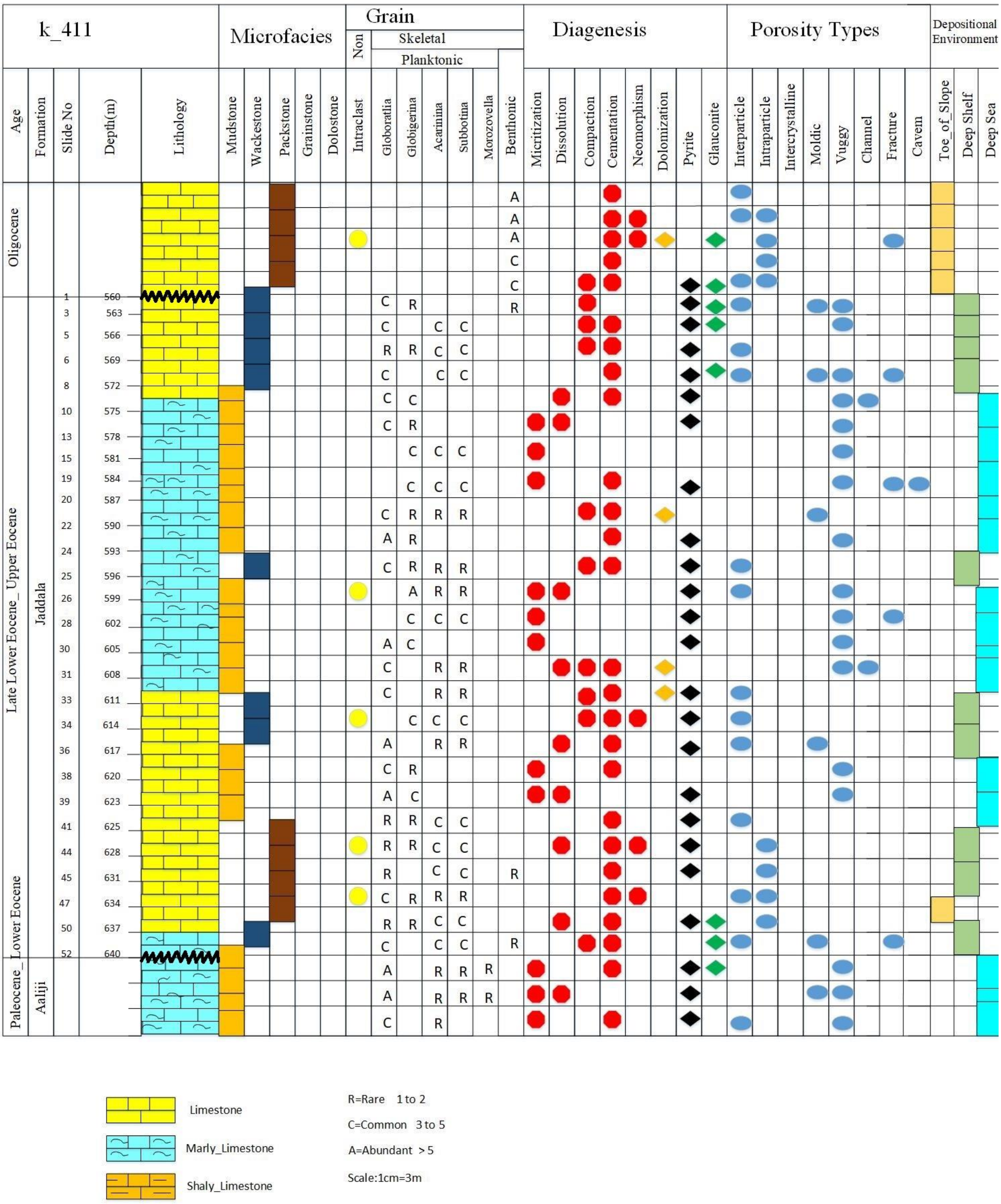

Fig. 4. Distribution microfacies and depositional environment of Jaddala Formation in a Well (K_411)

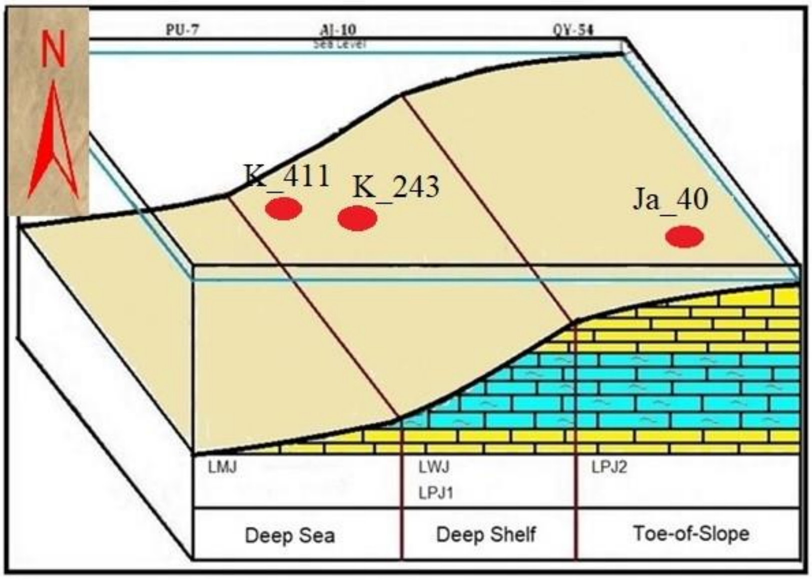

Fig. 5. Sedimentary model of Jaddala Formation in the present study

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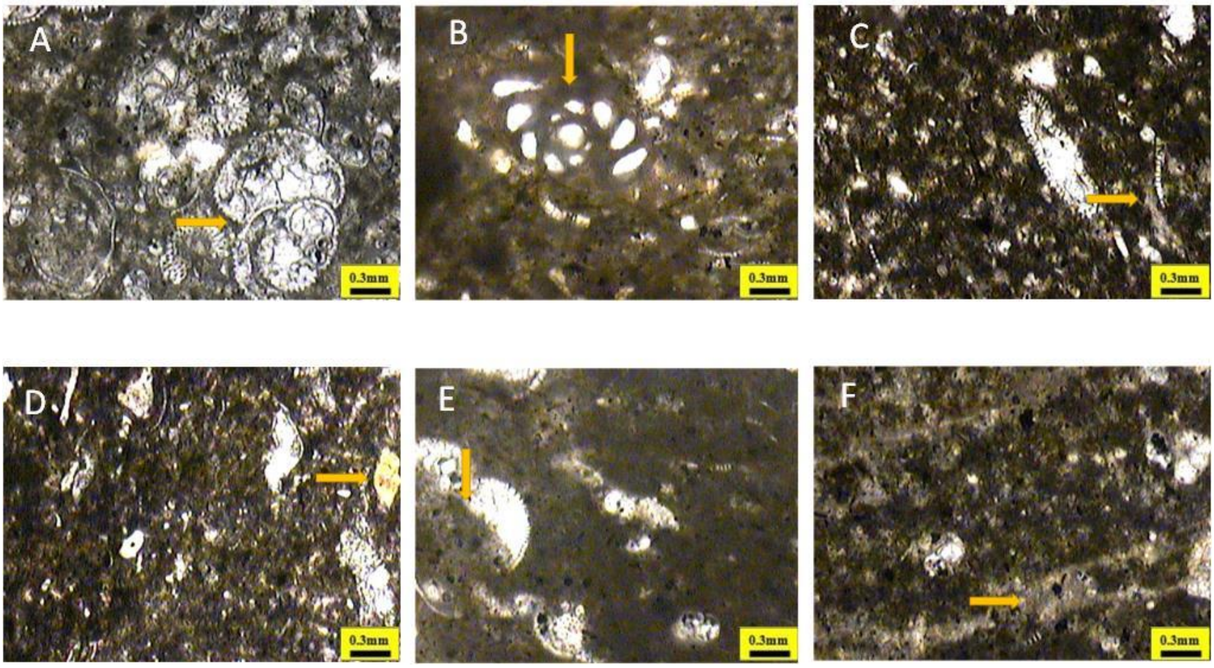
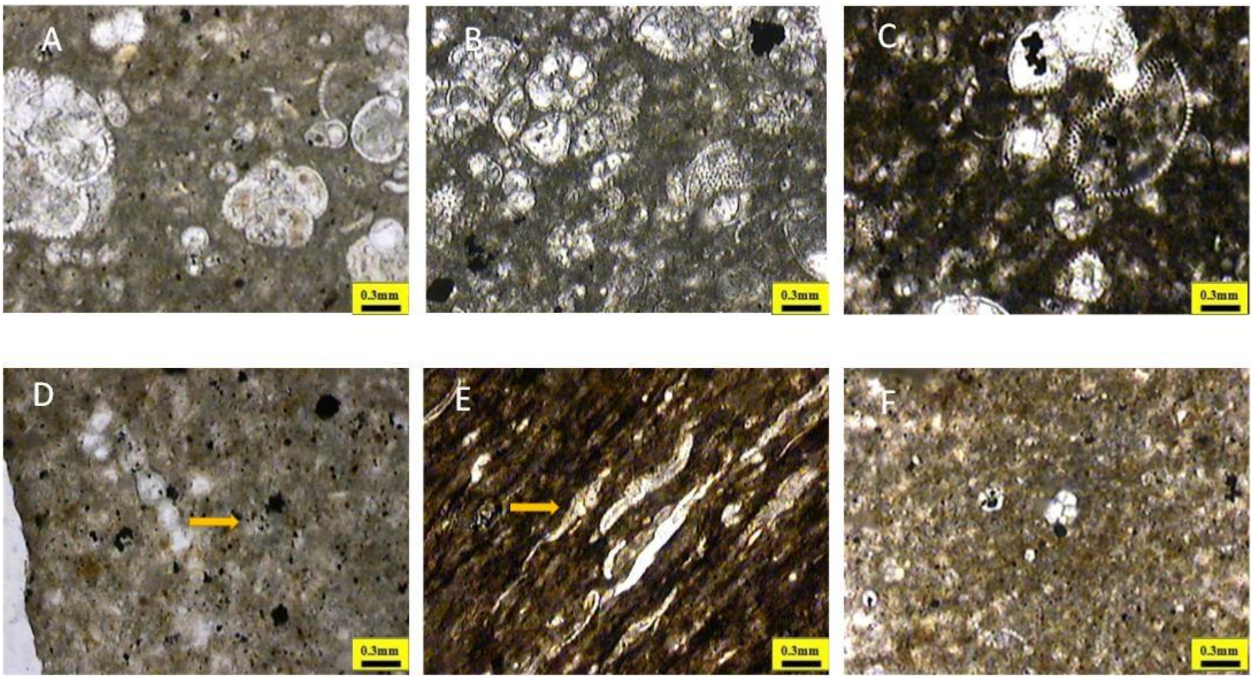
Plate (1)



A- Miscellaneous Planktonic Foraminifera Fossils Well (Ja_40) Depth (2025 m) (X40), B- Benthonic foraminifera Well (Ja_40) Depth (2033 m) (X40), C - Bioclastic Well (K_243) Depth (855 m) (X40), D- Phosphate Granules Well (K_411) Depth (636m) (X40), E- Groundmass and Micritization Process Well (Ja_40) Depth (2015 m) (X40), F- Groundmass of Spyrite Well (Ja_40) Depth (2018 m) (X40)

Plate (2)



A_ Lim Wackstone Microfacies well (Ja_40) Depth (1990m) (X40), B_ Planktonic Foraminiferal Lime Packstone Submicrofacies well (K_411), Depth (620 m) (X40), C_ Bioclastic Lime Packstone Submicrofacies well (K_411) Depth (858m) (X40), D_ Pyrite Mineral Well (K_243) Depth (830 m) (X40), E_ Mechanical Compression Process Well (K_411) Depth (640 m) (X40), F_ Lime Mudstone Microfacies well (Ja_40) Depth (2002 m) (X40)