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# Biostratigraphy of the Lower Miocene Nukhul Formation, Gulf of Suez, Egypt

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## Abstract

The lower Miocene Nukhul Formation from two onshore wells (ARS-6 and SIDRI-20) situated in the eastern side of the Gulf of Suez was investigated for their planktonic foraminiferal content to define its geologic age. The identified planktonic foraminifera contain 20 species belonging to nine genera. These planktonic foraminiferal assemblage enables the recognition of two planktonic biozones within ARS-6 well. The Gulf of Suez rift began with deposition of Nukhul Formation, and it is the first syn-rift rock unit to be formed. Although the age of Nukhul Formation is a controverse, and many papers proposed different ages for it, this biostratigraphic study indicate that the Nukhul Formation is assigned to the Burdigalian age.

***Keywords***: Lower Miocene; Burdigalian; Nukhul Formation; Biostratigraphy, Gulf of Suez, Egypt.

## Introduction

The Miocene rock units are distinguished by their facies variation, whether in vertical and lateral scales, due to the tectonic activities of the Gulf of Suez which make the correlation between these rock units very difficult. Many papers concerning the economic interest of the Miocene formations of the Gulf of Suez are carried out. The Nukhul Formation is a substantial exploration goal and oil-maker in the Gulf of Suez. It is the basic hydrocarbon creator for more than fifteen fields in the area. However, local tectonics affect the reservoir quality and the exact age of the Nukhul Formation.

The previous studies of the Miocene concerned with its tectonics and stratigraphy include (eg: Fraas, 1867; Fuchs, 1877; Blanckenhorn, 1901, 1921; Hume, 1916; Moon and Sadek, 1923; Macfadyen, 1931; Stainforth, 1949 and Said and Bassiouni, 1958). These early works were followed by more specific studies (eg: Imam and Refaat, 2000; Farhoud, 2009; Abed El-Naby et al. 2009; Al-Husseini, 2012 and Temraz and Dypvik, 2017). The studies concerning the stratigraphical, lithostratigraphical, biostratigraphical, structural, sedimentological, petrophysical and sequence stratigraphical studies of the Miocene rock units of the Gulf of Suez have been surveyed profusely on both surface and subsurface successions. Among the publications concerned with biostratigraphic analysis either in surface sections or subsurface boreholes of the Gulf of Suez (eg: El-Heiny and Martini, 1981; Haggag et al. 1990; El-Azabi, 2004; Abul-Nasr et al. 2009; Al-Husseini, 2012; El-Atfy et al. 2013; Hewaidy et al. 2016; Ied et al. 2019 and Shahin and ElBaz, 2021; Ayyad et al. 2023). The sequence stratigraphical studies include that of (Hughes et al. 1991; Krebs et al. 1997; Bosworth and McClay 2001; Catuneanu et al. 2011 and Gowthrope et al. 2003). Additionally, there are many Geophysical studies to determine the hydrocarbon prospects using well logging and seismic data interpretation (eg: Dolson et al. 2001; Radwan et al. 2021a-c; Sarhan 2020 & 2021 and Farouk et al. 2022 & 2023).

The age assignment of Nukhul Formation differs between these workers from lower Miocene age (eg: Said, 1962; Andrawis and Abdel Malik, 1981; El-Heiny and Martini, 1981; Faris et al. 2009 and Hewaidy et al. 2016) to upper Oligocene (Chattian) - lower Miocene (Aquitanian) age (eg: Hewaidy et al. 2012, 2014 and Ayyad et al. 2023).

## Aim of the work:

`The aim of the present work is to establish a biostratigraphic classification of the lower Miocene Nukhul Formation to define the age of the first Syn-rift rock unit in the Abu Rudeis-Sidri field at the eastern side of the Gulf of Suez using planktonic foraminifera. The age of Nukhul Formation is a matter of controverse between authors and oscillates between them from lower Miocene age and upper Oligocene - lower Miocene age.

## Geological background

Generally, there are three phases of sedimentation in the Gulf of Suez area from Paleozoic to Recent ages (Pre-rift, Syn- rift and Post-rift phases) (Said, 1990). The Gulf of Suez lies within the Arabian-Nubian shield and is considered as a part of the first continental crust from the Proterozoic to the lower Paleozoic (Said, 1990). There are two stages in the structural evolution of the Miocene Gulf of Suez rift can be identified in the (Gawthorpe et al. 1997).

The Gulf of Suez rifting initiated during the lower Miocene due to the divergent motion between the African and Arabian plates and this made a group of normal faults (Bosworth et al. 2005). It reached its climax during the opening of the Red Sea at middle Miocene age (Serravallian). A complete contact between the Mediterranean and Gulf of Suez is indicated by the biostratigraphic tool at lower Burdigalian (Bosworth et al. 2005). The insulation of the Gulf of Suez and the Red Sea in the middle Serravallian and this also is indicated by the faunal content. This caused the sedimentation of evaporites of the Belayim and other evaporites in the basin (Dolson, 2000). The Abu Rudeis-Sidri field is the elderly oil field on the eastern coast of the Gulf of Suez with a complex sedimentation and structural phases (Ayyad et al. 2023). The structure of Abu Rudeis-Sidri area is an asymmetrical NW–SE trending anticlinal feature separated by several NW–SE fault systems and formed during the late Oligocene-Early Miocene time (rifting phase) (Zahra and Nakhla, 2016b).

According to (Bosworth and McClay, 2001 and Dolson, 2000), the Gulf of Suez is considered as a restricted rift basin that made the exploration of the Miocene formation in the Gulf of Suez complex. (Garfunkal and Bartov, 1977) stated that rift happened meanwhile during the upper Oligocene (Chattian) to the lower Miocene.

The Syn-rift deposits overlie the Pre-rift ones through a large unconformity. The two lower syn-rift rock units (Abu Zenima and Nukhul formations) are locally disconnected by an angular unconformity and correlatable transgressive surface (Krebs et al. 1997).

## Material and methods

The two studied lower Miocene boreholes are ARS-6 (latitude 28 o 51' 20.23" N and longitude 33º 10' 33.52" E) and SIDRI-20 (latitude 28 o 50' 53.2" N and longitude 33º 10' 28.24" E). They are situated in Abu Rudeis-Sidri Field, east of the Gulf of Suez, Egypt (Figure 1). Twenty cutting samples from ARS-6 Well and eight rock samples from the SIDRI-20 Well (Depth 2560 – 2710 m) were studied representing the Nukhul Formation (very few materials due to the frequent barren intervals within this formation). The samples were prepared for micropaleontological studies using the standard techniques. Approximately 20 gm of each sample were soaked in 30% hydrogen peroxide solution, rinsed, heated and washed with water through a sieve of 63 μm size then desiccated in an oven with 40 C°.

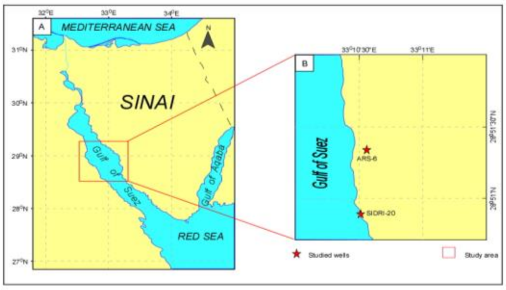



**Figure 1.** Location map of the studied wells.

From the sieved residue more than 63 μm, the planktic foraminifera were picked and identified under binocular stereo-microscope. Their stratigraphic ranges are shown in Figure (2A-B) and the identified planktonic foraminiferal species were photographed using Scanning Electron Microscope and illustrated in Plate (1).

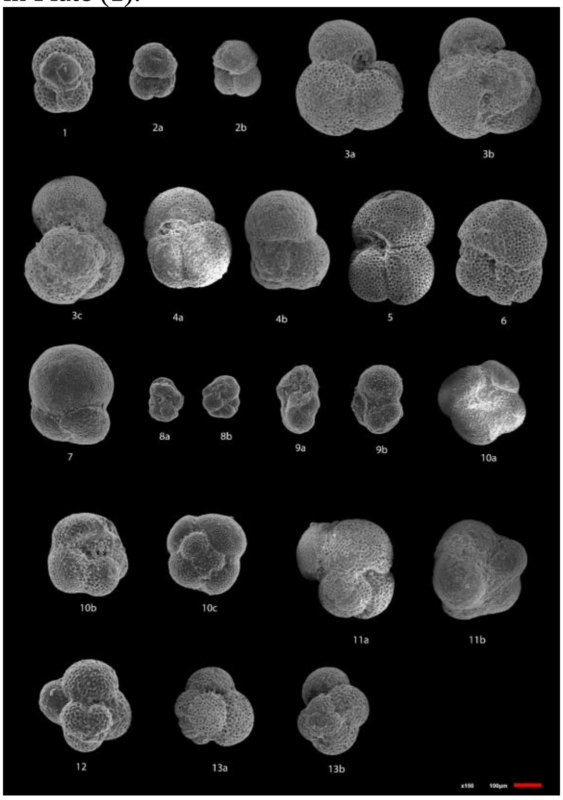


**Plate. 1.** Planktonic foraminifers (scale bar 100 μm): 1: Catapsydrax unicavus, sample 15, Nukhul Formation;Nukhul Formation, ARS-6 well; 2a-b: Globigerina praebulloides, sample 6, Nukhul Formation, ARS-6 well; 3a-c: Globigerina juvenilis, sample 5. Nukhul Formation, ARS-6 well; 4a-b: Globigerinoides immaturus ,sample 5,Nukhul Formation, SIDRI-20 well; 5: Trilobatus trilobus, sample 4, Nukhul Formation, ARS-6 well; 6: Praeorbulina sicana, sample 15, Nukhul Formation, ARS-6 well; 7: Paraorbulina sp.,sample 3, Nukhul Formation, ARS-6 well; 8a-b: Globorotalia challengeri , sample 3, Nukhul Formation, SIDRI-20 well; 9a-b: Globorotalia praescitula, sample 3.Nukhul Formation, SIDRI-20 well; 10a-c: Globoquadrina dehiscens, sample 1,Nukhul Formation, SIDRI-20 well; 11a-b: Globoquadrina sp.,sample 4, Nukhul Formation, ARS-6 well; 12: Globigerinita uvula, sample 8, Nukhul Formation, SIDRI-20 well, 13a-b: Globigerinita sp.,sample 1, Nukhul Formation, SIDRI-20 well.

## Results

*Lithostratigraphy of the Nukhul Formation:*

The Gulf of Suez has Pre-rift, Syn-rift and Post-rift successions. The pre-rift succession includes the sediments from Cambrian to Eocene (Bosworth and McClay, 2001).

The ongoing from the Pre to Syn-rift sediments is documented by the changes from Abu Zenima red beds to the overlying Nukhul Fm. In the study area, the deposition of rock units shows the change from continental to marine-environments (Farouk et al. 2023).

The Gulf of Suez Miocene sections is subdivided by many authors into many formations (Figure 2). In the current work, we follow the lithostratigraphic subdivisions of the National Stratigraphic Subcommittee of the Geological Sciences of Egypt NCGS (1976). According to EGPC (1964), the Miocene section in the study area is subdivided into:

1- (Gharandal Group): Nukhul, Rudeis and Kareem formations.
2- (RasMalaab Group): Belayim, South Gharib and Zeit formations.

These formations are differently named in other sites of the Gulf.

*Nukhul Formation:*

The Nukhul Formation encompasses a diverse range of depositional facies in our studied wells, including clastics of glauconitic sandstone grading to siltstone, shale, and calcareous shale, as well as argillaceous and snow-white limestones. The age of Gharandal Group, especially the Nukhul Formation, is a matter of controverse (Table. 1).

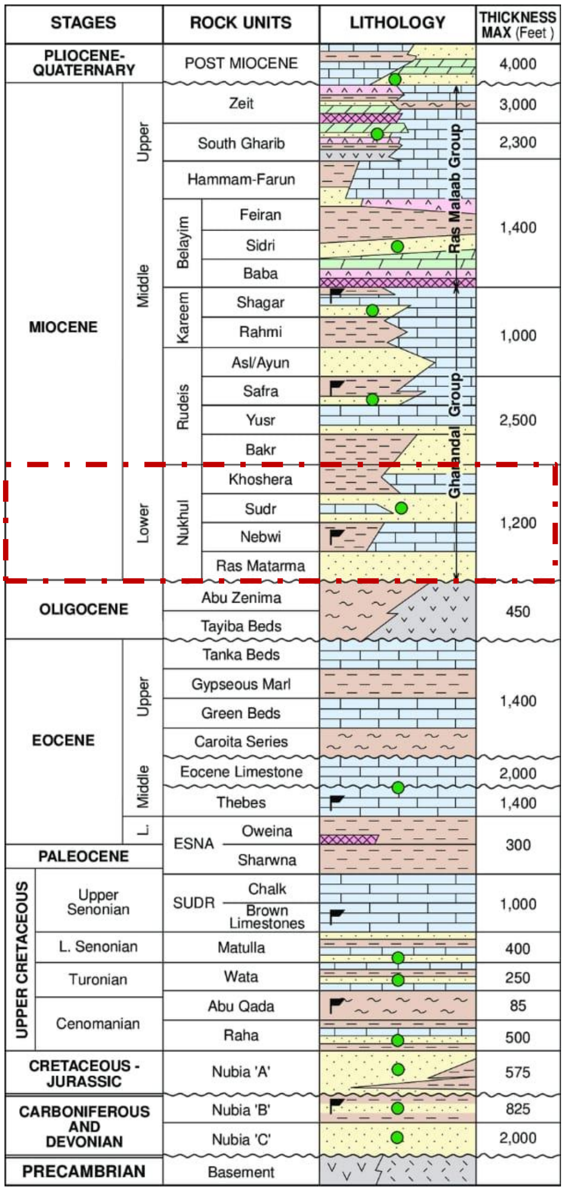
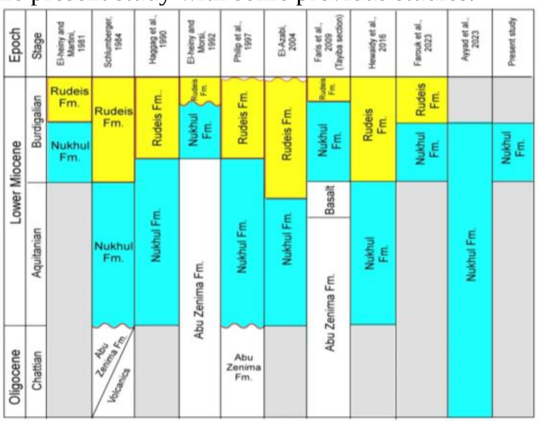



**Figure.2.** Lithostratigraphic column of the Gulf of Suez after (Badri et al. 1999). The Nukhul Formation is marked by the red rectangle)

**Table.1.**Lithostratigraphic Comparison of results of the present study with some previous studies.




**Author:** It was first introduced by (Ghorab, 1964), then by the NCGS (1976) in the subsurface successions.

**Type area:** Wadi Nukhul surface section, East side of the Gulf of Suez (Ghorab, 1964).

**Lithology:** The Nukhul Formation exhibits shallow marine sediments in many localities along the west central Sinai. It consists of shale intercalated with few limestones and sandstones in Abu Rudeis-Sidri Field (Abd El Gawad et al. 2016). In the present study, it consists of intercalations of shale with sandstone and limestone **(**Figure 3(A-B)**)**.

**Stratigraphic position:** The Nukhul Formation unconformably overlies the older formations of the Eocene age. However, in some areas, it conformably overlies the Oligocene continental deposits and underlies conformably the Rudeis Formation. In the present study, according to the Egyptian General Petroleum Corporation (EGPC) that allows us to have composite logs of the studied wells from Belayim Petroleum Company (PETROBEL), the Nukhul Formation conformably overlies the Abu Zenima Formation (Oligocene age) and underlies conformably the Rudeis Formation.

**Arial Distribution:** The Nukhul Formation exhibits shallow marine sediments in many localities along the west central Sinai.

**Correlation:** According to Schlumberger well logs, the stratigraphic committee (1984) the Nukhul Formation at some localities of west central Sinai is subdivided into four unofficial members arranged from bottom to the top:

- Ras Matarma Member: (lower calcareous sandstone Member).
- Sudr Member: (lower shale Member).
- Nebwi Member: (upper calcareous sandstone Member).
- Khoshera Member: (upper shale Member).

All these members could not be traced in the field but can be used only in the subsurface studies. However, these members are traceable in north of Wadi Gharandal which is considered the most active area through the sedimentation of Nukhul Fm. (EGPC (1964); NCGS (1976) and the stratigraphic committee (1984)).

**Faunal content and Age**: The shallow marine clastics of Nukhul Formation are characterized by the scarcity of planktic foraminiferal assemblages. However, this Formation is regionally rich in oysters such as *Ostrea carolinensis*, pectens such as *Pecten ziziniae* and *Clypeaster* sp. that refer to be lower Miocene Aquitanian in age (Ismail and Abdel

El Ghany, 1999). (El-Heiny and Martini, 1981 and Faris et al. 2009) studied the biostratigraphy of the Miocene of the Tayiba section, Gulf of Suez and assigned a Burdigalian age to the Nukhul Formation.
In the present study and according to its foraminiferal content the studied Nukhul Formation belongs to lower Miocene (Burdigalian) age.

## *Biostratigraphy*

In the present work the biostratigraphic analysis is based on the rare planktonic foraminiferal assemblage. The investigation of the Nukhul Formation in the studied boreholes has led to the identification of 20 planktonic species belonging to 9 genera. This content has led to the recognition of two biozones at ARS-6 well (*Globigerinoides altiaperturus* Zone (N6), *Trilobatus trilobus* Zone (N7) and no biozones were recognized in the SIDRI-20 well due to the absence of foraminifera (Figuress. 3A-B).

The foraminiferal biozonation followed that of (El-Heiny and Martini, 1981). The marker planktonic species of Aquitanian age are absent. According to (El-Heiny and Martini, 1981 and Faris et al. 2009), the Nukhul Formation belongs to the Burdigalian. Our results didn't match with worldwide zonal schemes due to the high tectonism of the Suez Gulf and the absence of the Aquitanian age (Table. 2) causing the absence of *Globigerinoides primordius* Zone.

**Table.2.** Comparison of planktonic foraminiferal zones in the present study with the most common zones outside and inside Egypt.

| Age | | Outside Egypt | | | Egypt | | | |
|---|---|---|---|---|---|---|---|---|
| Epoch | Stage | Kennett and Srinivasan (1983) | Iaccarino (1985) | Berggren et al. (1995) | El-Heiny and Martini, 1981 | Hewaidy et al. (2016) | Ayyad et al. (2023) | Present study |
| Lower Miocene | Burdigalian | *Gt. peripheroacuta* (N9) | *Pr. glomerosa* | *F. brimageae* M4b | *Gds. sicanus* | *Pr. glomerosa* | | |
| | | *Orbulina spp.* (N8) | | | | *Gds. trilobus* | | |
| | | *Gds. sicanus* (N7) | *Gds. trilobus* | *D. venezuelana* M4a | *Gds. trilobus* | | | *Trilobatus trilobus* (N7) |
| | | *Cds dissimilis* (N6) | *Cds.dissimilis-Gds.altiaperturus* | *Globigerinatella sp/ C. dissimilis* (M3) | *Gds. altiaperturus* | *Gds. altiaperturus* | *Globigerinoides altiaperturus* (M2) | *Globigerinoides altiaperturus* (N6) |
| | Aquitanian | *Gtl.. insueta* (N5) | | *G. binaiensis* (M2) | | *Gds. primordius* | | |
| | | *Gt. kugleri* (N4B) | *Gqd. dehiscens* | *G.dehiscens /P. kugleri* M1b | | | | |
| | | *Gqd. dehiscens* (N4A) | *Gt. kugleri* | *Gt. kugleri* M1a | | *Gt. kugleri* | | |
| Oligocene | Chattian | | | | | | *Trilobatus primordius* (O7) | |

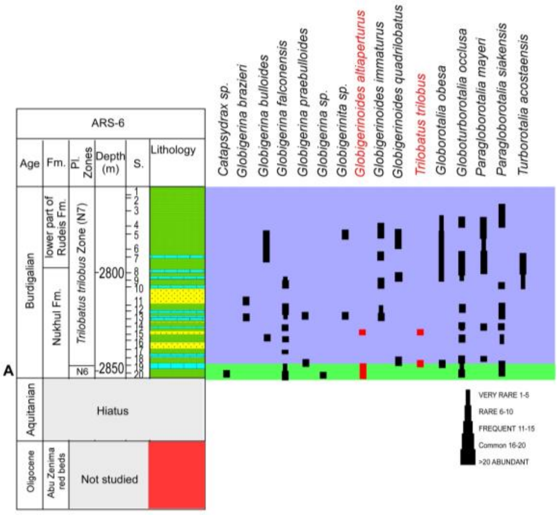



**Figure 3 A**. Lithostratigraphic log (after Farouk et al. (2023)) against distribution chart of planktonic foraminifera of the ARS-6.

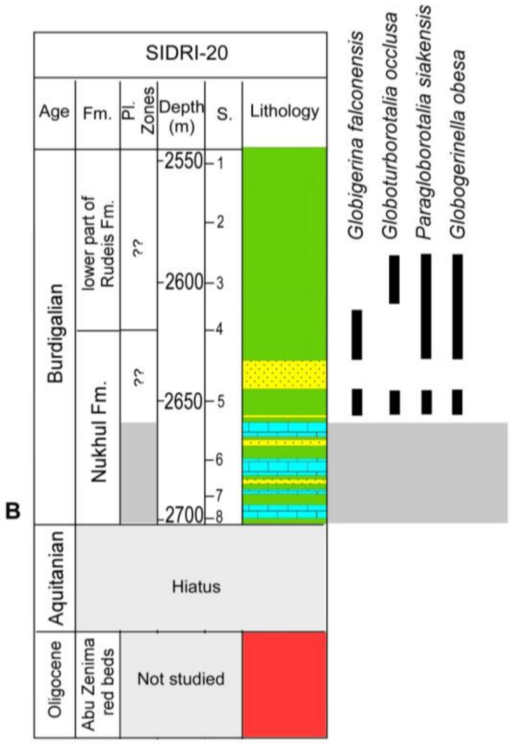



**Figure 3 B.** Lithostratigraphic log (after Farouk et al. (2023)) against distribution chart of planktonic foraminifera of the SIDRI-20.

The most remarkable planktonic foraminiferal species are seen on Plate 1.

These planktonic foraminiferal zones in the studied wells are arranged from the older to the younger as follows:

### *Globigerinoides altiaperturus Zone(N6):*

**Age:** (Lower Miocene) Burdigalian age is assigned to this zone.

**Author:** (El-Heiny and Martini, 1981).
**Definition:** The topmost of this zone is marked by the Lowest Occurrence (LO) of *Trilobatus trilobus*
**Stratigraphic position and thickness:** This zone is found at the base of Nukhul Formation of (ARS-6 Well, depth 2865 m. with a thickness of 6 m.) and it is found in this depth only and not found at the SIDRI-20 well.
**Equivalents:** This zone is equal to the *Globiginantella insueta-Catapsydrax dissimilis* Zone of (Berggren et al. 1995) and the *Catapsydrax dissimilis* Zone of (Abul-Nasr et al. 2009)
**Characteristic foraminiferal assemblage:** This zone in the ARS-6 well is specialized by the *Globigerinoides altiaperturus* and *Globigerina spp.*

*Trilobatus trilobus (=N7) Interval Zone:*

**Age:**Lower Miocene (Burdigalian) age is assigned to this zone.
**Author:** (El-Heiny and Martini, 1981) as *Globigerinoides trilobus* Zone.
**Definition:** This zone is marked by the LO of *T. trilobus* to the LO of *Praeorbulina sicana*.
**Stratigraphic position and thickness:** This zone is found at the Nukhul Fm. to the lower part of Rudeis Fm. of (ARS-6 Well, depths 2860-2740 m. with a thickness of 120 m.) and not found at the other well.
**Equivalents:** This zone is equal to the *Globigerinoides bisphericus* Zone of (Wade et al. 2011).
**Characteristic foraminiferal assemblage:** This zone is specialized by the **Globigerina** spp., Globigerinoides altiaperturus, Trilobatus trilobus, and Paragloborotalia siakensis.

## Discussion

The Miocene facies in the Gulf of Suez are characterized by variations in vertical and lateral scales owing to the active rift conditions that made a complex biostratigraphic analysis and different age determination for the Miocene rock units. So, the determination of the rift of the Gulf varies between the researchers. The lithostratigraphic distribution of the Gulf of Suez Syn-rift sediments shows the moving from continental red-beds (Abu Zenima Fm.) to the shallow-marine Nukhul Formation and the Rudeis Formation above (NCGS, 1976). The Nukhul Fm. reveals shallow marine environment in many locations along the Suez Gulf. The age of Nukhul Formation proposed by many authors extends from Oligocene (Chattian) to lower Miocene (Burdigalian) age (Table. 1) and it’s a matter of controverse due to the influence of local tectonics related to the Gulf of Suez rift and global eustatic sea-level fluctuations. Some authors assigned the lower Miocene age to the Nukhul Fm. (eg: Said and El Heiny, 1967; NSSC, 1976; Faris et al. 2009). Others (Hewaidy et al. 2012, 2014 and Ayyad et al. 2022) assigned the late Oligocene–lower Miocene age (Chattian to Aquitanian) to the Nukhul Formation. The sedimentation rate and time are affected by the eustatic sea-level fluctuations (Ayyad et al. 2023). In the present work and based on the two proposed biozones (*Trilobatus trilobus* Zone and *Globigerinoides altiaperturus* Zone), the Nukhul Formation belongs to the lower Miocene (Burdigalian) age. The absence of *Globigerinoides primordius* Zone of the Aquitanian age in the studied sections are due to the depositional hiatus caused by a tectonic uplift.

## Conclusions

Planktonic foraminiferal analysis allowed the subdivision of the Miocene Nukhul Formation into two biozones at ARS-6 well (*Globigerinoides altiaperturus* Zone (N6), *Trilobatus trilobus* Zone (N7) while there was no biozones encountered in the other well due to the rare foraminiferal content. The proposed biostratigraphic classification enabled the age determination for the lower Miocene syn-rift Nukhul Formation. According to these biozones, the Nukhul Formation was assigned to a Burdigalian age in this present study.
There are vertical facies change between the Pre-rift Au Zenima Formation and the earliest Syn-rift Nukhul Formation.

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## الملخص العربي

## عنوان البحث: الطباقية الحيوية لمتكون نخل في العصر الميوسيني المبكر، خليج السويس، مصر

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تمت دراسة متكون نخل من العصر الميوسيني المبكرلبئرين بريين ARS-6) و(SIDRI-20 الواقعين في الجانب الشرقي لخليج السويس لمعرفة محتواهما من الفورامينفرا الهائمة لتحديد عمرها الجيولوجي. تحتوي الفورامينفرا الهائمة التي تم تعريفها على ٢٠ نوعًا تنتمي إلى ٩ أجناس. بناء على المحتوي الاحفورى من الفورامينفرا الهائمة تم تقسيم متكون نخل الي نطاقين حيويين في بئر ARS-6. يعد تكوين نخل أقدم رواسب الصدع المتزامن في نظام الصدع بخليج السويس في مصر، وهو هدف استكشافي مهم وخزان لإنتاج النفط في خليج السويس. يهدف هذا البحث إلى تحديد عمر أول وحدة صخرية متصدعة في حقل أبو رديس-سدري باستخدام الفورامينفرا الهائمة. إن عمر متكون النخل مثير للجدل الدراسات السابقة عليهم تظهر الاختلافات في أعمارهم. تشير التحليلات الطباقية الحيوية إلى أن متكون نخل ينتمي الى العصر البورديجالي.