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RESERVOIR CHARACTERIZATION OF THE UPPER ABU ROASH "G" SANDSTONE IN WEST OF NILE AREA, WESTERN DESERT, EGYPT.

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ABSTRACT

Accurate reservoir characterization is an important stage in developing, managing the reservoir, and enhancement the production which depends mainly on a good description and precise interpretation of the reservoir facies. The study area is considered as a part of Qarun Petroleum Company's development leases which are located in the western side of Beni Suef Basin, the northeastern Western Desert which is considered the most important petroleum province in Egypt. Integrated sedimentological analysis of core description, petrographic and mineralogical constituents were carried out on the Upper Abu Roash "G" sandstone reservoir. The core description included 81.25 feet from the WON C-18 borehole helps to identify various sand bodies and distinguish four main facies groups: carbonate facies, mudstone facies, heterolithic facies, and sandstone facies. Petrographically, the sandstone facies samples have frequent amounts of monocrystalline quartz grains, few amounts of plagioclase, traces of polycrystalline quartz, common amounts of ferron dolomite, minor amounts of pore-filling kaolinite booklets and chlorite, amounts of well-developed syntaxial quartz overgrowths, traces of feldspar overgrowths. Also, we have secondary inter-and intraparticle pores, with moderate to good pore interconnectivity and the reservoir quality is moderate to good. Based on the facies, characterization, it is proposed that the stratigraphic intervals of the Upper Abu Roash "G" unit were deposited in subtidal-intertidal settings, where deposition of muddy-flat and intertidal sediments are locally interrupted by tidal-flat sand-channel deposits.

KEYWORDS: Reservoir Characterization; WON; Core; Beni Suef Basin.

1. INTRODUCTION

The study area under covers about 54 Km^2 (13,292.2 acres) of, west Beni Suef Basin in northeastern Western Desert, Egypt. It represents a part of the development lease of West Of Nile (WON) oil field which is bounded by latitudes 29° 04'-28° 59' N and longitudes 30° 53'-30° 57' 55'' E (Fig. 1). The reservoir characterization provides valuable information on the three-dimensional distribution, heterogeneity and petrophysical properties of the concerned resevoir[1]. The borehole data of WON exhibited variations in both reservoir thickness and facies quality which require more investigations. The subsurface geologic evaluation was carried out in terms of lithofacies description, and depositional environment of the studied reservoir resulted in determining the implications on it.

2. METHODOLOGY

The present work aims to integrate between the available geological data to study the reservoir characterization that controlling the hydrocarbon potentialities of the study area through the following steps: subsurface geological investigations which included the structural setting, stratigraphic relation, and thickness variation; reservoir characterization which included the analysis and interpretation of the available core and thin-section data of WON C-18 well to identify the lithological and mineralogical components of the identified hydrocarbon reservoir within the studied intervals.

3. GEOLOGICAL SETTING

Throughout the Late Cretaceous time, the paleogeography was characterized by a decrease in tectonic activity and marine transgression over northern and western Central Africa which are terminated with the compressional event of Campanian Mastrichtian [2]. The greater part of the North-Western Desert forms a platform characterized by relatively mild subsidence. However, local depocenters of limited dimensions were developed in different places over this platform and formed several basins e.g. Abu ElGharadig Basin, Beni Suef Basin,..etc [3] (Fig. 2). The Beni Suef Basin by far, quite similar to that of the northern territories of the Western Desert with the exception that the basin is controlled by the Aptian/Albian NE-SW extension movement which resulted in the deposition of Albian Kharita Formation directly on the crystalline of the Basement Complex [4]. The main structural pattern of this basin is a wide major graben, between two structural high areas in the NE and SW sides of the graben with NW-SE, WNW-ESE normal faults [5]. In the study area, the majority of the drilled wells revealed the same stratigraphic column of the North-Western Desert with a few exceptions in the variations of the thickness and absence of some rock units. The stratigraphic sequence ranges in age from the Albian (Kharita Formation), which is non-conformably overlain the Pre-cambrian Basement rocks, to the Santonian (Abu Roash "A" Member) while Khoman and Tertiary rocks units (Apollonia, Dabaa & Moghra) were eroded by the old ancestral Nile (Fig. 3).

4. RESERVOIR CHARACTERIZATION

4.1. Reservoir geology

According to the global eustatic sea-level curve [6], the global sequence surfaces [7], palynology zonation, and lithological stacking pattern the Abu "Roash "G" unit may be

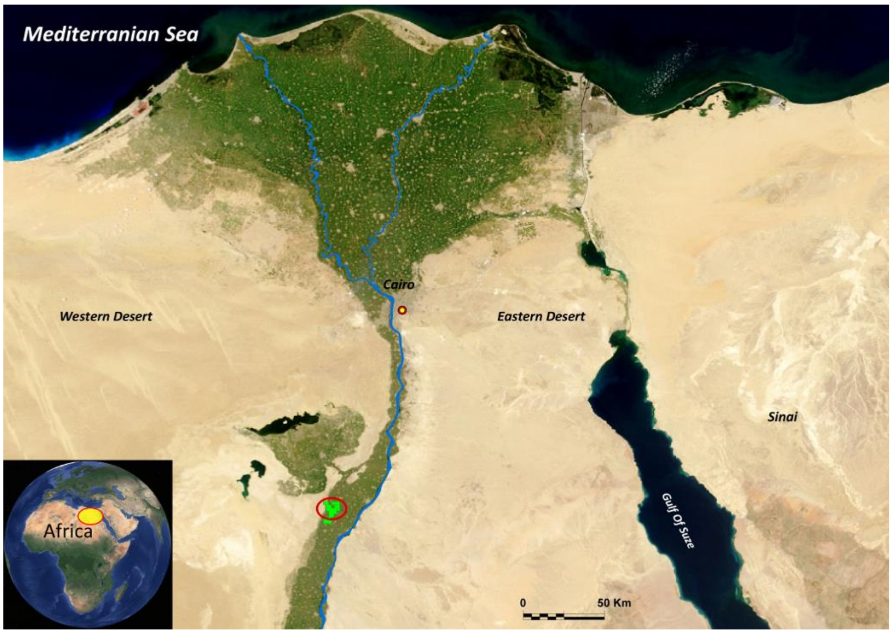


Fig. 1: Location map of the study area.

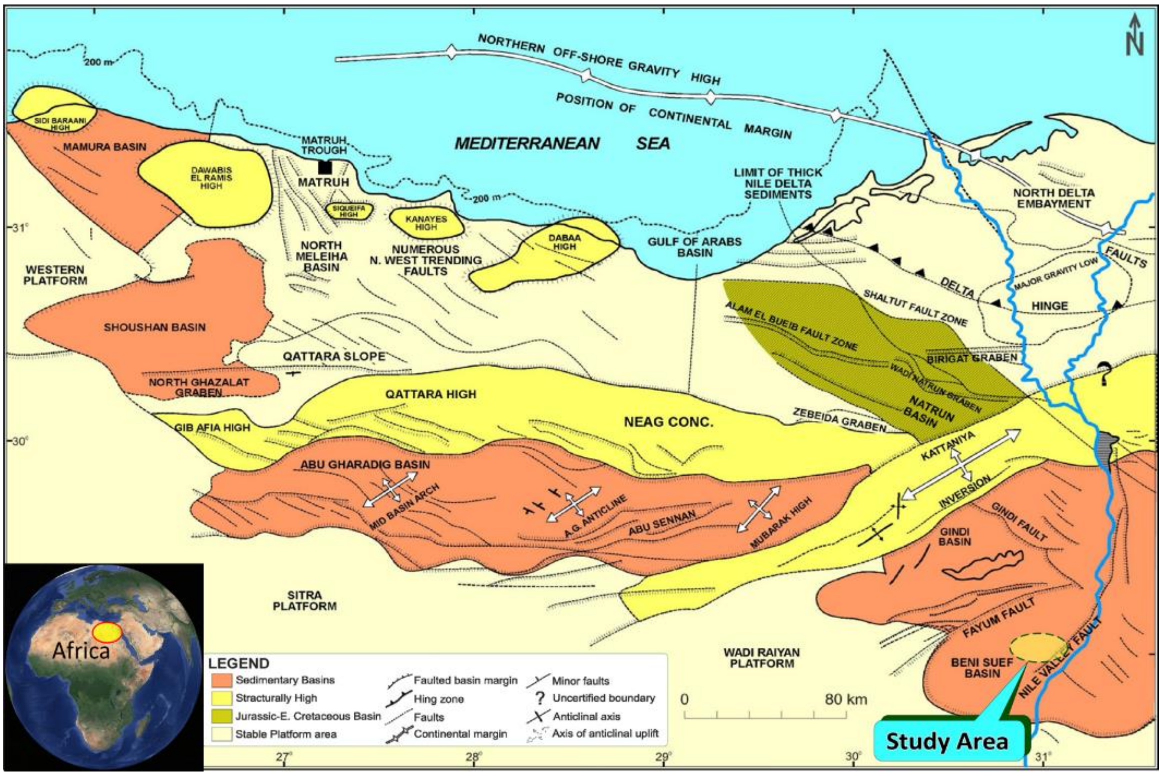


Fig. 2: Basin distribution map (Bayomi, 1996 [3])

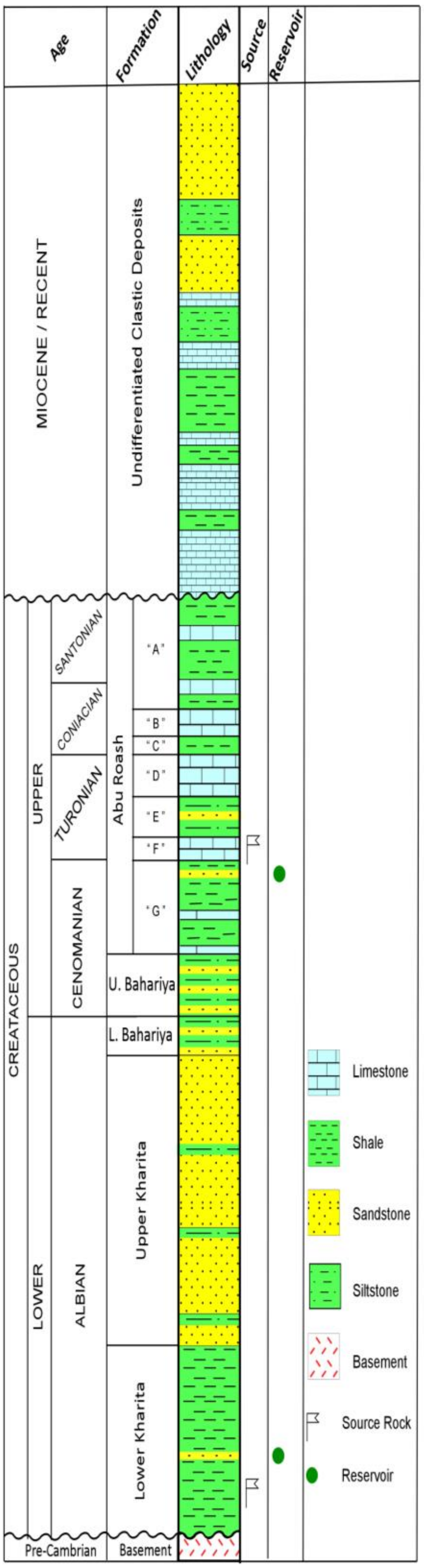
subdivided into three 3rd order genetic sequences bounded from top and base by maximum flooding surfaces, with the unconformity surface in the middle [8]. These sequences correspond with the three Upper, Middle, and Lower Abu Roash"G" subdivisions. Each 3rd order genetic sequence has alternating regressive and transgressive cycles which in turn affect the stacked facies [9] (Fig. 4). The lithofacies and environment of deposition can be interpreted by the identified lithological characteristics and primary sedimentary structures as well as the vertical facies relationships and the diagenetic features of the described core.

4.2. Lithofacies Interpretation

Stratigraphically, the studied intervals are belonging to the Upper Cretaceous (Cenomanian), top Abu Roash "G". Detailed sedimentological analysis was performed on 81.25 feet cored interval from WON C-18 well-covering depth intervals from 6515 feet to 6596.25 feet. In this cored succession, four main facies groups were identified as: carbonate, mudstone, heterolithic, and sandstone facies.

4.2.1. Carbonate lithofacies

The carbonate lithofacies is recorded in the basal part of the Upper Abu Roash "G" subdivision with an average thickness of 40 feet. Compositionally, it contains bioclastic, glaucony, and amounts of pelecypods (mollusk) shell fragments and benthic foraminifera. These lithofacies can be marked by a low gamma-ray log response (40-60 API) of symmetrical (blocky) shape which indicate quiet energy environment. Moreover, they have high resistivity and density, and low porosity log responses (Fig. 5).



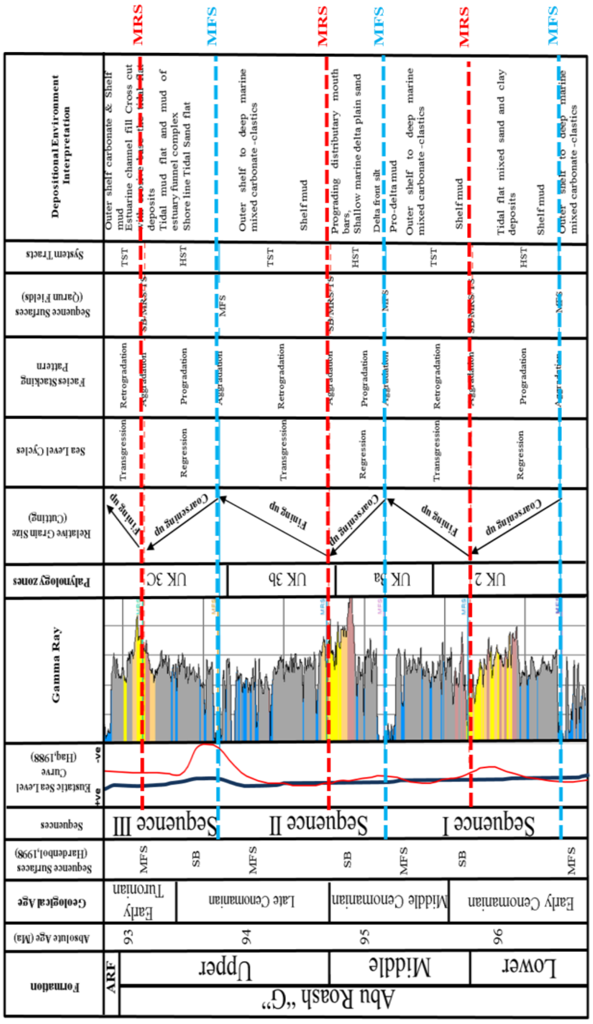


Fig. 4: Sequence stratigraphic summery for Abu Roash"G" (After Hassen,2016).

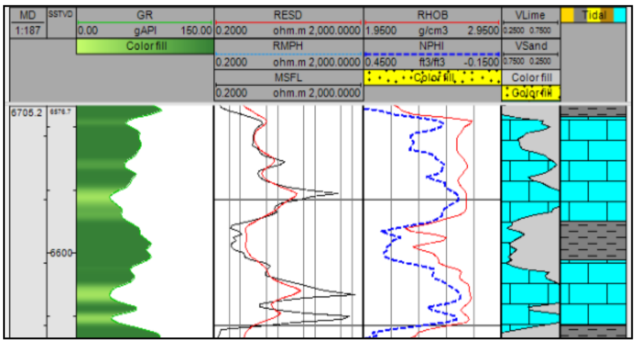


Fig. 3: Local stratigraphic column of the study area.

Fig. 5: Open hole logs responses of Limestone lithofacies in Upper Abu Roash "G".

4.2.2. Mud rock lithofacies

These identified lithofacies can be distinguished into two types:

-Laminated mudstone: This is the major lithofacies in Abu Roash "G" Member with an average thickness of approximately 360 feet. This shale is dark grey, fissile, carbonaceous, with local pyrite occurrences which refer to shallow marine shale (Fig. 6 from 6574`to 6575`).

-Bioturbated sandy mudstone: This lithofacies is composed of medium to dark grey, slightly sandy mudstones, which are locally bioturbated, with burrows filled by sandstone, this lithofacies has very rare, thin, discontinuous sandstone laminas (Fig. 6 from 6582`04`` to 6583`).

4.2.3. Heterolithic facies

-Clay-rich heterolithic facies: Thinly interlaminated medium to dark grey mudstone and light grey, locally bioturbated, mostly very-fine grained, well-sorted sandstone laminas, with rare pyrite and carbonaceous debris (Fig. 6 from 6571`02`` to 6573`04``).

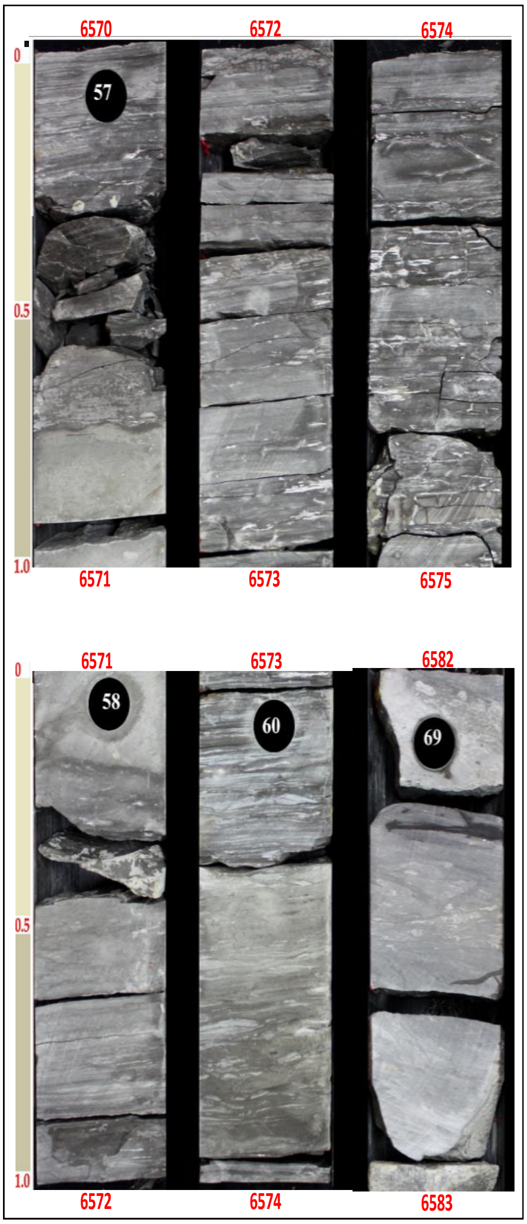


Fig. 6: Core photo-1 of Upper Abu Roash"G" subdivision in WON C-18 well.

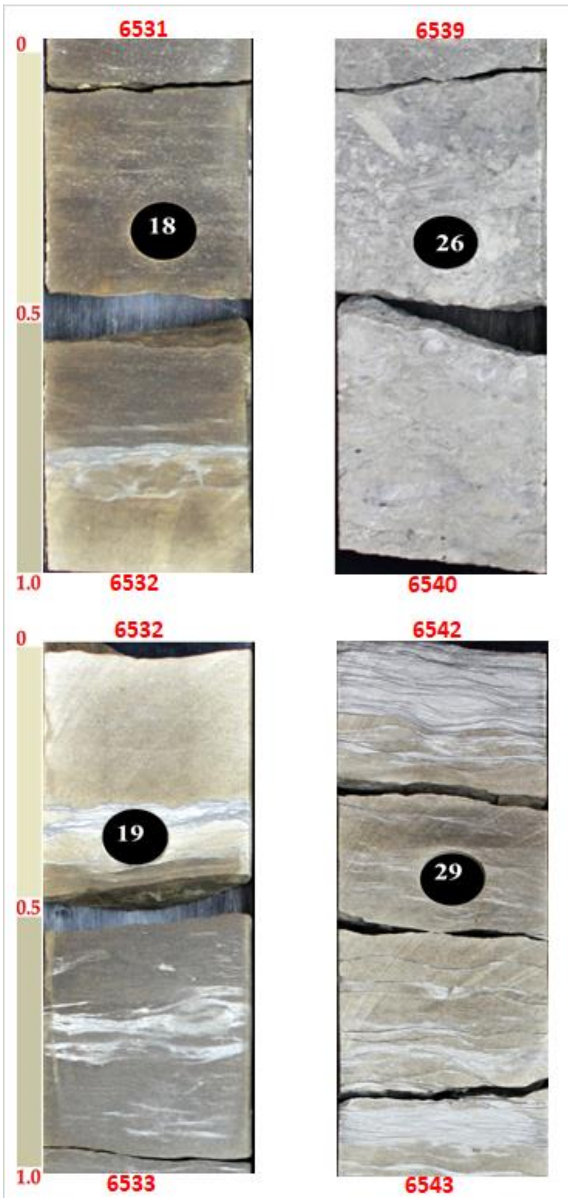


Fig. 7: Core photo-2 of Upper Abu Roash"G" subdivision in WON C-18 well.

-Sandy heterolithic facies with ripple laminated sandstone: Thinly interlaminated light grey sandstone (very fine to fine-grained, well-sorted, locally bioturbated/ripple laminated, discontinuous) with dark grey (carbonaceous) mudstone, locally with light brown, faintly ripple-laminated, fine-grained sandstone beds, slightly grading downward to more clay-rich intervals, gradational base (Fig. 7 from 6542` to 6543`). In thin-section, there are frequent amounts of monocrystalline quartz grains (Qz), K-feldspars, common amounts of glaucony pallets (G), few amounts of plagioclase (Ps), micas, lithic fragments, polycrystalline quartz, common amounts of ferron dolomite (fD), minor amounts of pore-filling kaolinite booklets (Kao) and chlorite (Ch), minor amounts of well-developed syntaxial quartz overgrowths (Purple arrows), rare amounts of barite and dark brown residual hydrocarbons (Red arrows), traces of illite and hydrocarbon stains. Also, we have minor secondary inter-and intraparticle pores (Orange arrows), with poor to moderate pore interconnectivity and the reservoir quality is poor to moderate (Fig. 8).

4.2.4. Sandstone lithofacies

These facies are considered the important facies because they represent the main reservoir of Upper Abu Roash “G”. Different sand bodies were recognized throughout studying the core and thin section data which were deposited in different environments which are related to the different depositional settings and different lithofacies. The sandstone lithofacies recorded in Upper Abu Roash “G” subdivision can be described based on the core images and thin section plates as follow:

-Massive to ripple-laminated sandstone: Dark brown (oil-stained), massive to faintly cross-laminated/bedded, with local argillaceous laminations, slightly fining upward from medium-fine up to fine-grained, well-sorted, local siderite clasts of pebble size, with rare stylolites, sharp-irregular base (Fig. 7 from 6532`006`` to 6533``).

- Massive sandstone: The sandstone in this lithofacies is Light brown, very fine to fine-grained, well-sorted, calcareous, with rare stylolites, thin mudstone laminae at the top (Fig. 7 from 6531`10`` to 6532`06``). In thin-section, there are frequent amounts of monocrystalline quartz grains (Qz), few amounts of plagioclase (Ps), K-feldspars and micas, rare amounts of lithic fragments, glaucony pallets and heavy minerals, traces of polycrystalline quartz, common amounts of ferron dolomite (fD), minor amounts of pore-filling kaolinite booklets (Kao) and chlorite (Ch), rare amounts of well-developed syntaxial quartz overgrowths (Purple arrows), siderite, disseminated black pyrite crystals, barite, and dark brown residual hydrocarbons, traces of feldspar overgrowths, illite and hydrocarbon stains. Also, we have secondary inter-and intraparticle pores (Orange arrows), with moderate to good pore interconnectivity and the reservoir quality is moderate to good (Fig. 9).

- Bioturbated argillaceous sandstone: Light to medium grey, strongly deformed due to bioturbation, very fine to fine-grained, well-sorted, argillaceous, with rare shell fragments, slightly calcareous, gradational base (Fig. 7 from 6539` to 6540`).

-Laminated argillaceous sandstone: Light to medium grey, faintly laminated, argillaceous, very fine-grained, well-sorted, sharp bases (Fig. 7 from 6570`08`` to 6571`02``).

- Ripple laminated argillaceous sandstone: Light greenish grey, locally ripple-laminated, very-fine to fine-grained, well-sorted, argillaceous, carbonaceous, sharp base (Fig. 6 from 6573`04`` to 6574`).

4.3. Facies association

The identified lithofacies types can be grouped into four main facies types: (1) Sandstone facies; (2) Heterolithic facies; (3) Mudstone facies and (4) Limestone facies and each facies group would represent a distinct depositional setting.

(1) Sandstone facies group includes massive to ripple-laminated, mostly oil-stained,

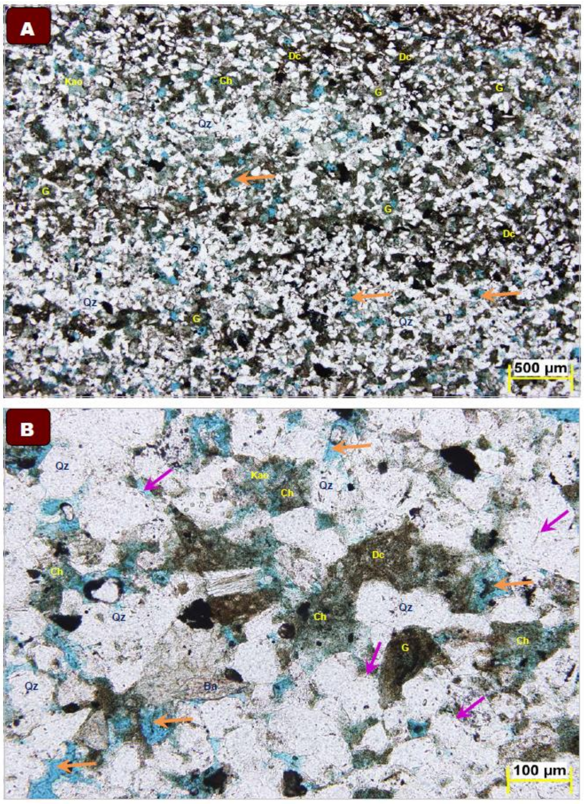


Fig 8: Photomicrographs of Glauconitic Subfeldspathic Arenite sandstone under normal light sample at depth 6542.4 ft.

Fig 9: Photomicrographs of Fe-Dolomitic Subfeldspathic Arenite sandstone under normal light sample at depth 6531.4 ft.

(A. scale 500 µm, B. scale 100 µm). (quartz grains (Qz), plagioclase (Ps), ferron dolomite (fD), kaolinite (Kao) and chlorite (Ch), glaucony pallets (G), Detrital clays (Dc), quartz overgrowths (Purple arrows), inter-and intraparticle pores (Orange arrows).

well-sorted, fine to medium-grained sandstone beds, with chlorite and kaolinite. The clay-rich lenses/ laminas most probably indicate flaser bedding in which mud lenses were deposited in ripple troughs. Sandstone intervals are assumed to be deposited in a high-energy marine environment, on a subtidal setting representing tidal channel deposits which laying directly on mud-rich facies types (mudstone and heterolithic facies types) with sharp-irregular erosional boundary. Identified sedimentary and biogenic structures indicated deposition in a high to moderate energy marine environment, most probably proximal subtidal to the intertidal setting.

(2) Heterolithic facies group comprises thinly interbedded light grey sandstone and dark grey mudstone. The latter is locally display wavy bedding, sub-vertical small-sized burrows filled by sandstone. On the other hand, the sandstones have various shapes including laminae, lenses that are mostly ripple-laminated or slightly deformed due to bioturbation. This facies type is considered to be deposited in a low-energy marine environment, preferably in an intertidal setting with a fair amount of clastic sediment input. The existence of low abundances and low diversity of bioturbation indicated a calm depositional setting.

(3) Mudstone facies group includes dark to medium grey, laminated, mostly fissile, carbonaceous, locally pyritic mud-rich intervals. These intervals' recovery stage is moderate to low due to their fissile nature, a

reason which affected the identification of any internal structures. Where mudstone intervals are slightly sandy with blocky nature. These fine-grained sediments were deposited from suspension in a low water-energy environment, probably on a muddy flat (suggested by the high amount of carbonaceous matter) or a distal subtidal setting.

(4) Limestone facies group comprises creamy to locally reddish colored, bioclastic, and slightly argillaceous carbonate-rich intervals. The presence of glaucony and the identified bioclasts in the limestone intervals indicates possible deposition in a shallow marine intertidal environment.

4.4. Conceptual depositional model

Generally, the tidal-flat facies tracts are composed of three basic depositional environments; the supratidal zone is above high tide and is flooded only at spring tide or during storms, The intertidal zone between mean high tide and mean low tide which is exposed twice daily and the subtidal zone is below mean low tide and is rarely if ever, exposed [10]. Based on previously facies observation and description, the assumed conceptual model for Upper Abu Roash "G" unit is the subtidal-intertidal setting, where deposition of muddy-flat and intertidal sediments are locally interrupted by tidal-flat sand-channel deposits. Studied successions are slightly affected by late diagenetic events shown by the presence of stylolites and fractures.

4.5. CONCLUSION

Detailed sedimentological analysis was performed on 81.25 feet cored interval from WON C-18 well in which four main facies groups were identified: carbonate facies, mudstone facies, heterolithic facies, and sandstone facies. Different sand bodies were recognized throughout studying the core and thin section data which were deposited in different environments which are related to different depositional settings and the lithofacies is changed. The sandstone lithofacies recorded in Upper Abu Roash "G" subdivision can be described based on the core images and thin section plates as massive to ripple-laminated sandstone, massive sandstone, bioturbated argillaceous sandstone, laminated argillaceous sandstone, and ripple laminated argillaceous sandstone, interpreted to comprise units of stratigraphic intervals deposited from subtidal-intertidal setting, where deposition of muddy-flat and intertidal sediments are locally interrupted by tidal-flat sand-channel deposits.

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توصيف خزان الحجر الرملي لأبو رواش "G" العلوي

في منطقة غرب النيل ، الصحراء الغربية ، مصر.

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الملخص:

تم إجراء وصف للرواسب على 81.25 قدمًا من عينات اللب من بئر WON C-18 حيث تم تحديد أربع مجموعات سحنات رئيسية: سحنات كربونية ، سحنات من الحجر الطيني ، سحنات غير متجانسة ، سحنات من الحجر الرملي. تم التعرف على أجسام رملية مختلفة من خلال دراسة البيانات الأساسية والقطاعات الميكروسكوبية التي تكونت في بيئات ترسيبية مختلفة مرتبطة بإعدادات ترسيبة مختلفة مما ادي الي تغير السحنات الصخرية. بناءً على ما تقدم يمكن وصف الخزان الرملي لأبو روش "G" العلوي علي انه يتضمن الحجر الرملي المموج ، والحجر الرملي المتماسك، والحجر الرملي الطيني ، والحجر الرملي الرقائقي ، والحجر الرملي الرقائقي المموج ، والتي ترسبت علي هيئة شرائط من الرمال التي قطعت بواسطة قناة رملية في بيئة المد والجزر.