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CHARACTERIZATION OF PRE-RIFT RESERVOIRS OF WEST HURGHADA DISTRICT, EGYPT.

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ABSTRACT

The West Hurghada area is located on the southern margin of the Gulf of Suez, Egypt. The simple reason is that better reservoir characterization means higher success rates and fewer wells for reservoir exploitation. In this research work the well log data were analysed to characterize the Pre-rift (Nubia and Matulla) reservoirs and evaluation them on West Hurghada oil fields.

The objective of this paper is to use the well log data to determine the reservoir characteristics, fluid contents, evaluation of the prospectively and hydrocarbon potentialities of the West Hurghada basin area, and its importance in the development of this area.

These petrophysical properties were mapped and helped in the delineation of sweet spots for the reservoir horizons, which in turn, helped along with other elements, in the promotion of the new exploration places interpreted from the seismic data into prospects and they will represent potential reserve additions in the study area.
Nubia sandstone is anticipated to be wet in this area. A part of covenants reservoir concentered in Nubia Formation and its extensive areas, there is an ENE-WSW trending host running between Rabeh and Rabeh East oil fields in the form of a hogback zone that should have the interest to be tested by a new exploration wells.
Based on the well data of each Nubia, and Matulla formations of the West Hurghada area, it is recommended to evaluate the oil potentialities of the two important reservoirs, and this will be resulting in adding more reserves in the study area. Both of them considered a very good and high-quality reservoir as they have a high net pay thickness, low shale content, high effective porosity, and high hydrocarbon saturation.

INTRODUCTION:

The Gulf of Suez is considered as the principle prolific province in Egypt. It was saving the main energy supply for the country and is still challenging the petroleum companies.
The classical Gulf of Suez rift asymmetry (Moustafa, 1976) is shaped by a long rift change of the half-graben dip polarities.
The West Hurghada area is located on the Southern margin of the Gulf of Suez, between latitudes 27° 12′ 00″ N to 27° 17′ 00″ N and longitudes 33° 42′ 00″ E - 33° 48′ 00″ E (Figures 1& 2).
It was penetrated essentially by several wells and has stratigraphic section comprises Precambrian-Tertiary rock units.
The Basement rock is overlain by Pre-Miocene and Miocene sediments. The Cretaceous sediments are represented by the Nubia sandstone and the post-Nubia sediments. They occupy all parts of the study area, comprising rock units, known as a Nezzazat group (represented by Matulla Formation), Nukhul, Rudeis, Belayim, South Gharib and Zeit formations.
The Post-rift deposits are playing an important role in lateral and vertical sealing in the Gulf of Suez and in the area of the current study, (Figure 4).

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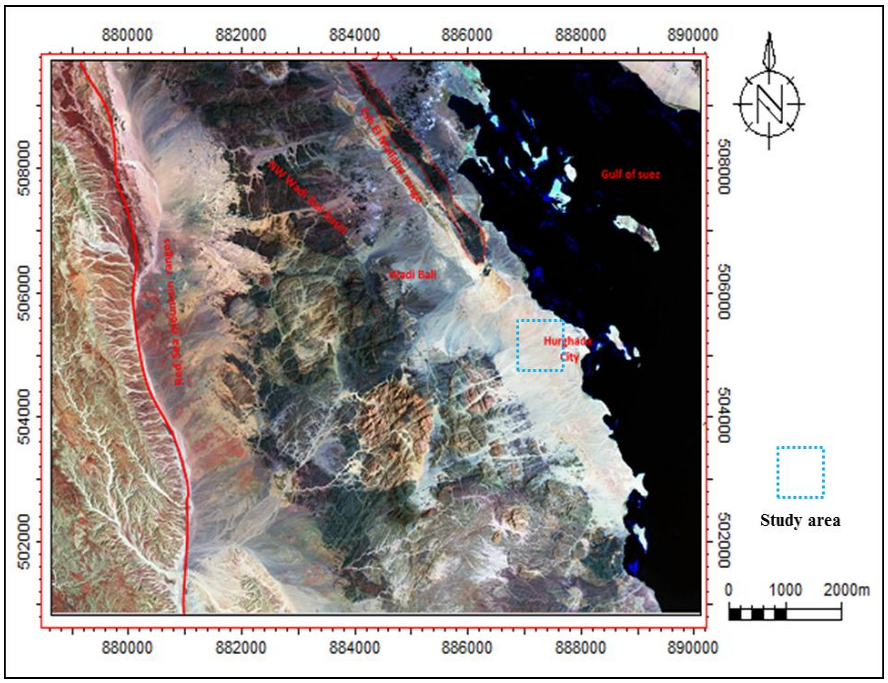

Figure 1: Land sate image shows the location of the study area.

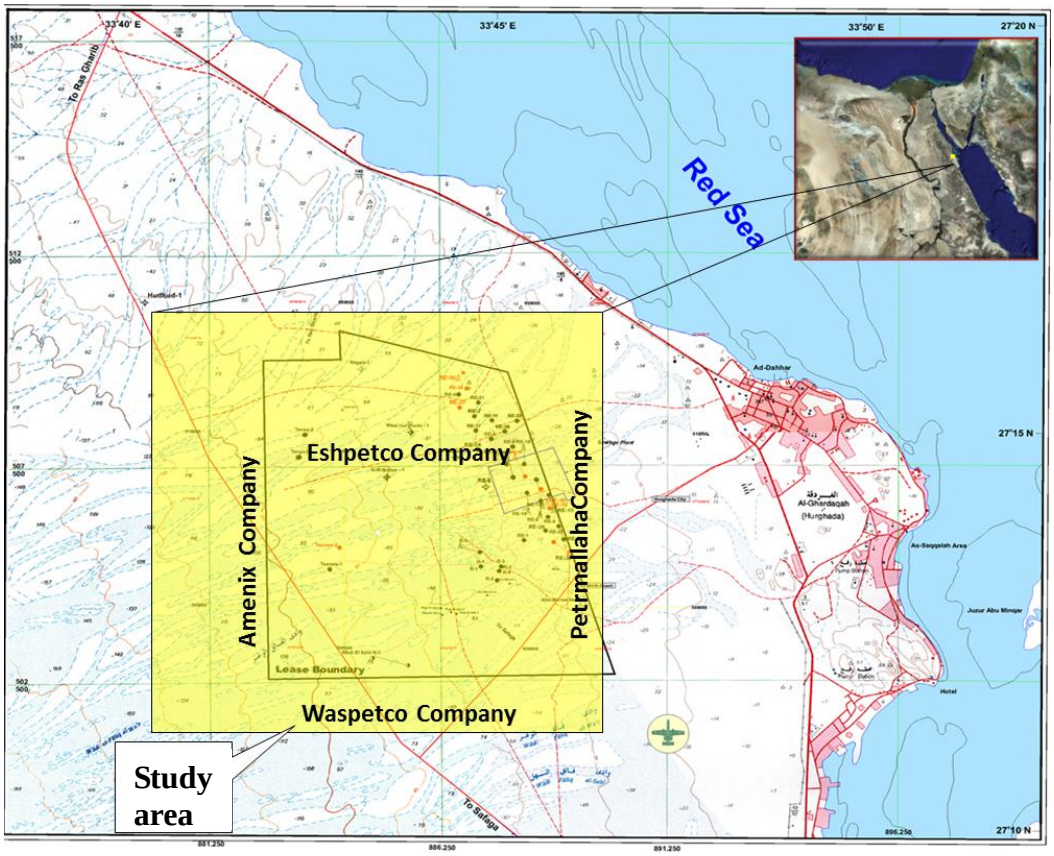

Figure 2: Location map shows the topography and the oil company's activity of West Hurghada Area.

The present work attempts to provide a better understanding of the reservoir petrophysical characterization of Pre-rift sediments (Nubia and Matulla formations) in the study area to deduce new prospective areas. This basin extends parallel to the northwest trend of the Gulf of Suez rift and is flanked from the eastern and western sides.

GEOLOGIC SETTING:

1. STRATIGRAPHY:

The southern margin of the Gulf of Suez province is a huge platform consisting of thick-layered sedimentary rocks largely affected by tectonic disturbances (Said, 1962). Sandstone with a slight southwestward regional slope and dip makes up the largest part of the exposed and subsurface strata. The Late Mesozoic-Early Cenozoic sediments, formed the primary sedimentary cover of the study area are subdivided into a number of lithostratigraphic units. The oldest unit in the section is the Nubia Formation, which rests unconformably over the Precambrian Basement in the most parts of the study area. The Post-rift (Post-Miocene) formations are the youngest sedimentary unit in the study area, (Figure 4).

1.1. PRE-RIFT SEQUENCE:

This sequence refers to the sedimentary section deposited before the Oligo-Miocene Gulf of Suez rifting (Robson, 1971 and the National Stratigraphic Subcommittee, 1974). It is completely exposed at the point of the study which had been penetrated by some wells. The basal part is characterized by stacked sandstone section, of the Nubia facies, lying unconformably above the Precambrian Basement rocks and ranges in age from Paleozoic to the Early Cretaceous. This section attains measuring more than 500 meters and is known for the subsurface geologists as Nubia sandstone (Said, 1962).

The first marine transgressive sequence is represented by the Cenomanian Raha Formation. It is composed of alternating clastics and carbonates of 80 to 100 meters thickness (Ghorab, 1961). While the sandstone intervals of Raha Formation are good hydrocarbon reservoir in several fields (e.g., Ramadan, Shukheir Bay, and North October).
The overlying carbonate section is represented by the Turonian Wata Formation and followed by Lower Senonian marl and shale with sandstone and carbonates of Matulla Formation. It is one of the known reservoirs of moderate characteristics in the central and southern Gulf of Suez (e.g., West Hurghada oil fields). The overlying section of carbonates represented by the Upper Senonian Sudr Formation. The lower part of this Formation (Campanian Brown Limestone) is commonly rich in organic content and regarded as the main source rock in the Gulf of Suez (Youssef, 1957; Ghorab, 1961, and Bosworth and McClay, 2001). Thermal gradients in some of the drilled wells in the study area measures "1.43 ºF/ 100 feet", and the modeled burial curve had assigned shallow oil expulsion (6500-7000 feet; El Le body, 2008).

The Paleocene Esna Shale rests unconformably above the Cretaceous section and followed by the cherty limestone of the Lower Eocene Thebes Formation. This carbonate section measures 230-300 feet and is known as a local reservoir rock especially in the central dip province of the Gulf of Suez where it is getting thicker and fractured.

1.2. SYN-RIFTING SEQUENCE:

It is applied in the sedimentary section deposited whiles the phases of the Gulf of Suez rifting (Robson, 1971; Evans, 1988; Evans and Moxon, 1988, and Bosworth and McClay, 2001). This sequence is subdivided into seven formations represented in (figure 4).

The first Gulf of Suez rifting marine sediments in the study area is the Nukhul Formation (Aquitanian - Early Burdigalian). It composed of shallow marine deposits, which include calcareous conglomerates, sandstones and marl in its type section in Wadi Nukhul (central eastern part of the Gulf of Suez).
In West Hurghada area, the Nukhul Formation includes channelized submarine sandstones, near-shore chert cobble and conglomerates and various carbonate shelf and slope facies (Bosworth et al., 1998).

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The wells in the transfer area of the study had penetrated the sandstone of the Nukhul Formation occasionally interbedded with limestone and shale. Outcrops along the Esh El Mellaha Range; on the western side of West Hurghada basin, the basal syn-rift conglomerates are sometimes referred to as the Abu Gerfan Formation (Ghorab and Marzouk, 1967; National Stratigraphic Subcommittee, 1974; Darwish and El Arabi, 1993, and Bosworth and McClay, 2001).

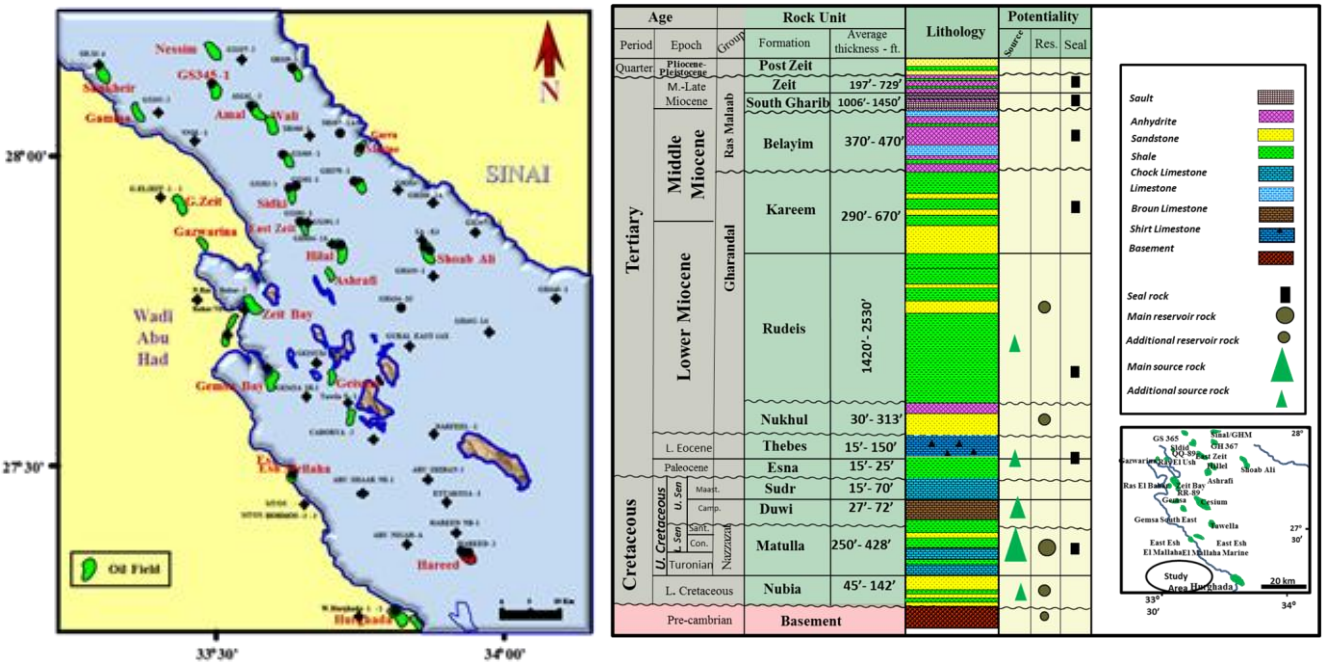


Figure 3: Oil fields distribution of Southern Gulf of Suez district based on well data, and Figure 4: General lithostratigraphic column of West Hurghada district based on well data.

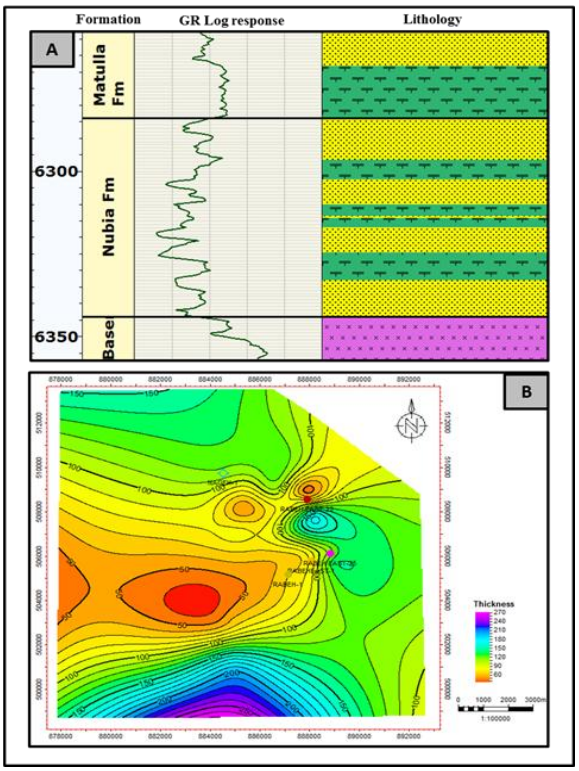
1.3. POST-MIOCENE SEQUENCE:

This stratigraphic sequence is ranging in age from Pliocene to Holocene. In marginal areas, this sequence is composed of sands and sandstone with shale predomination while limestone and clastics are forming the section in the offshore part of the Gulf of Suez. Although this section was deposited in the post-rifting stage, it owns a greatly variable thickness from 50 to greater than 4900 feet. This is anticipated as attributing to the post-rifting thermal sagging.

The main source rocks in the area are the Campanian Brown limestone and Lower Eocene Thebes Formation. The Miocene shale of Rudeis and Kareem formations are being at shallow burial and found immature source rocks. The hydrocarbon bearing reservoir in the area was representing by the sandstone intervals in the Nubia and Matulla formations. These intervals were representing the pay zones in oil fields in the West of Hurghada district. These thicker sandstone intervals exist in the stratigraphic column and are showing better reservoir characteristics and they were found oil bearing. The thick salt and anhydrite section of the Late Miocene South Gharib and Zeit formations are the regional cap rock in the entire Gulf of Suez, (Figure 2). On the local scale, the well distributed shale and marl in the stratigraphic section are providing the top and lateral seal for the thin pay zones in the study area. The lithology shows thinning upwards to Rabeh East direction (transfer area) and gradual transition to the overlying deposits with similar lithology along the study area, (Figures 5&6).

Although thickening upwards to South Malak direction (basinal area), thicker sandstone intervals exist in the stratigraphic column and are showing better reservoir characteristics (e.g., Nubia and Matulla formations), they were found oil bearing. The burial of the West Hurghada basin achieved around 11900 feet for the available Campanian source rock. And although the geochemical data is not available, it is anticipated that the main charge is coming from this source rock. The burial history indicates the moderate depth of oil and gas peaks (~7000 and 11,500 feet respectively, El Le body, 2008). This is an indication of the hydrocarbon charge from a near distance to the

hydrocarbon discoveries and before reaching the trough area. The migration routes toward the fields on the eastern basin flank indicate an northeast-direction of the up-dip way of charge. Northeastern-trending faults would participate like corridors while charging.



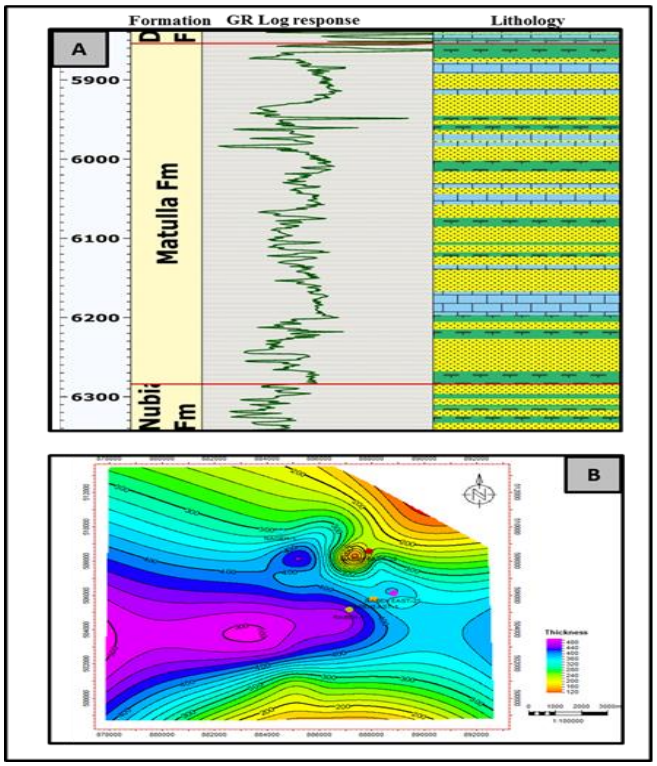


Figure 5: Lithostratigraphic section (A), and isopach map (B) of Nubia Formation, and Figure 6: Lithostratigraphic section (A) and isopach map of Matulla Formation.

2. STRUCTURAL SETTING:

The East-West Tethyan trend formed during the Paleozoic and part of the Mesozoic as the African continent was uplifted. As Pangea began to break up during the Mesozoic, uplifting throughout most of Egypt came to an end (Klitzsch and Squyres, 1990). The controversy surrounds much of the origins of the structural features formed during the Mesozoic, but there is general agreement that it was a period of major extensional tectonics (Morgan, 1990). The two main tectonic forces were sinisterly sharing during the late Jurassic to early Cretaceous, and then a transition to dextral shearing until the Paleocene, as North Africa collided with Laurasia, (Meshref, 1990). Nelson (1986) postulated that Mesozoic tectonics resulted from extensional wrench faulting acting on the preexisting east-west Tethyan trend, as well as re-activation of the older Precambrian trends. The West Hurghada area is affected by many faults dating from the Cretaceous Trending E-W, N-S, NNE, and NNW. The majority of these fault is extensional and crossing (transfer) faults, that displace Precambrian crystalline rocks, Late Cretaceous Nubian Sandstone and shale, Late Cretaceous shale of the Pre-rift formations.

PETROPHYSICAL RESERVOIR CHARACTERISTICS:

The available well-log data used in this work is in the form of Gamma -Ray, Porosity (Density and Neutron) and DLL (deep and shallow) Resistivity logs. The cut-offs used for the Nubia of West Hurghada area as follows: effective porosity **(15&19)** %, the volume of shale (**24&21)** % and water saturation **(36&44)** %. The result of Techlog 2010 software mark of Schlumberger used for petrophysical analysis showed in (Table 2).

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NET PAY SAND THICKNESS OF PRE-RIFT RESERVOIRS:

Figure (7) illustrates the distribution of the Nubia net pay reservoir in the study area where it is observed within the range of 7600 – 7700 feet. The highest net pay sand distributed in the South and southwestern parts of the area and decreases in the Northeastern part of the study area.

Figure (8) illustrates a net pay reservoir thickness map of the Matulla reservoir. The calculated net pay ranges between 18 and 55 feet. This reservoir spreads to the Western and Eastern parts of the study area. The thickness of pay zone increases toward the West and central direction but rapidly decreases to the transfer area in the Eastern and Northwestern direction. This distribution pattern indicates the presence of hydrocarbon potential of the Matulla Formation, (Table 1&2).

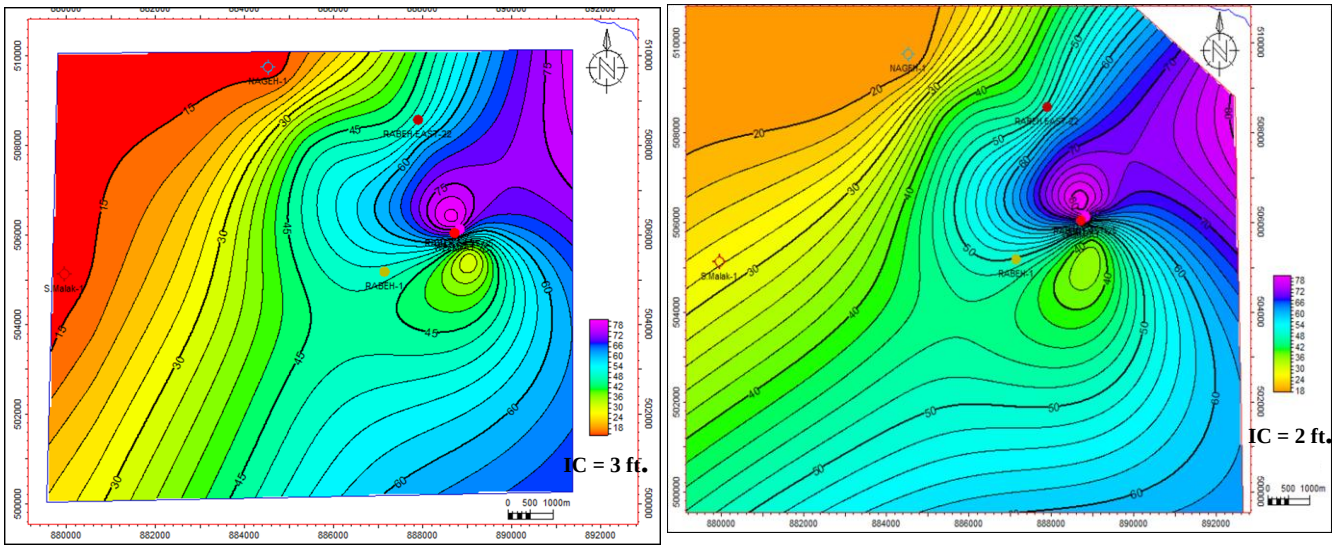

Figure 7: Net pays reservoir thickness of the Nubia Formation, and Figure 8: Reservoir Net pay thickness of the Matulla Formation in the west Hurghada area.

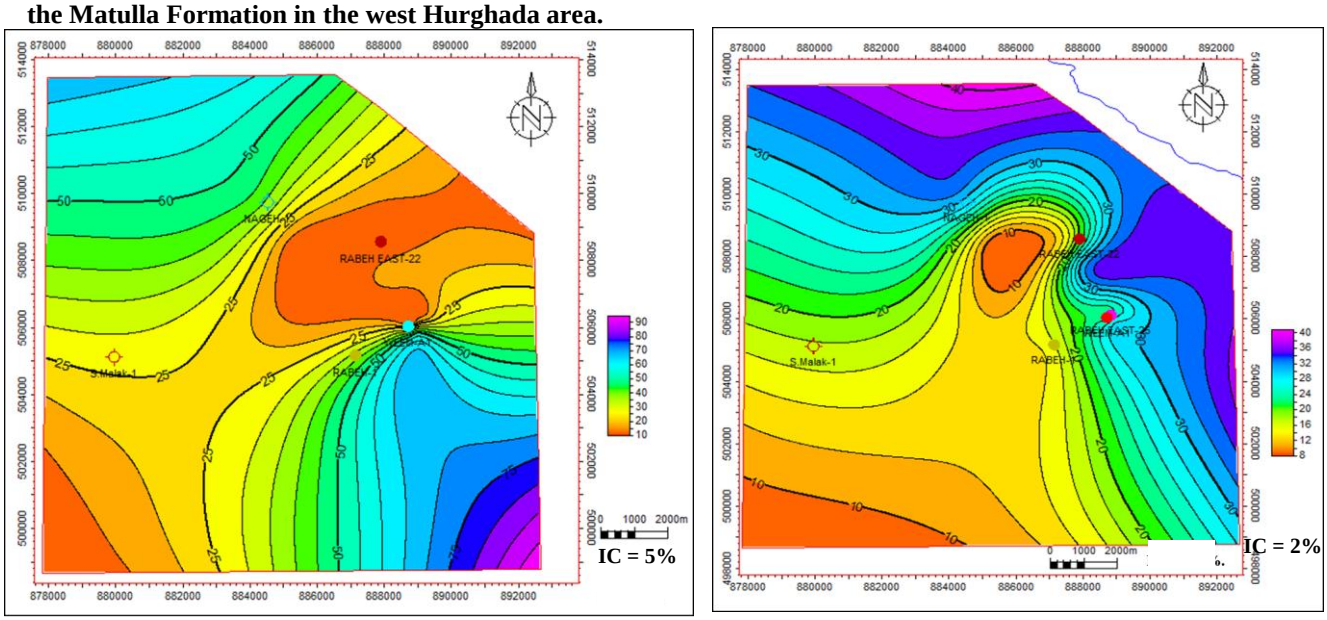

Figure 9: Shale volume content (V sh) of the Nubia Formation in west Hurghada area, and Figure 10: Shale volume content (V sh) of the Matulla Formation in west Hurghada area.

SHALE CONTENT OF THE PRE-RIFT RESERVOIRS:

Figures (9 &10) illustrate the distribution of the shale content (Vsh) in the area of West Hurghada where it is observed within the range of **(4 – 42) %** for the Lower Cretaceous Nubia Formation, and **(13 -29**) % for the Upper Cretaceous (Lower Senonian) Matulla Formation. The highest value of shale content distributed in the Eastern and Northeastern parts of the area and decreases to the Southwestern part of the study area, (Table 1&2).

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POROSITY OF THE PRE-RIFT RESERVOIRS:

Figures (11 &12) illustrate the distribution of the Effective porosity in the study area. The frequent porosity occurrences are observed within the range of (**7-22 &13-25**) %. The high porosity distribution is found in Southeastern part of the study area, whereas the lowest porosity distribution is found in the Northwestern part of the study area, (Table 1&2).

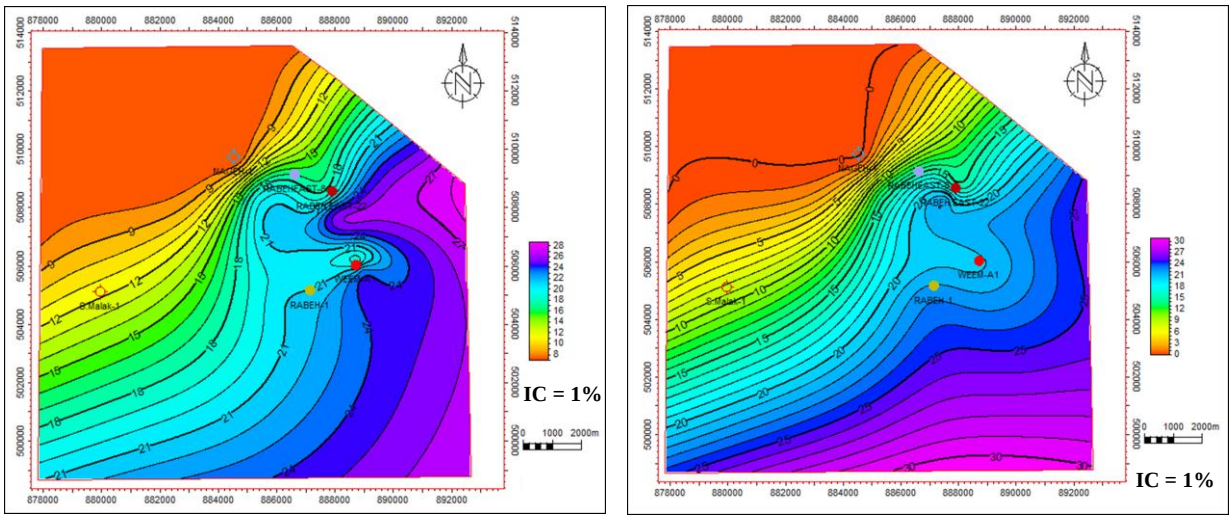

Figure 11: Average porosity map thickness of the Nubia Formation, and Figure 12: Average porosity reservoir map of the Matulla Formation in west Hurghada area.

WATER SATURATION OF THE NUBIA AND MATULLA RESERVOIRS:

Figures (13 &14) illustrate the distribution of the water saturation (SW) in the area where it is observed within the range of 30-100%. The highest water saturation distributed the western part of the study area and decreases toward the eastern part of the area, (Table 1&2).

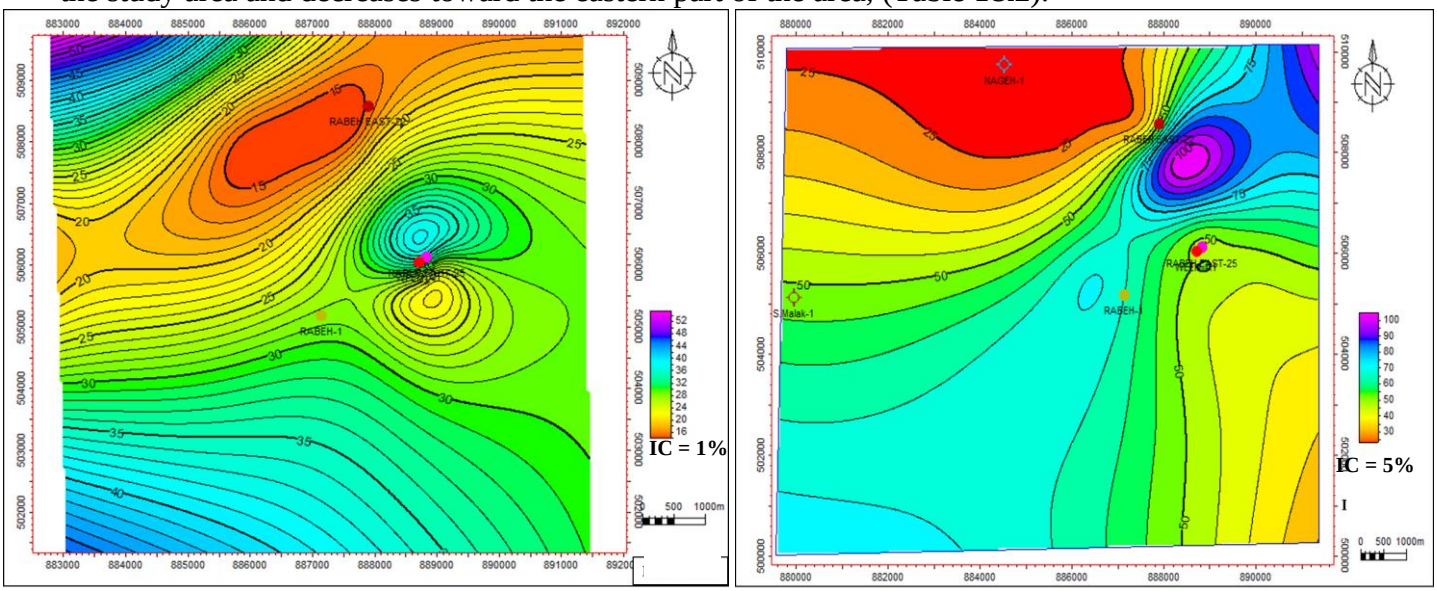

Figure 13: Average water saturation (Sw) map thickness of the Nubia Formation, and Figure 14: Average water saturation (Sw) reservoir map of the Matulla Formation in west Hurghada area.

HYDROCARBON SATURATION OF THE PRE-RIFT RESERVOIRS:

Figures (13 &14) illustrate the distribution of the hydrocarbon saturation (S_{hr}) in the area where it is observed within the range of (**25-47&23-65**) %. The highest hydrocarbon saturation distributed the Western and Southwestern parts of the study area and decreases toward the Eastern and Northeastern parts of the study area, (Table 1&2).

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PETROPHYSICAL EVALUATION OF THE PRE-RIFT RESERVOIRS:

The CPI (Computer Processed Interpretation) plot of the studied interval of Nageh-1 well, Figure (15) shows the Gamma-ray curve show less shale content against sand intervals penetrated in the well. The high Gamma-ray may represent shale or argillaceous sandstone interval. The resistivity curve indicates the presence of hydrocarbon accumulation where there is a good separation between deep resistivity curve and shallow resistivity curve.

Table 1: shows the petrophysical analysis of Nubia and Matulla formations reflects.

Zones	Top	Bottom	Gross	Net	Av. Shale Volume %	Av. Effective Porosity %	Av.Water Saturation %
Nukhul Clastics	6986	7287	301	40	34	5	95
Matulla Fm	7287	7590	303	29	29	…….	…….
Nubia Fm	7590	7706	116	30	36	7	91
Petrophysical analysis and pay zone summary of reservoir for Nageh-1well.							
Matulla Fm	7287	7590	303	18	29	……..	……..
Nubia Fm	7590	7706	116	25	39	7	47

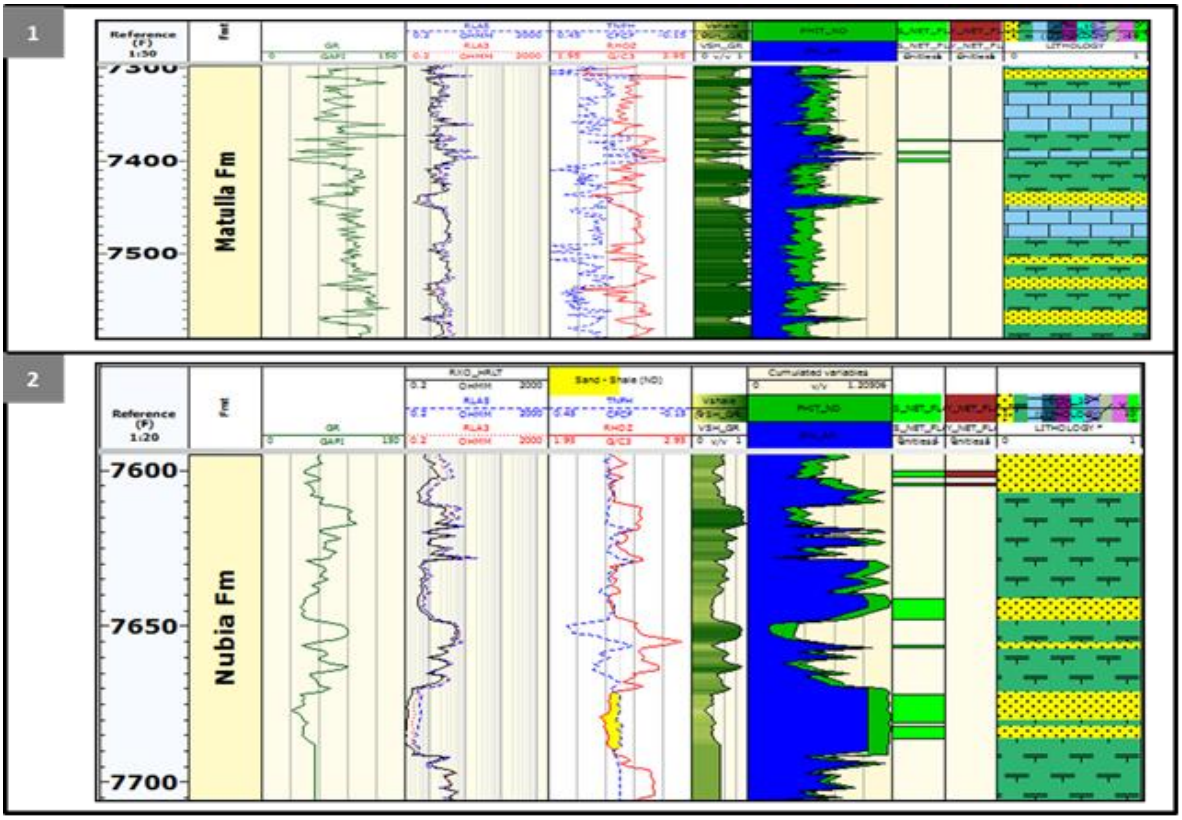

Figure 15: (CPI) plot for the Early Cretaceous Nubia (A), and Late Cretaceous Matulla in Nageh-1 well.

PETROPHYSICAL ANALYSIS OF NAGEH-1 WELL:

This vertical and exploratory well located at the northern part of the study area and northwest of Rabeh East oil field, (Figure 16). It considered as dry well and was reached to the final depth at 7733 (-7559) feet in basement, (Figure 16). The Log evaluation distinguished that there are 25 feet of net pay in Nubia Formation(Early Cretaceous) and 18 feet of net pay in Matulla Formation(Lower Senonian), with oil shows in this well and there is a petroleum system in this area, (Table 1), The Nageh-1 well was drilled in the downthrown side of the fault and failure of the lateral fault seal, (Figure 16). The Petrophysical parameters of the Pre-rift pay zones are

summarized in figure (15). It was clear that the Pre-rift (Nubia and Matulla) reservoirs sands are pinching out in the up-dip direction toward eastern hogback of the West Hurghada area, and showing facies deterioration on the way to the basin trough, (Figure 16).

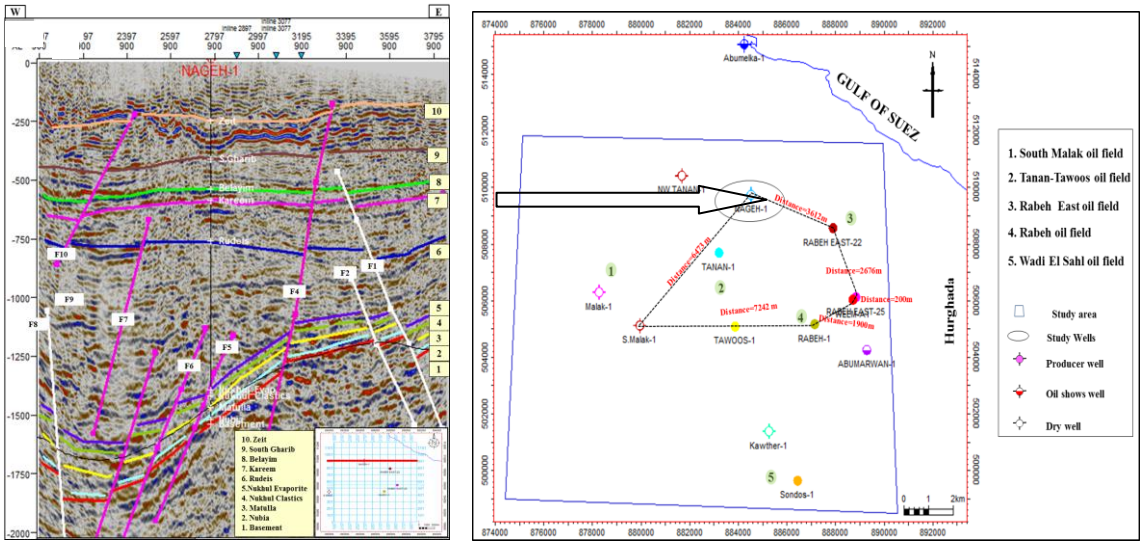

Figure 16: Location map and distribution of the study wells and trends of the oil fields in West Hurghada area, and E-W Seismic section (cross line 900) showing the identified faults and Pre-rift section.

SUMMARY AND CONCLUSIONS:

The West Hurghada basin is located on the main offshore Gulf of Suez through. The main source rock of the Senonian Brown Limestone and is characterized by enough burial depth furnishing hydrocarbon maturity. The conventional reservoirs of West Hurghada province represented by Nubia, Matulla and Lower Miocene Nukhul Clastics. The Miocene shale of Rudeis and Kareem formations are being at shallow burial and found immature source rocks. The last and most important element in the hydrocarbon trap is the reservoir rock. Evaluation of the reservoir rock parameters was only possible through using well log data sets available of this study. As a result of seismic interpretation which indicates that the calculated depths in the basement range from about 6000 feet (at the eastern side) to about 12000 feet depth (western basin) of the study area. The properties for the reservoir encountered by the wells drilled in the study area were obtained from detailed petrophysical analyses.

The petrophysical analyses conducted for Nagesh-1oil shows well drilled in the study area resulted in an understanding of the reservoir rock parameters of the reservoir of interest. These properties were mapped and helped in the delineation of sweet spots for the reservoir horizon, which in turn, helped along with other elements, in the promotion of the leads interpreted from the seismic data into prospects.

Mapping the petrophysical (net-pay, porosity and water saturation) characteristics of the different reservoirs encountered in West Hurghada area indicated the presence that the hydrocarbon potential of Nubia and Matulla formations is promising at the central and eastern part of the study area. Drilling more wells in these parts could result in adding more reserves in West Hurghada area.

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تضمنت الدراسة الحالية تسجيلات الآبار كما تم حساب المعاملات البتروفيزيقية مثل كمية الطين والمسامية وأيضا درجة التشبع بالماء كما تم حساب السمك الصافي المنتج للهيدروكربونات لكل من متكون الحجر الرملي النوبي والمطلة, كما تم عمل خرائط توضح توزيع كل معامل من هذه المعاملات في المنطقة لكل من متكون الحجر الرملي النوبي والمطلة, هذه الخرائط هي المسامية وكمية الطين ودرجة التشبع بالماء وكذلك السمك الصافي المنتج للهيدروكربونات لكل من متكون الحجر الرملي النوبي ومتكون المطلة.

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