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# EVALUATION OF HYDROCARBON POTENTIALITY OF RAS ABU DARAG CONCESSION (GULF OF SUEZ) USING PETROPHYSICAL AND GEOCHEMICAL DATA

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**الخلاصة:** تقع منطقة امتياز رأس أبودرج فى الجزء الشمالى من خليج السويس حوالى ١٥٠ كم شمال شرق القاهرة. الهدف الأولى هو تكوين النوبيا والحجر الرملى لتكوين الخطاطبة ( العصر الجوراسي). واتضح من تحليل تسجيلات الآبار أن مسامية الصخور تتراوح بين ( ١١ – ٢٠% ) فى تكوين النوبيا وذلك فى سمك خزانى يقدر ب ٤٠٠ قدم. و أن تكوين سدر / ديوى والذى يحوى على الصخر المصدر ( الأم ) لخليج السويس، ذو سمك يقدر بحوالى ٦٠٠ قدم كما تقدر قيمة تشبع الصخر بالماء بمنطقة الدراسة بقيمة تتراوح بين ( ١٢ – ٤٠ % ).

وأوضح التحليل الجيوكيميائى أن مصدر الزيت هو صخور الكربونات ( عصر الكريتاسي) وهذه الصخور بسبب ضحالة عمقها فى المناطق البرية فهى غير ناضجة لتكون الزيت ولكن تولد الزيت فى الصخور العميقه منها فى المناطق البحرية. وأوضحت البيانات أيضاً أن تكوين الخطاطبة ( الجوراسي) له خواص من معتدل إلى جيد من ناحية كونه مصدراً لتكوين الزيت وتقترح البيانات الخاصة بنضوج الزيت أن تجمعات الزيت يتم تغذيتها من صخور المصدر المجاورة وهو ما يسمى بالهجرة القصيرة أو من المناطق الأكثر نضوجاً (أحواض أبودرج ) وهو ما يعنى بالهجرة الطويلة، هذا وتقدر الاحتياطيات البترولية لمنطقة امتياز أبودرج بحوالى ١٨٠ مليون برميل مكافئ.

**ABSTRACT:** *The Ras Abu Darag (RAD) concession is located offshore in the northern part of the Gulf of Suez basin, about 150 km ESE from Cairo. The Primary targets were the Nubia and underlying Jurassic Khatatba sandstones. Log analysis from several offset wells has shown that the rock porosity varies between 11-20 % in the Nubia, with an average net potential reservoir thickness of some 400 ft . The Jurassic section also has shown a good reservoir potential, reaching 200 ft net in some wells. The Sudr / Duwi Formation, which holds the primary source rock for the Gulf of Suez (Senonian Brown Limestone), proved to be present in many onshore Sinai wells in and around the shallow Sudr / Asl and Ras Matama fields, with an average thickness of over 600 ft. As regards water saturation, log analysis in the study wells shows values ranging between 12% to more than 40%. The geochemical analysis data indicates that the source of the onshore oil is the Cretaceous carbonates. These rocks are too shallow onshore to be mature, but are expected to be present and generative in the deep offshore basinal area . The RAD-1X prospect trend is deep within the kitchen area and should have direct access to migration fairways out of the basin . In addition , the data indicates that the deeper Jurassic clastic section (Khatatba Formation ) has fair to good source rock potential for oil. The maturity data suggest that accumulations may have been changed from relatively nearby, early mature sources meaning short migration pathways or from the more mature areas of the Nebewei and Darag basins meaning longer, more tortuous pathways .*

*The potential estimated hydrocarbon reserves in the study area confirmed that it holds an estimated 180 million barrel oil equivelant, typed to the Jurassic and Cretaceous.*

## INTRODUCTION

The Ras Abu Darag concession is located offshore, in the northern part of the Gulf of Suez

Gas basin, about 150 km ESE of Cairo. It is one of the largest exploration blocks in the Gulf of Suez ( 928 square kilometers) where only six wells are drilled and a thick section of evaporites and clastics is encountered. Figure (1) shows a location map of the area under study.

The primary targets of the present study are the Nubia and Jurassic Khatatba sandstone reservoirs.

The Miocene Gulf of Suez rifting created multiple petroleum systems with over 10 billion oil equivelant discovered to date. The defined source rocks are the Cretaceous Brown Limestone and Eocene Thebes Formations, with a minor contribution from Lower Miocene shales. The Jurassic Khatatba Formation shales are also believed to have a good source potential in the northern Gulf of Suez (Ras Abu Darag area). The Precambrian (fractured basement) through Miocene rocks produce in the basin, with most of the reserves found within Tertiary syn-rift clastic reservoirs. Most wells and producing fields are located along the crests of tilted fault blocks and/or overlying, draped four-way closures. Traps are charged from numerous flanking sub-basins within the rift system.

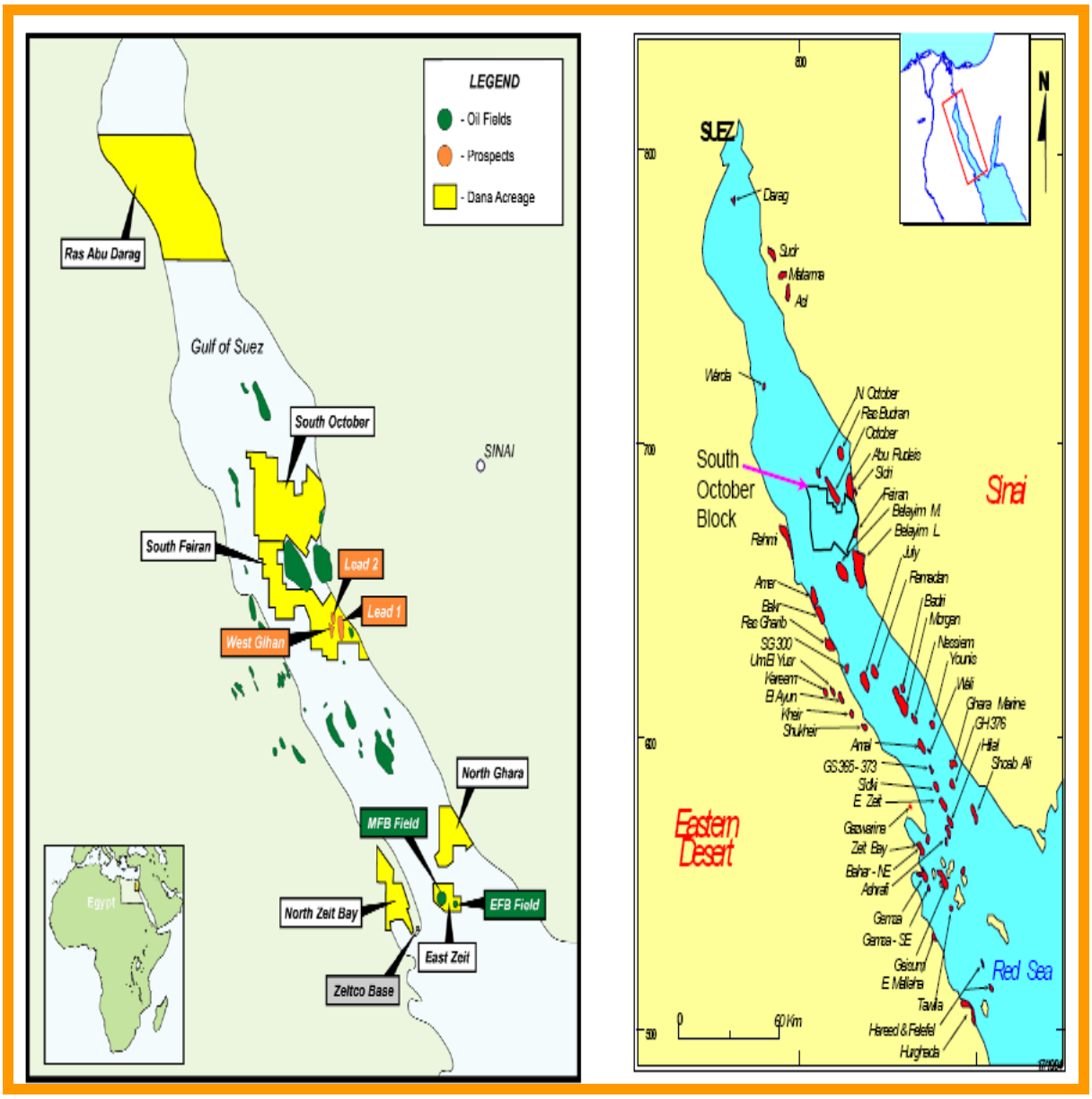


**Fig. (1): Location map of the study area.**

Top seals are dominantly Middle Miocene shales and the evaporites of the Rudeis and South Gharib Formations, respectively.

The 2D seismic acquired in the area failed to image the objective intervals due to multiple energy overwhelming and obliterating the primary reflections. Consequently, previous wells were drilled off structure and, therefore, failed to test the basin potential at all.

The RAD concession includes most of the deep Darag and Nebewei sub-basins in the northern-most Gulf of Suez rift system. These are deep asymmetric half-grabens created in the Early Miocene with incipient rifting. Multiple pre-Miocene source rocks (Cretaceous/Jurassic) are preserved beneath the floor of these foundered blocks and are mature for hydrocarbon generation.

Five shallow oil fields flanking the basin confirm this and hold an estimated 180 MMBOE, typed to the Jurassic and Cretaceous. Several authors (Lelek, J., Shepherd, D and Abdine) have published studies indicating a conservative generative capacity for this basin from the known source intervals of well over one billion barrel oil recoverable. Devon's work program was designed to identify multiple traps in the migration fairway between the deep kitchen areas and these shallow oil fields.

As mentioned earlier, the targets are Lower Cretaceous fluvial sandstone and reservoirs (Nubia) and the underlying Jurassic Khatatba shallow marine sandstones. These beds are expected to be structured in rotated fault blocks bounded by rift-axial and oblique or transfer faults, typical to basement involved extensional regimes. The northern Gulf of Suez underwent minimal extension relative to the entire Gulf of Suez / Red Sea

rift system, and consequently, deformation is not as severe as elsewhere in the Gulf. Trap-door or dog-leg style fault block traps are expected to be larger, less faulted, and with only minor rotation (< 20°) relative to what has typically been exploited elsewhere in the GOS. The primary reservoirs in these structures will be top and cross-fault sealed by very thick sections of syn-rift shales and marls (Rudeis Formation).

The RAD acreage has been previously held in parts by Amoco (GUPCO), TOTAL and FINA, who acquired the various 2D seismic surveys and drilled the wells. In the late 1990's, Seagull (later merged with Ocean), one of Devon's predecessor companies, was one of the last lease holders in the area. Unfortunately, the acreage went into force majeure and no exploration activity took place. However, a significant amount of regional interpretation work was done, including geochemistry studies, biostratigraphic analysis, sequence stratigraphic interpretation, and 2D seismic mapping.

The first exploration period for the Ras Abu Darag concession is 4 years, beginning January 5, 2003, including 3 exploration wells, 3D seismic acquisition / processing and high resolution areomag. The second and third exploration periods are optional, with 3 and 2 years respectively and commitment to drill two exploration wells.

**STRATIGRAPHY:**

The Stratigraphy of the study area can divided into three groups :

**1- Basement rocks:**

The Pre-Cambrian Basement rocks penetrated in several wells within the northern part of the Gulf of Suez. The Pre-Miocene sediments (Pre-Rift sequence) have been super imposed on the Cretaceous Syrian Arc System. The Pre-rift is represented by Nubia sequences overlain the Early Cretaceous sequences (figure 2). These Nubia sandstone are ovelain by Nazzazat Group that include Raha, Wata, Matulla Duwi and chalky limestone.

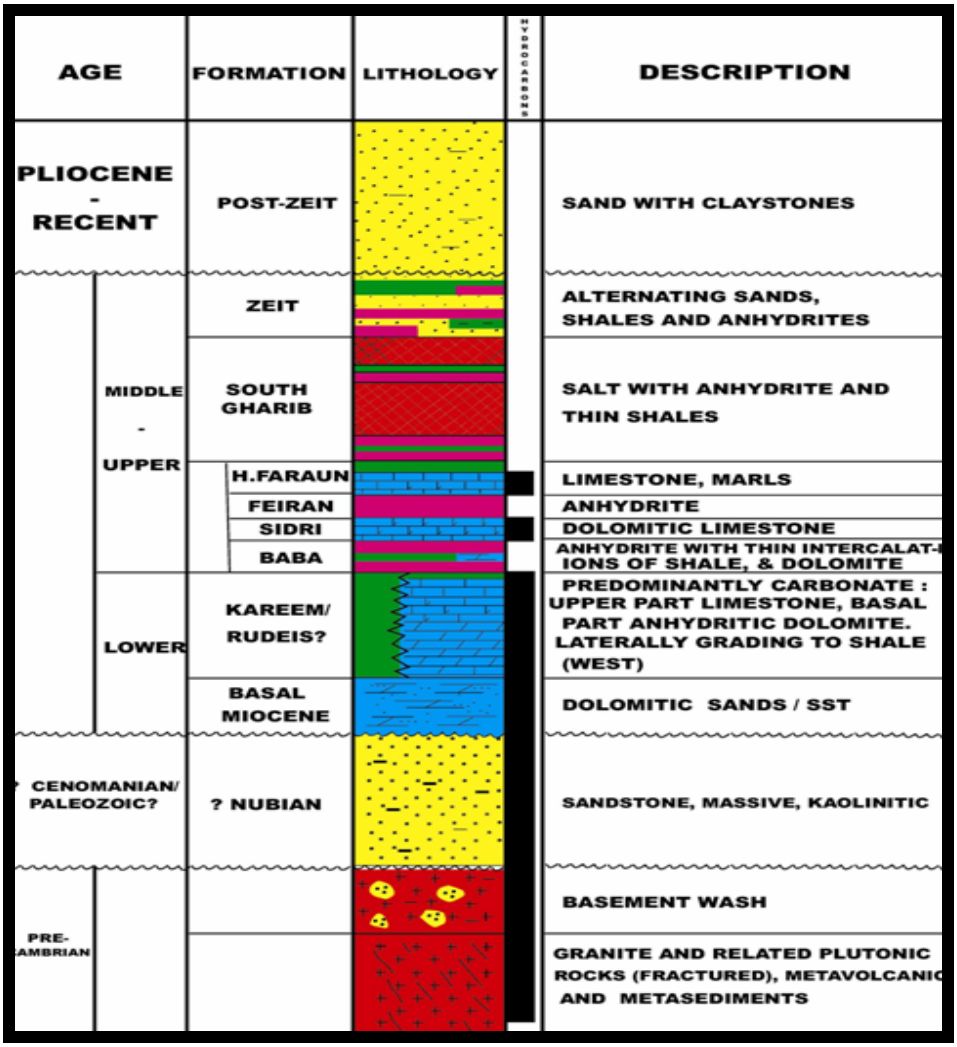


**Fig. (2) :Generalized Stratigraphic column of Ras Abu Darag area, Gulf of Suez, Egypt.**

These systems of stratigraphic units are overlain by Paleocene and Thebes Formation. These are overlain through a remarkable unconformity by the Early Miocene sequences.

**2- The Miocene rocks:**

The Miocene rocks overlie Pre-Miocene everywhere in the block. The oldest Miocene rocks recorded in the area are Nuhkul Formation. The Nuhkul Fm and Lower Rudeis consist mainly of calcareous shale with interbeds of dolomite and sandstone. The upper Rudeis & Kareem Formation are absent on the top of the structural high while reaching up 500m thick in the basinal area.

**3- The Belayim Formation:**

The Belayim Formation overlies the Rudeis Formation and is composed of a clastic and non-clastic units which are divided in to "Baba Member, Sidri Member, Feiran Member and Hammam Faraun Member". All the four members of the Belayim Formation are penetrated on the crestal part and thicken towards the down dip on all sides.

From isopach maps, it seems that the deposition was controlled by syn-depositional fault control (growth fault). The South Gharib Formation which rests directly over the last sequence of Belayim Formation (Hammam Faraun Member) is characterized by the deposition of massive salt with anhydrite, shale and rarely sandstone streaks. Three sand and silt packages were noticed and can be correlated especially in the North to Northwestern part of the block but relativly it is thinner compared by the central part of the Gulf. The South Gharib is overlain and capped by the Zeit Formation. The Zeit Formation is overlain by Post-Zeit Formation.

## STRUCTURAL SETTING

Gulf of Suez is a Miocene extensional rift system, divided into three distinct dip-sub basins, partitioned by two major fault accommodation zones. These accommodation zones provide access points for Syn-Rift sediments to allow for multiple reservoir targets along with the prerift Nubia Sandstone.

The main trapping mechanisms are structural, with tilted fault blocks sealed by shales or tight limestones, and broader anticlinal / monoclinal traps (figure 3) sealed by the overlying regional evaporite seal. Downthrow faut traps also work, being sealed against basement. The RAD – 1X prospect is a pre-Miocene tilted fault block structural trap defined by 3D seismic, subsurface well control, and quantitative structural interpretation of high resolution aeromagnetic data. It is located in the northwest concession area under the south bound shipping lane in water depth of 203 ft. This prospect, and the large, NW – SE structural trend.

It was unknown in the basin prior to the Devon work program. The trap is controlled by a large, down to the NE rift parallel normal fault intersecting obliquely a major, down to the NW cross-fault or relay fault (figure 4). The Pre-Miocene section dips to the SW at about 15 degrees. The total area of the trend under mapped closure being tested by the RAD-1X well is over 13500 acres. Top seal and cross-fault seal will be provided by thick Rudeis Formation basinal shales and marls.

## RESERVOIR CHARACTERESTICS

The primary reservoir targets, in the study area are the Nubia and underlying Jurassic Khatatba sandstones. Log evaluation, using a software programme, from several offset wells has shown that the rock porosity ranges between 11-20% in the Nubia with an average net potential reservoir thickness of over 400 feet (Figure 5). The Jurassic section also shows a good reservoir potential over 200 feet in some wells.

The surface location of the rig is to be positioned approximately 2100 meters SW of the proposed Nubia target location which is located inside the south bound shipping lane.

Drilling will be directionally controlled with KOP at 3000 ft. and about 33 deg. Inclination and azimuth of N 66.51 E.

The following summarizes the play / prospect parameters, their perceived associated risk, and potential oil reserve estimate:

## NUBIA FORMATION

• **Reservoir:**

The Nubia Formation is over 600 feet thick gross average, with a N/G of about 60 – 70%. Porosity over the prospect depth is expected to be 12 percent average based on petrophysical analysis. The sandstones in the underlying Jurassic section also show excellent reservoir potential. The chance that the Nubia and / or Jurassic potential reservoirs are missing or eroded from the prospect area is nil.

• **Seal:**

The Miocene syn-rift fill is expected to be predominantly shale in the Darag / Nebewei basin, given the lack of any nearby coarse clastic source areas feeding sand into the sub-basin. This is confirmed by the thick Rudeis Formation shale section drilled by the basinal wells GS 78 and Galala 1 as shown in figure 6. Therefore, the Rudies Formation is expected to provide an excellent fault and top seal for the prospect.

**Fig. (3): Depth structure map on top Nubia Formation, Ras Abu Darag concession, Gulf of Suez area, Egypt.**

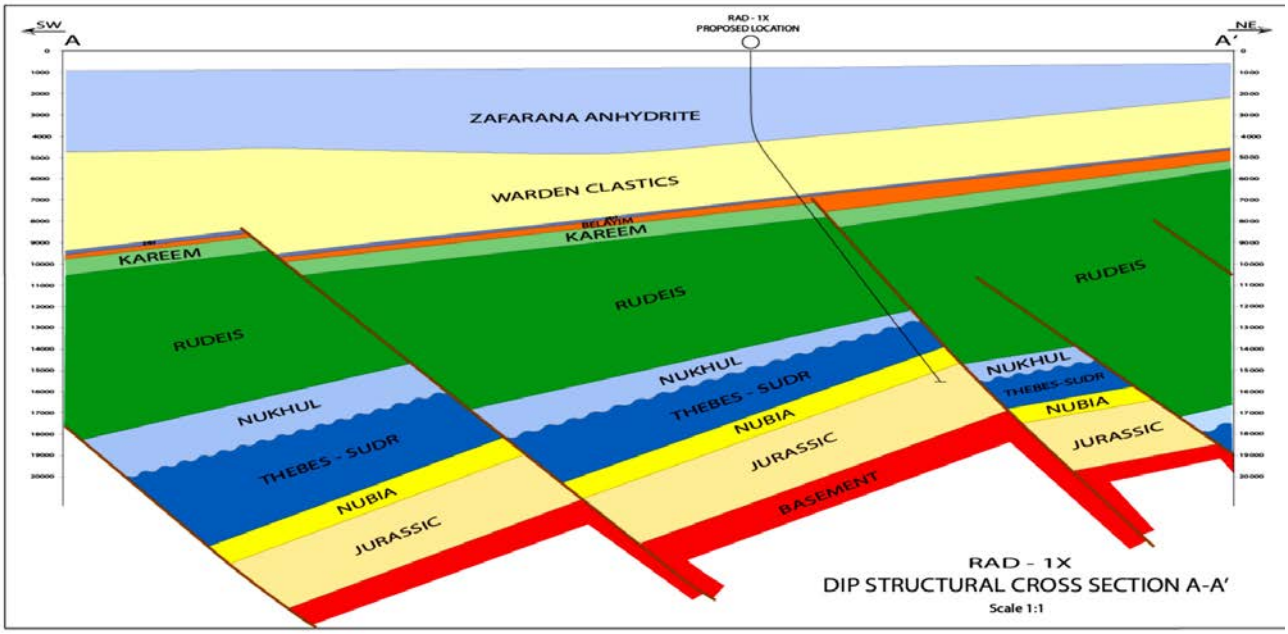


**Fig. (4): Dip structural cross section along A-A', Ras Abu Darag concession, Gulf of Suez area, Egypt.**

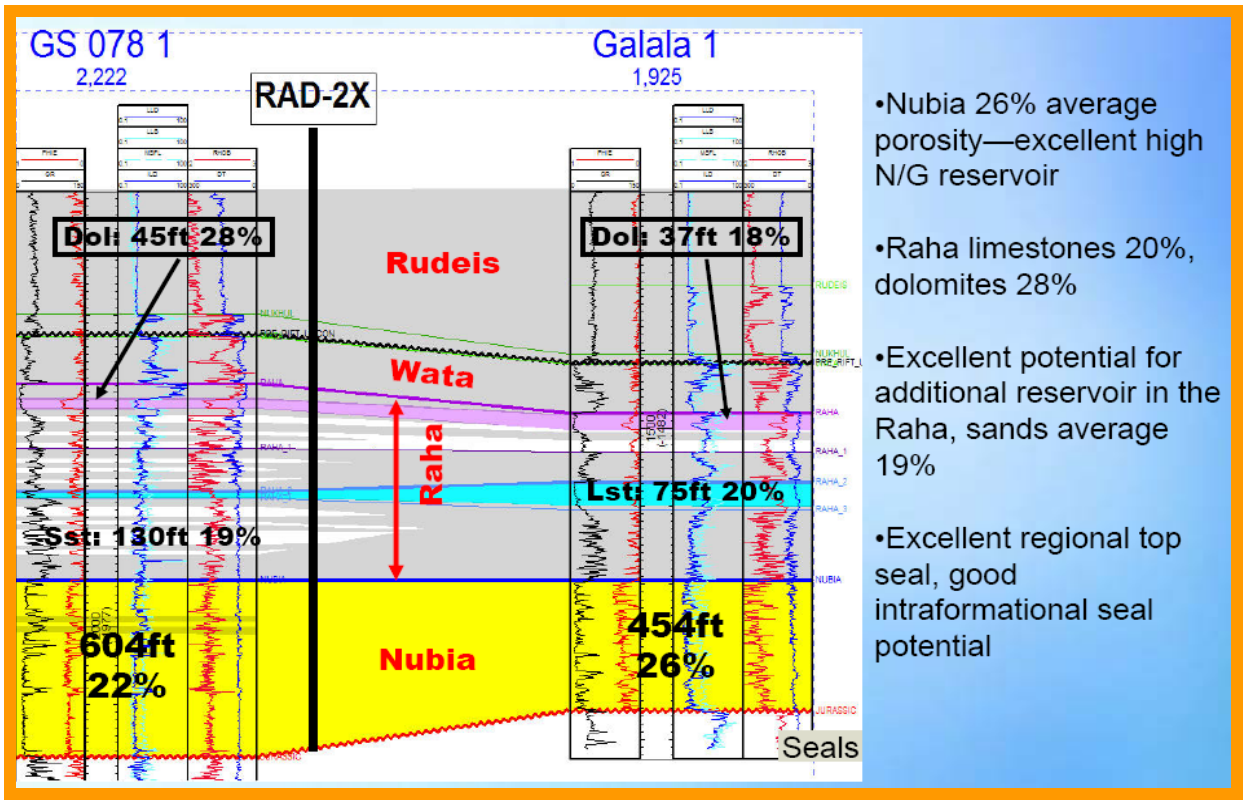


**Fig. (5): Nubia/Raha reservoirs and seals, Ras Abu Darag concession, Gulf of Suez area, Egypt.**

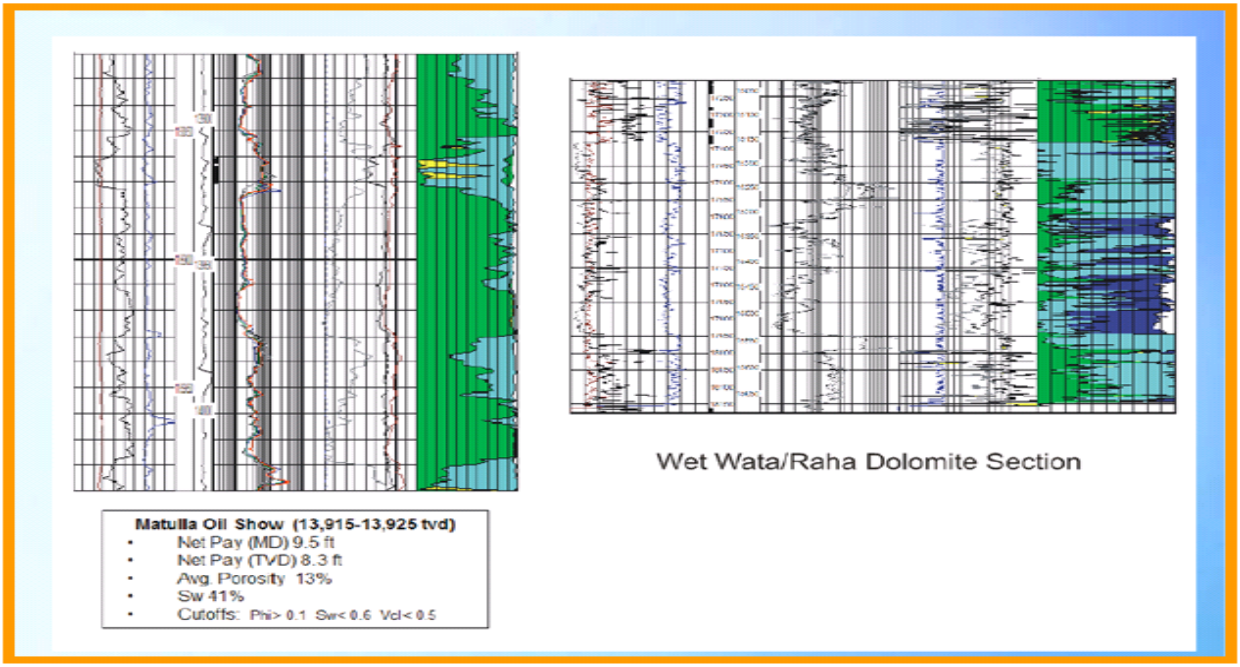


**Fig. (6): Log interpretation results of Wata/Raha Dolomite section of RAD1-x well, Ras Abu Darag concession, Gulf of Suez area, Egypt.**

• **Source, Maturation and Timing:**

The Sudr / Duwi Formation, which holds the primary source rock for the Gulf of Suez (the Senonian Brown Limestone), is proven present in many onshore Sinai wells in and around the shallow Sudr / Asl / Ras Matarma Fields. Its average gross thickness is over 600 ft. The geochemical analysis carried out in the area indicates that the source of these onshore oils are the Cretaceous carbonates. These rocks are too shallow onshore to be mature but are expected to be present and generative in the deep, offshore basinal areas. The RAD-1X prospect trend is deep within this kitchen area and should have direct access to migration fairways out of the basin. Geochemical analysis also indicates that the deeper Jurassic clastic section (Khatatba Formation) has good to fair source rock potential for oil.

• **Source Rock and Burial History:**

Several intervals of Miocene source rock facies are encountered in the Belayim (Hammam Faraun and Sidri Members), Kareem and Rudeis Formations in the different parts of the Gulf of Suez. So, it is suggested that Miocene and potential Pre-Miocene source rock facies may be present in the northern Gulf of Suez basin.

The primary source rock facies of the Upper Senonian carbonates are Duwi and Sudr Formations in the Gulf of Suez. Basins are expected to exist in the sedimentary sequence found in RAD area. The Miocene source rocks range from type II (mixed oil and gas prone) to type III (gas- prone) kerogen.

The Pre-Miocene source rocks are predominately of Type II Kerogen. The main source rocks are located in the Pre Miocene succession. They are represented by fine clastics and carbonates deposits belonging to the Nubia B (Carboniferous), Brown Limestone of the Duwi Formation (Upper Cretaceous), and Esna Shale. (Paleocene) and the Thebes Carbonate (Eocene) and some Cretaceous deposits. Thebes and Duwi Formations are the main source rocks (figure 7). The average T.O.C. is 2%, the kerogen type is mainly type II, the expected hydrocarbon is oil (API degree range between values of 18-23). The basin located in the center and in the north of the block (figure 8). Nebwi and Darag basins are considered as the feeder area (kitchen area).

**Maturity and Migration:**

Maturity data from wells in the RAD Concession Area (from 14 well geochemistry study) suggests that:

- Accumulations may have been charged from relatively nearby, early mature sources meaning short migration pathways, or from the more mature areas of the Nebwi and Darag Basins meaning longer, more tortuous pathways as shown in figure 9.
- Maturity in the wider Darag-Nebwi area does not seem to be an issue, however migration and charge may be a risk.

**SUMMARY AND CONCLUSIONS**

In Ras Abu Darag offshore concession, the primary targets were the Nubia and underlying Jurassic Khatatba sandstones . Log analysis from several offset wells has shown that the rock porosity varies between 11-20 % in the Nubia with an average net potential reservoir thickness of some 400 ft . The Jurassic section also has shown a good reservoir potential, reaching 200 ft net in some wells. The Sudr / Duwi Formation, which holds the primary source rock for the Gulf of Suez (Senonian Brown Limestone), proved to be present in many onshore Sinai wells in and around the shallow Surd / Asl / Ras Matarma fields, with an average thickness of over 600 ft. As regards water saturation, the log analysis in the study wells shows values ranging between 12% to more than 40%. The geochemical analysis data indicates that the source of the onshore oils is the Cretaceous carbonates. These rocks are too shallow onshore to be mature, but are expected to be present and generative in the deep , offshore basinal area. The RAD-1X prospect trend is deep within the kitchen area and should have direct access to migration fairways out of the basin . In addition , the data indicates that the deeper Jurassic clastic section (Khatatba Formation) has fair to good source rock potential for oil. The maturity data suggest that accumulations may have been changed from relatively nearby, early mature sources meaning short migration pathways or from the more mature areas of the Nebewei and Darag basins meaning longer, more tortuous pathways.

The primary source rock facies are the Upper Senonian carbonates (Duwi and Sudr Formations) in the Gulf of Suez. Basins are expected to exist in the sedimentary sequence found in Ras Abu Darag area. The Miocene source rocks range from type II (mixed oil and gas prone) to type III (gas- prone) kerogen. The Pre-Miocene source rocks are predominately of Type II Kerogen. The main source rocks are located in the Pre Miocene succession. Thebes and Duwi Formations are the main source rocks: the average T.O.C. is 2%, the kerogen type is mainly type II, the expected hydrocarbon is oil (API degree range between values of 18-23). The basin located in the center and in the north of the block (Nebewei and Darag basins) is considered as the feeder area (kitchen area). The potential estimated hydrocarbon reserves in the study area confirmed that it holds an estimated 180 million barrels oil equivelant, typed to the Jurassic and Cretaceous.

Based on the study results, it is recommended that the development/exploration activity to be conducted to assess the Nubia and underlying Jurassic Khatatba sandstones at the Abu Darag concession in the area of interest.

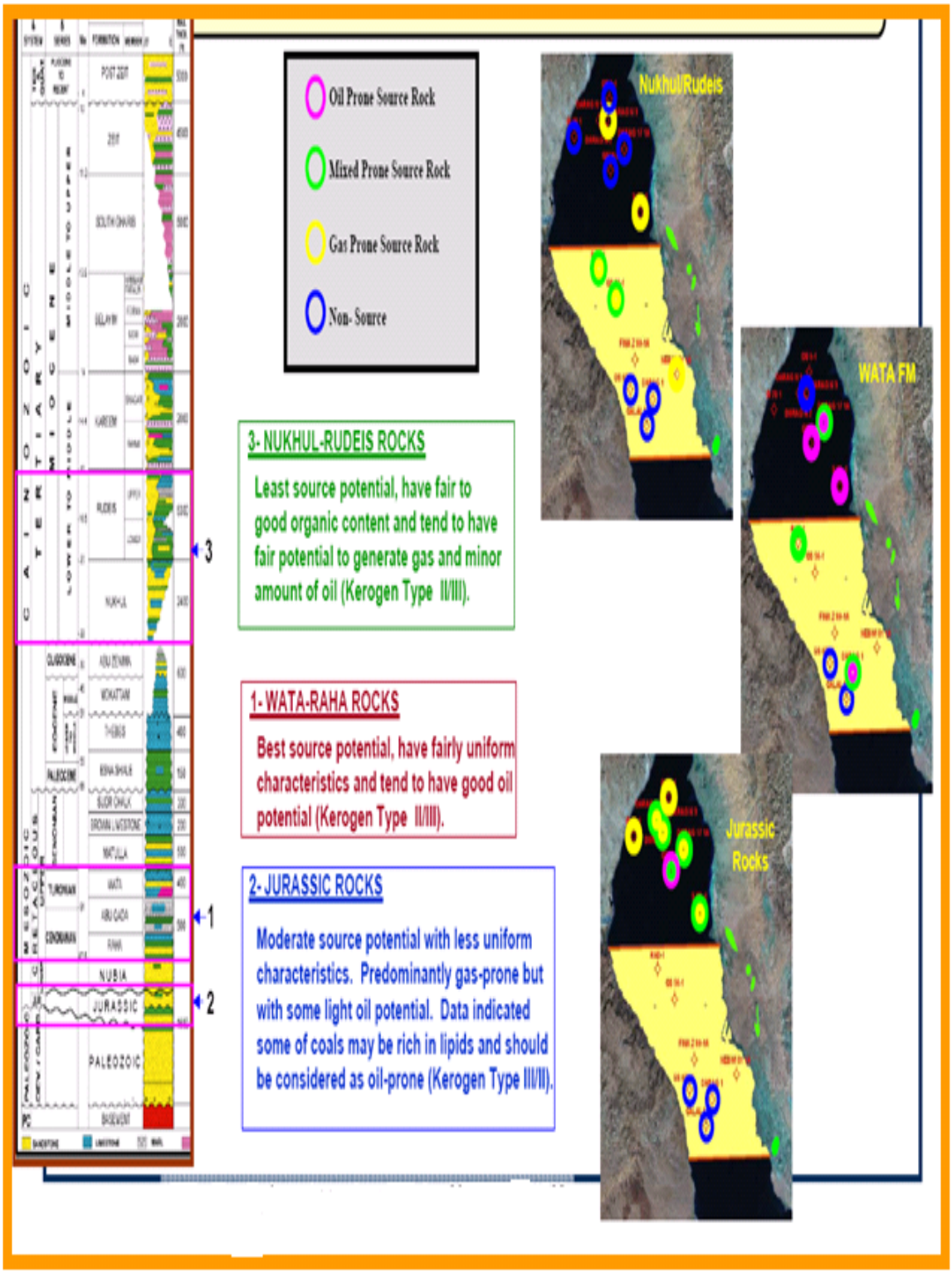


**Fig. (7): Ras Abu Darag potential source rock.**

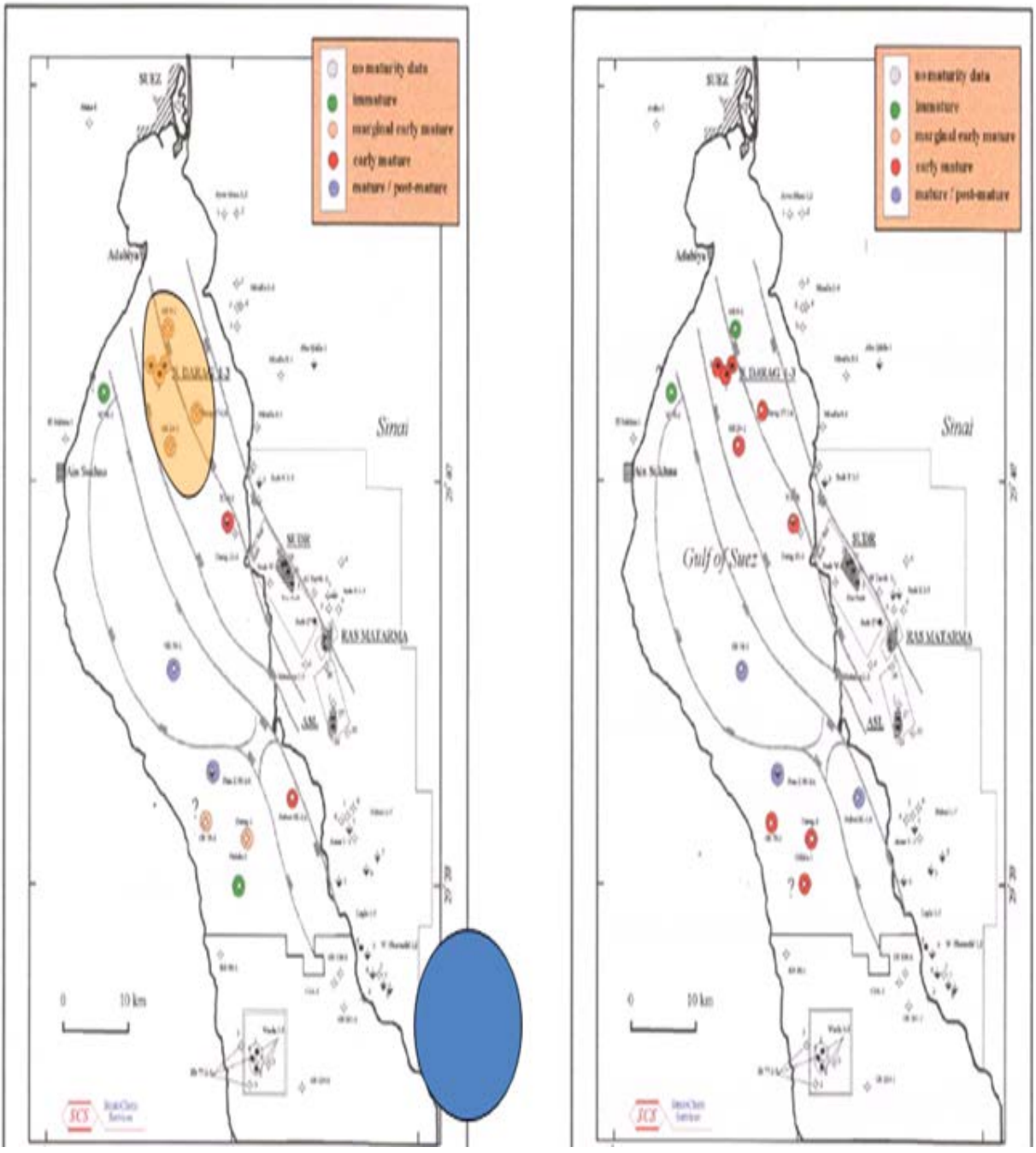


**Fig. (8): Maps showing maturity for Wata/Raha and Jurrasic source rock, Ras Abu Darag concession, Gulf of Suez area, Egypt.**

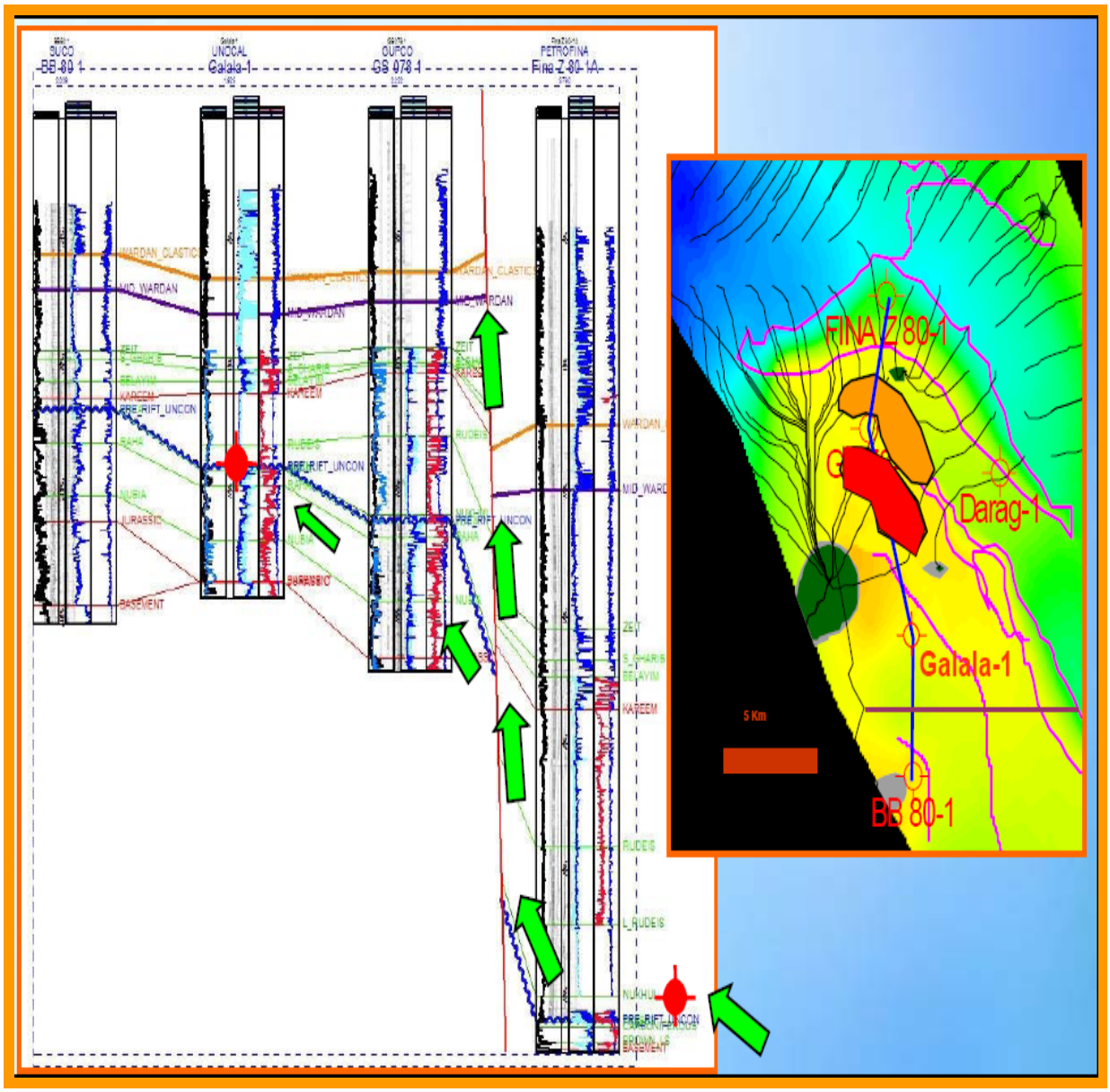


**Fig. (9): Migration pathway and prospect potential, Ras Abu Darag concession, Gulf of Suez area, Egypt.**

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