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Reservoir quality of Nullipore formation, Ras Fanar oil field concession, Gulf of Suez, Egypt

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Abstract

The present paper deal with the evaluation of the petrophysical parameters of Nullipore formation at Ras Fanar oil field oil field in the central province of Gulf of Suez through the analysis of well logging data available for six wells. A comprehensive formation evaluation has been applied through number of crossplots and use their out-put parameters as in put data for interactive petrophysics software in order to evaluate the lithological constituents and fluid saturations. The lithosaturation crossplots indicate that the Nullipore formation consists of limestone and dolomite with few clay and anhydrite the lithosaturation crossplots also illustrated that zone III and II of Nullipore are the main reservoir zones in the Nullipore.

Keywords: Nullipore formation, Ras Fanar oil field, Well logging, Petrophysical parameters.

1. Introduction

Gulf of Suez is a northwest trending intracratonic basin and separated from the Red Sea by the Aqaba trans-form fault. Gulf of Suez and the Red Sea with the Gulf of Aqaba are structurally and genetically closely related, they form the northern branches of the great East African Rift. System. They developed as a result of early rifting between the African and Arabian Plate in the Late Mesozoic to Early Tertiary. (**EGPC 1996**). (Figure 1.1)

The Gulf of Suez Basin is still considered the most prolific petroleum province with the potential to achieve Egypt's Goals. More than 800 exploratory wells were drilled in this basin resulted in 230 oil discoveries and 77 oil fields with a cumulative footage of almost 7 million feet. It has 80% of Egypt oil reserve and gives 75% of Egypt oil production. Consequently, all factors controlling hydrocarbon accumulation should exist in the basin. (Figure 1.2)

Gulf of Suez can be geomorphologically described as a rejuvenated, slightly arcuate NW-SE trending taphrogenic depression known as the clysmic gulf. It extends along a northwest trend from latitude 27° 30' N. Its width varies from 30 to slightly over 50 Kms. in the central part. The length of the Gulf from the south tip of Sinai Peninsula to Suez City is about 350 Kms. The Graben, however most likely extends from Suez City further north to the Mediterranean Sea. The Gulf itself is a rather shallow and narrow body of water with an overall covered surface of 25000 Sq. Km. Several islands formed by emerging fault blocks are present near the junction with the Red Sea. The overall onshore and offshore area with oil potential is estimated to be about 38000 Sq. Km. This extension is masked by the alluvial and deltaic deposits of the Nile along which Suez Canal was eventually built. It is bounded by Sinai massive on the east and Red Sea hills of the Eastern Desert on the west.

The Gulf of Suez is currently subdivided into three structural provinces according to their structural setting and regional dip direction:

I. Northern Province

It represents the northern pan of the Gulf of Suez restricted by Galala Hinge zone that extends on a line drawn from South Galala Plateau to the offshore of Asl Oil Field. This province is characterized by high structural features "Galala Plateau Westward", and has been much affected by Tethyian sedimentation. The regional dip of strata is southwest. The main fault trends (the clysmic and the Aqaha) throw toward northeast and southeast respectively.

II. Central Province

It occupies the central part of the Gulf of Suez, The characteristic feature of that province is the Pre- Miocene shallow structures underlying the Miocene sediments as in Ras Gharih, Ras Fanar, Bakr and Amer Oil Fields. These highs were subjected to severe erosion. The eroded Pre-Miocene sediments were deposited in the Early Miocene troughs such as October and Gharib troughs. The reefal limestone of the Middle Miocene is developed on the Pre-Miocene highs. The regional dip is

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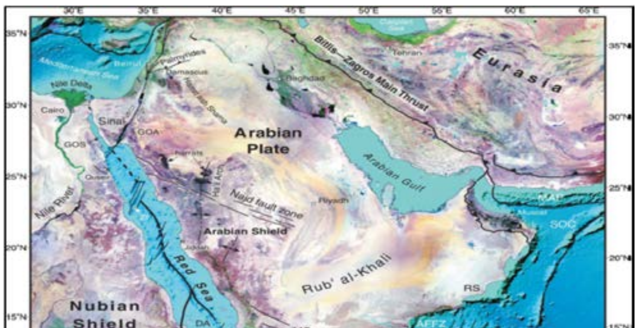
northeast. The main clysmic and Aqaba trending throw towards southeast and northwest respectively.

III. Southern Province

This province is bounded from the north by the Morgan hinge zone pathing from the northern end of Esh El Mellaha to Ras Shukheir to the north of well LL 87-1, then the offshore north of Gebel Araba on the eastern bank. It is characterized by the occurrence of surface outcrops of Miocene, Pre- Miocene sediments and basement rocks in Gehel El Zeit and Esh El Mellaha ranges, The regional dip of strata is towards southwest as the northern province and the main clysmic and cross faults throw towards northeast and southeast respectively. Galala and Morgan hinge zones are shift.ed southwards on the eastern bank of the Gulf of Suez some 45 Km at Zeneima and 30 Km. at Gebel Nakus respectively. (Figure 1.3) (**EGPC 1996**).



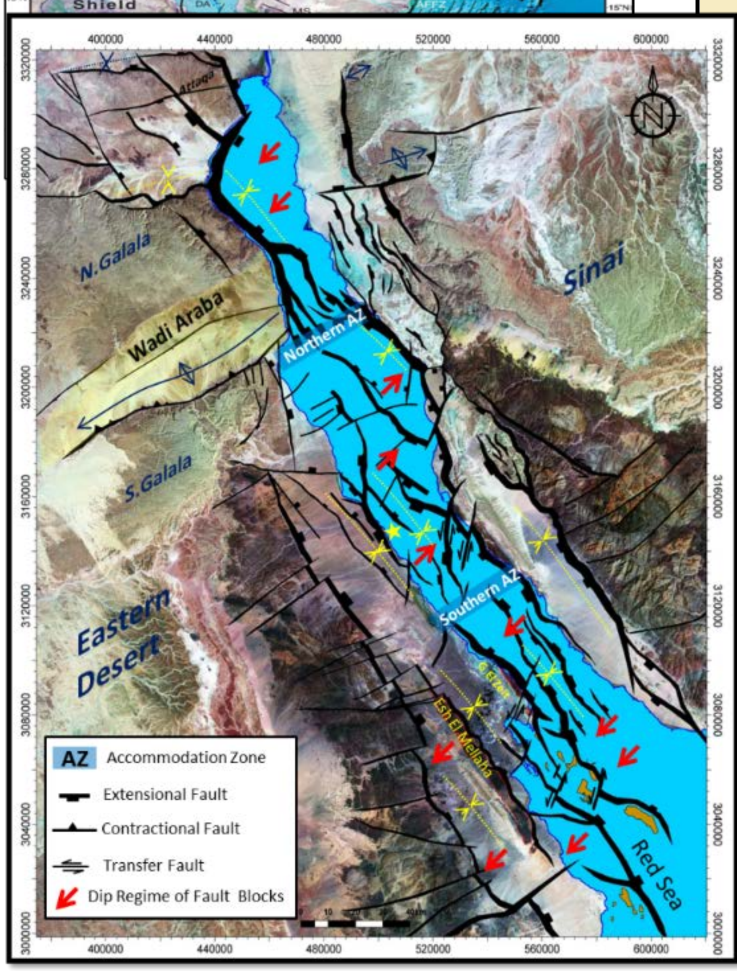


Figure 1.1: Landsat imagery of the Red Sea–Gulf of Suez, Gulf of Aden rift. system and environs.after William Bosworth, Philippe Huchon ,and Ken McClay

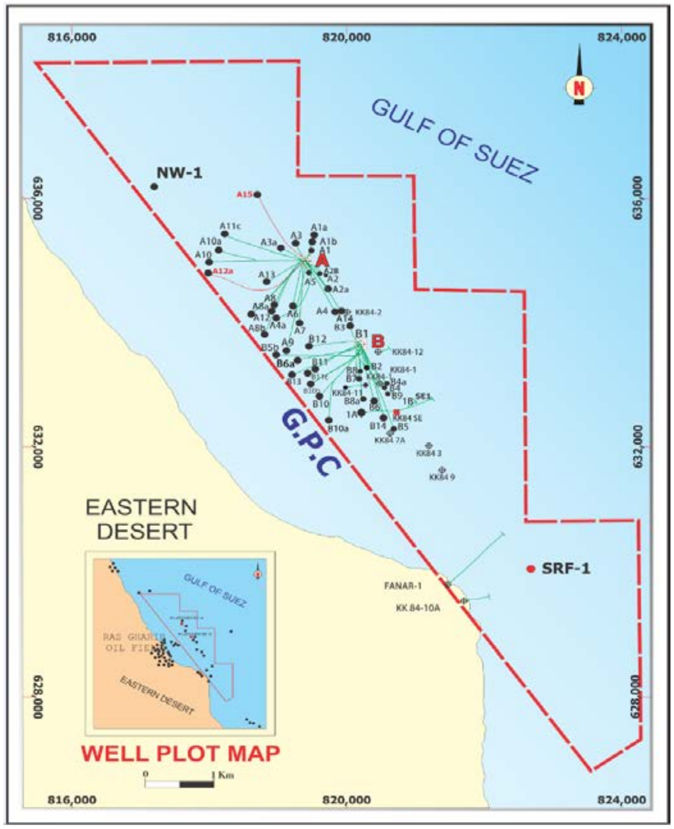
Figure 1.2: Gulf of Suez with oil field, , SPTEC Advisory – 2013 Country Review

Figure 1.3: General structural setting of the Gulf of Suez. After A.Sehim ,2015

The study area is located offshore of the western side of the Gulf of Suez, 3.5 km east of Ras Gharib shoreline. It is present in the Belayim dip province of NE direction (Moustafa, 1976) which includes most of the famous oil fields (e.g. Badran, Rudeis, October, Belayim, Fieran, Rahmy, Amer, Bakr, Ras Gharib, Sheab Gharib, Kareem, Shukheir, Ramadan, July, .etc.). Our Studied area is Ras Fanar oil field which is one of the Miocene marginal marine facies along the central part of the western

coast of the Gulf of Suez province.

Our study will focus on the reservoir unit in the field, which is called Nullipore. The term "Nullipore Carbonate" was first used by Moon and Sadek (1923) to



describe the sequence that underlies the Evaporite Group (Ras Malaab Group) of middle to late Miocene age and is equivalent to the Hammam Faraun Member of the Belayim Formation. The limestones have been given the name "Nullipore" due to their richness in algal nodules and fragments. The distribution of wells drilled in the field can be shown in the spider map Figure (1.4) while the selected wells for the study in figure (1.5).

Figure 1.4: Spider map of Ras Fanar oil Field.

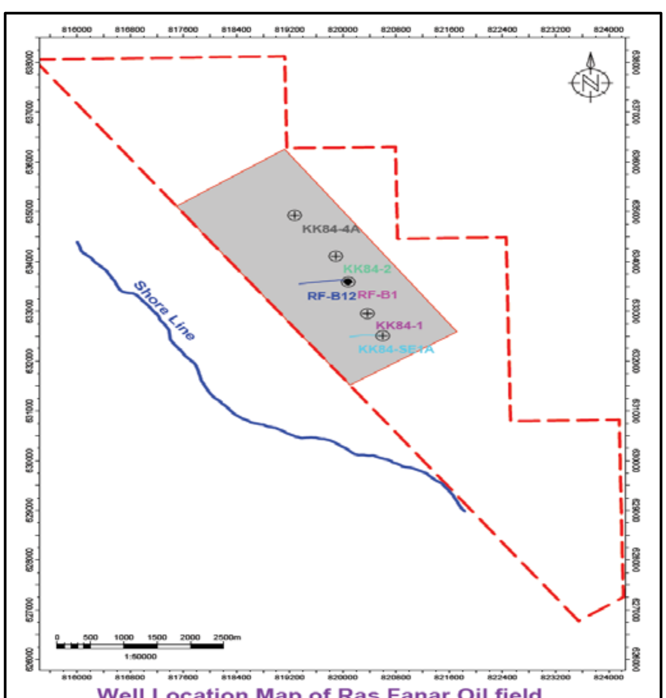


Figure 1.5: Ras Fanar Oil Field with the Studied wells and the intersted area

2. The Geological Setting of Ras Fanar oil field

Ras Fanar area is located in the central part of the western margin of the Gulf of Suez. Geologically; the area is located in the eastern part of Gharib horst block which is characterized by northeast dipping direction (**Meshref and Abu El Karuma, 1988 and Salem et al. 1994**). The Pre-Miocene strata are highly faulted to narrow elongated rectangular blocks. These blocks aligned mainly in a NW- SE direction. The cross faults of Aqaba trend may shift or terminated these blocks (**Moustafa, 1977, Sultan and Moft.ah, 1985**).

The area is characterized by intensive faulting and unconformities. It remained as a high land during the Lower Miocene time, when erosion continued over the high relief (**El-Naggar, 1988**), while thick organic rich shale was deposited in the adjacent troughs (**Moustafa, 1977**). During the Middle Miocene time the area was submerged and suitable for reefal growth of the Nullipore facies. More arid environments dominated the latter part of the Middle Miocene which led to the deposition of evaporites of South Gharib and Zeit Formations.

2.1 The Stratigraphy of Ras Fanar:

The subsurface sedimentary sequence in Ras Fanar area ranges in age from the Paleozoic to Recent (**El-Naggar, 1988; Darwisli and Saleli, 1990**). Several erosional and/or non-depositional hiatuses are recorded. The generalized stratigraphic succession is represented in Fig. (2.1). this sequence resembles, to a great extent, its counterparts in most of the Gulf of Suez province (**Beats, 1948; Said, 1962; Abdallah and Adindani 1963 Chowdliary and Taha, 1986 and Naggar, 1988**). El- It is represented by the following units (from older to younger):

I- Pre-rift Succession:

The pre-rift rocks that existed before the opening of the rift. These rocks include the Pre-Cambrian basement, Nubia Formation, Raha Formation, Abu Qada Formation, Wata Formation, Matulla Formation, and Brown Limestone Formation, Sudr Chalk Formation, Esna Shale Formation, and Thebes Formation.

II- Syn-rift Succession:

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In the study area the Miocene syn-rift sequences unconformably overlie the pre- Miocene sequences. The syn-rift sequences in the study area consists of Belayim, South Gharib, and Zeit Formations. These syn-rift sequences composed of interbedded limestone, shale, marl and sandstone. The Miocene syn-rift rocks in Ras Fanar Field include only one main reservoir, the reefal limestone of the Nullipore of Hammam Faraun Member of the Belayim Formation. The Nullipore limestone is the main reservoir in Ras Fanar Field and contributes about one half of Ras Fanar Field production. The syn-rift sequences are bounded at the top and the base by sequence boundaries (unconformity surfaces). Sequence boundaries can be verified by Foraminifera. The combined effect of the tectonic events led to intense structuring and breaks up into an enormous number of fault blocks.

The Miocene rocks are well developed in the Gulf of Suez basin where they were accumulated between the two shoulders of the basin. These sediments include mature source and excellent reservoir rocks and provide suitable cap rocks for most oil fields.

The Miocene sequence penetrated in the Ras Fanar field is represented by a relatively thick carbonate succession that is overlain by the upper units of the Evaporite Group (Ras Malaab Group). This sequence consists of the following rock units:

The term "Nullipore Carbonates" as applied by Moon and Saclek (1923) is maintained to describe the Pre-Evaporite sequence. They described the series at Wadi Gharandal (type section about 130 m thick) as being composed of (from top to bottom):

- Massive limestone, mottled with pink stained white bands
- White gypseous limestone, contains Lithothamnium as well as casts of Lucina sp. and Lithodoma sp. This is the main member of the Group and it has been given the name "Nullipore" due to its richness in algal nodules.
- Yellowish calcareous marl, well-bedded and fossiliferous.
- Siliceous and flinty beds

The Stratigraphic Sub-Committee (1974) considered this "Nullipore" rock as being equivalent to the Hammam Faraun Member of the Belayim Formation, which was deposited under shallow marine warm water conditions favourable for reefal development with slight changes to shallow neritic and/or littoral environments.

III- Post-rift Succession:

This sequence (Pliocene to Recent) is composed mainly of gravel, sandstone, sand, marl, shale and thin limestone and anhydrite intercalations. These sediments overlie unconformably the Miocene evaporites (**Schlumberger, 1984**). The thickness of the Post-Miocene deposits is quite variable from the western to the eastern side of the Gulf of Suez. It is about 1200 ft. in the Ras Fanar field. These deposits were accumulated under continental to very shallow marine conditions.

2.2 DEPOSITIONAL ENVIRONMENT OF NULLIPORE FACIES

The term Nullipore rock was attributed to the bio-clastic lithology due to frequent occurrence of red algae, formerly often referred to as Nullipore, in this shallow marine carbonate facies from outcrops along the Gulf of Suez (**Thiebaud and Robson, 1979**). In the absence of age indicative fossils, this unit was given an uncertain Middle Miocene to basal Late Miocene age. The occurring biota indicate a shallow marine reefoid environment.

In Ras Fanar, frequent occurrence of certain organisms (red algae, bryozoan colonies, echinoids, molluscs, gastropods and blue-green algae), their degree of sorting (almost unsorted fossil fragments), and the presence of some coral-algal boundstone intervals indicate a shallow marine, normal saline depositional environments of moderate to low energy for these Nullipore rocks (**Kulke, 1984**).Small patch reefs or biostromes (without reef talus debris) grew on this carbonate platform. Equilibrium between subsidence and deposition over a certain period permitted these environments to produce several hundred feet of Nullipore facies on the broad high eroded platform trend of Gharib-Fanar (Fig.2.2). The widespread extent of the Nullipore platform facies is further supported by reservoir data where pressure evidence suggests that Ras Gharib, Sheab Gharib and Ras Fanar fields share a common aquifer. This period was terminated by the development of overall evaporitic conditions in the Gulf of Suez basin. The early deposits of this formation obviously filled the sedimentary relief which was present at the end of Nullipore time and which then was exposed by the drop of sea level. Locally, this may bring in lateral contact older Nullipore facies and younger South Gharib anhydrites.

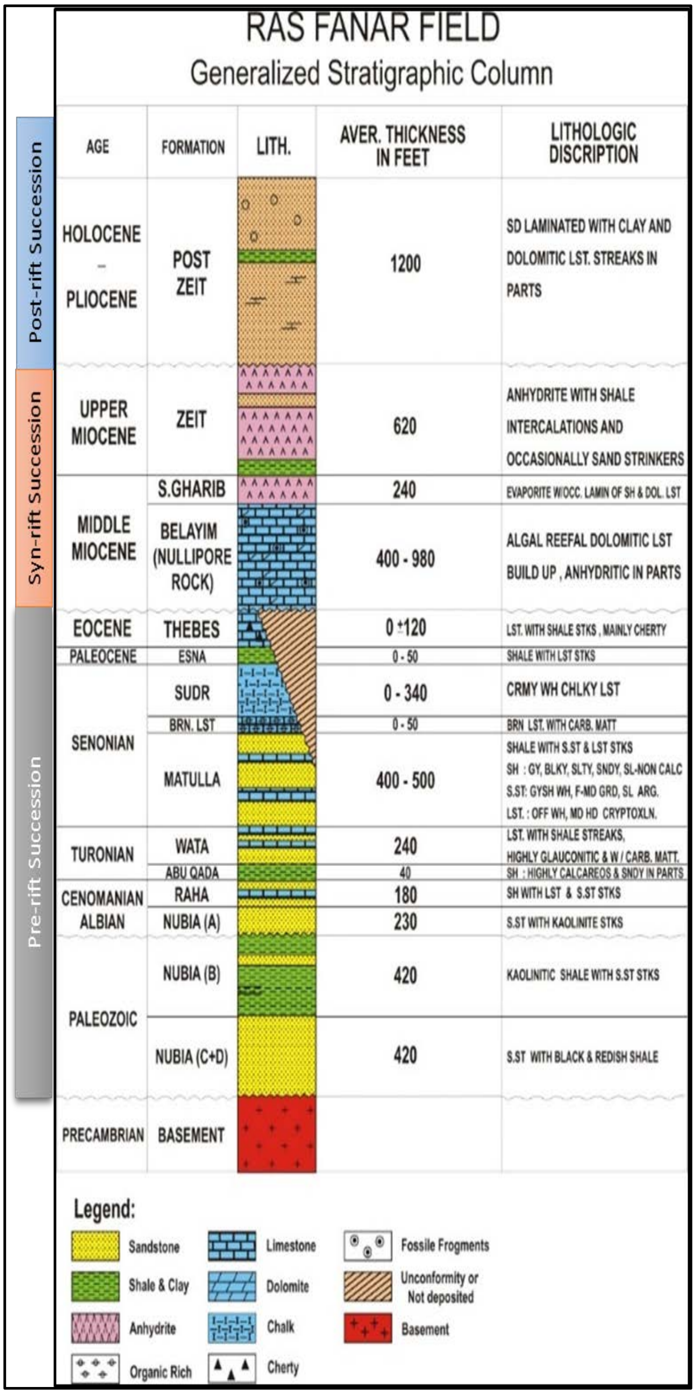

Figure 2.6: General Stratigraphic Column of Ras Fanar Oil Field after after El~Naggar, 1988

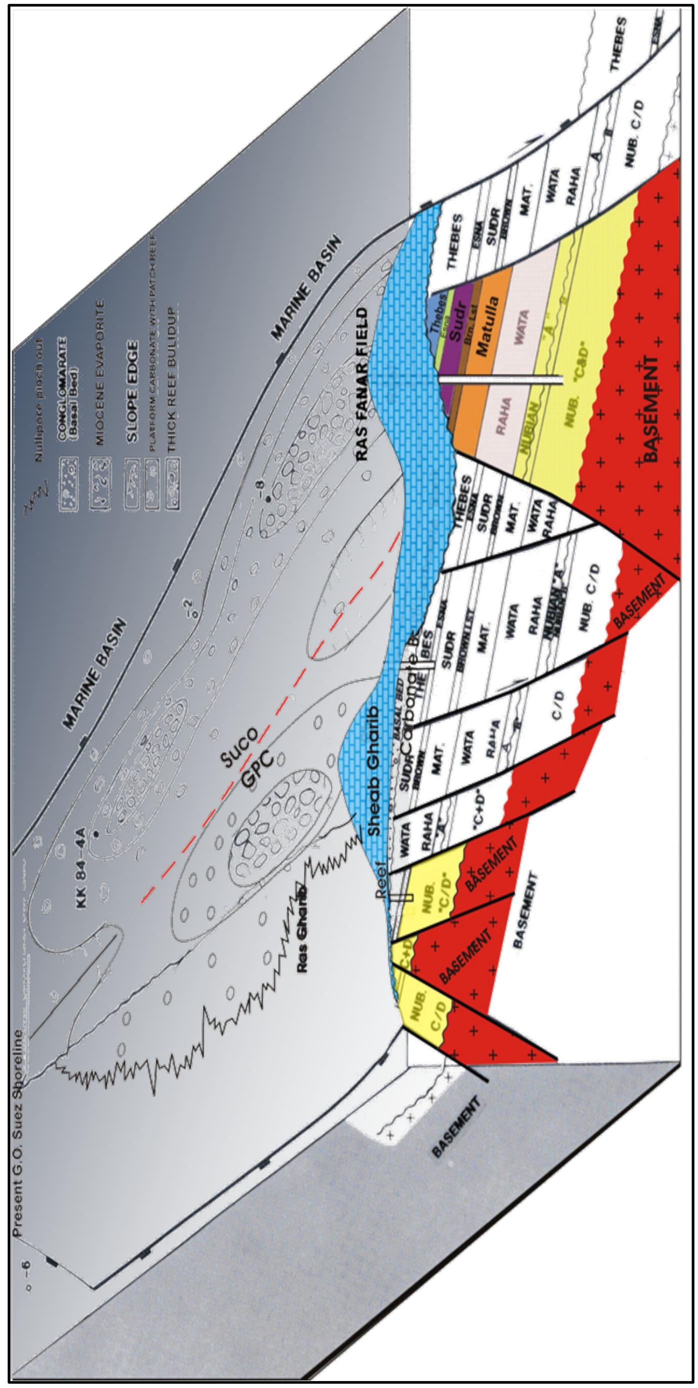

Figure 2.7: Geologic Diagram showing Ras Fanar , Shoab Gharib and Ras Gharib structure and stratigraphy of Reef build-up which extended from the shore in Ras gharib to Ras Fanar offshore directly above the Pre-Miocene(after chowdary and Taha ,1986)

2.3 Tectonics and Structure of Ras Fanar Field

The Ras Fanar area is located within a highly tectonized structural feature, trending from Gebel El Zeit ridge parallel to the western coast of the Gulf and extending to the north passing by SG 300 well (GUPCO field), Ras Fanar - Ras Gharib, Bakr, Amr, HH 83, FF 83, GG 83 highs. The Pre - Miocene sequences are highly faulted forming narrow elongated rectangular blocks lined mainly NNW-SSE (Gulf of Suez trend) (El-Naggar, 1988). Cross faults of younger age (Aqaba trend) may shift or terminate these blocks (Fig. 2.3). The Pre- Miocene sediments were deposited in the area almost as sheet - like deposits. However, the area was subjected to the following tectonic phases during its geologic history.

2.3.1 The First Tectonic Phase

Following the deposition of the Rod El Hamal Formation, the area was uplift.ed during the Paleozoic Hercynian movement and then subjected to erosion and peneplanation. The presence of an almost unifonn thickness indicates that the area was not tilted until that time. Mesozoic sediments representing Triassic, Jurassic and Early Cretaceous ages are not recorded in the area. The upper part of Nubia A of Albian age (Melha Formation) was deposited unconformably on the eroded surface of the Rod El Hamal Formation.

2.3.2 The Second Tectonic Phase

The Alpine movement started during the Early Cretaceous and continued till the Pliocene and the opening of the Gulf of Aqaba. This movement started as weak pulses during the deposition of the Cenomanian Raha Formation till the Lower Senonian Matulla Formation. This was followed by the accumulation of shelf marine carbonates of Late Senonian to Middle Eocene age. This phase of sedimentation was followed by a noticeable sea regression. Uplift. and major fault tectonics prevailed and resulted in the development of narrow parallel fault blocks tilted towards the northeast with a dip angle of about 20° during the Oligocene, Early Miocene as well as the early times of the Middle Miocene during the deposition of Baba, and Feiran Members of the Belayim Formation. This coincides with the secondary stage which was described by Montenat et al. (1988).

This was followed by a deep differential erosion which stripped away large quantities of sediments with a deeper erosion at higher edges. During the Early Miocene, clastic facies were deposited in the graben area of the Gulf of Suez while Ras Gharib - Ras Fanar area was still structurally high and suffering from erosion. It is described as a horst and graben pattern of the third stage described by Montenat et al. (1988).

2.3.3 The Third Tectonic Phase

This phase started by the late Middle Miocene sea transgression all over the Gulf of Suez. The Miocene water depth in Ras Fanar area was favourable for the development of a sheet-like carbonate bank on top of the erosional surface of the pre - Miocene and the buildup of carbonate "Nullipore" of several hundreds of feet. In case of the Ras Fanar field, the "Nullipore" was interpreted as generally dipping eastwards. During the Late Miocene, the sea started a slow regression and relatively capped the "Nullipore" buildup.

2.3.4 The Fourth Tectonic Phase

During the Pliocene-Pleistocene and Quaternary, the Alpian movement reached its last maximum intensity and the Gulf of Aqaba was opened. This was associated by the development of the cross faults of Aqaba trend in the Gulf of Suez area (Montenat et al. 1988). Again, the study area was intermittently invaded by the sea during the Pliocene and Quaternary times. This led to the deposition of the post - Miocene clastic sediments derived from high areas. Accordingly, the Alpian tectonic phase terminated the development of the structure of Ras Gharib - Ras Fanar areas and was responsible for the drape and final settlement of the present structural features.

The interpreted structure of Belayim Nullipore can be shown in fig. (2.3) after (**Hateel, 2015**)

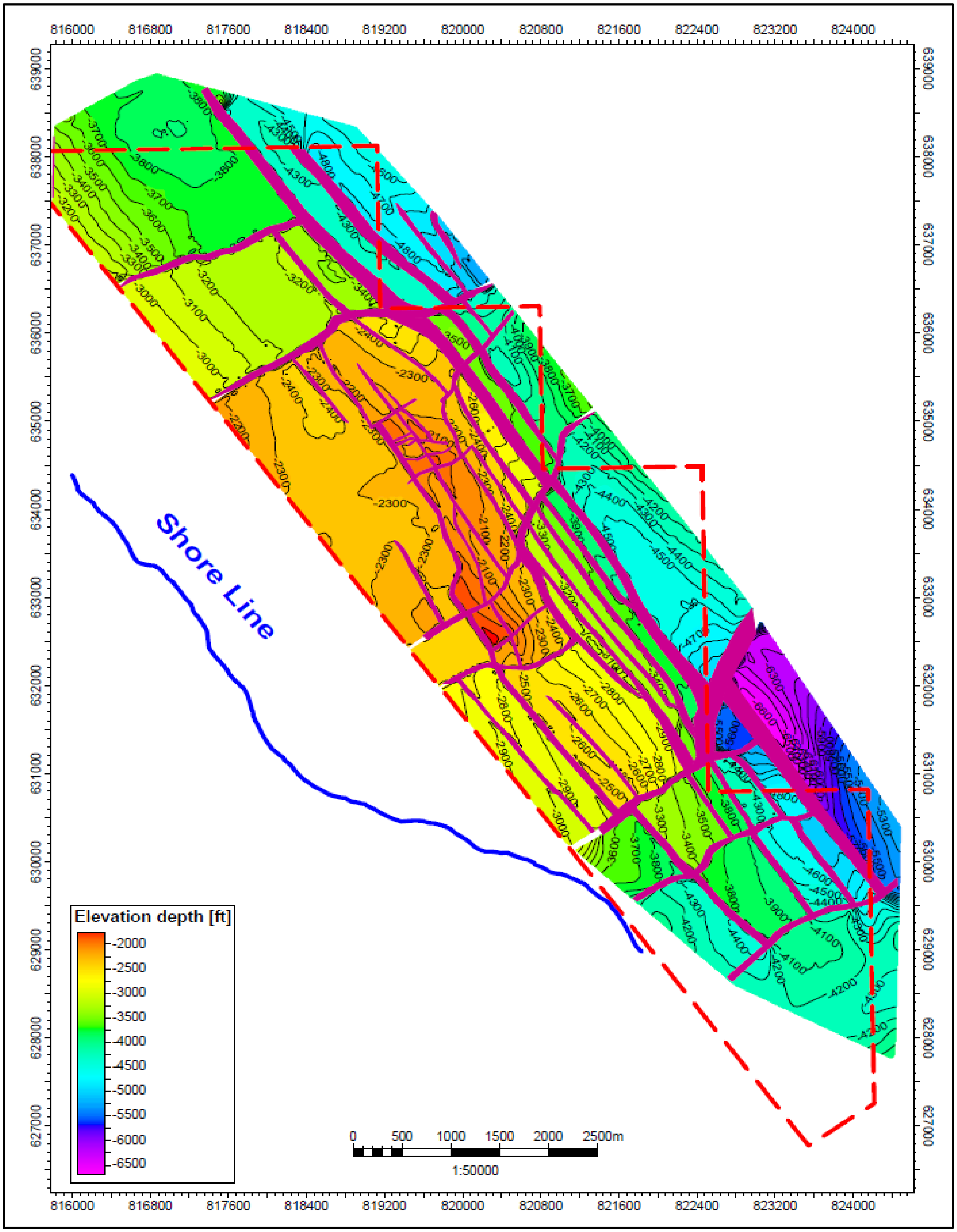

Figure 2.8: 2D Structure Contour map on top Belayim Nullipore

3. Materials and Methods

3.1 Clay Volume Analysis

The interpretation problem in shaly formation is the calculation of porosity and saturation values free from the shale effect. Because the shale effect depends on the shale content, the estimation of the Vsh is of prime importance. Qualitatively, Vsh, indicates whether the formation can be considered clean or shaly. This determines the types of the model or approach to be use in the interpretation. Quantitatively, Vsh is used to estimate the shale effect on log responses and to correct them to the clean formation responses.

A- Single Clay Volume Indicator

The volume of shale can be calculated using gamma ray, Neutron or resistivity logs:

Gamma Ray

Shale content can be calculated using the following equation:

$V_{sh} = GR_{log} - GR_{min} / GR_{max} - GR_{min}$ *Schlumberger (1972)*

Where;

V_{sh} is the shale content GR_{log} is the gamma ray reading of the analyzed zone.

GRmin is the minimum Gamma ray reading in front of clean sand.

GR max is the maximum Gamma ray reading in front of a shale bed.

Neutron clay indicator can be calculated as follow:

Shale content can be calculated using the following equation:

Vsh = ϕN - ϕNmin / ϕNsh- ϕNmin Schlumberger (1972)

Where;

Vsh is the shale content

ϕN is the porosity of the Neutron log.

ϕNmin is the porosity of the neutron log opposite clean sand.

ϕNsh is the porosity of the Neutron log opposite a shale zone.

Resistivity clay indicator can be calculated as follow:

(Vsh)R= {(Rsh/Rt) * (Rmax – Rt.) / (Rmax- Rsh)} 1/b

Where;

(Vsh)R is the shale content by using Resistivity log data.

Rmax is the maximum resistivity in clean pay sand.

Rt is the shaly sand layer resistivity.

b is an empirical constant.

B- Double Clay Volume Indicators:

These are indicators utilizing a pair of the porosity tools. These may be Neutron/Density, Sonic/Density or Neutron/Sonic combinations.

-Neutron/Density:

The Neutron-Density crossplot can be used to determine shale volume and effective porosity of the zone composed from only shale and sands. The shale content (Vsh) is determined using the following equation, *Schlumberger 1972*

Vsh= ϕN - ϕD/ϕNsh - ϕDsh

Where;

Vsh is the shale content

ϕN is the porosity derived from the Neutron log.

ϕ D is the porosity derived from the Density log.

ϕNsh is the porosity derived from the neutron log opposite a shale zone respectively.

ϕ Dsh is the porosity derived from the Density log opposite a shale zone respectively.

-Sonic/Density:

For determination of Vcl from Sonic/Density logs:

$$V_{Cl\,ND} = \frac{\left[(Den_{Cl}2 - Den_{Cl}1)(Son - Son_{Cl}1) - (Den - Den_{Cl}1)(Son_{Cl}2 - Son_{Cl}1)\right]}{\left[(Den_{Cl}2 - Den_{Cl}1)(Son_{Clay} - Son_{Cl}1) - (Den_{Clay} - Den_{Cl}1)(Son_{Cl}2 - Son_{Cl}1)\right]}$$

Where DenCl1 & SonCl1 and DenCl2 & SonCl2 are the density and sonic values for the two ends of the clean line.

3.2 Porosity Types Determination

The formation porosity is very important parameter for formation evaluation. Porosity is the percentage of voids to the total volume of rock. It is measured as a percent and has the symbol ϕ. The amount of internal space or voids in a given volume of rock is measure of the amount of fluids a rock will hold.

The total, primary, secondary and effective porosities can be calculated by using sonic, density and neutron logs. Porosity logs are affected differently and independently by shaliness, lithology and hydrocarbons. Porosity estimated from different logs are not perfectly similar, so the best estimate of the porosity is through combination of porosity tools rather than single porosity log.

A- Total Porosity Determination

Total porosity values are obtained from one of the nuclear logs (i.e. Density or Neutron) and combination of Neutron and Density log.

-Density log:

It is of the best tool for total porosity determination, due to its minor influence by the argillaceous matter. To determine total porosity from density log, the matrix density and type of fluid in the borehole must be known. The density log derived porosity can be calculated in clean and shaly zones.

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In Clean Zones

Total porosity ϕt from Density log in Clean zones :

$$\phi_D = \frac{\rho_{ma} - \rho b_{\log}}{\rho_{ma} - \rho_f}$$ *Schlumberger (1974)*

Where

ϕD is the Density derived porosity

ρma is the matrix density (gm/cc)

ρblog is the Density log reading for each interval (gm/cc)

ρf is the fluid density in gm/cc (salt mud=1.10, fresh mud=1.0 and oil based mud=0.90)

In shaly zones:

The effect of shaliness on the density log is independent of the type of shale distribution

Total porosity ϕt from Density log in shaly zones:

$$\phi_D = \frac{\rho_{ma} - \rho b_{\log}}{\rho_{ma} - \rho_f} - V_{Sh} \frac{\rho_{ma} - \rho_{Sh}}{\rho_{ma} - \rho_f}$$ *Dresser Atlas (1982)*

-Neutron Log:

In clean zones:

In clean formations, the total porosity can be read from the Neutron log in limestone porosity units after making corrections for the borehole conditions.

In Shaly zones:

Neutron log reading gives overestimate porosity of reservoir rocks, where shales have an appreciable hydrogen index. The neutron porosity is corrected for shale effect by using the following equation:

Total porosity ϕt from Neutron log in shaly zones:

$$\phi_{Ne} = \phi_N - V_{Sh} * \phi_{N(Sh)}$$ *Dewan (1983)*

-Combination of Neutron and Density Logs:

The combination of Neutron and Density are considered a good approach for calculating total porosity in clean and shaly zones.

Total porosity calculation by combination of Neutron and Density in clean zones:

$$\phi_{Nd} = \sqrt{\frac{\phi_N^{\,2} + \phi_D^{\,2}}{2}}$$ *Asquith and Krygowski (2004)*

Total porosity calculation by combination of neutron and density in shaly zones, *Schlumberger (1974)*

$$\phi_{De} = \phi_D - \left[\left(\frac{\phi_{DSh}}{0.45}\right) * 0.13 * V_{Sh}\right]$$

$$\phi_{Ne} = \phi_N - \left[\left(\frac{\phi_{NSh}}{0.45}\right) * 0.03 * V_{Sh}\right]$$

$$\phi_{Nd} = \sqrt{\frac{\phi_{Ne}^{\,2} + \phi_{De}^{\,2}}{2}}$$

B- Effective Porosity Determination:

The amount of interconnected void space, and so able to transmit fluids, is called effective porosity. Isolated pores and pore volume occupied by adsorbed water are excluded from definition of effective porosity. It calculated as the following:

$$\phi_{eff} = \phi_t (1 - V_{Sh})$$ *Shaaban (1989)*

3.3 Determination of Fluid Saturation

Numerous interpretation techniques are used for determining the fluid saturation. In all cases, the first step is to determine the type of fluids occupied in the pore space and to differentiate them into water and hydrocarbon (oil and/or gas). Because oil and gas are nonconductors, the resistivity of the rock partially saturated with hydrocarbons ($R_{t.}$) is higher than the resistivity of the same rock when fully saturated with water (R_o).

3.3.1 Water Saturation Determination

Water saturation is the fraction (or percentage) of the pore volume of the reservoir rock that is filled with water. It can be determined in both clean and shaly formations. Water saturation in clean formation is determined using Archie's equation, the equation is:

$S_w^{\,n} = a.\ R_w / \Phi^m.\ R_{t.}$

and

$S_{xo}^{\,n} = a.\ R_{mf} / \Phi^m.\ R_{xo}$ for flushed zone.

3.3.2 Hydrocarbon Saturation Determination

Once water saturation (S_W) is calculated, then it is possible to determine hydrocarbon saturation (S_h) by using the normal linear equations as follows:

$$S_h = 1 - (S_W + S_g)$$

Where:

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S_h is the hydrocarbon saturation.
S_w is the water saturation.
S_g is the gas saturation.

The petrophysical evaluations have been made using Interactive petrophysics "IP" software. This program gives a quantitative determination of shale volume, porosity, water saturation and hydrocarbon saturation. Table (3.1).

Well	Zone	Top	Net pay	Phi	Vsh	SHc	Sw
KK84-4A	Nullipore III	1984.18	171	26	3.8	92	8
KK84-4A	Nullipore II	2155.5	202	20.7	5.9	89.6	10.4
KK84-4A	Nullipore I	2375	59	21.3	1	61.2	38.8
KK84-2	Nullipore III	2448	55	29.9	5.6	75.6	24.4
KK84-2	Nullipore II	2503	30	29	6.7	78.3	21.7
KK84-2	Nullipore I	2533	0	33.7	0	66.6	33.4
RF-B12	Nullipore III	3704.78	74	24.1	3.1	89.5	10.5
RF-B12	Nullipore II	3771.5	87	23.4	4.8	88	12
RF-B1	Nullipore III	2171	144	31.6	6.8	84.8	15.2
RF-B1	Nullipore II	2315	119	25.1	8.5	82.9	17.1
RF-B1	Nullipore I	2435	10	36.5	3.8	50.8	49.2
KK84-1	Nullipore III	2056	174	26.6	0.7	90.9	9.1
KK84-1	Nullipore II	2246	119	27.3	5.5	77.5	22.5
KK84-1	Nullipore I	2371	60	34.7	1	60.3	39.7
KK84-SE1A	Nullipore III	2255	119	23.5	3.9	84.4	15.6
KK84-SE1A	Nullipore II	2344	132	29.8	5.8	87.4	12.6
KK84-SE1A	Nullipore I	2506.5	128	27.5	0	83.2	16.8

Table 6.1: Average reservoir parameters for Nubian Sandstone reservoir rock.

3.4 Reservoir Zonation

Detailed examination of the electrical logs in Ras Fanar field reveal that Nullipore sequence consists of three electro-lithofacies zones. Because the Nullipore depositional environment was ranging from few centimetres to numerous meters water depth and since this environment is very sensitive to the advance of the sea level and the clay input, consequently gamma ray curves would be of help in defining the environment. These three zones are the only ones that could be fully correlated across the field. Each of these zones is occurred nearly at the same stratigraphic level with similar petrophysical characters and is characterized by certain log responses which are different from those displayed by the overlying and underlying ones in all studied wells. This Nullipore is subdivided into three third-order sequences (I, II & III).

5.2.1 Reservoir Sequence-I:

This zone is showing relative low gamma ray. This sequence is generally showing moderate reservoir. The oil water contact is mainly in this zone. The amount of limestone show some increase.

5.2.2 Reservoir Sequence-II:

This zone exhibits high Gamma Ray response, which is readily correlated throughout the field. The base of this zone is taken at the abrupt shift in the Sonic and Density-Neutron log readings, which generally reflect a change to tighter carbonates in the underlying zone. The rock facies in this zone are mostly characterized by very high porosity with well-connected pore system as compared with the other zones.

5.2.3 Reservoir Sequence-III:

This zone comprises the uppermost part of the Nullipore reservoir. The upper boundary is taken at a characteristic increase in the gamma ray response below the anhydrite of the South Gharib Formation. The rock facies in this zone are mostly characterized by relatively low porosity (anhydritic) as compared with the lower zone.

The crossplots of the six wells canbe shown in the following figures (3.1), (3.2), (3.3), (3.4), (3.5) and (3.6).

3.4.1 Correlation between the Nullipore Zonation:

The strike correlation of the studied wells extended from KK84-4A in the north till KK84-SE1A in the south reveals that KK84-4A penetrating Bel.Nullipore III at depth (1984.18 ft.) is the highest well although KK84-2 is the deepest well penetrating Bel.Nullipore III at depth (2448 ft.).The thickness of Bel.Nullipore III show an increase toward the south in the direction of KK84-SE1A. The thickness of Bel.Nullipore II in KK84-4A is the most thickness in our studied wells, although KK84-2 show the lowest thickness. Bel.Nullipore II show a relative higher gamma ray values than Bel.Nullipore III and Bel.Nullipore I. All wells penetrated Bel.Nullipore I except RF-B12 in which the total depth stopped in it. Bel.Nullipore I is the lowest zone in which the oil-water-contact may be found for example: in RF-B1. (Fig.3.7)

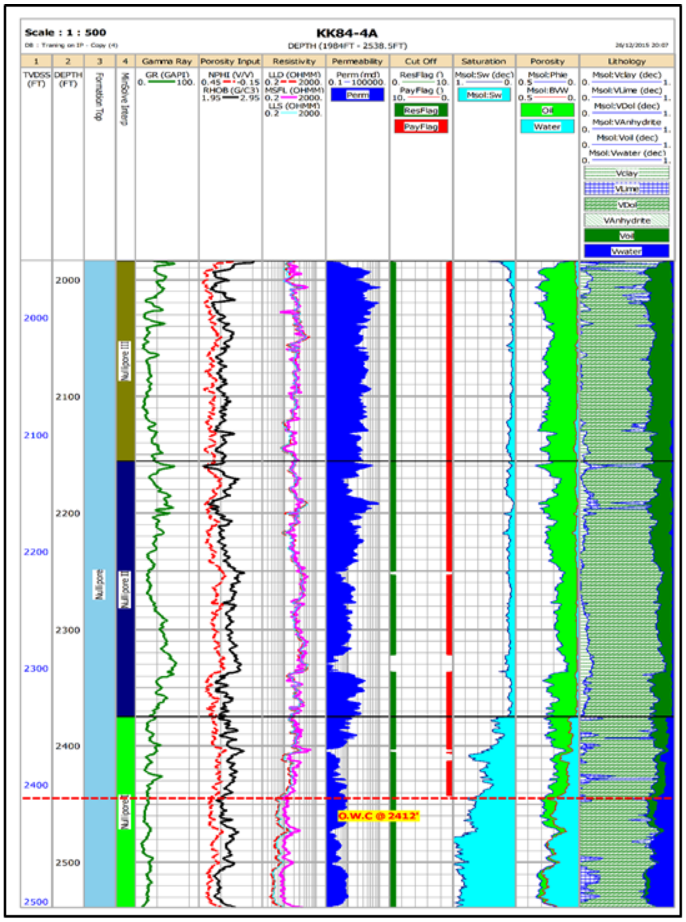

Figure 3.1: Crossplot of BEL.NULLIPORE in KK84-4A showing the main zones of reservoirs and pays

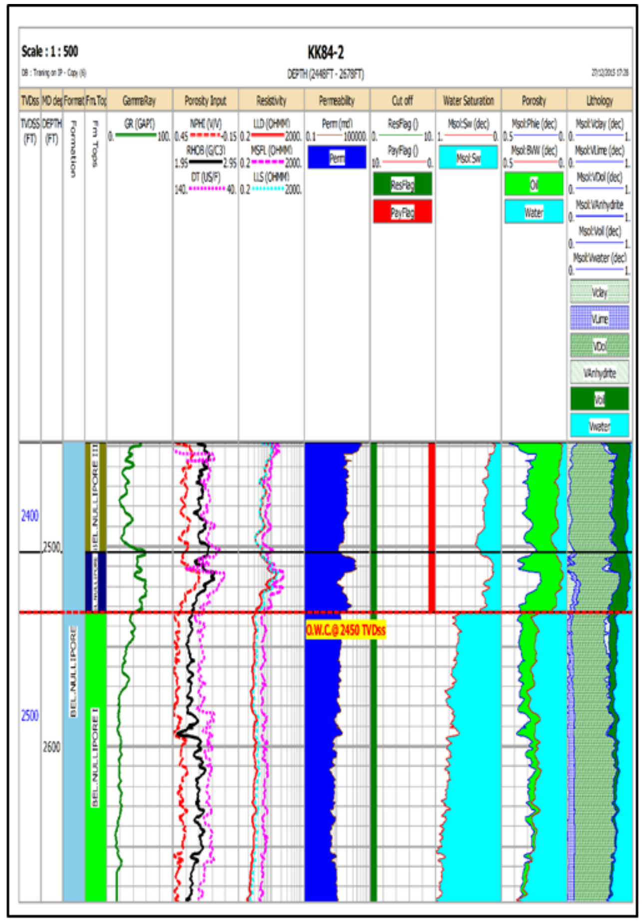

Figure 3.2: Crossplot of BEL.NULLIPORE in KK84-2 well showing the main zones of reservoirs and pays.

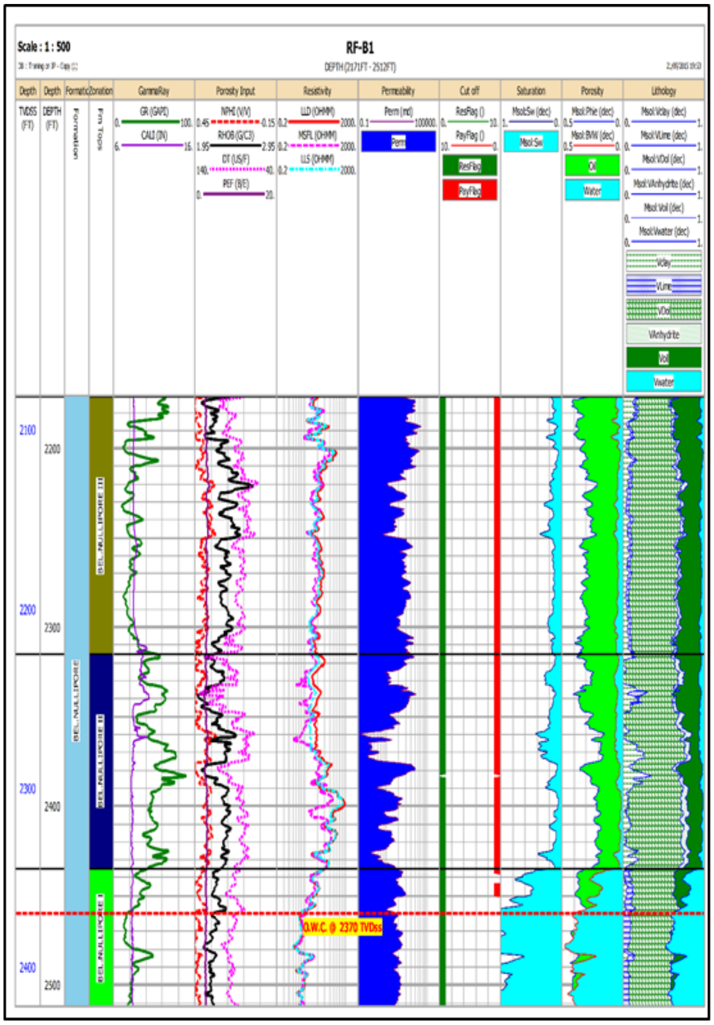

Figure 3.3: Crossplot of BEL.NULLIPORE

in RF-B1 well showing the main zones of reservoirs and

pays.

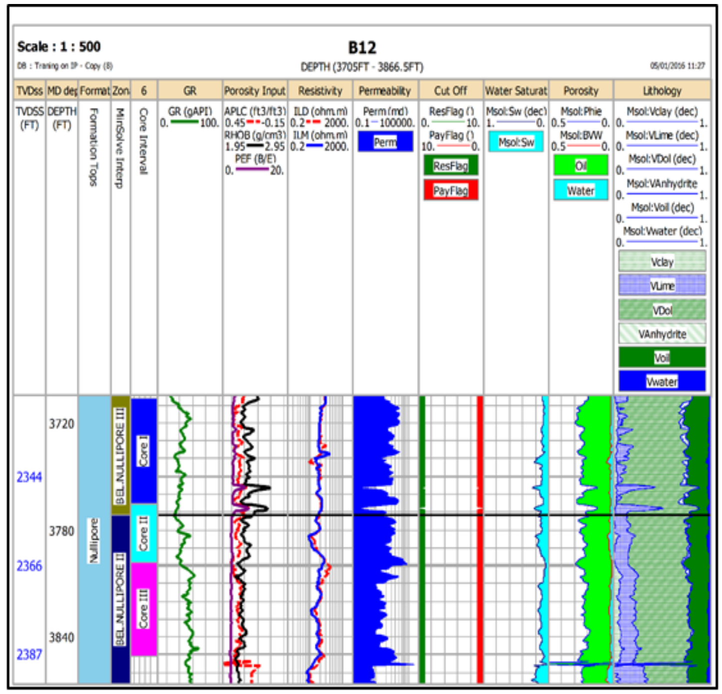

Figure 3.4: Crossplot of BEL.NULLIPORE

in RF-B12 well showing the main zones of reservoirs and

pays

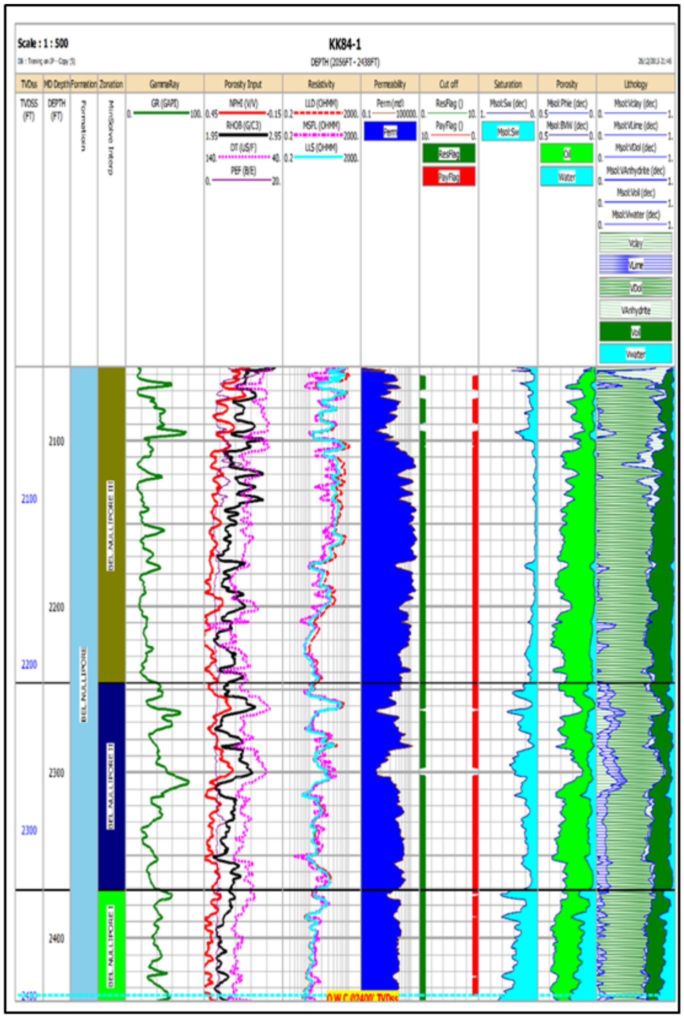

Figure 3.5: Crossplot of BEL.NULLIPORE in KK84-1 well showing the main zones of reservoirs and pays

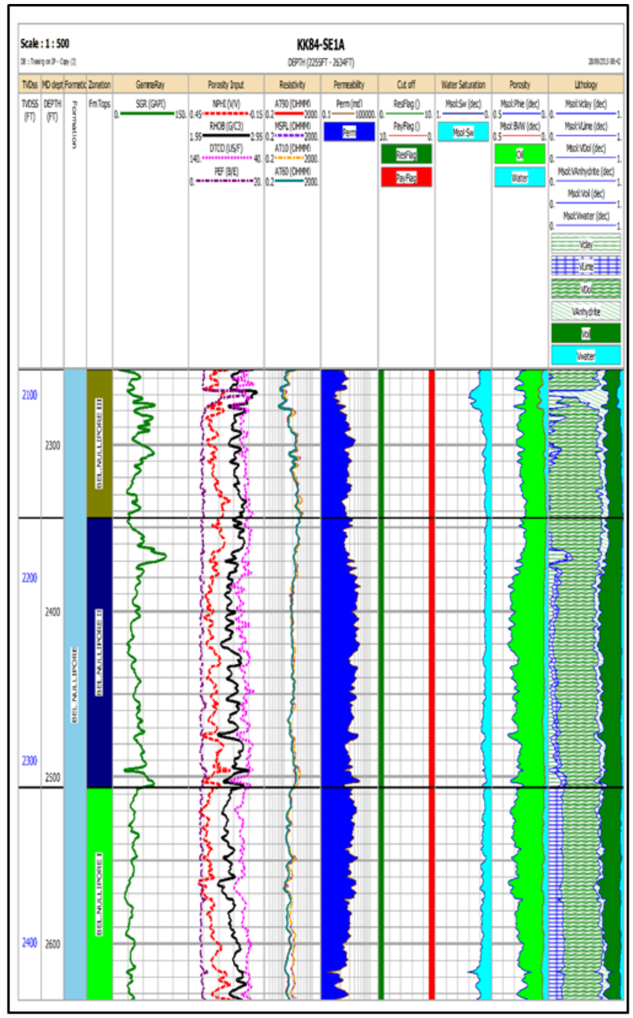

Figure 3.6: Crossplot of BEL.NULLIPORE in KK84-SE1A well showing the main zones of reservoirs and pays.

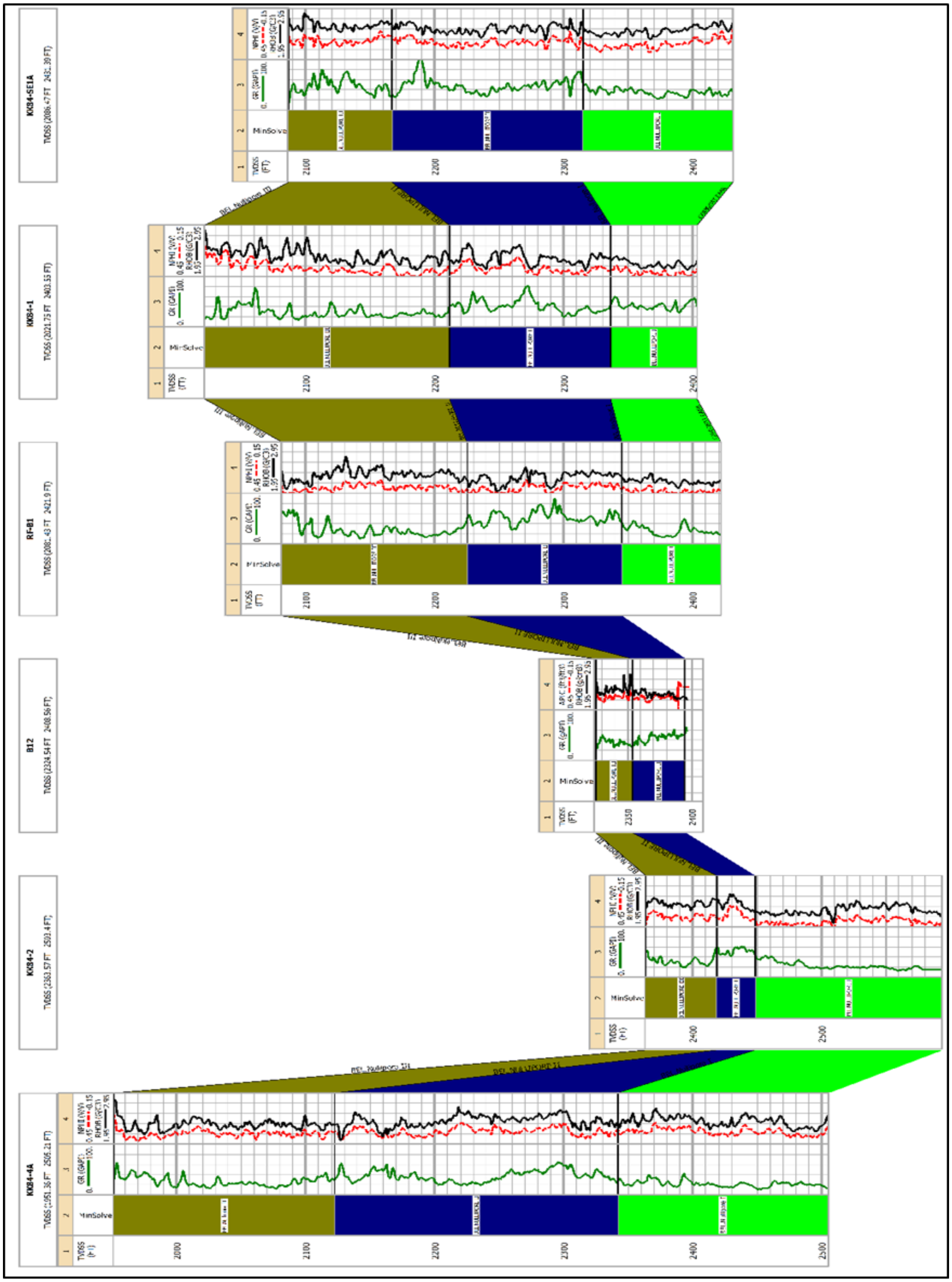

Figure 3.7: NW-SE Strike Correlation along Ras Fanar field.

4. Summary and Conclusions

The available open-hole well log data used in the analysis of Nullipore Formation are in the form of resistivity logs (deep and shallow), porosity tools (sonic, density and neutron) and the gamma-ray log. The Nullipore represent the main reservoir in Ras Fanar oil field. The gamma ray has a good impact on the Nullipore zonation. The productivity of the Nullipore III and Nullipore II is higher than I in which the oil water contact is detected.

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