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Source Rock Evaluation and Maturity Levels of the Rudeis Formation, Northern Gulf of Suez, Egypt, Using Well Log Analysis and Rock-Eval Pyrolysis

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Abstract: Gamma-ray, density, sonic, resistivity and neutron are the commonly used wireline logs to identify and quantify source rocks. Several models were developed to use the conventional wireline logs for evaluating the thermal maturity of the source rocks and calculating the total organic carbon (TOC) content. Application of Schmockr and Hester [1] approach with some required modifications for the Rudeis Formation, Northern Gulf of Suez, Egypt, is the main purpose of this paper. The results, which compared with those obtained from the Rock-Eval pyrolysis, show that cautions must be taken into consideration when applying this model, because most of the models reflect empirical relatinoships and their validation takes place under certain conditions. It can be concluded that, the Rudeis Formation represents fair source rock potential with type III kerogen and terrestrial supply of the organic matter and is marginally mature for the generation of minor amounts of oil and gas.

Key words: Source Rock · Well Logs · Rock-Eval Pyrolysis · Northern Gulf of Suez · Rudeis Formation

INTRODUCTION

The area of concern is a part of the prolific Gulf of Suez oil basin, which contains an excess of more than 800 exploratory wells drilled in this basin, resulted in 230 oil discoveries and 77 oil fields, with a cumulative footage of almost 7 million feet. The preliminary interpretation of the new 3D seismic reflection data showed the possibility of finding new oil fields having more than 100 million barrels of oil reserves, EGPC [2]. The interpretation of both geological and geophysical data showed that, the Northern Gulf of Suez consists of northwest-trending elongated troughs. The lithostratigraphic units in the study area have been divided into three major sequences relative to the Miocene rifting events; post-rift lithostratigraphic units (post-Miocene units); syn-rift lithostratigraphic units (Miocene units) and pre-rift lithostratigraphic units (pre-Miocene units). These units vary in lithology, thickness, areal distribution and depositional environments. The major pre-rift and syn-rift source rocks have potentials to yield oil. The source rock potential of the Gulf of Suez must be evaluated in order to determine the total organic carbon (TOC wt.%) content and type and the thermal maturity of kerogen, based on Rock-Eval pyrolysis and well log data. These have been studied by many authors, such as: Rohrback [3], Barakat [4], Shahin and Shehab [5], Chowdhary and Taha [6], Atef [7], Mostafa [8], Mostafa *et al.* [9], Alsharhan and Salah [10, 11], Alsharhan [12], Abdel Fattah [13] and El-Shahat *et al.* [14].

The geologic setting of the study area has been studied, as a part of the Gulf of Suez province by many authors, such as: Abd El-Gawad [15], Khalil [16], Renolds [17], Steen [18], Hagras [19], Said [20], Shutz [21], Dolson [22], El-Awady *et al.* [23], Abd El-Rahman [24] and others. The identification of the total organic content of the source rocks in the subsurface, its type and levels of maturity are a very important motive in the field of petroleum exploration. So, this work can be considered as a trial to provide information about the hydrocarbon source rock potential of the Rudeis Formation in the Northern Gulf of Suez, using well log data. In the present study, six wells were chosen from seventeen ones; these GS 56-1, GS 78-1, Fina Z 80-1A, Darag-1, Nebwi 81-1A and Galala-1 wells; were studied for the evaluation of source rock in this part of the Gulf of Suez (Fig. 1).

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Stratigraphy: The stratigraphic succession of the rock units encountered in the study area was determined through the study and correlation of the electric logs of the wells drilled in this area, as well as their litho-and biostratigraphic subdivisions. The lithostratigraphic units in the study area have been divided into three major sequences relative to the Miocene rifting events; post-Miocene units; Miocene units and pre-Miocene units. The oldest sediments peneterated in the area under study belong to the Basement Pre-Cambrian (where the Fina Z 80-1A well was bottomed, Fig.2). The stratigraphic sequence penetrated by these varying wells is interrupted at many levels by several unconformities of different magnitudes and times. Emphasis was made on the Rudeis Formation, as it represents one of the most important hydrocarbon exploration activities and includes proper source and reservoir rocks.

Rudeis Formation (Syn-rift Sediments): The Rudeis Formation varies greatly in lithology, thickness and depositional setting [25]. These variations are related to the irregular paleo-relief exhibited by the underlying surface. The Rudeis Formation was subdivided, in the Eastern Desert stratigraphic section by the EGPC [26], into four members, which are in ascending order: Bakr, Yusr, Safra and Ayun. The Rudeis Formation, in Western Sinai, was subdivided by the EGPC [27], into four members, shown in ascending order as: Muheiherat, Hawaia, Asl and Matarma.

Several operating oil companies have further subdivided the Rudeis Formation. Most of them have subdivided the Rudeis Formation into a lower unit and an upper unit, separated by a tectonic event, that resulted in uplifting, block faulting and deep erosions and coincided with the mid-Clysmic event (Choudhary *et al*. [28]). The type section in Rudeis-2 well (lat. 28° 51' 04" and long. 33° l0' 36.6") was chosen by the EGPC [27]. Here, the formation reaches a thickness of 780 m. It is dated as Early Miocene, based on the presence of the planktonic group of Globigeruw sp. It was called the Globigerinal marl by Moon and Sadek [29] and was dated as Burdigalian-Langhian by the EGPC [27]. The Rudeis Formation consists mainly of shales and limestones interbedded with sandstones. The sandstone content generally increases toward the marginal areas. It unconformably overlies the Nukhul Formation (Sadek, [30]) and unconformably underlies the Kareem Formation. Rudeis deposition occurred in a variable, shallow open to deep marine setting.

The thickness map of the Rudeis Formation (Fig. 3) indicates that, the thickness increases eastwards (basinal areas) with a local thickenning around GS 56-1A well, while the ridge-like areas (thinning parts) are occupying the central part of the study area. This ridge extends rather NW-SE. It also shows a nose running in the NW-SE direction, which is controlled by the northwest oriented normal faults dissecting the area. The thickness is ranging from 0 m (in GS 132-1 and

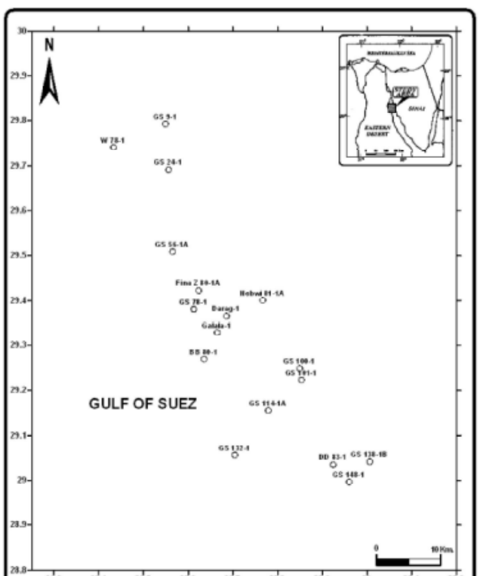

Fig.(1) : Location map of the study area, Northern Gulf of Suez, Egypt.

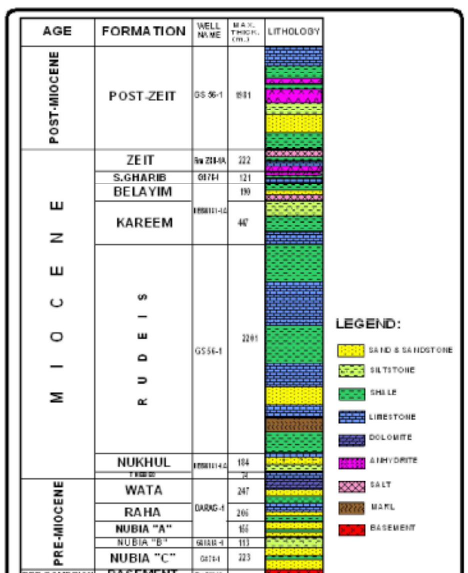

Fig.(2): Composite ideal stratigraphic column of the study area.

BB 80-1 wells, in the west) to 2200 m (in GS 56-1A well, in the north). This may attributed to the Mid-Rudeis tectonic event.

The shale percentage map of the Rudeis Formation (Fig. 4) reflects that, the whole area of study shows an increase in the shale percentage from west to east. In this map, the nose existing in the previous map has its position and magnitude, which is probably related to the effect of the Mid-Rudeis tectonic event. The high value of 100% is in GS 78-1 well and the low value of zero is in GS 132-1 and BB 80-1 wells.

MATERIALS AND METHODS

To evaluate a source rock, it is important to determine the quantity of organic matter (ORG, Vol.%), the maturity of the organic matter and the type of organic matter. The quantity of organic matter in the sedimentary rocks is commonly assessed by a measure of the total organic carbon (TOC, Wt.%) content, which is the FIrst and most important screening technique used to indicate, which rocks are of no interest to us (TOC < 0.5%), which ones might be of slight interest (TOC between 0.5% and 1%) and which are deFInitely worthy of further consideration (TOC > 1%). Determinations of the aforementioned concepts take place by using a geochemical analysis on the core or ditch samples, which is expensive and not available in most cases. So, many researchers use the well logging data to evaluate source rocks. Fertle [31] and Hertzog *et al.* [32] used the gamma-ray spectral log for identifying the organic-rich rocks. Schmoker and Hester [1] proposed the use of the density log for estimating the organic matter content. Hussain [33] developed a method, using the transit-time and gamma-ray curves, to provide a parameter, that relates linearly to organic richness. A method involving a combination of the resistivity, density and sonic logs has been introduced by Meyer and Nederlof [34]. This method discriminates between the source rocks and the non-source rocks without attempting to quantify the organic richness from the combination of logs. Mendelson and Toksoz [35] applied a multivariate analysis of log data to characterize the source rocks. At last, Passey *et al.* [36] invented a new technique called DLogR. This technique employs the overlaying of porosity logs (sonic, density and neutron) and resistivity log for identifying and calculating the total organic carbon content.

In the present work, six wells were selected in the Northern Gulf of Suez to evaluate the Rudeis Formation source rock potential using the available well log data. One of them (Fina Z 80-1A well) has measured the TOC and Rock-Eval Pyrolysis results. Many techniques were proposed to use the well log responses to the source rock, to determine the amount of TOC. In this paper, the source rock indicators, such as the organic-content (ORG, Vol.%), the total organic-carbon (TOC, Wt.%) and the discriminant function analysis to differentiate between the source and non-source rocks were also estimated for the shales in the investigated section, by using the well-logs technique. This was carried out through Meyer and

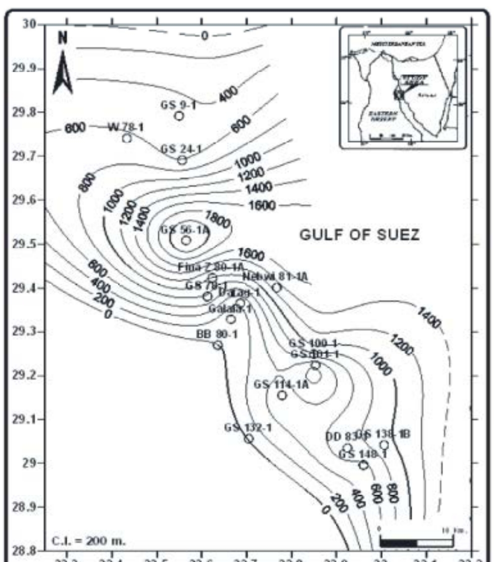

Fig.(3) : Thickness contour map of the Rudeis Formation, Northern Gulf of Suez, Egypt.

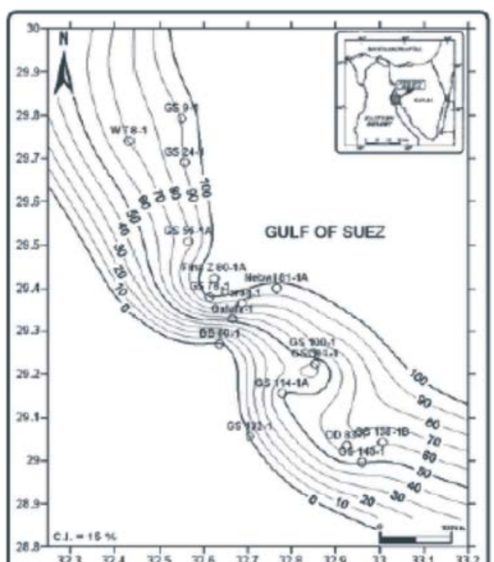

Fig. (4) : Shale percentage contour map of the Rudeis Formation, Northern Gulf of Suez, Egypt.

Nederlof approach [34] and Schmoker and Hester relation [1], with some required modifications. These indicators are executed as follows:

Determination of the Organic-Content: Density log method was applied to estimate the organic matter using the relation by Meyer and Nederlof [34]:

$$Ø_o = (\rho_b - \rho) / (\rho_b - \rho_o) \quad (1)$$

where: $Ø_o$ is the organic matter content by volume (ORG, Vol.%), ρ_b is the bulk density of the evaluated zone across the studied rock unit (ρ_b =2.7), ρ is the density of the shale sequence within the studied units and ρ_o is the organic matter density, the value of (ρ_o) is approximately the same ρwater (i. e. +1.0 g/cm3).

Determination of the Organic-carbon Content: The organic carbon content (TOC) is the most frequently used measure of organic richness. The weight percent organic carbon content can be obtained from the fractional volume of organic matter using the relation by Schmoker and Hester [1], as follows:

$$TOC = Ø_o (100 * \rho_o) / R * \rho \quad (2)$$

where: TOC is the organic carbon content by weight (Wt. %), R is the ratio between weight percents of organic matter and organic carbon and it depends on certain parameters; such as: member, depth, temperature, or location (Schmoker used R = 1.3).

In the present study, where the used samples contain no pyrite, the relation of Meyer and Nederlof [34] can be applied for the studied section. We can substitute for ($Ø_o$), using relation (1), relation (2) becomes :

$$TOC = 100 * \rho_o (\rho_b - \rho) / (\rho_b - \rho_o) * R * \rho \quad (3)$$

Or

$$TOC = 100 * (2.7 - \rho) / 1.7 *R * \rho \quad (4)$$

(modified after Schmoker and Hester [1])

The relation (4) reduces to the form:

$$TOC = (A / \rho) - B$$

where: A and B are constants, specifically calculated for a particular formation, member,or area.

Schmoker and Hester [1] stated that, the parameters used in their relation (ρ_o, ρ_b and R) could vary from an area to another. The values of the TOC analysis of the studied core samples were found to be lower than those obtained in the work of Schmoker and Hester [1], (about 1/10 of their values). The obtained low TOC values may be due to a large value of (R). The value of (R) used in the work of Schmoker and Hester (R = 1.3) could be modified. The value of (R) can be estimated from a test calculation through comparing the-fi results of the previous relation with the laboratory analysis of organic-carbon content of the studied core samples. It was found that (R = 21) realizes the best fit for the line expressing the relation between the two sets of TOC data interpreted log and measured laboratory. Such a high value of (R), which means a small amount of carbon in the organic matter, may be attributed to the presence of relatively heavy elements (such as, N, O, S) and water in the organic matter, in addition to hydrogen. This assumption means that the organic matter in the studied samples may be in the marginal to early stages of maturation, as shon later through the rock-eval pyrolysis (Fig. 8). Moreover, the presence of low carbon content in the organic matter may be due to the high sulfur content (Hammad *et al*. [37]).

Discrimination of Source Rocks from Non-source Rocks: Meyer and Nederlof [34] developed an approach to recognize the source rocks from non source rocks using well log readings, that based on the resistivity log values crossplotted with either the sonic or density log values. The resistivity values used in these plots must be standardized to 75°F using Arps formula (Dresser Atlas [38]).

$$R_{75} = R_t * (T - 7) / 82 \quad (5)$$

where: R_{75} is the resistivity of rocks corrected to a standard temperature of R_{75} °F (24°C) and T is the formation temperature at the concerned depth. The formation temperature is derived from a gradient derived from the bottom hole temperature of the various logging runs (Schlumberger [39]).

Two linear equations, postulated by Meyer and Nederlof [34] for the discriminant score (D), are used on the basis of log combination R_{75} - ρ_b and R_{75} - fit (ρ_b is the bulk density in g/cm^3 and fit is the interval transit time in μ sec/ft)in the form:

$$D = -6.906 + 3.186 \log_{10} fit + 0.487 \log_{10} R_{75} \quad (6)$$

$$D=2.278-7.324 \log_{10}{}^{\rho}{}_{b} + 0.387 \log_{10} R_{75} \quad (7)$$

If D is positive, the rock is a probable source rock; if D is negative, the rock is probable barren; and if D is zero, the case remains undecided.

Rock-Eval Pyrolysis: Rock-Eval pyrolysis gives information about the quantity, type and thermal maturity of the organic matter. Pyrolysis is a widely used degradation technique, that allows breaking a complex substance into fragments by heating it under inert atmosphere. Rock-Eval data are expressed as mg/g of rock and include four basic parameters (Peters [40]):

- S_1 represents the quantity of free hydrocarbons present in the rock and is roughly analogous to the solvent extractable portion of the organic matter;
- S_2 represents the quantity of hydrocarbons released by the kerogen in the sample during pyrolysis;
- S_3 is related to the amount of oxygen present in the kerogen; and
- T-max is the temperature at which the maximum rate of generation (of the S_2 peak) occurs and can be used as an estimate of thermal maturity.

In addition, the ratio S_2/ S_3 provides a general indication of kerogen quality (type) and reveals whether oil or gas is likely to be generated. The ratio $S_1/(S_1 + S_2)$, or the productivity index (PI), is an indication of the relative amount of free hydrocarbons (in-place or migrated) present in the sample. PI increases with maturity from near zero for immature source rock to 0.15 in post-mature one. Hydrogen Index (HI) and Oxygen Index (OI) values are expressed as mg of hydrocarbons (S_2 peak) or carbon dioxide (S_3 peak) per gram of the organic carbon. When plotted against each other on a Van Krevelen-type diagram, information about the kerogen type and maturity can be obtained. Potential yield is an indication of the produced yield of hydrocarbon, from source rocks at the optimum maturity and is a measure of quality of source rock.

RESULTS AND DISCUSSIONS

The presence of sufficient organic matter is a necessary pre-condition for the hydrocarbon generation. The quantity of organic matter is proportional to the organic-carbon content of the respective sediments (Hunt [41]). Hence, the total organic-carbon content, expressed in weight percent (Wt. %) in a whole rock, is employed to evaluate the organic richness of the analyzed samples.

Organic Matter Content (Vol.%) and Total Organic Carbon (Wt.%) of the Rudeis Fromation: The organic matter content (Vol. %) of the Rudeis Formation (Fig. 5) varies from (0 %) in BB 80-1 and GS 132-1 wells to (36.5%) in Galala-1 well and it gradually increases towards the central part around Galala-1 and GS 78-1 wells in the study area. Also, the total organic-carbon content distribution of Rudeis Formation (Fig. 6) is almost matched with the organic matter content percentage map. Generally, the organic-carbon content increases gradually towards to the central part around Galala-1 (0.85 %) and GS 78-1 (0.73 %) wells in the study area. The analogy between the ORG and TOC results of the study area reflects the indigenous type of oil (in-situ oil).

Type of Organic Matter: The organic matter quality controls the hydrocarbon generating capacity of a source rock. Hence, the recognition of the organic matter type, of a particular source rock, is essential for the prediction of it is oil and / or gas potential. The kerogen type was determined using the pyrolysis data. A plot of the hydrogen index versus oxygen index (Fig. 7) shows that, the quality of the organic material is very poor indicating a type III kerogen of terrestrial supply of organic matter. The organic material is at best marginally mature. However, the kerogen quantity and type is such that large scale oil generation have not occurred.

Level of Maturation: The temperature of maximum rate of pyrolysis is influenced by the type of organic matter during the diagenesis stage and the beginning of the catagenesis. It is lower in the terrestrial kerogen of type III and higher in the marine or lacustrine types I and II. However, the Tmax values are almost equivalent for the different kerogen types in the peak zone of oil generation and later in the gas zone (Tissot and Welte [42]).

Espitalié *et al*. [43] reported that, the beginning of the oil window occurs at Tmax values of approximately 430 °C. The main gas generation phase for type II organic matter occurs at Tmax values of 450-455 °C and for type III matter at 465-470 °C. End of oil generation is indicated by a Tmax value of approximately 465 °C and the values greater than 520 °C indicate dry gas zone. To determine the maturity stage of the organic matter, the values of hydrogen index have been ploted against the Tmax values in Fig.(8), which showed that the estimated Tmax values of analyzed samples range from 428 °C to 439 °C, indicating immature to mature organic organic matter. Full maturity is never shown by the Tmax results. The low level of maturity is such to preclude any large scale gas generation from the sediments analyzed.

A plot of the Tmax versus depth (Fig. 9) reveals that, the Tmax values show irregular direct relation. However, the increasing in the Tmax values as a function of depths is very small, which may reflect a low geothermal gradient in the study area. Based on the estimated Tmax values, the Rudeis Formation represents an immature to marginally mature level (Tmax 428 °C - 439°C).

Genetic Potential: Tissot and Welt [42] defined the genetic potential (S_1+ S_2) of a given formation as the amount of petroleum (oil and gas), that kerogen is able to generate, if it is subjected to an adequate temperature during a sufficient interval of time. This potential depends on the nature and abundance of kerogen and to the conditions of microbial degradation and the rearrangement of organic matter in the sediments. The genetic potential gives a qualitative estimate of the hydrocarbon resource potential; however, it can be used to predict the type of hydrocarbons (gaseous or liquid) produced during pyrolysis. Tissot and Welte (1978: in Pitman et al. [44]) predicted the source rock quality, according to the genetic potential as poor (< 2 GP), moderate (2-6) and good (> 6). The total organic carbon (TOC) versus genetic potential (S_1+ S_2) Figure (10) shows that the organic matter within the studied samples observed to be have a poor potentiality.

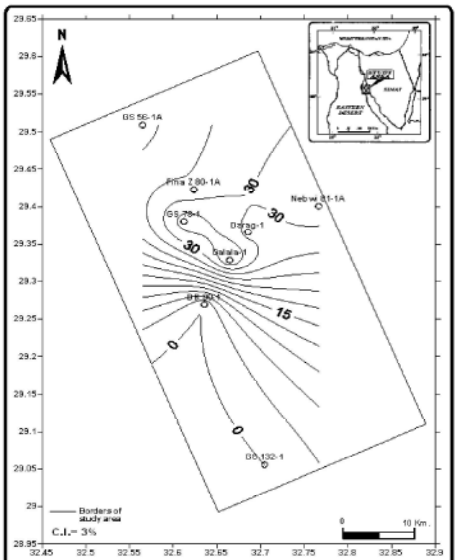

Fig.(5): Organic matter content (Vol. %) of the Rudeis Formation, Northern Gulf of Suez - Egypt.

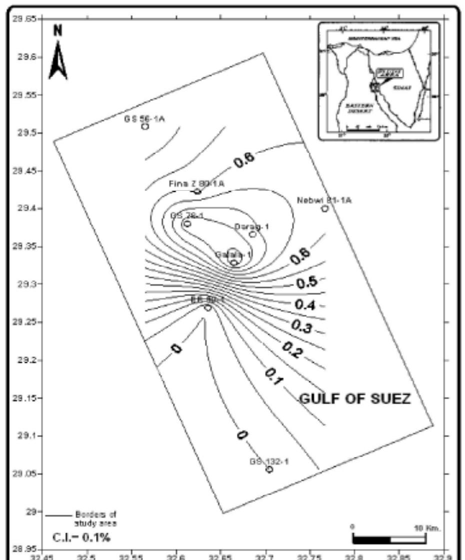

Fig.(6): Total organic carbon (Wt. %) of the Rudeis Formation, Northern Gulf of Suez - Egypt.

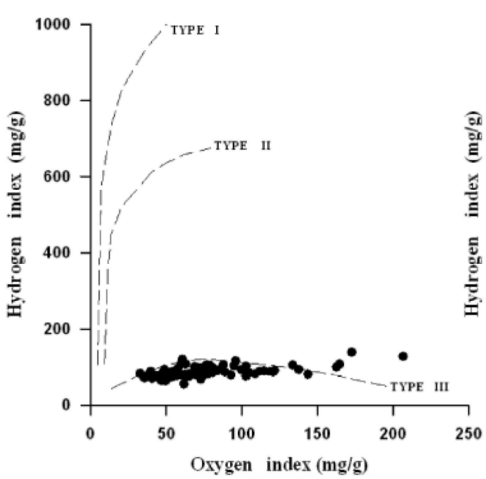

Fig.(7): Hydrocarbon index versus oxygen index, showing the Kerogen types, as illustrated by Van Krevelen diagram.

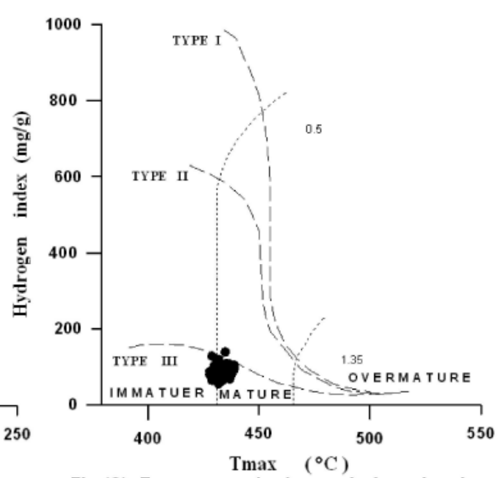

Fig.(8): Tmax vesus hydrogen index, showing the types of organic matter and the levels of maturity.

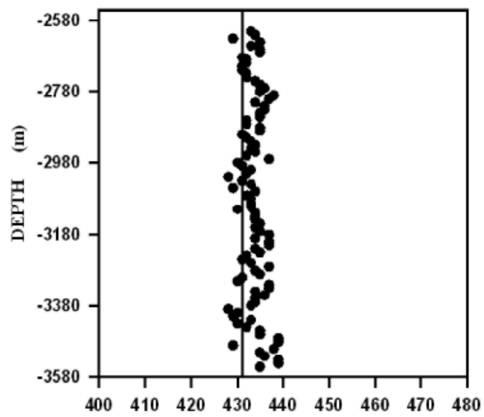

Fig.(9): Tmax versus depth of the Rudeis Formation.

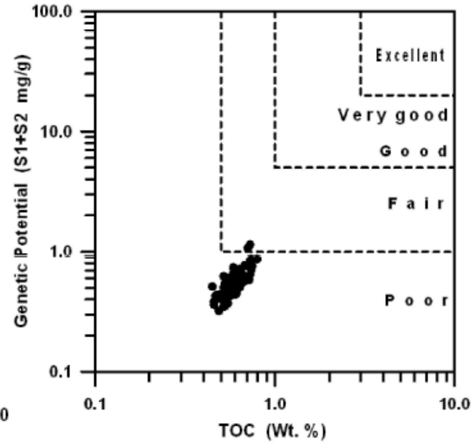

Fig.(10): Genetic Potential (S1+S2) versus total organic carbon (TOC), showing the etroleum generatin potential of the Rudeis Formation.

Transformation Ratio: The transformation ratio or production index (S_1/ S_1+ S_2) is the proportion of free hydrocarbons in relation to the total amount of hydrocarbon compounds obtained by the sample analysis (Espitalié [45]). Transformation ratio depends on the nature of the organic material and on the subsequent geological history as a time history (Tissot and Welte [42]). The production index is often used to assess the relative thermal maturity of organic matter and the presence of migrated hydrocarbons. The crossplot between the production index and Tmax Fig. (11) shows that, the organic matter is immature to marginally mature organic matter. The crossplot of the free hydrocarbons versus depth (Fig. 12) indicates that, the majority of the interval shows an absence of any quantity of free hydrocarbons from the cuttings analyzed.

Bitumen Index: The main use of bitumen index (S_1/TOC), which is sometimes called migration index (Hunt [46]), is to determine the depth, at which a source rock begins to expel oil. Generally, the S_1 increases with depth as oil being generated. According to Smith (1994 : in Hunt [46]), the ratio of S_1 to TOC % should be between 0.1 and 0.2 for oil expulsion to start in the source rock. When S_1 is high and the TOC is low, the migrated hydrocarbons are indicated. The bitumen index (S_1/TOC) versus depth of the analyaed samples Fig. (13) show that the expulsion occurred from depth 3510 m to the total depth of the wells, as the S_1/TOC values within the expected range of 0.1 to 0.2.

The crossplot of free hydrocarbons (S_1) versus total organic carbon (TOC) is commonly used to distinguish the migrated hydrocarbons and the contaminants from indigenous hydrocarbons (Hunt [46]). Figure (14) represents the plot of S_1 versus TOC for the analyzed samples in this study. Values above the slanted line suggest exogenous hydrocarbons and the values below it are indigenous. It is clear from the plot that, the hydrocarbons in the studied samples are indigenous.

Source Rock Identification in the Study Area: Density-resistivity and sonic-resistivity crossplots have been made for the evaluated formation, showing the classification boundary, based on the discriminant relation (Meyer and Nederlof [34]), which roughly separates the source rocks from non-source rocks (Figs. 15 & 16). The results of the analysis exhibit negative and positive values. The negative values are considered as non-source rocks, whereas the positive values are considered as source rocks. The density-resistivity crossplots show that, the majority of the Rudeis Shale is a non-source rock, except for little readings. The sonic-resistivity crossplots revealed almost the same results.

Laboratory Data and Test Calculation: A laboratory TOC analysis was made by EXLOG [47] for (96) cores and cutting samples of the Rudeis shale from Fina Z 80-1A well in the study area. It denotes with the TOC values a range from 0.45 to 0.8 %. A plot of these laboratory measurements of the TOC versus the log derived formation density by relation (4) is shown in (Fig. 17). The relationship between the TOC (Wt. %) and density (ρ_b) for most of the samples is an inverse relationship.

The organic-carbon content calculated from the density log are crossploted versus the TOC derived from the laboratory analysis (Fig. 18). The best fit for the line expressing the relation between the two

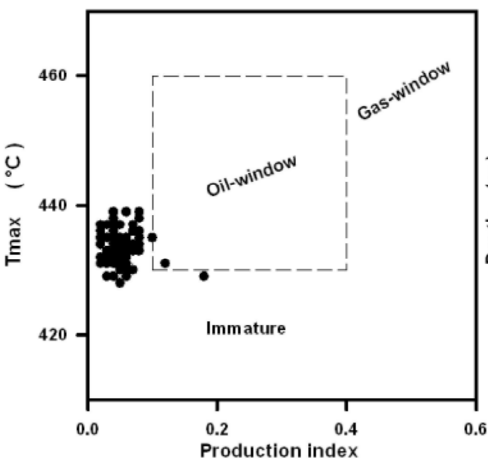

Fig. (11): Production index versus Tmax, showing the thermal maturation of the Rudeis Formation.

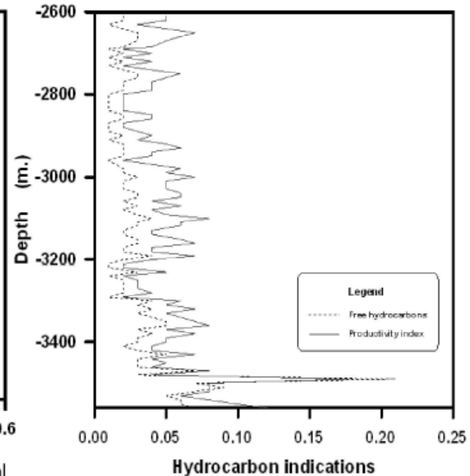

Fig.(12): Free hydrocarbons versus depth of the Rudeis Formation in Fina Z80-1A well.

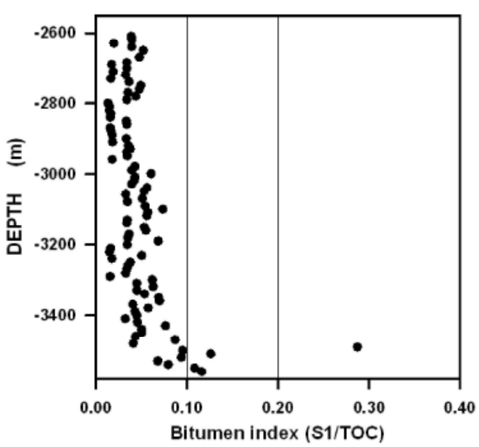

Fig.(13): Bitumen index (S1/TOC) versus depth for the analyzed samples.

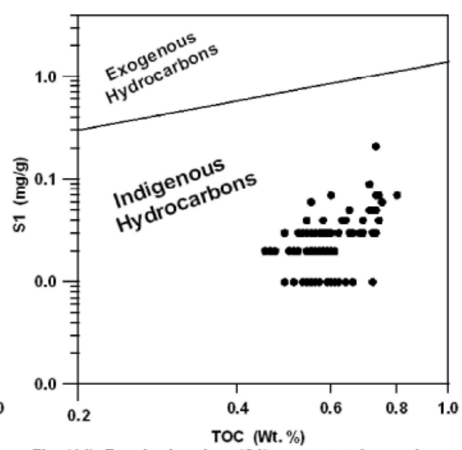

Fig. (14): Free hydrcarbon (S1) versus total organic carbon (TOC) of the Rudeis shale Formation, showing the petroleum generation potential.

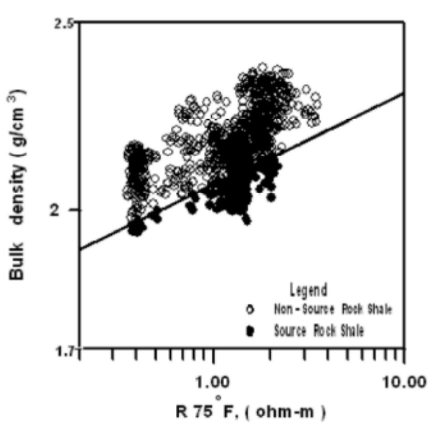

Fig. (15): Bulk density and resistivity crossplot for the Rudeis shale in the study area. Oblique line is the position of D=0 (discriminant analysis). Points below this line (D=positive) are of source rocks; points above this line (D=negative) are of no source rocks.

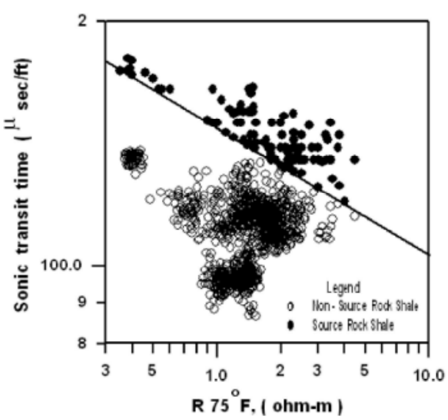

Fig. (16): Sonic transit time and resistivity crossplot for the Rudeis shale in the study area. Oblique line is the position of D= 0 (discriminant analysis). Points below this line (D=negative) are of no source rock; and points above this line (D=positive) are of source rock.

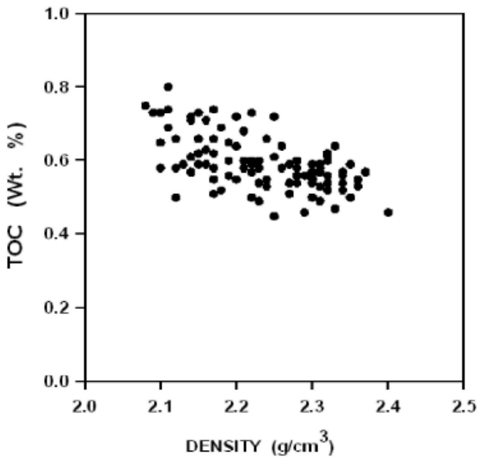

Fig.(17) : Laboratory measurements of the organic-carbon content of the Rudies Formation versus log-derived formation density in Fina Z 80-1A well.

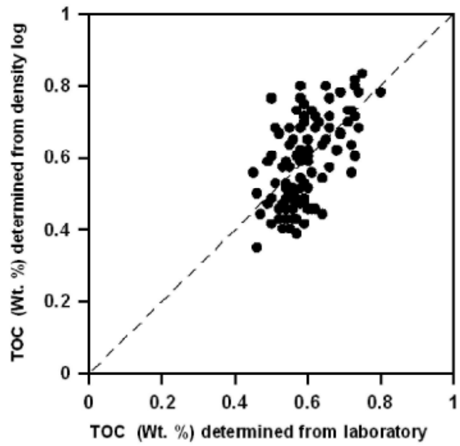

Fig.(18) : Comparison between the total organic - carbon content (TOC) calculated from density log and that laboratory measured of the Rudies shale Formation in Fina Z 80 -1A well. Ideal agreement shown by the dashed line.

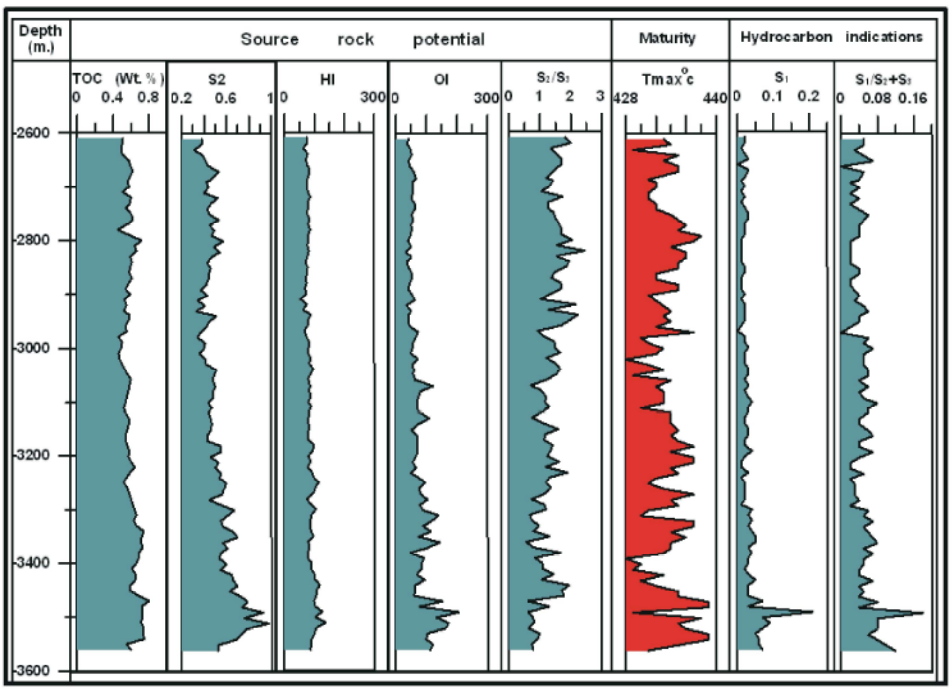

Fig. (19): Source rock evaluation log of the Rudeis Formation, Fina Z 80-1A well.

Key of abbreviations: OI= Oxygen index, HI= Hydrogen index, TOC= Total organic carbon, S2= Oil potential, S1= Free hydrocarbon, Tmax= Temperature of maximum rate, S2/S3= Hydrocarbons generated to trapped CO2, S1/S2+S3= Production index or transformation ratio.

sets of data could be achieved when R; the inverse ratio of the organic-carbon in the organic matter to the organic matter, Schmoker relation [1] is equal to 21. The average of the absolute values of the differences between the TOC laboratory determined values and those calculated from the density logs is (0.08 %). The average of the log measured (TOC %) of the studied samples is 0.59 %. The ratio of the average of the absolute values of the differences to the average of the (TOC) is about (0.1), which corresponds to nearly the same value obtained by Schmoker [1].

From the foregoing discussion, it could be concluded that, the TOC in the Rudies shale ranges from 0.45 to 0.8 %. Neglia [48] assessed the organic-carbon content (TOC) present in source rock as lean or poor (<0.5 TOC), fair (0.5-1%), good (1-2%), very good (2-4%) and excellent (>4%). Therefore, the Rudeis Formation in the study area could be considered potential fair source, that could generate oil and/or gas, if the buried deeper or at temperature high enough to alter the contained organic matter into hydrocarbons. This result has a good matching with the results of the laboratory analyses.

Source Potential: Throughout the whole sequence analyzed, the amount of organic-carbon was low, with the highest TOC value being 0.8 % (Fig. 6) and the highest potential yield (S_2) value being 0.89 mg Hc/g rock (Fig. 19). The average values for these parameters are 0.59 % and 0.52 mg Hc/g rock, respectively. These quantities are considered to be poor to moderate in terms of the source potential. The quality of the organic material is very poor, indicating a type III kerogen, is consistent with the terrestrial supply of organic matter.

CONCLUSIONS

The shale, that constitute the Rudeis Formation in the Northern Gulf of Suez, is considered best marginally mature. However, the kerogen quantity and type is such that large scale oil generation, have not occurred. The low levels of maturity are such to preclude any large scale gas generation from the sediments analysed. There is a possibility of a localized migrated hydrocarbon build-up in the deepest well section. The amount of organic matter and organic-carbon increase towards the central part of the study area in the Rudeis Formation. According to the TOC measurements, the Rudeis Formation is considered as fair source rock quality. The comparison between the TOC (Wt. %) laboratory measured values and those calculated from the density logs shows a good matching between the two sets of data. Density/resistivity and sonic/resistivity crossplots show that, the major part of Rudeis Formation is a non-source rock type.

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