

Full length article

Thorium normalization as a hydrocarbon accumulation indicator for Lower Miocene rocks in Ras Ghara area, Gulf of Suez, Egypt

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ABSTRACT

An exploration method has been developed using surface and aerial gamma-ray spectral measurements in prospecting petroleum in stratigraphic and structural traps.

The Gulf of Suez is an important region for studying hydrocarbon potentiality in Egypt. Thorium normalization technique was applied on the sandstone reservoirs in the region to determine the hydrocarbon potentialities zones using the three spectrometric radioactive gamma ray-logs (eU, eTh and K% logs). This method was applied on the recorded gamma-ray spectrometric logs for Rudeis and Kareem Formations in Ras Ghara oil Field, Gulf of Suez, Egypt.

The conventional well logs (gamma-ray, resistivity, neutron, density and sonic logs) were analyzed to determine the net pay zones in the study area.

The agreement ratios between the thorium normalization technique and the results of the well log analyses are high, so the application of thorium normalization technique can be used as a guide for hydrocarbon accumulation in the study reservoir rocks.

1. Introduction

Ras Ghara concession, 100 km², is located in the southern part of the Gulf of Suez, 30 km to the south of El Tor City El-Khadragy et al. (2017). This study is applied on Rudeis and Kareem Formations selected in the Miocene sequence. Ras Ghara Concession is located approximately between latitude 27°56'10" to lat. 28°03'38"N and longitude 33°38'41" to long. 33°50'54"E. The area is represented by ten wells namely: SINAI-1, SINAI-2, SINAI-3, SINAI-4, GM-ALEF-1, GM-DAL-1, GM-DAL-2, GM- GEM-1, GM-HAA-1 and GM-4 wells scattered in the oil field (Fig. 1).

The history of radioactivity measurements associated with produced oil dates back to Bogoyavlenskiy (1929).

Petroleum explorationists have been experimenting with gamma-radiation measurements as a petroleum prospecting method since the early 1950s (Armstrong and Heemstra, 1973). Saunders et al. (1987), used the thorium content as alithologic control to define "ideal" potassium and uranium values. The present study deals essentially with the analysis and interpretation of the aerial gamma-ray spectrometric survey data. These analysis and interpretation are mainly devoted toward prospecting hydrocarbon accumulations in the stratigraphic and

the structural traps.

Thorium normalization technique was first applied on well logging data by Al Alf (2009) who concluded that the results of thorium normalization agree with the results of well log analysis on the Lower Miocene (Rudeis) Formation in Belayim marine oil field in 82% of the cases studied. This work applies the thorium normalization technique in Rudeis and Kareem Formations in Ras Ghara oil Field, Gulf of Suez, Egypt to determine the oil bearing zones using only the gamma ray spectrometric log and comparing it to the conventional well log analysis.

2. Geologic setting

Fig. 2 shows the lithostratigraphic column of Ras Ghara Oil Field, compiled from the drilled wells in the study area.

According to Brooks and Hagras (1971) the Miocene sediments are deposited on a surface of marked relief. This has a strong bearing on the understanding of the rapid lateral facies changes. The data obtained from the wells indicated the presence of an important unconformity between the Miocene and Pre-Miocene (Barakat, 1982).

Kareem Formation conformably overlies Rudeis Formation and

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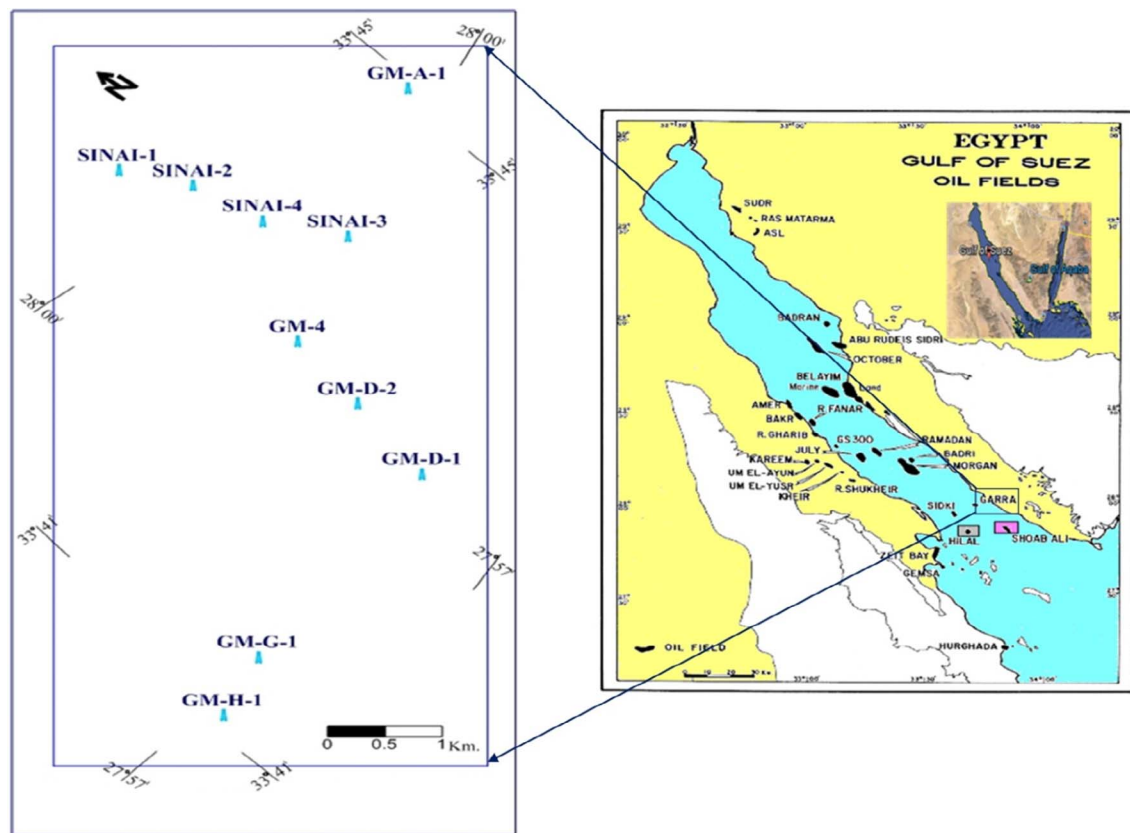


Fig. 1. Location map of the study area displaying ten selected wells.

consists mainly of interbedded sandstone, shale and carbonates with thin streaks of anhydrite in the lower part of the section. Generally, the sand percentage increases toward the marginal boundaries Tawfik et al. (1993). The thickness of the Kareem Formation in the southern Gulf of Suez varies from 15 to 539 m. The depositional setting of the Kareem Formation was shallow, partly open marine, with localized lagoonal conditions.

According to Takasu, et al. (1982) the Rudeis Formation lies conformably between Nukhul and Kareem Formations. The Rudeis Formation varies greatly in lithology and thickness in response to the irregular paleorelief over which sedimentation took place. It consists mainly of shale and limestone interbedded with sandstone. The unit varies in thickness from about 11 to 1304 m. The depositional setting of the Rudeis Formation is considered shallow to deep marine, (Alsharhan and Salah, 1994).

3. Methodology

According to Saunders et al. (1993), a new exploration method was developed which uses surface and aerial gamma-ray spectral measurements in prospecting petroleum in stratigraphic and structural traps.

An early form of thorium normalization of potassium and uranium measurements of aerial gamma-ray spectral data was developed to eliminate the effects of the uncontrolled variables for the National Uranium Resource Evaluation (NURE) program (Saunders et al., 1987).

Saunders et al. (1987), used the thorium content as a lithologic control to define “ideal” potassium and uranium values for each sample. The basic assumption was that whatever happens to influence the apparent concentration of thorium also affects uranium and potassium in similar and predictable ways.

Normalizing to thorium will also suppress these effects. This similarity in behavior allows use of thorium values to roughly predict uranium and potassium by determining their general relationships.

Significant differences between predicted (or “ideal”) uranium and potassium amounts, and actual (measured) values must be due to factors other than lithology, soil moisture, vegetation, shielding, or counting geometry. By measuring these secondary effects, one can define possible petroleum prospects (Saunders et al., 1993).

The well logging gamma-ray spectrometry are used in this work to determine the oil bearing zones using this technique in Ras Ghara area, Gulf of Suez, Egypt. This technique is applied on SINAI-1 well.

Uranium and potassium data for each surface or aerial subsurface gamma-ray spectrometry logs were normalized to equivalent thorium data, using the procedures of Saunders et al. (1993). Plots were made for the logs of measured K_s versus eTh_s and eU_s versus eTh_s values for all readings. The simplest effective Eqs. (1) and (2) relating these variables were determined to be linear and pass through the origin. The slopes of the lines were determined by the ratios of mean K_s to mean eTh_s , or mean eU_s to mean eTh_s . The equations are

$$K_i = (\text{mean } K_s / \text{mean } eTh_s) eTh_s \quad (1)$$

$$eU_i = (\text{mean } eU_s / \text{mean } eTh_s) eTh_s \quad (2)$$

where K_i is the ideal equivalent thorium defined potassium value for the reading with a real equivalent thorium value of eTh_s , and eU_i is the ideal equivalent thorium defined equivalent uranium value for that reading.

Using this approach, the equations were calculated directly from the data and quick field evaluations may be made without preparing the plots and resorting to curve fitting. Deviations of the real values from the calculated ideal values for each reading were obtained using equations of the form

$$KD \% = (K_s - K_i) / K_s \quad (3)$$

$$eUD \% = (eU_s - eU_i) / eU_s \quad (4)$$

where K_s and eU_s are the measured values at the reading stations, and

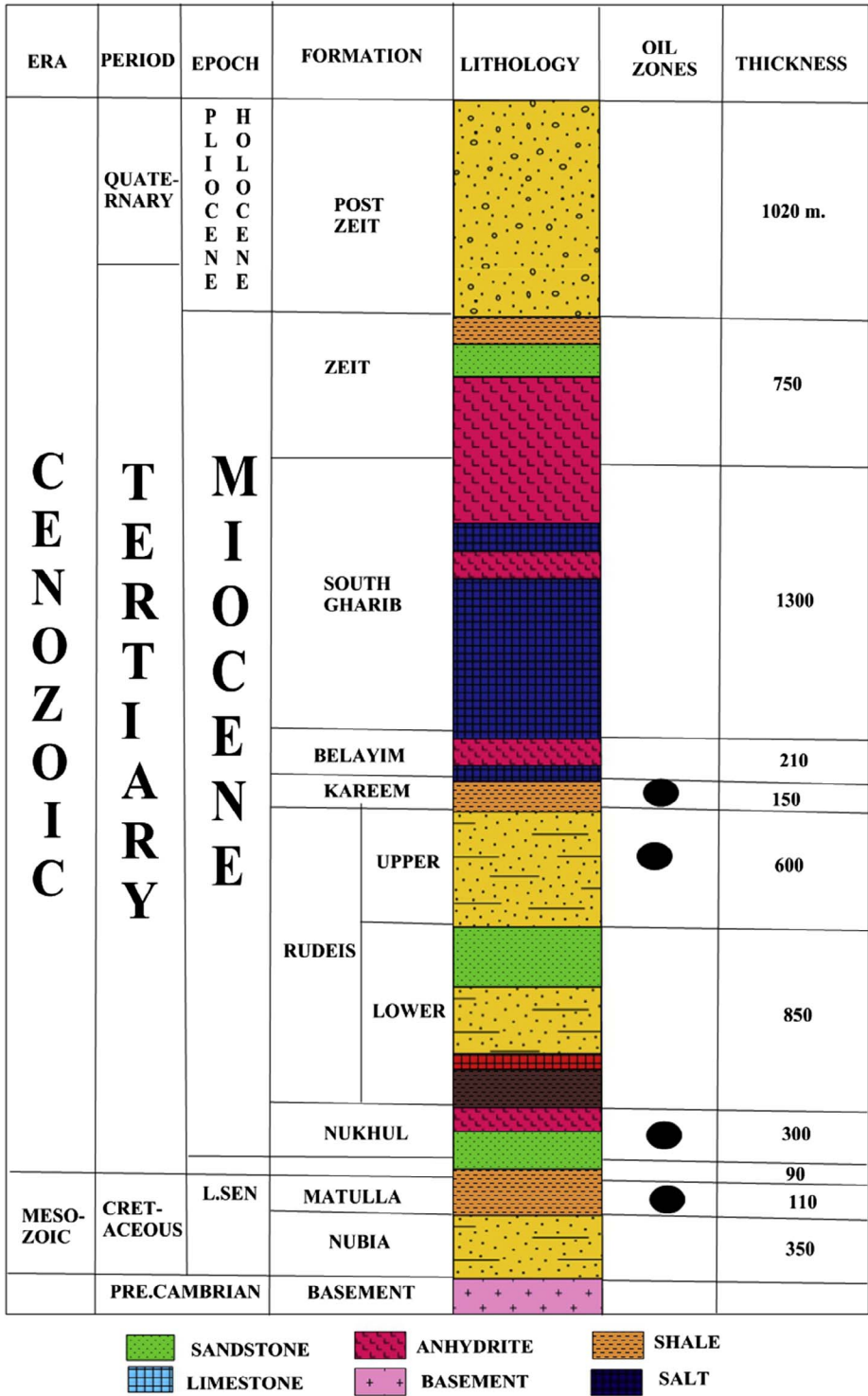


Fig. 2. Schematic stratigraphic column of Ras Ghara Area (modified after Salama et al., 1994).

KD% and eUD% are the relative deviations expressed as a fraction of the reading values. Experience has shown that KD% yields small negative values and eUD% yields smaller negative or sometimes positive values (Saunders et al., 1993).

KD% and eUD% variations can be combined as a single positive number, DRAD, which is the difference between both of them:

DRAD = eUD%–KD% (5)

where positive DRAD values are favorable indications of petroleum accumulation.

The petrophysical parameters have been determined using Techlog software using the different conventional logs (gamma-ray, caliper, resistivity, sonic, density and neutron logs).

4. Result and discussions

The comparative profiles of KD%, eUD% and DRAD was plotted for SINAI-1 well to illustrate the oil bearing zones. Determination of the oil bearing zones depend on the values of shale volume (less than 35%), effective porosity (more than 10%) and hydrocarbon saturation (more

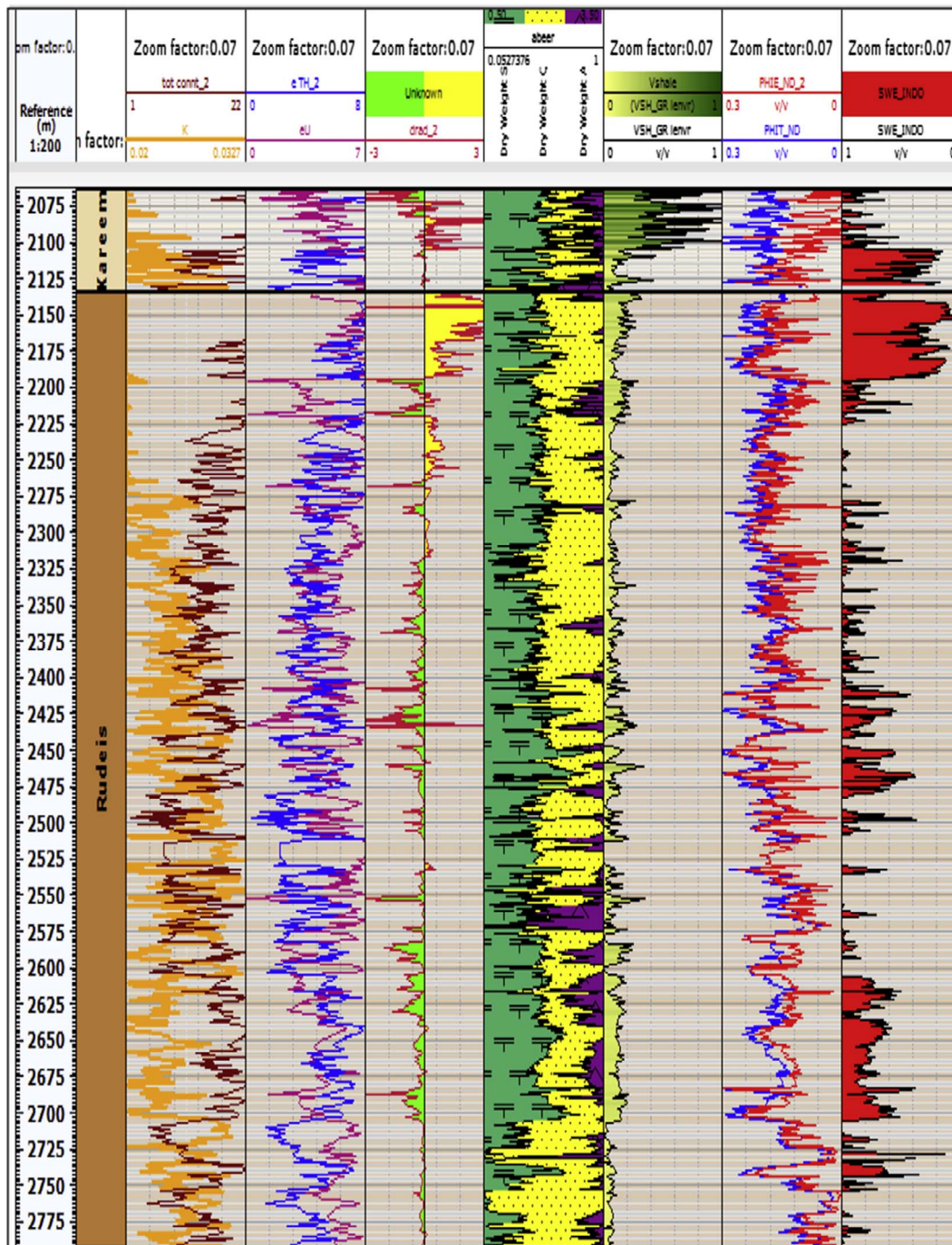


Fig. 3. Relationship between thorium normalization DRAD results and well log analyses results of SINAI-1 well in the studied area.

than 50%) (Al Alfay et al., 2013). These values are calculated by the analysis of the conventional well logs by using Techlog software.

The following is interpretation for the curves:

Volume of shale curve:

The high values of shale volume are matched with the negative DRAD as shown in Fig. 3 from depth 2267 to 2791 m. for Rudeis Formation and from 2066 to 2105 m. for Kareem Formation.

Effective porosity curve:

The effective porosity curve is compatible with the DRAD curve as

shown in Fig. 3. The high values of effective porosity are noted from depths 2137 to 2231 m. for Rudeis Formation and from 2101 to 2130 m. for Kareem Formation.

Hydrocarbon saturation curve:

The net pay zones are the zones which have hydrocarbon amounts more than 50% of all fluids in different zones, thus the zones which are considered as pay zones are from depths 2138 to 2197 m in Rudeis Formation and from 2093 to 2133 m in Kareem Formation as shown in Fig. 3. This indicated that the hydrocarbon saturation curve frequently agrees with the positive DRAD curve.

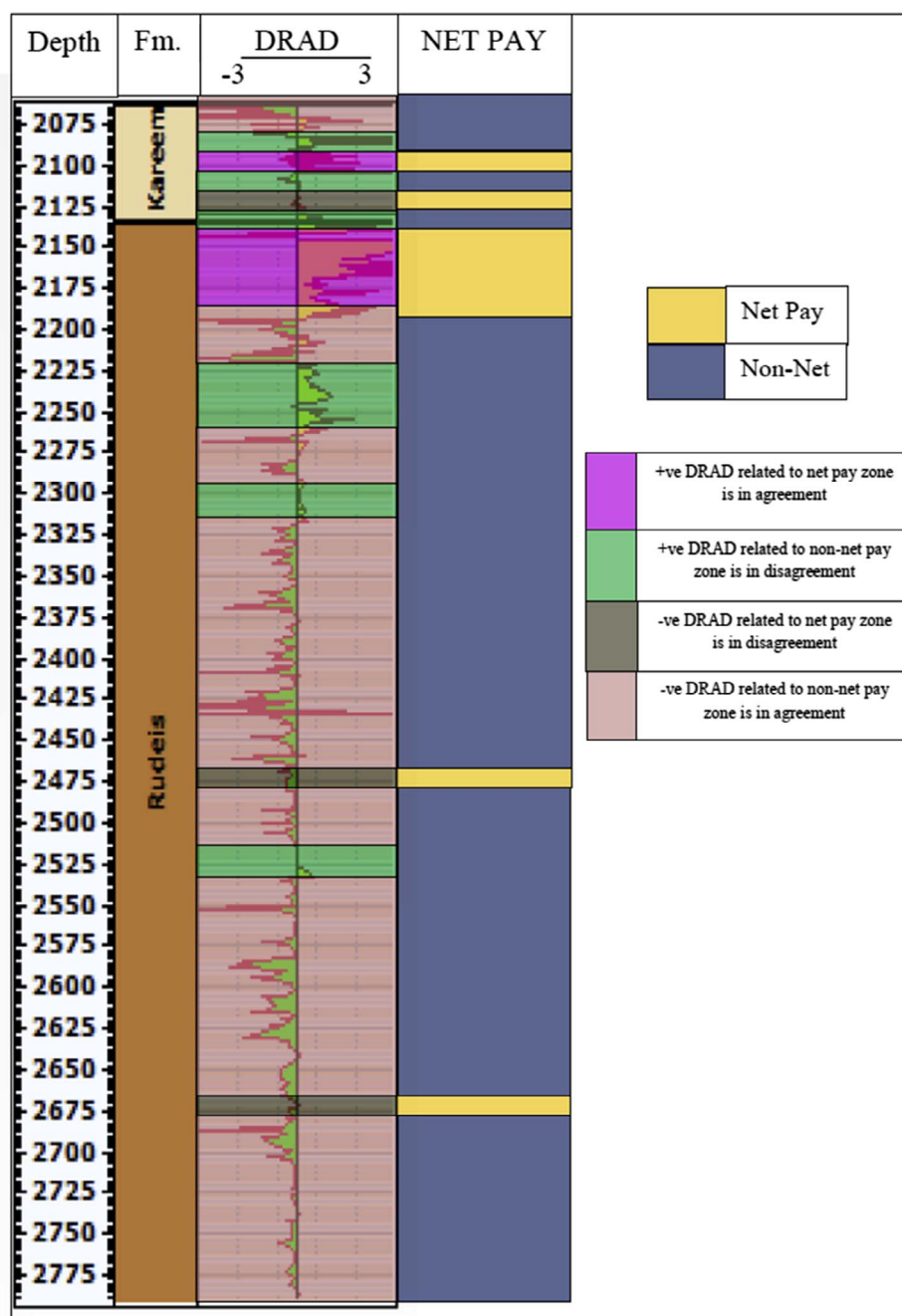


Fig. 4. The agreement between the results of DRAD curve and the net pay zones of SINAI-1 well in the studied area.

DRAD curve

Fig. 3 shows the plots of the processed gamma spectrometry data and DRAD values. The positive DRAD is expected to be good oil bearing zones and have larger amount of hydrocarbon accumulations. The positive DRAD are presented in the zones from depths 2134.5 to 2266 m. for Rudeis Formation and from 2106 to 2134 m. for Kareem Formation. While the negative zones are recorded from depths 2267 to 2791 m. and from 2066 to 2105 m. for the same Formations respectively.

From the previous discussion and according to Fig. 3 it can be noted that zones which have positive DRAD values have low values of shale volume, high effective porosity values and high hydrocarbon saturation values. On the other hand, the negative DRAD values zones are recorded in zones which have high values of shale volume, low effective porosity values and low hydrocarbon saturation percentage.

The agreement ratio in SINAI-1 well between the results of DRAD

curve and the net pay zones (Fig. 4) is calculated along the depth of the well as follows:

- Positive DRAD related to net pay zone is in agreement.
- Positive DRAD related to non net pay zone is in disagreement.
- Negative DRAD related to net pay zone is in disagreement.
- Negative DRAD related to non net pay zones is in agreement.

As shown in Table 1, the agreement ratio between thorium normalization technique and well log analyses of the wells under investigation in the studied area was found to be 79 % and 74 % for Kareem and Rudeis Formations respectively.

5. Conclusions

In this work, thorium normalization technique was applied as a tool

Table 1

The agreement ratio for Kareem and Rudeis formations in Ras Ghara area, Gulf of Suez, Egypt.

Wells	Agreement Ratio, % Rudeis Fm	Agreement Ratio, % Kareem Fm
SINAI-1	87	59
SINAI-2	65	74
SINAI-3	76	91
SINAI-4	55	73
GM-ALEF-1	73	88
GM-DAL-1	92	95
GM-DAL-2	59	–
GM-GEEM-1	79	98
GM- HAA-1	87	55
GM-4	67	75

to determine the petroleum accumulation in the studied wells.

The agreement ratios between thorium normalization and well log analysis are 79% and 74% respectively for the studied Kareem and Rudeis Formations.

The obtained results matched well with those obtained using well log analysis, so the calculated DRAD curve can be used as an indicator for oil bearing zones in different wells.

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