ARTICLE IN PRESS

NRIAG Journal of Astronomy and Geophysics xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

NRIAG Journal of Astronomy and Geophysics

journal homepage: www.elsevier.com/locate/nrjag

Full length article

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

A.A. El-Khadragy[a], T.F. Shazly[b], I.M. AlAlfy[c], M. Ramadan[b], M.Z. El-Sawy[b,*]

[a] *Geology Department, Faculty of Science, Zagazig University, Egypt*
[b] *Exploration Department, Egyptian Petroleum Research Institute, Egypt*
[c] *Exploration Division, Nuclear Materials Authority, Egypt*

ARTICLE INFO

Keywords:
Thorium normalization
Hydrocarbon accumulation
Spectral gamma ray
Gulf of Suez

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 km^2, 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 Alfy (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

Peer review under responsibility of National Research Institute of Astronomy and Geophysics.

* Corresponding author.
E-mail address: marwa_epri@yahoo.com (M.Z. El-Sawy).

https://doi.org/10.1016/j.nrjag.2018.01.002
Received 18 June 2017; Received in revised form 27 December 2017; Accepted 15 January 2018
2090-9977/

Please cite this article as: El-Khadragy, A.A., NRIAG Journal of Astronomy and Geophysics (2018), https://doi.org/10.1016/j.nrjag.2018.01.002

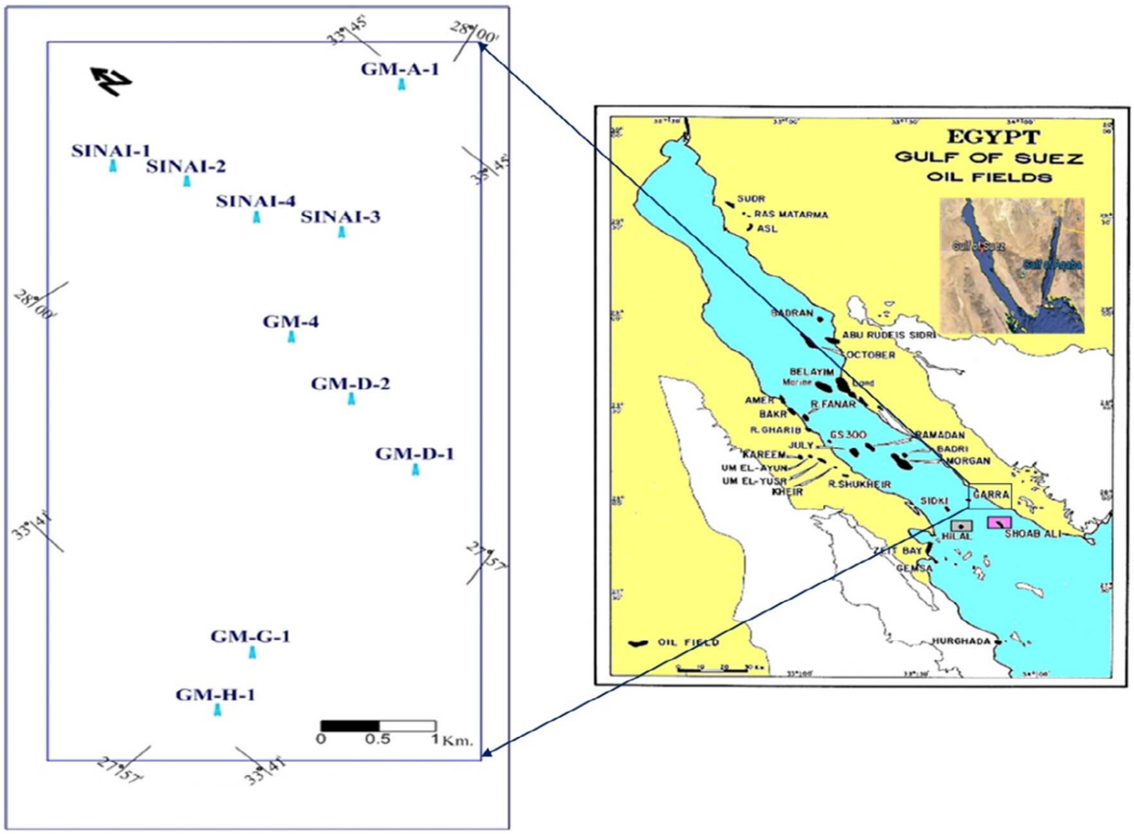

Fig. 1. Location map of the study area displaying ten selected wells.

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 ofSuez 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 Ks versus eThs and eUs versus eThs 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 Ks to mean eThs, or mean eUs to mean eThs. The equations are

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

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

where Ki is the ideal equivalent thorium defined potassium value for the reading with a real equivalent thorium value of eThs, and eUi 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

$$KD\ \% = (K_s - K_i)/K_s \tag{3}$$

$$eUD\ \% = (eU_s - eU_i)/eU_s \tag{4}$$

where Ks and eUs are the measured values at the reading stations, and