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Utilizing of Resistivity Log to Discriminate Between Effective and Ineffective Porosity for Raha Formation in Ras Budran Field, Gulf of Suez, Egypt

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Abstract: The present study deals with the computerized well logging analysis for Raha Formation, using eight wells scattered in Ras Budran Field in the Gulf of Suez. This study was done utilizing different types of open-hole well logs such as: gamma-ray, density, and resistivity. The considered wells don't produce from the Raha Formation although it has suitable amount of oil with good values of the different petrophysical parameters. This is related to the absent of effective porosity which is considered in this paper through the discrimination of effective from ineffective porosity by using resistivity logs. These logs are considered as the most useful and helpful tool in detecting high effective porosity zones.

Key words: Gulf of Suez - Raha Formation - Effective Porosity - Resistivity logs

INTRODUCTION

Ras Budran oil field is located in the northern part of Belayim offshore area, approximately four km. from the eastern coast of Gulf of Suez, it is defined by latitude 28° 57′ and 28° 59′ N; and by longitude 33° 7′ and 33° 9′ E (Fig. 1). The field was discoverd in 1978 after drilling of well EE85-1 based on seismic interpretation at base miocene evaporite, the well penetrated 1500 ft. of oil bearing sandstone of Raha and Nubian Formations (Cenomanian to Paleozoic age).

The studied rock unit (Raha Formation) is penetrated by eight drill holes distributed in the area of study. The evaluated wells are: EE85-2, RB-A1, RB-B1, RB-B8B, RB-C1A, RB-C2, RB-A2A and RB-B3, as shown in Fig. (1).

The target Formation for this study, is mainly composed of sandstone with few shale streaks of Early Cenomanian age. In addition the Middle and the Upper Raha units are mainly composed of shale, sandstone and limestone of Late Cenomanian age. The units conformably underlay the Abu Qada Formation of Turonian age.

Effective porosity depends largely on the degree of connection between the rock pores with each other forming channels, to facilitate the path of fluids through the lithologic contents. This effective porosity can be distinguished from ineffective porosity by the resistivity logs which are the most reliable tool for this method.

Most high-permeability units have deep induction values more than 100 ohm m. and separation of more than 10 ohm m. between the medium and deep induction curves (Langhorne *et al*., 2003). The ineffective intervals with micro porosity, burrow porosity, and moldic porosity have lower resistivity and little separation between the medium and deep induction curves.

The purpose of this paper is to show the methodology used to determine the causes of the production shortfall at Ras Budran Field in Raha Formation through distinguishing effective from ineffective porosity by using resistivity logs.

1. Methods:

The starting point for this study was studying the outcrops because it gives the most reliable way to learn about common rock types, depositional environments, lateral facies variation and the high-resolution sequence stratighraphy of the reservoir interval. The main lithology is sandstone and limestones with minor amount of dolomitic limestones in Raha Formation with medium grains which indicate suitable reservoir rock.

Effective porosity will be studied in this paper by plotting the resistivity, gamma ray and density log in a single plot for each well to detect the suitable zones for the effective porosity, and then it will be determined quantitatively.

2. Porosity Types:

The porosity logs of Raha Formation at Ras Budran Field show consistently high porosity values. The reservoir is, however, very difficult to be accurately evaluated because there are five different types of porosity, four of which may not be effective or only contribute a small amount of production**.**

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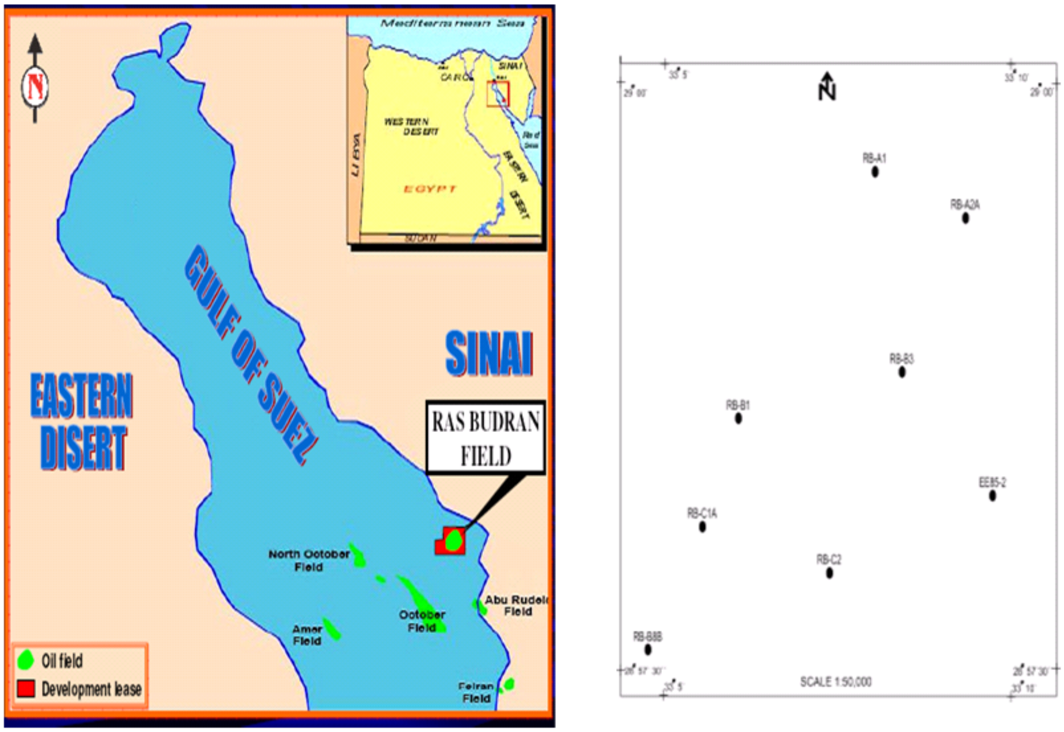

Fig. 1: Location map of the study wells in Ras Budran Field.

A. Interparticle Porosity:

The skeletal-peloidal grainstone reservoir facies has solution-enhanced interparticle porosity (Danford *et al*., 1997). Reservoir quality is directly controlled by the degree of leaching. Porous grainstones with relatively low permeability have not corroded yet. Grainstones with good porosity and good permeability have most or all of the leached cement**.** Grainstones with the highest porosity and permeability are leached so intensely that they are essentially floating carbonate grains primarily held together by the oil**.**

We interpret that the well-cemented grainstones with little or no permeability were completely cemented early and this cement prevented sub-sequent leaching**.** Grainstones that have been extensively leached probably had some remaining primary porosity that provided a pathway for the fluids that did the subsequent leaching.

B. Microporosity:

Micro porosity is most common in the mud-dominated facies, such as the burrowed wackestone and the algal wackestone (Wilson, 1975; Moshier, 1987, 1989a, b; Budd, 1989)**.**

Micro porosity is porosity that occurs between calcite rhombs**.** Micro-porosity is productive in Mesozoic and Tertiary carbonate gas and has high-gravity oil reservoirs in the Middle East (Perkins 1989).

C.Burrow Fill and Internodular Porosity:

The burrowed nodular packstone and wackestone facies have abundant 0.5-2 cm burrows that are commonly filled with partially dolomitized grainstone-packstone with solution-enhanced interparticle porosity**.** Burrow fillings comprise between 10 and 50% of the rock volume, and the microporous and tight host rock comprises between 50 and 90% of any given interval in the burrowed and nodular facies. The edges of the burrows are commonly obscured by later leaching, which creates more diffuse and irregular boundaries.

D.Moldic Porosity:

Moldic porosity is most likely effective where it is connected to interparticle porosity and most likely ineffective where it is isolated in a tight or microporous matrix.

E.Intragranular Porosity:

Isolated intragranular porosity occurs in some foraminifera and is probably ineffective. Intraskeletal porosity is most common in textularids and miliolids, but can occur in all foraminifer's types. The abundance of foraminifera in some rock types could comprise a significant portion of the total porosity in some rock units.

3. Log Response to Rock and Porosity Types:

The main purpose of this work was to link our observations to wire-line logs. These features can be recognized in the considered wells in Ras Budran field for analyzing the Raha Formation.

A-Gamma-Ray Logs:

Gamma-ray logs show amount of shale which can be correlated from well to well, it detects the clean formation through the low values of gamma ray. Gamma-ray logs are therefore valuable when used with resistivity log to detect the effective porosity but not by themselves (Langhorne, 2003).

B-Resistivity Logs:

The most useful tool for evaluating permeability in Raha Formation at Ras Budran Field is the resistivity logs. Zones that have readings greater than 100 ohm m. on both the deep lateralog and deep induction curves are characterized by high permeability. Further evidence that the resistivity logs are detecting high-permeability zones is the separation between the medium and deep induction curves (Langhorne, 2003) as shown in Figs. (2-9)**,** that correlates with the oil-stained grainstone intervals. This separation indicates invasion of drilling fluid into the formation that only occurs in this case in the permeable reservoir units. There is little to no separation between the medium and deep resistivity curves in the burrowed wackestone facies, which suggests that it has much lower permeability (Langhorne, 2003).

The relatively gradual increase in resistivity from 1 ohm m. to 2 ohm m. suggests that there is a significant microporosity- dominated transition zone between the water and oil-bearing parts of the formation (Langhorne, 2003). Smaller pore throats produce greater capillary pressure, which leads to bound water above the oil-water contact and lower resistiveity. In green silty dolomite facies, the reading of resistivity is below 1 ohm m. This sharp decrease may be related to smaller pore throats in the clays that occur between dolomite rhombs and quartz grains.

C- Porosity Logs:

The total porosity of Raha Formationcan can be determined by density and neutron porosity logs but these tools are not very useful for distinguishing effective from ineffective porosity. Interparticle, moldic, microporosity, and burrow fillings with interparticle porosity are all measured together by these tools. Thus, none of the porosity logs is very useful for distinguishing effective from ineffective porosity by itself. But it becomes most important tools in the considered method when it is used with the gamma-ray and resistivity logs.

D-Sonic Logs:

As mentioned above, sonic logs are not very useful for discriminating effective porosity from ineffective porosity in Raha Formation. Micro porosity and interparticle porosity have roughly the same effect on the sonic tool because they slow down the velocity equally (Langhorne, 2003).

Secondary porosity (Sclumberger, 1972, 1974; Asquith, 1985; Lucia, 1987) or sonic deviation logs can be useful for detecting moldic or vuggy porosity in some carbonate reservoirs. The sonic deviation is calculated by subtracting the porosity-derived velocity from the sonic velocity. In the intervals where the sonic velocity is higher than the density derived velocity, moldic and vuggy porosity are thought to dominate where the two have similar values, interparticle and microporosity are thought to dominate (Anselmetti and Eberli 1999). Interparticle porosity typically has a lower sonic velocity than density-derived velocity. Microporosity varies from having approximately equal sonic and density-derived velocities to having a response very similar to that of interparticle porosity (Anselmetti and Eberil, 1999).

4. Discussion:

The mentioned method was applied on the considered formation where Figs. (2-9) include representation curves of gamma ray, deep resistivity, density and the difference between deep and medium resistivity logs. These curves are used to determine the suitable reservoir rock by discriminating the effective from ineffective porosity.

In RB-A1 well (Fig. 2), at the interval depths 10548 and 10573 ft. are characterized by high porosity (low density), clean formation (low Gr) and also characterized by the presence of effective porosity where the reading of the deep resistivity reaches to more than 100 ohm.m, also the separation between the deep and medium resistivity is more than 10 ohm.m.

In RB-A2A well (Fig. 3), although the formation is clean and has a high value of porosity (through the reading of gamma ray and density tool) but there is no indication to the presence of effective porosity (low permeability).

Fig.(4) exhibits that at the depths of 10860 and 10930 ft in RB-B1 well there is a presence of effective porosity, as indicated from resistivity logs, with low reading of Gr (clean formation) and low density reading (high porosity) while the entire interval has a low permeability.

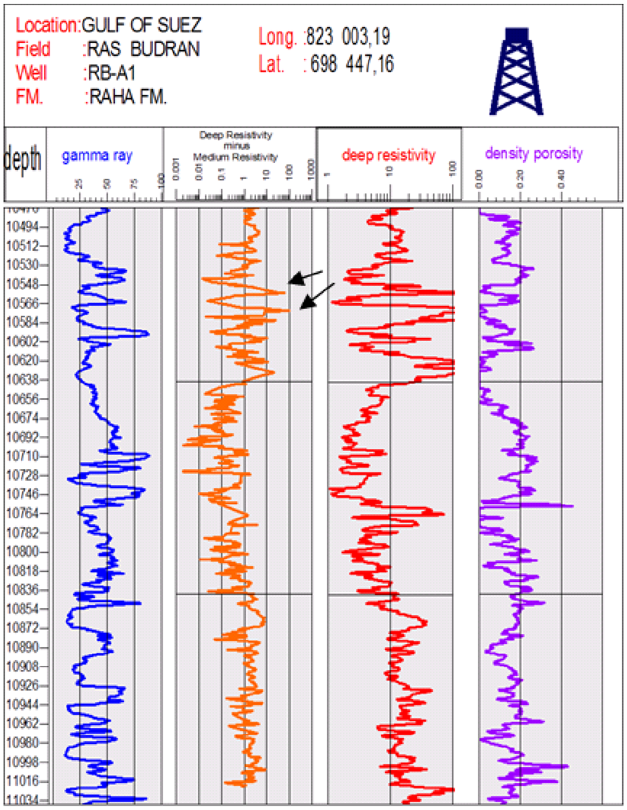

Fig. 2: Discrimination of effective from ineffective porosity in RB-A1 well.

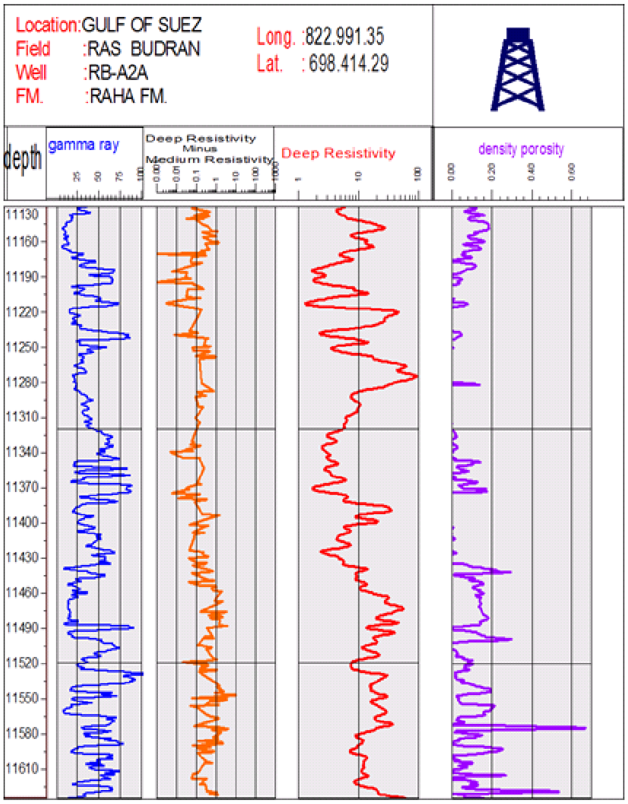

Fig. 3: Discrimination of effective from ineffective porosity in RB-A2A well.

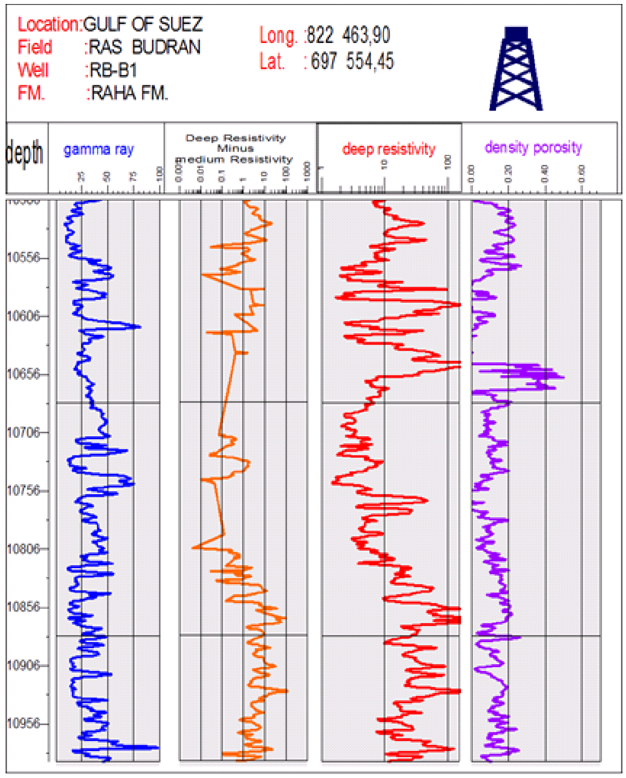

Fig. 4: Discrimination of effective from ineffective porosity in RB-B1 well.

Figs. (5 - 9) represent the rest of the wells for the studied formation in the study area. All these wells are characterized by the presence of clean formation (low Gr), high porosity (low density) but no one of these wells have an effective porosity where the deep resistivity log didn't reach to the value of 100 ohm.m. and there is not a separation between the deep and the medium resistivity.

This interpretation gave the answer for why Raha Formation couldn't to be a suitable reservoir rock.

This interpretation can be ensured by the quantitative interpretation as follow:

The effective porosities can be calculated through two ways; the former is the general equation.

$$\phi_{e1} = \phi_t * (1-V_{sh}) \quad (1)$$

The latter is the empirical formula:

$$\varphi_{e2} = \frac{2\varphi_{NC} + 7\varphi_{DC}}{9} \quad (2)$$

Where:

ϕ_{NC} is the neutron porosity corrected for shaliness effect and,

ϕ_{Dc} is the density porosity corrected for shaliness effect.

The corrected neutron and density porosities are calculated (schlumberger, 1972) from the equations.

$$\varphi_{NC} = \varphi_N - \left[\frac{\varphi_{Nsh}}{0.45}\right] * 0.30 * V_{sh} \quad (3)$$

$$\varphi_{DC} = \varphi_D - \left[\frac{\varphi_{Dsh}}{0.45}\right] * 0.13 * V_{sh} \quad (4)$$

Where:

ϕ_{Nsh} is the neutron porosity of a shale zone and,

ϕ_{Dsh} is the density porosity of a shale zone.

Volume of shale is determined according to Schieber, Zimmerle, and Scthi, (1998), from the gamma-ray log. Also the total porosities have been calculated throughout using the density and the neutron logs.

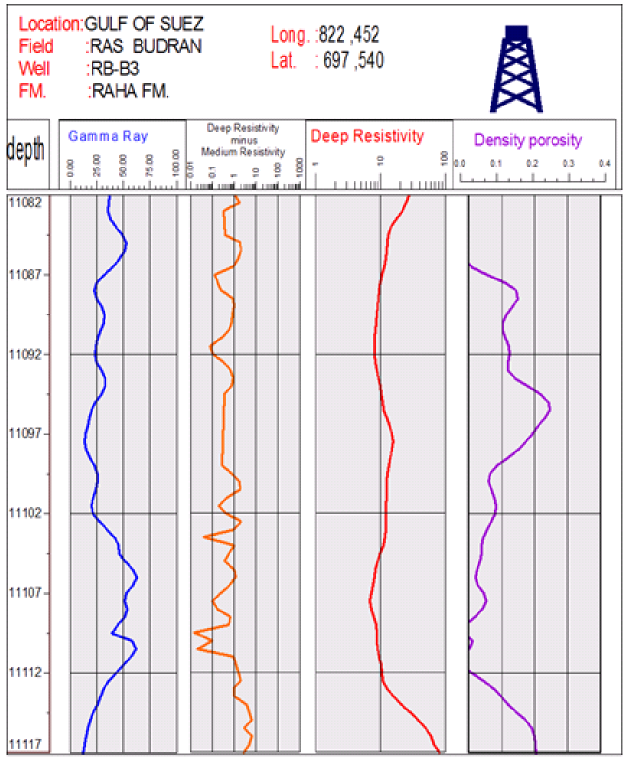

Fig. 5: Discrimination of effective from ineffective porosity in RB-B3 well.

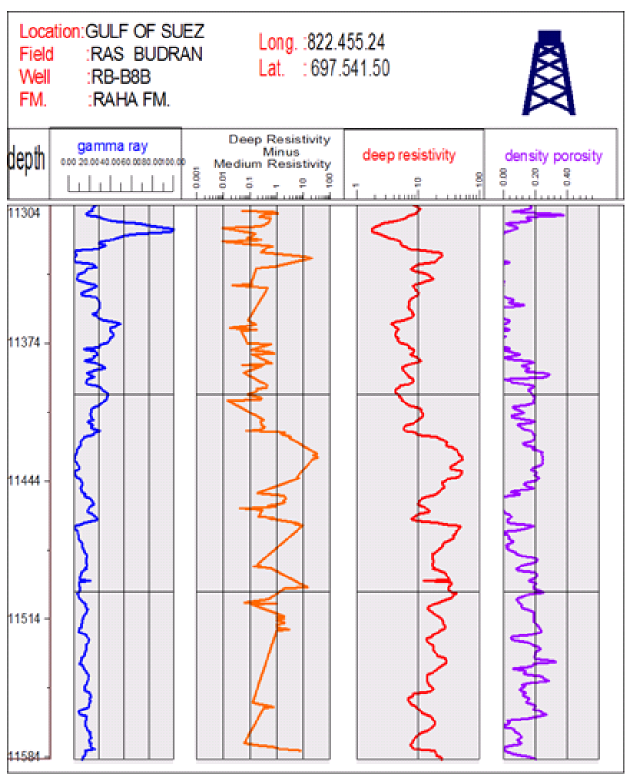

Fig. 6: Discrimination of effective from ineffective porosity in RB-B8B well.

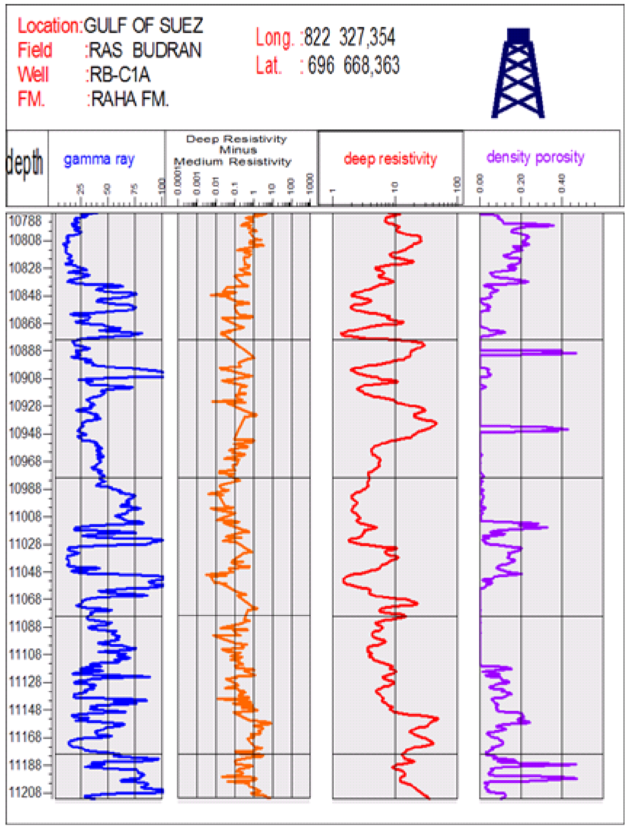

Fig. 7: Discrimination of effective from ineffective porosity in RB-C1A well.

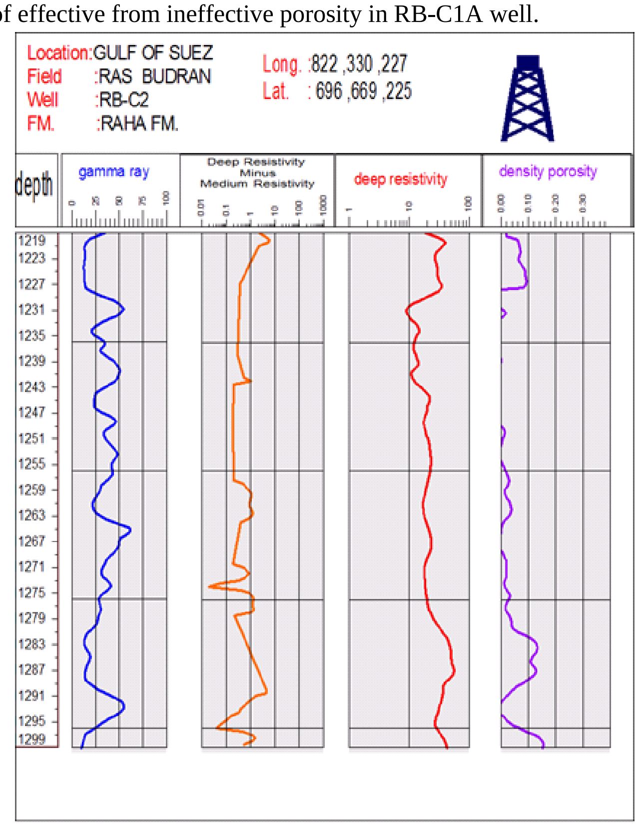

Fig. 8: Discrimination of effective from ineffective porosity in RB-C2 well.

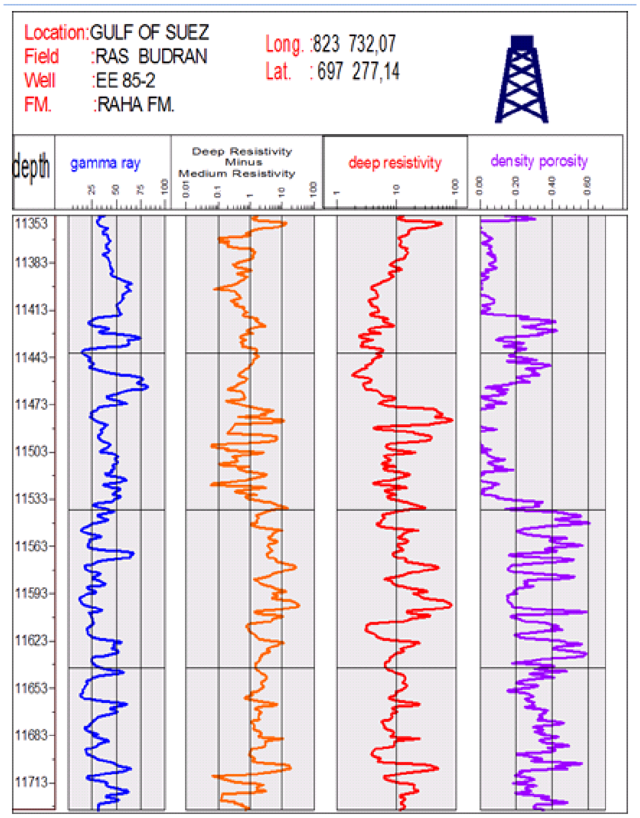

Fig. 9: Discrimination of effective from ineffective porosity in EE85-2 well.

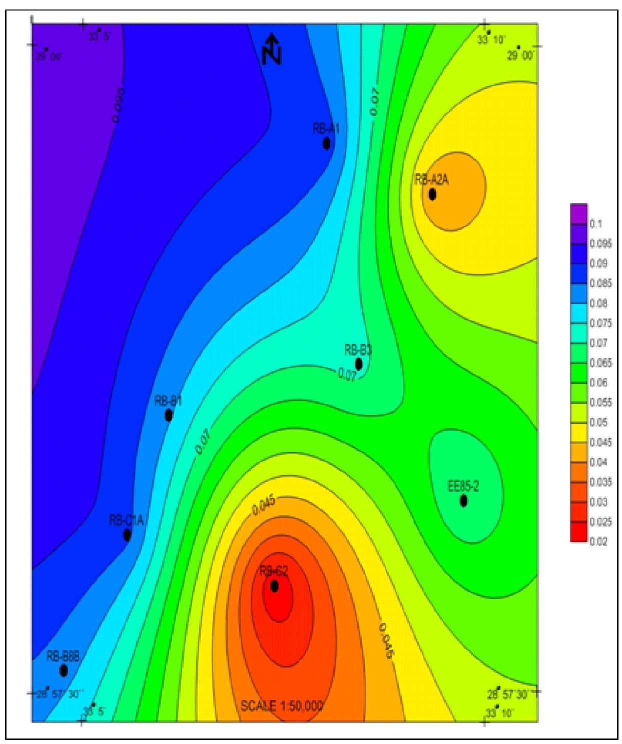

Fig. 10: Effective porosity distribution map of Raha Formation.

The effective porosity distribution map of Raha Formation (Fig. 10) reflects a gradual increase to the northwest and west directions where the maximum value (8%) is recorded at RB-A1 well, while it decreases to the south direction where the minimum value is recorded at RB-C2 well (2%).

Summary and Conclusions:

The present work deals with the computerized well logging analysis for Raha Formation of eight wells (RB-AI, RB-A2A, RB-B1, RB-B3, RB-B8B, RB-C1A, RB-C2 and EE85-2) distributed in Ras Budran oil field which located in northern belayim offshore concession area where it is defined by latitudes 28° 57' and 28° 59' N; and longitudes 33° 7' and 33° 9' E, in the Gulf of Suez approximately 4 kms. from the Sinai coast and 13 kms. from North West of Abu Rudies Field.

The effective and ineffective porosity are discriminated by resistivity logs where it is the most useful tool in detecting high effective porosity zones based on the values of deep and medium resistivity logs which reach to 100 ohm m. and also the separation between them which is about 10 ohm m., this separation indicates to permeability and effective porosity which appeared in wells RB-A1 at depths 10548 and 10573 ft and also appeared in RB-B1 well at the depths 10860 and 10930 ft. The mentioned depths in the two wells also show the high value of porosity and the presence of clean formation. The rest of wells did not show any presence for the effective porosity.

It is clearly that some porosity types will not contribute to production. Moldic, vuggy and interparticle porosity are good on logs, but not always connected well enough to share in production.

This study indicated to absent of effective porosity from most of wells in the study area and this gives the answer "why Raha Formation cauldn't act as reservoir rock" in spite of the presence of high porosity.

Also this method is confirmed through the quantitative interpretation of effective porosity.

So, resistivity logs are the most important tool for discriminating effective from ineffective porosity for any reservoir.

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