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Petrophysical and Electrofacies Analysis of Nullipore Reservoir, Ras Fanar Field, Gulf of Suez-Egypt

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The present study deals with petrophysical analysis and electrofacies zonation of the Nullipore carbonate reservoir rocks of Ras Fanar filed, Gulf of Suez-Egypt. The wire line logs of 14 wells, the available capillary pressure data, and the special core analyses of some cored intervals, as well as the coralline algae content, were analyzed and interpreted together for reservoir evaluation and zonation. Three electro-lithofacies zones (I, II, and III) are detected. However, zone (II) is considered the most important, in terms of the high porosity (18%) and hydrocarbon saturation (80%), which it attains. The petrophysical analysis of the Nullipore reservoirs shows two lobes (A and B) of good hydrocarbon potentialities, extending along northwest-southeast direction. However, "B" lobe attains better reservoir quality than "A" lobe. Net pay cutoff values of 14% and 65% are taken for porosity and water saturation, respectively.

Keywords: electrofacies, Gulf of Suez, Nullipore reservoir, petrophysical, Ras Fanar field

1. INTRODUCTION

Reef deposits are of great economic significance, and because of their porosity they often make good hydrocarbon reservoirs when suitably sealed. So, considerable attention has been given to methods of locating oil fields in ancient reefs and petroleum exploration has already revealed a number of significant reefs, and related oil and gas reservoirs in these areas.

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 in the Gulf of Suez. The National Stratigraphic Sub-Committee (1974) considered this "Nullipore" rock as being equivalent to the Hammam Faraun Member of the Belayim Formation. The "Nullipore" name was given for these rocks because of their richness in algal nodules and fragments.

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2. GEOLOGIC SETTING

Ras Fanar area is located offshore of the western side of the Gulf of Suez, 3.5 km east of Ras Gharib shoreline (Figure 1A). It is characterized by intensive faulting and unconformities and the cross faults of Aqaba trend may shift or terminate these blocks (Moustafa, 1977). The subsurface sedimentary sequence in Ras Fanar area Figure 1B ranges in age from the Paleozoic to Recent (Kulke, 1982; Chowdhary and Taha, 1986; El-Naggar, 1988; Darwish and Saleh, 1990). This sequence resembles, to a great extent, its counterparts in most of the Gulf of Suez province (Abdallah and El Adindani, 1963; Chowdhary and Taha, 1986; El-Naggar, 1988; Said, 1990).

3. MATERIALS AND METHODS

The different well logging data of 14 wells available in Ras Fanar field were interpreted. Special core analyses of some intervals in these wells and coralline algae were incorporated together with other logging data and used for Nullipore reservoir zonation and evaluation. The laboratory measurements were covered through the core data measurements for some important parameters including porosity, permeability, fluid saturation, and capillary pressure. Nullipore reservoir zonation was carried out using different techniques including well log data, special core analysis and coralline algae. A comprehensive petrophysical analysis was carried out over the Nullipore carbonate rocks. Hydrocarbon potential (oil and/or gas) was evaluated and a number of vertical analogs and petrophysical property distribution maps were constructed.

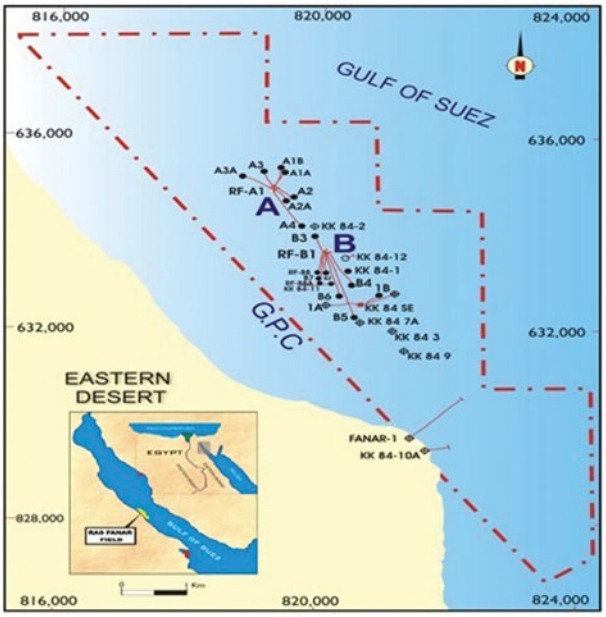
4. ELECTROFACIES ZONATION OF NULLIPORE RESERVOIR

In multiwell studies, the facies types and the depositional environments can be accurately recognized using correlation techniques. The integration of different logging analyses has been applied to identify and clarify some of the important properties of certain zones in the reservoir, which may otherwise have been missed by using one of them alone. Velocity parameters associated with synthetic seismic traces are used together with other logs to correlate and identify the different reservoir zones. Detailed examination of the electrical logs in Ras Fanar field and correlation with the core description, coralline algae, and the sedimentological analysis of the carbonates reveal that Nullipore carbonates consist of three zones (Lashin et al., 2005). The followings are the different methods used in Nullipore reservoir zonation.

4.1 Log Correlation

The most common wire line logs used in the identification, correlation, and electrofacies classification of reservoirs are gamma ray, sonic, density, and neutron logs. Based on log correlation, three electrolithofacies zones that could be fully correlated across the field (Figure 2) are recognized in the Nullipore rocks. Each of these zones is found 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. Zones (I) and (II) correspond to what was previously known as Nullipore Reef, and meanwhile zone (III) corresponds to the carbonate bank or platform.

Furthermore, Figure 3A shows the constructed synthetic seismogram of one well (KK84-4A) selected as example to demonstrate the presence of different zones in Nullipore carbonate rocks. The constructed model (velocity, acoustic impedance and synthetic seismic traces) reveals the



(a)

AGE	FORMATION	LITHOLOGY	AVERAGE THICKNESS (FT)
HOLOCENE-PLIOCENE	POST ZEIT		1200
UPPER MIOCENE	ZEIT		620
MIDDLE MIOCENE	SOUTH GHARIB		240
	BELAYIM (NULLIPORE ROCK)		400-980
EOCENE	THEBES		120
PALEOCENE	ESNA		0 - 50
SENONIAN	SUDER		0 - 340
	BROWN LIMESTONE		0 - 50
	MATULLA		400 - 500
TOURNAIN	WATA		240
	ABU QADA		40
CENOMANIAN-ALBIAN	RAHA		180
	NUBIA (A)		230
PALEOZOIC	NUBIA (B)		420
	NUBIA (C + D)		420
PRECAMBRIAN	BASEMENT		

(b)

FIGURE 1 Shows location map of Ras Fanar field, Gulf of Suez (a) and the generalized stratigraphic column (b).

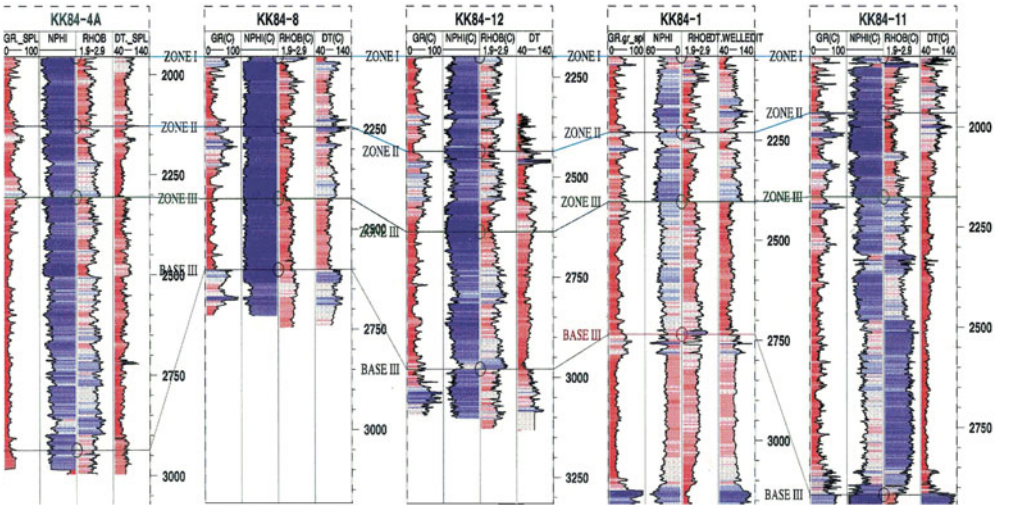


FIGURE 2 Correlation chart inferring the presence of three different electro-lithofacies (zones I, II, and III) in Nullipore reservoir rocks, Ras Fanar field.

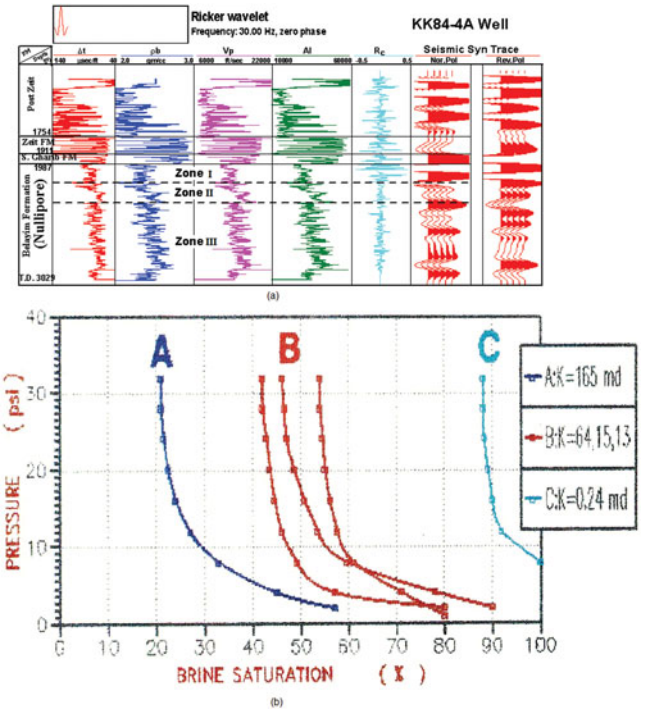


FIGURE 3 Synthetic seismogram and the capillary pressure curves of KK84-4A well indicating presence of three zones. (a) plot of synthetic seismogram and (b) plot of the capillary pressure curves.

presence of three zones with different petrophysical characters. The upper boundary of Nullipore rocks is characterized by velocity inversion due to transfer of velocity from the overlaying high velocity rock salt of South Gharib Formation to the underlying low velocity Nullipore carbonate rocks.

4.2 Special Core Analysis

Air-brine capillary pressure and mercury injection tests are used to determine the pore-to-pore throat sizes relationship in the different zones constituting the Nullipore rocks. Air-brine (wetting phase) pressure measurements were performed on nine core samples (five samples from KK 84-4A well and 4 from KK 84-8 well) by Core Lab (1982). The fully saturated samples were desaturated in a porous plate cell by introducing of humidified nitrogen at increasing incremental pressures up to 30 psi. Figure 3B illustrates the air-brine capillary pressure (Cp) curve established in KK84-4A well. It reflects the effect of cement on capillary pressure curves and indicates the presence of well-identified three petrophysical zones (A, B, and C) in the Nullipore rocks.

4.3 Coralline Algae Content

Bosence (1990) sampled in situ coralline algae from the Miocene reefal facies in Esh El Mellaha, Egypt, and correlated them with other Late Miocene coralline algal facies in Mallorca, Spain. Based one the algal content, four depth indicative coralline algal genera are found in Ras Fanar field (i.e., *Lithophyllum*, *Archaolithothamnium*, *Lithothamnium*, and *Lithoporella*).

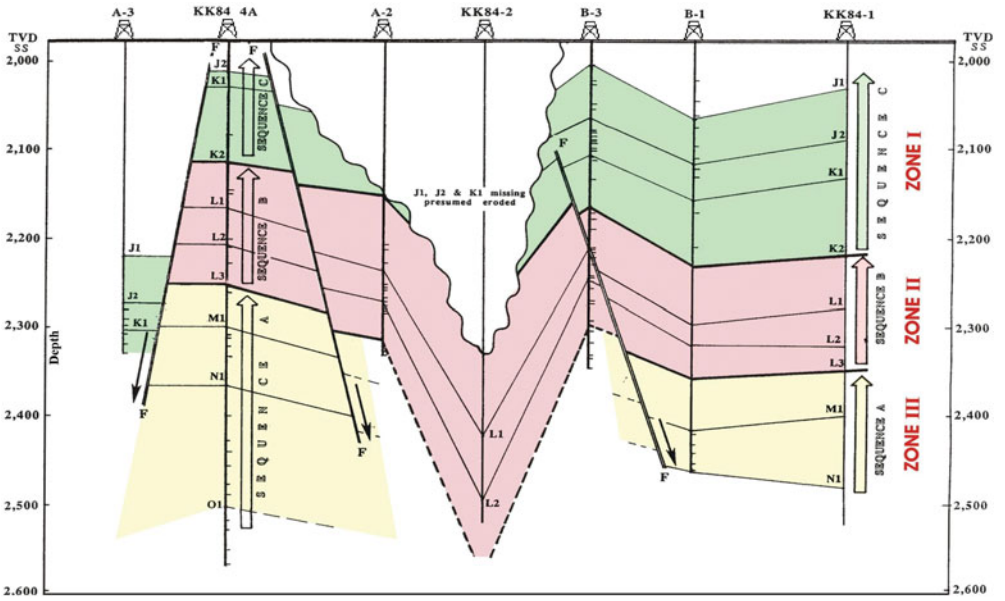


FIGURE 4 Ting of Nullipore electrozones (I, II, and II) with the regressive sequences (A, B, and C) in Ras Fanar field.

Facies characteristics and coralline algae content of the Nullipore succession indicate that it can be broadly divided into three regressive sequences. The main recognized facies are Peritidal (P), Inner Ramp (IR), and Mid Ramp (MR). Figure 4 ties the electro-lithofacies zones with these regressive sequences and shows a remarkably close fitting with the boundaries. The top of zone (III) coincides with the top of the lower regressive sequence (A), top of zone (II) matches with the top of the middle regressive sequence (B) and the top of the uppermost zone (I) presumably correlates with the top of the regressive sequence (C).

5. PETROPHYSICAL ANALYSIS OF NULLIPORE RESERVOIR

Based on well logging and core sample analyses, it is found that the petrophysical characteristics of Nullipore rocks in the different studied wells are nearly similar, to a large extent, with some relative differences in the percentages of pore spaces, fluid content, and the lithological components (Lashin et al., 2005; Lashin, 2006).

5.1 Hydrocarbon Potentialities

Hydrocarbon potentiality regarding the study wells in Ras Fanar field is represented mainly by oil, with downward increase of water saturation. One exception is found in KK84-11 well, where little saturations of secondary gases are detected (Figure 5). The lithological content of this well is mainly dolomitic, with little percent of limestone lithology. The pore spaces are uniform allover the whole section except in the upper and lower parts of the rock. They range from 17% (zone III) to 23% (zone II). Water saturation increases remarkably in the lowermost parts of the rock. An average water saturation value of 37% is given for Nullipore rocks in this well. Hydrocarbon content is represented by oil with little saturations of secondary gases occupied in the whole section of zone (I) and the uppermost part of zone (II). Depth of 2,185 ft is considered the gas-oil contact in this well.

5.2 Property Distribution Maps

Figures 6A–C show the porosity distribution maps of the Nullipore reservoir zones (I), (II), and (III). In the three maps, a characteristic low porosity semi-closure is well recognized between another two high porosity lobes (A and B lobes). The porosity values increases towards the northwest (A lobe) and southeast (B lobe) directions. Furthermore, the porosity values given for B lobe in zone II (Figure 6B) are much higher than the other comparable values recorded for zones III and I. However, the maximum attained porosity value (31%) is detected in zone III (Figure 6C).

Figures 7A and 7B illustrate the water and hydrocarbon saturation distribution maps. It reveals the presence of two low water saturation closures (A and B) extended along a northwest-southeast direction. Outgoing of these lobes, hydrocarbon saturation decreases towards the eastern and western boundaries of the field (55% and 57%). In general, B attains higher porosity, hydrocarbon saturations, and better reservoir quality than A lobe.

5.3 Nullipore Reservoir Cutoffs

The Nullipore reservoir cutoff has been further examined by plotting equivalent hydrocarbon column against a varying porosity cut-off for KK 84-4 well. A porosity cutoff of 14% will reduce the

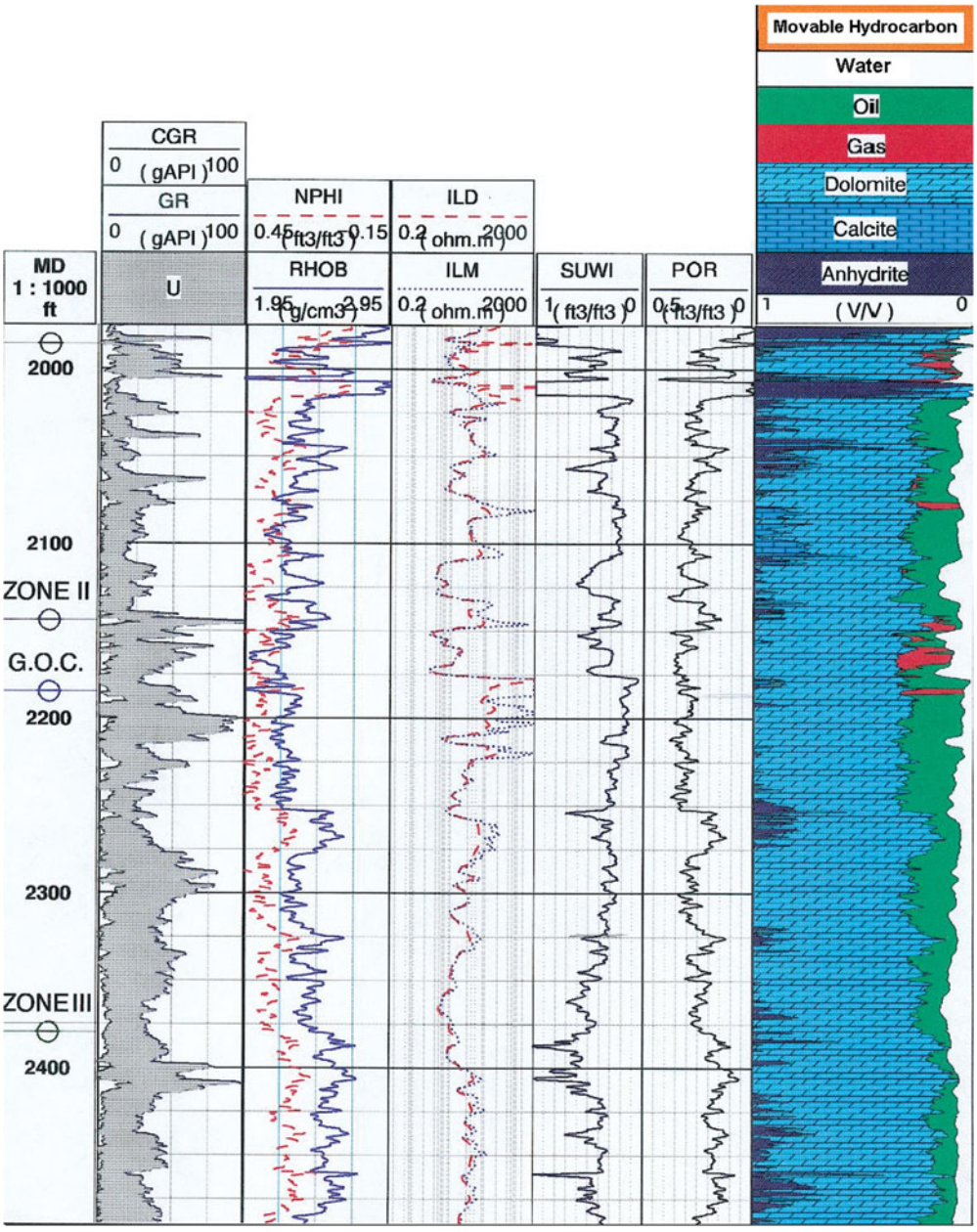


FIGURE 5 Petrophysical analog of Nullipore reservoir rocks in KK 84-11 well, Ras Fanar field.

equivalent hydrocarbon column by approximately 2%, while a hydrocarbon saturation cutoff of 35% (65% water saturation) will discount approximately the same amount of oil as the 14% porosity cutoff (2%).

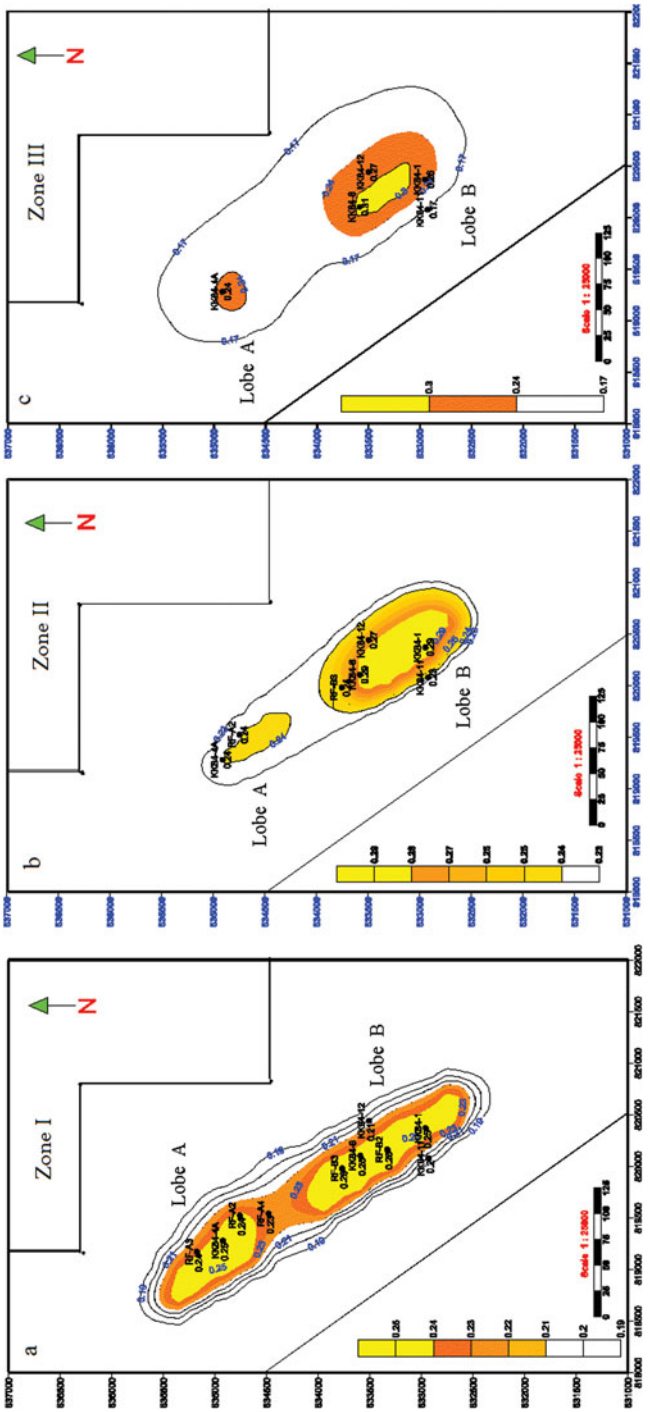


FIGURE 6 Porosity distribution maps of Nullipore reservoir zones. (a) Zone (I), (b) zone (II), and (c) zone (III).

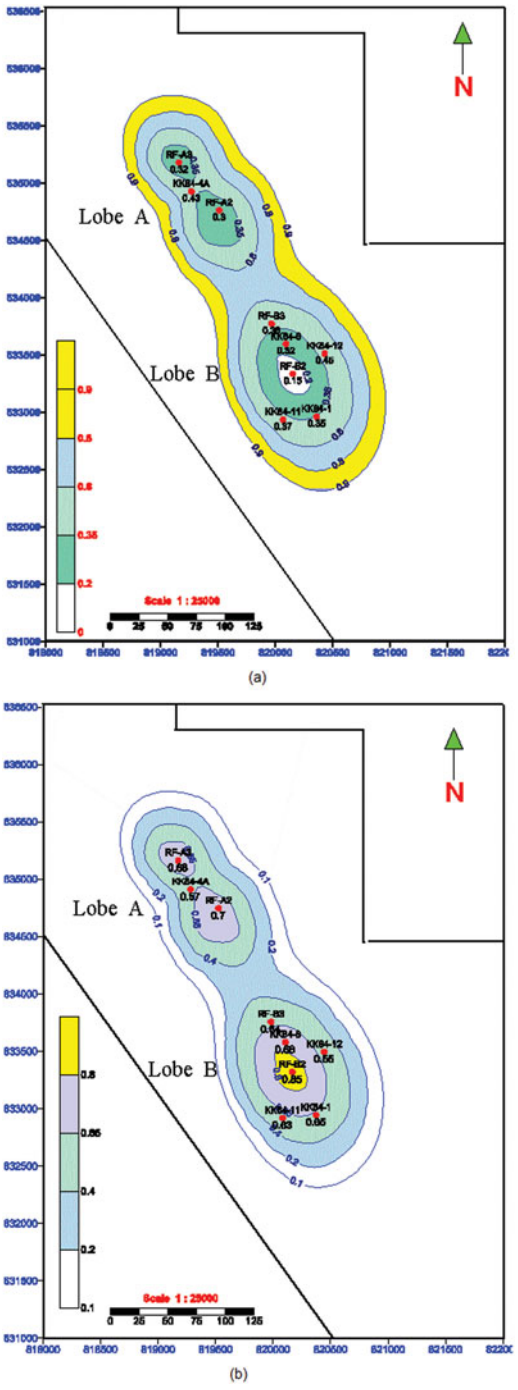


FIGURE 7 Lateral distribution maps of water and hydrocarbon saturations of Nullipore reservoir rocks, Ras Fanar field. (a) plot of water saturation and (b) plot of hydrocarbon saturation.

6. SUMMARY AND CONCLUSIONS

Nullipore reservoir rocks consist mainly of algal rich dolomitic limestone rocks. The petrophysical and electrofacies characteristics of these rocks are evaluated through analyzing the well logging data, synthetic seismic traces, special core analysis data, and the algal content of 14 wells scattered in the field. Three distinguished electro-lithofacies zones (zones I, II, and III) are well recognized. The petrophysical analysis of the Nullipore reservoir shows that hydrocarbons are mainly oil in type, while little secondary gases. Two lobes (A and B) of good petrophysical characters are found extending along a northwest-southeast direction. The hydrocarbon saturation increases toward the center of these lobes. Cutoff values of 14% porosity and 64% water saturation are considered the net pay evaluation of Nullipore reservoir rocks.

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