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Quantitative Well-log Analysis and Petrophysical Evaluation of Port Fouad Field, Offshore, Nile Delta, Egypt

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Abstract— The present study deals with the evaluation of subsurface geology and hydrocarbon potentialities of the Miocene Wakar Formation, based on surface borehole geological, quantitative well-log analysis that was encountered in Six exploratory and development wells, These wells were distributed in the Port Fouad Marin Field in the eastern part of the offshore Nile Delta area Egypt.

Keywords — Quantitative Well-log Analysis, Petrophysical Evaluation, Port Fouad Field, Nile Delta.

1 Introduction

THE Nile Delta basin is one of the most important gas producing provinces in Egypt and contains a thick sequence of potential hydrocarbon source rocks that generate essentially gas and condensate.

The total area of Nile Delta is 26,450 Km2 of which 19, 200 Km2 inland and 7,250 Km2 offshore. The Nile Delta is locate sedimentary build up began in the Miocene time with a very thick section of Late Tertiary – Quaternary sediments indicating a rapid and continuous deposition in a gradually subsiding basin. This section consists mainly of shale with sandstone intercalations.

Since 1993, renewed exploration of the offshore, eastern Nile Delta of Egypt has been dramatically successful.

Significant new gas fields have been found in Pliocene and Miocene sandstone reservoirs which have been tested with flow rates of 25 to 36 million cubic feet per day, with 500 to 2000 barrels of condensate. (Philip D. and Martin L. AIbertin 1998 Heppard).

In 1967 IEOC discovered the first gas field in the country, Abu Madi, one of the largest in Egypt.

Over the years, other significant gas discoveries have been made and put on production by eni: the onshore East Delta and El Qar', as well as the offshore Port Fouad, Darfeel, Barboni, Anshuga, Baltim East, Baltim North, El Temsah, Tuna, Denise and Denise South fields .

Thick sandstones in the Qantara, Sidi Salem, Wakar and Kafr El Sheikh Formations have proved to be the most suitable reservoir units in the study area (EGPC, 1994). Seals are provided by shales within the Sidi Salem and Wakar Formations

The Nile Delta is generally known as a natural gas-prone (esentiallymethane/gas condensate) region with production from Miocene and Pliocene fields.

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1.1 Area of Study

The study area is located in the eastern offshore area of the Nile Delta of Egypt, between long. 31^o 84', 32^o 44' E, and lat. 31^o 52', 31^{o}30' N approximately, 35 km NE of Port Said City, It measures about 13.85 in width and 10.40 km in length and a total area of 144 km2, Port Fouad Field is a big gas field discovered in 1992 by the International Egyptian Oil Company (IEOC).(Khaled K.A.,Attia G.M., Metwalli F.I. and Fagelnour M.S2014).

It lies in Petrobel's offshore North Port Said block. With reserves proven so far at 3 Trillion Cubic Feet (TCF) from reservoirs lying at a depth of 4,000 meters.

Port Fouad field came on stream in April 1996 to initial production 70 MCF/d of gas and 3,500 b/d of condensate. Wakar field lies also in the same block 17 km north of Port Said city, proving reserves of 1.5 TCF. The pay zone is at a depth of 4,000 meters. It began production in February 1997 from a platform similar to that used in Port Fouad, field with a capacity of 42 MCF/d of gas and 2,740 b/d of condensate.

The present study deals with the evaluation of subsurface geology and hydrocarbon potentialities of the Miocene Wakar Formation, based on surface borehole geological and well logging data that were encountered in five exploratory and development wells. These wells were distributed in the Port Fouad Marin Field in the eastern part of the offshore Nile Delta area (Fig 1).

1.2 Materials and Methodology

Reservoir Evaluation to evaluate the hydrocarbon potentialities of the studied interval on the light of the petrophysical and lithological parameters achieved for each well individually. Both petrophysical parameters evaluation and reserve estimation for the study area calculated by using the available wireline data for some conventional/advanced logging tools .

The well-logging data comprise resistivity, sonic, neutron, density, nuclear magnetic resonance, spontaneous potential,

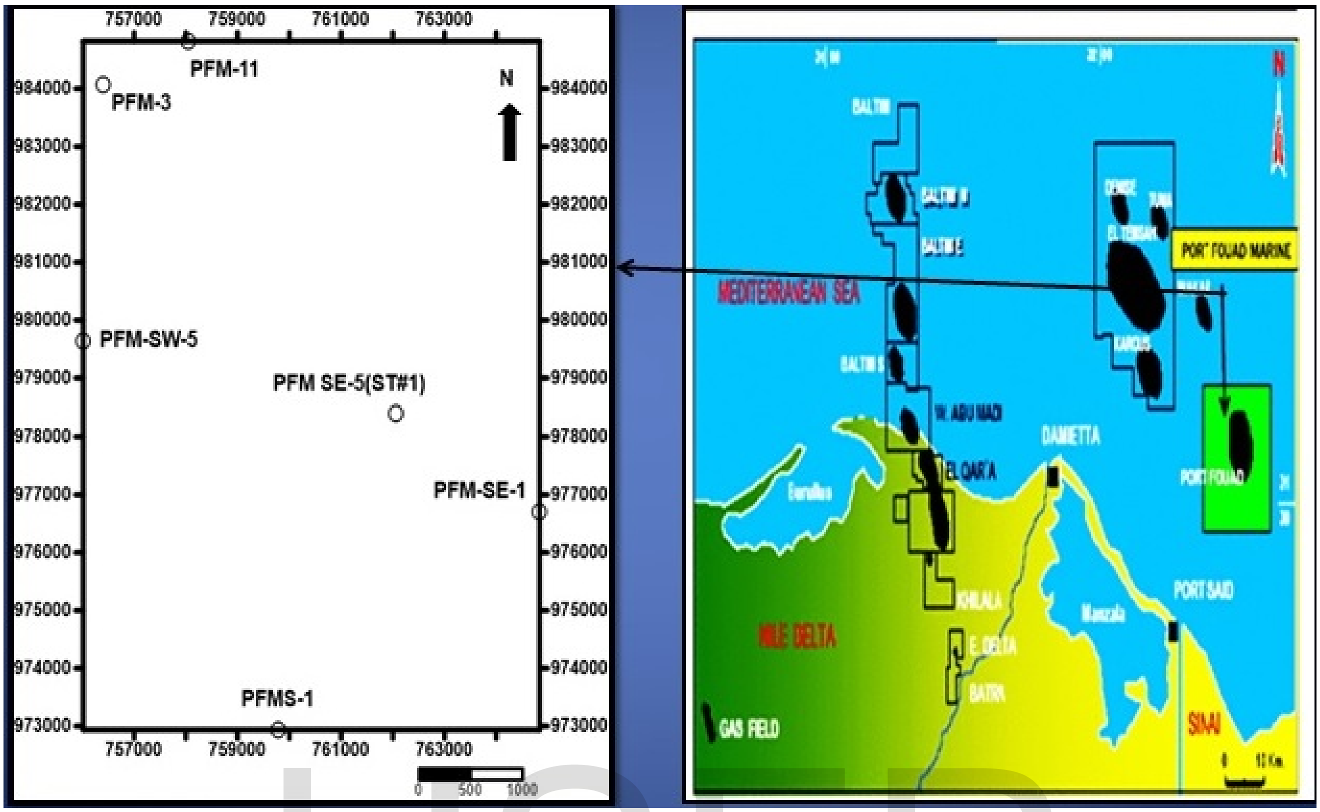

Fig. 1. Study Area and Location map of the Studied Wells, port fouad marine field, Nile Delta, Egypt, after Petrobel.

caliper, and gamma ray and natural gamma ray spectrometry logs, where the geological data are represented by composite logs.

A CPI was accomplished through IP Program, to determin the main petrophysical parameters (Vsh, PHI, Sw and Sg), net reservoir and net pay and to construct lithosaturation plots CPI and isoparametric contour maps.

Resistivity method and Pickett plots were used to estimate Formation water resistivity (Rw) in each reservoir.

2 SUBSURFACE GEOLOGICAL SETTING

The Nile Delta is one of the most important gas-producing provinces in Egypt. The geological framework and structural evolution of the Delta have been the subject of considerable research (see for example Said,1990; Kamel et al., 1998).

2.1 Stratigraphy

The lithostratigraphy of the Nile Delta has been studied by many geologists of which one may mention: (Said, 1962 and 1982); (Barakat, 1987); (Sarhan, Barsoum and Bertello, 1996); (Nashaat, 1990, 1992, and 2000).

The generalized stratigraphic sequence show in fig. 2.

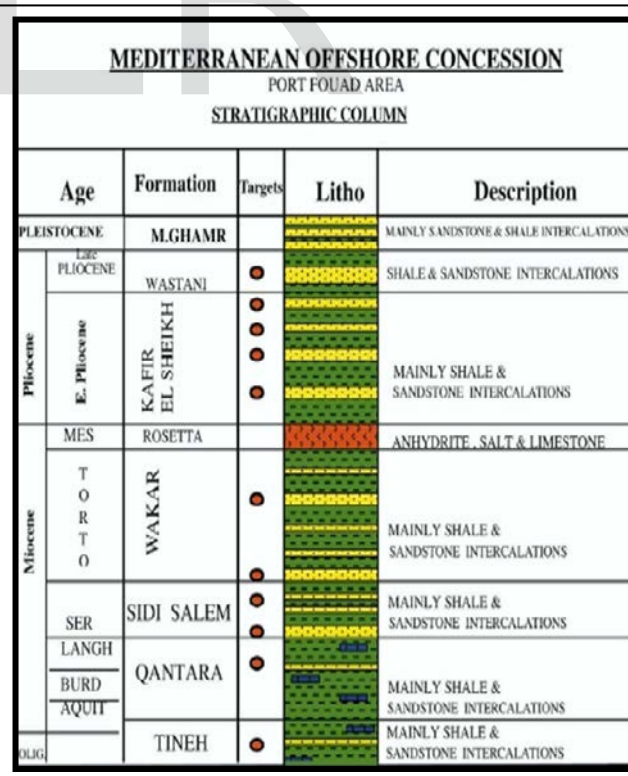

Fig: 2 Mediterranean offshore concession, aftet Petrobel.

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2.2 Structural Framework .

The Nile delta sub divided into two sub provinces by a faulted hinge line oriented WNW to ESW allocated at Kafr El Sheikh Latitude city. This hinge line is known as the faulted flexure that is separates the south delta province from the north delta plain basin. The southern delta province the subsurface structure is complicated by the interaction between tectonic elements of different ages and with different orientation on these structures is superimposed.These are The E-NE and NE trending folds of Late Cretaceous to Eocene age (the Syrian arc folds). The Oligocene to Early Miocene NW-SE trending faults which were associated with a major up lift in the south coupled with basaltic extrusion. The Late Miocene and Pliocene delta subsidence was mainly concentrated along the axis of the Nile valley

2.2.1 The Western margin of delta province

The western margin of the Nile Delta is marked by high nature, forms a ridge of Aptian carbonates, and seen at about 1.2 seconds on the seismic sections, The Natrun high block with basement at a depth of 12,000 feet, may have been a positive feature since the Paleozoic(Abdel Azim,2004).

2.2.2 The Northern slop province and faulted fexture:

In the intermediate "Slope" province over and north of the faulted flexure, rotated faulted blocks represent gravity-induced displacements on curved normal fault surfaces dipping sea ward (Fig. 3). The block separated by relatively planner faults in the zone of interest are four to eight kilometres wide and dip 3 to 8 to the south. Major displacement occurred in the Middle Miocene time, since the block are truncated by the Seravallian Tortonian unconformity and overlying younger strata are broken only rarely by the faults.

2.2.3 The Eastern Margin of the Delta Province

Along the eastern part of the intermediate “Slope " belt between Mansoura and the Suez canal, linear fault blocks from a series of E-W peripheral ridges created from the Middle-Upper Miocene uplift of Oligocene Lower Miocene fault blocks that are terminated towards the north by major E-W faults. These Structure were later inverted.

2.2.4 The South Delta province

Structure in the south delta providence affect essentially an Eocene to Triassic succession similar to that of the West Desert and North Sinai cross the southern part of the Nile Delta, in apparent continuity with a zone of liner uplifts SE of Khatatba. The north boundary of the area is marked by the faulted flexure where a rapid northward increase in slop of the Pre-Oligocene takes. In the south delta province, there is a contrast between structure in the southeastern part from Abu Sultan to Abu Roash-Khatatba, which have SW-NE and W-SW to E-NE trends. The north western and center delta regions, have a deep structure trending to E-W, W-SW and E-NE trend. Both types of structure were uplifted essential in the Late Cretaceous to Eocene and suffered considerable erosion.

2.2.5 The Nile Delta Core

On and under continental slop the surface sediments are affected by extensive superficial faulting, large scale slumping and diapiric phenomena. The north eastern margin of th Nile Delta and the south western margin of the Nile Delta cone is marked by the Bardawil escarpment which delineates a major W-NW to E-SE fault zone comprise of several seep N-NW to SE fault Zone comprise of several steep N-NE facing fractures and the S-SW ward tilting of sediments. Salt walls parallel the faults.

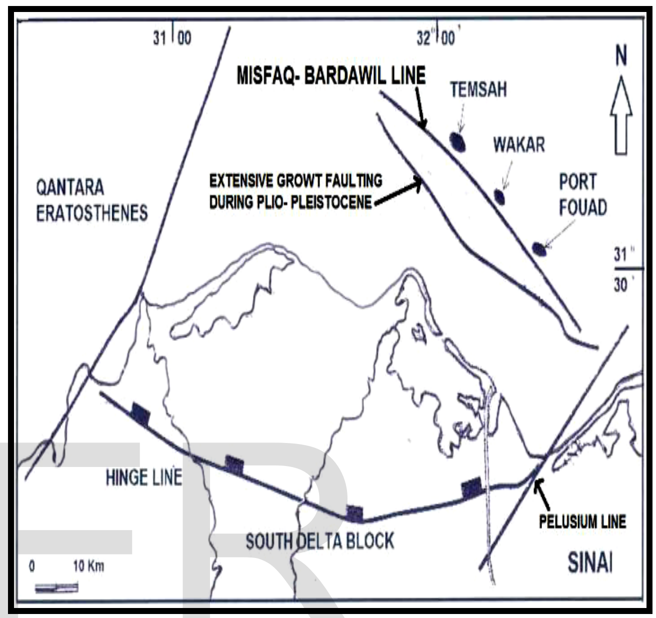

Fig.3 Regional structural setting, north Nile Delta.
Khaled K.A., Attia G.M., Metwalli F.I. and Fagelnour M.S.2014

2.3 Tectonic Setting

Tectonics has played a dominant role in the location and inthe structural and depositional history of the Nile delta. The region occupies a key position in the context of the plate-tectonic evaluation of the eastern Mediterranean and the Red Sea. It lies on the moderately deferent external margin of the African plate (the Unstable Shelf of Said, 1962) which extends well north of the Mediterranean coast.

The geological development of the Nile Delta and its submarine extension, the Nile cone is a recent phenomenon when compared with other major deltas, such as the Niger and Mississippi. The Nile Delta can be subdivided into the following structural sedimentary provinces (Fig. 4).

(A) The South Delta province, a continuation of Western Desert stratigraphic sequences and structure.
(B) The North Delta basin.
(C) The Nile cone.
(D) The Levant platform.

The basal rocks underlying the Neogene Nile Delta are the folded platform carbonates of the Mesozoic to Lower Eocene. Their location under the offshore Nile Delta and the major structural trends are presently unknown because they lie

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beyond both the usual recording time of commercial seismic data and the penetration of the deepest wells drilled.

The tectonic development and the deformation patterns in the Nile Delta are complicated by the interaction of diversely oriented structural features, which are the result of the following stages of tectonic deformation:

(A) The differential vertical movement of E-W oriented horst blocks and grabens a long the passive margin of the African plate as well as the overall subsidence of the Tethy a basin versus the up lift of the Afro-Arabian margin.

(B) The arching of the Red Sea region followed by NE–SW and NNE– SSW rifting and sea floor spreading as the Western Desert basement structure map show a NW-S right, lateral shear movement of regional extent, which together with the NNW to SSE faults, displace the NE-SW oriented Syrian Arc structures.

(C) Sediment loading at the expanding Plio-Pleistocene delta front resulted in the formation of growth faults, shelf margin slumping and normal faulting.

The northeast margin of the Nile Delta continental shelf is intensely down faulted with SW tilted blocks and a major WNW to ESE diaperic salt ridge forming the Bardawil fault zone. This feature belongs to original NW-SE fault system with dextral strike-slip component formed in the Late Miocene, which was later rejuvenated in the Pleistocene.

Fig.4: Major Structural Features in the Nile Delta.
(Sahran and Hemdan,1994).

3 WELL LOG INTERPRETATION & PETROPHYSICAL EVALUATION

3.1 Vertical Variation of Petrophysical Parameters, Wakar Fm. Sand Level-1

Vertical variation of petrophysical parameters was constructed for the studied wells in the area under investigation using IP (Interactive Petrophysics) program. In order to illustrate the vertical distribution of hydrocarbon saturation through petrophysical parameters, a number of litho-saturation crossplots were constructed. These plots exhibit a number of continuous logs showing the variations inherited in rocks materials and parameters against depth.

Figures From 5 To 10 represents the combined litho-saturation cross-plot of Study wells (Wakar Fm. Sand Level-1), Wakar Formation characterized by the predominance of shale and sandstone layers.The main target of this study is Sand Level -1.

3.1.1 Litho-Saturation Cross-Plot of PFMS-1 Well

Fig.5 Represent the combined litho-saturation cross plot for PFMS-1 Well (Wakar Fm. Sand Level-1).The net sand of Wakar Fm. Sand Level-1 is 0.6 meters, the shale content is about 14 %, the effective porosity is 30.5%, and the hydrocarbon saturation is about 55.7 %.

3.1.2 Litho-Saturation Cross-Plot of PFM-3 Well

Fig.6 Represent the combined litho-saturation cross plot for PFM-3 Well (Wakar Fm. Sand Level-1).The net sand of Wakar Fm. Sand Level-1 is 1.52 meters, the shale content is about 4 %, the effective porosity is 24.3%, and the hydrocarbon saturation is about 61.5 %.

3.1.3 Litho-Saturation Cross-Plot of PFM-SE-1 Well

Fig.7 Represent the combined litho-saturation cross plot for PFM-3 Well (Wakar Fm. Sand Level-1).The net sand of Wakar Fm. Sand Level-1 is 5.5 meters, the shale content is about 6 %, the effective porosity is 29.4%, and the hydrocarbon saturation is about 77.1 %.

3.1.4 Litho-Saturation Cross-Plot of PFM-SW-5 Well

Fig.8 Represent the combined litho-saturation cross plot for PFM-SW-3 Well (Wakar Fm. Sand Level-1).The net sand of Wakar Fm. Sand Level-1 is 6.23 meters, the shale content is about 5 %, the effective porosity is 23.3%, and the hydrocarbon saturation is about 68.8 %.

3.1.5 Litho-Saturation Cross-Plot of PFM-11 Well

Fig. 9 Represent the combined litho-saturation cross plot for PFM-11 Well (Wakar Fm. Sand Level-1).The net sand of Wakar Fm. Sand Level-1 is 2.3 meters, the shale content is about 1 %, the effective porosity is 25.6%, and the hydrocarbon saturation is about 59 %.

3.1.6 Litho-Saturation Cross-Plot of PFSE-5 Well

Fig. 10 Represent the combined litho-saturation cross plot for PFSE-5 Well (Wakar Fm. Sand Level-1).The net sand of Wakar Fm. Sand Level-1 is 3.25 meters, the shale content is about 13 %, the effective porosity is 13.7%, and the hydrocarbon saturation is about 5.7 %.

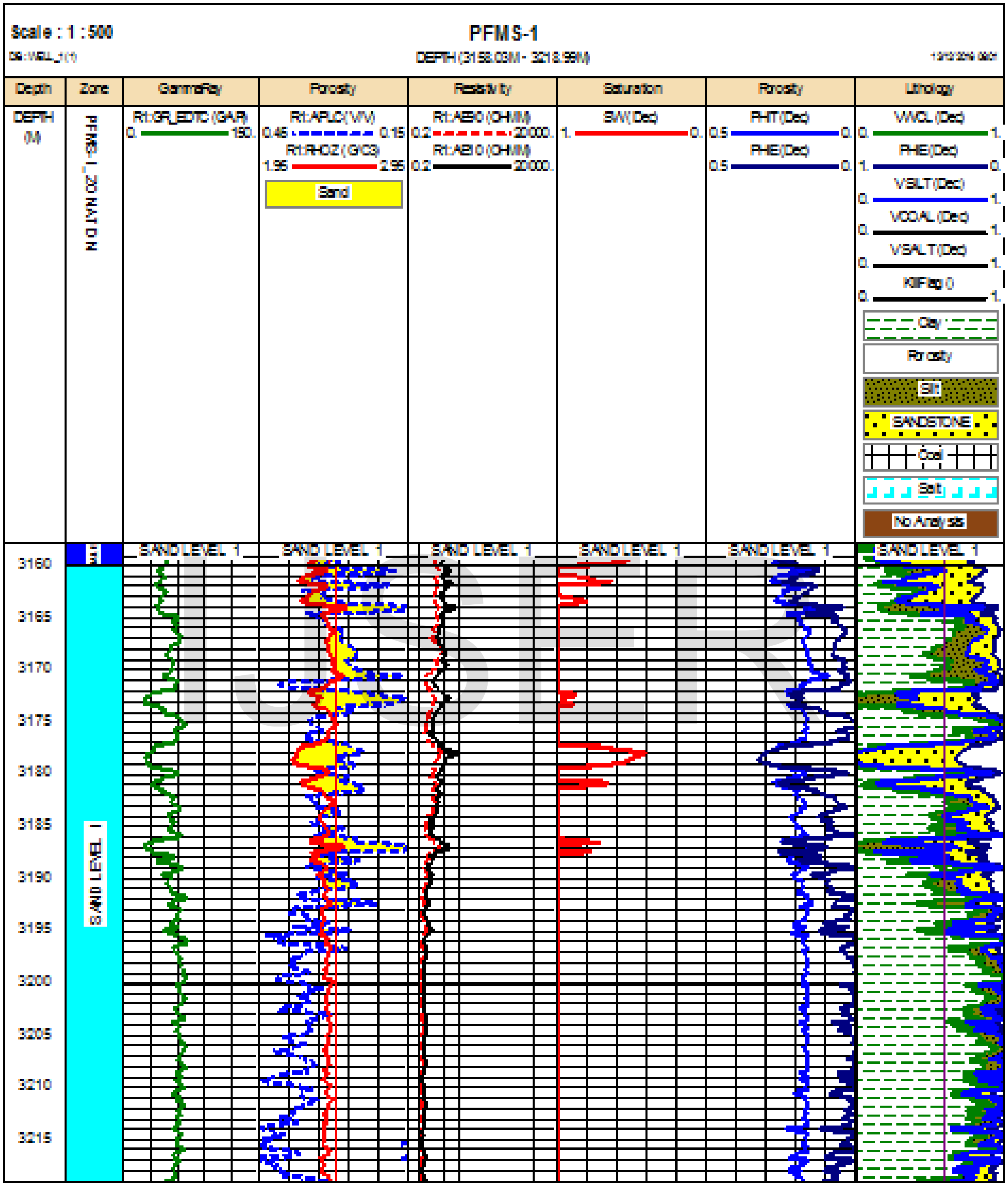

Fig.5 Litho-SaturationCross-Plot of PFMS-1 Well
(Wakar Fm Sand Level-1).

Fig.6 Litho-SaturationCross-Plot of PFM-3 Well
(Wakar Fm. Sand Level-1).

Fig.7 Litho-SaturationCross-Plot of PFM-SE-1 Well
(Wakar Fm. Sand Level-1).

Fig.8 Litho-SaturationCross-Plot of PFM-SW-5 Well
(Wakar Fm. Sand Level-1).

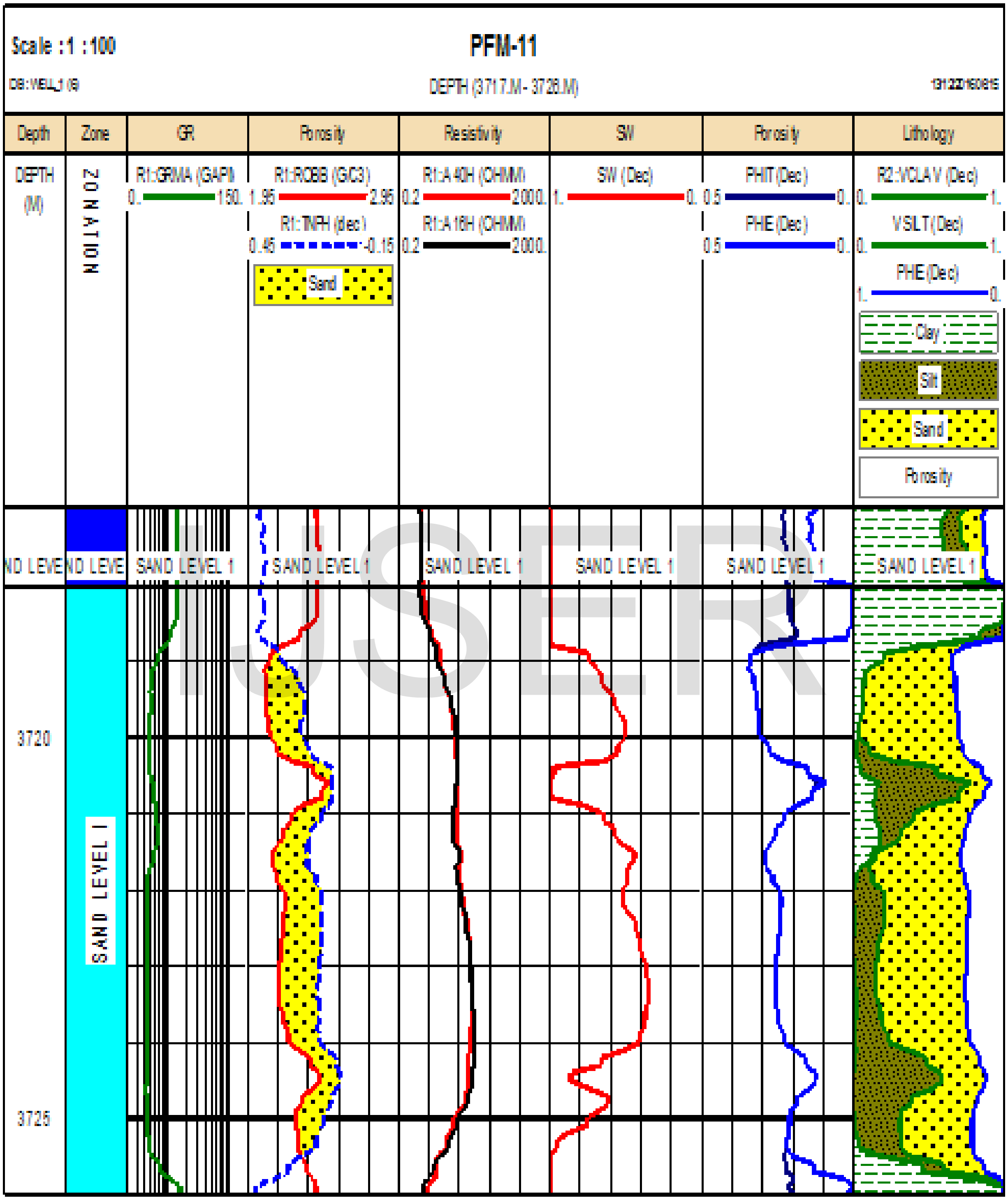

Fig.9 Litho-SaturationCross-Plot of PFMS-11 Well
(Wakar Fm. Sand Level-1).

Fig.10 Litho-SaturationCross-Plot of PFSE-5 Well
(Wakar Fm. Sand Level-1).

3.2 Lateral Variation of Petrophysical Parameters, Wakar Fm. Sand Level-1

Four iso-parametric contour maps of Wakar Fm. Sand Level-1 were constructed to illustrate the lateral distribution of the petrophysical parameters in the investigated area figure 11.

As illustrated in fig.11 Effective thickness of Wakar Fm. Sand Level-1 increases in the Western and South Eastern part of the study area, Shale volume increases in the South Western part, Effective porosity and Hydrocarbon saturation increases in the South Eastern part in the investigated area.

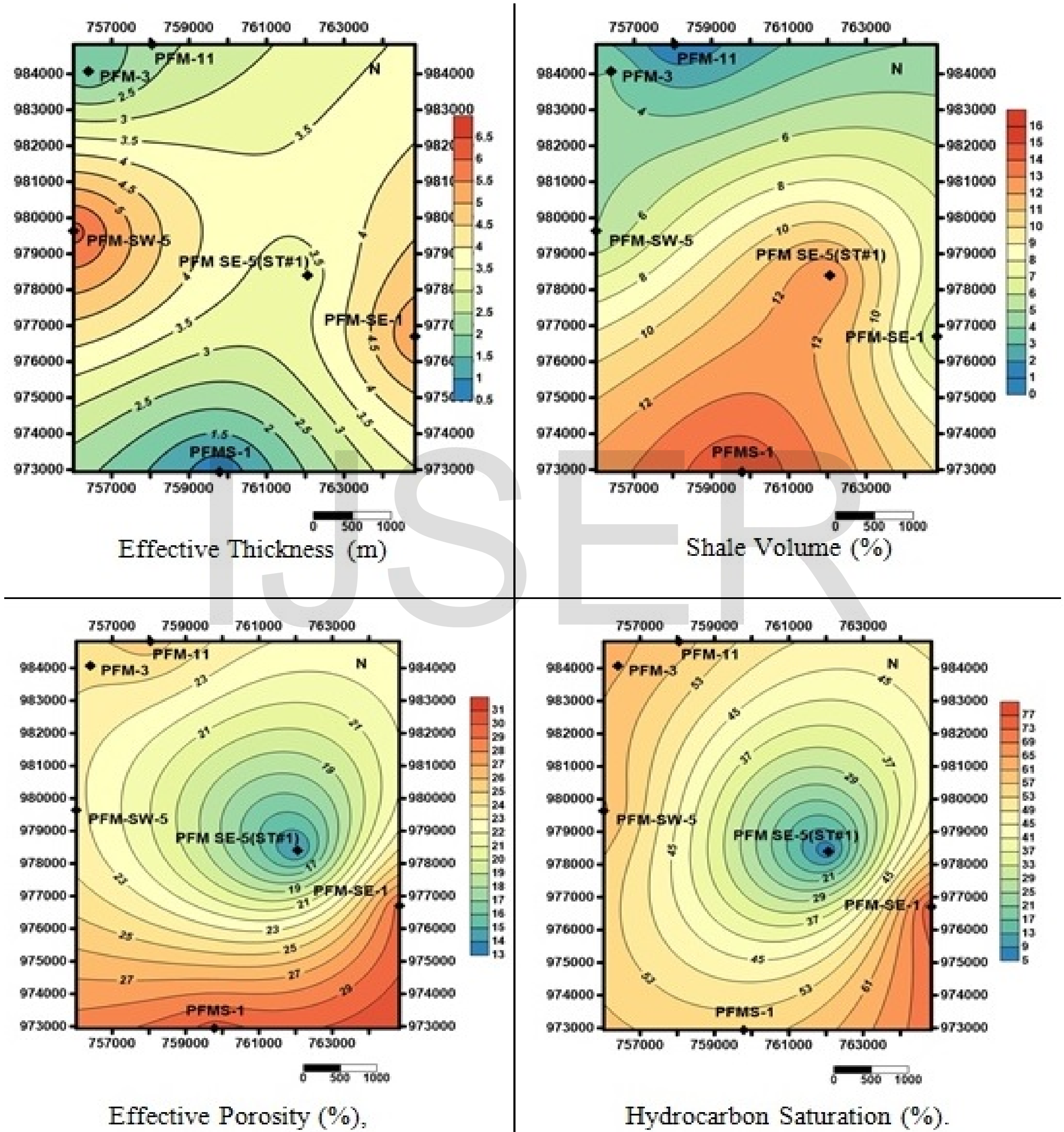

Fig.10 Distribution of Wakar Fm. Sand Level-1 Petrophysical Parameter.

SUMMARY AND CONCLUSIONS

The present study deals with the evaluation of subsurface geology and hydrocarbon potentialities of the Miocene Wakar Formation, based on surface borehole geological, quantitative well-log analysis that was encountered in Six exploratory and development wells (PFMS-1, PFM-03, PFSE-1, PFM-SE-05, PFM-SW-05 and PFM-11).

These wells were distributed in the Port Fouad Marin Field in the eastern part of the offshore Nile Delta area Egypt, The target obtained in the present study is Wakar formation and especially Sand Level 1 zone the most productive one.

As a result of evaluating reservoir rock in Port Fouad Field through Computer Processed Interpretation (CPI), it can be concluded that the main reservoirs in the investigated area is Wakar Formation Sand Level 1.

The net sand (Effective thickness) of Wakar Fm. Sand Level-1 ranges between 0.6 and 6.25 meters and increases in the Western and South Eastern direction of the study area, Shale volume ranges between 1 and 15% and increases in the South Western direction, Effective porosity ranges between 13.7 and 30.5 and increases in the South Eastern direction, and the hydrocarbon saturation varies between 5.7 and 77.1 % and increases South Eastern direction in the investigated area.

Based on the output data in this study, it is highly recommended to drill new wells in South east direction for the following reasons: Increase in the net sand thickness of Wakar Formation, Decrease Shale volume in Side Sand Levels, Increase in the Effective porosity and Hydrocarbon saturation.

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