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PETROPHYSICAL EVALUATION OF WAKAR FORMATION, PORT FOUAD MARINE FIELD, OFFSHORE NILE DELTA

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ABSTRACT

The offshore Nile Delta is emerging as an important source of natural gas for Egypt. Port Fouad Marine field is a big gas field discovered in 1992 by the international Egyptian oil company in the eastern part of the offshore Nile Delta, it is a gas producer from Wakar reservoir. It is located between longitudes 31° 84', 32° 44'E and latitudes 31° 52', 31° 30'N.The aim of this study is to determine the petrophysical parameters of wakar reservoir that are estimated from the analysis of the available log data such as (GR, neutron,density and Resistivity logs) of four wells (PFM-1, PFM-2, PFMSE-1and PFM-3 by using Schlumberger techlog, (2015.3) software. The Wakar reservoir classified into three levels of S-1, S-2 and S-3. The lithologic components of the three levels are mainly shale and some `sandstone that determined using neutron & density cross plot. The resultant petrophysical parameters values revealed that Wakar level S-1 is gas bearing zone except PFM-2 well and Wakar level S-2 is gas productive zone in PFM-3 only. But Wakar level S-3 is mainly water bearing in all wells. Wakar level S-1 show the most advanced petrophysical characterization as a desired reservoir with shale volume ranges from 5.6% to 17.2%, good effective porosity ranges from 14.7% to 24.9% and high values of hydrocarbon saturation ranges from 46.4% to 72.1%. wakar level S-2 in PFM-3 with shale volume 0.7%, effective porosity 21.8%, water saturation 63.8%n and hydrocarbon saturation 36%. Finally drawing Iso-parametric maps of petrophysical parameters to reflect the variation of reservoir properties in the area of study.

Key Words: petrophysical parameters - Wakar Formation - iso -parametric map -Port Fouad marine field.

INTRODUCTION

The area of study is located in the eastern offshore area of the Nile Delta between longitudes 31° 84' and 32° 44' E and between latitudes 31° 52' and 31° 30'N. It lies in petrobel's offshore north Port said block covering offshore concession to the north of Port Fouad city with 13,85KM width, 10,40 KM in length and total area 144Km2 (Fig.1).

The offshore Nile Delta is emerging as an important source of natural gas for Egypt and will increase in economic importance as depletion of the major oil fields of the Gulf of Suez. Until the Mid-1990, Nile Delta was considered minor hydrocarbon province as the exploration had been confined to shallow water and perceived weak gas.

This study aims to evaluate petrophysical parameters of Miocene Wakar Formation such as volume of shale, total and effective porosities and hydrocarbon saturation in addition to determine the lithology using neutron - density cross plot which are encountered in four studied wells .the parameters distribution represented horizontally through a number of maps and vertically through the lithosaturation cross plots.

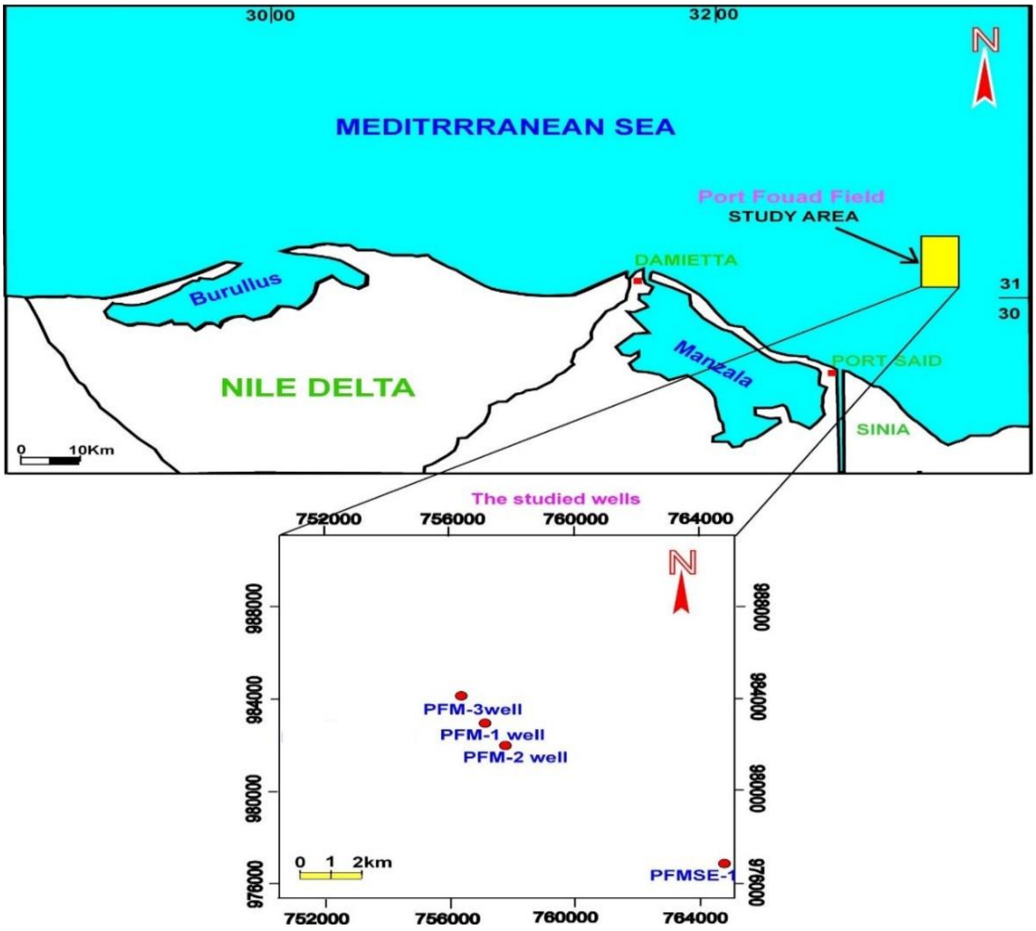

Fig. 1: Location map of the study area and location map of studied wells.

GEOLOGIC SETTING

The Nile Delta is a part of the Egyptian Mediterranean coast with area of about 25000 Km^2.Its surface slopes gently northwards, where the difference in elevation between its apex in the south and the Mediterranean coast is 18 m (El-Ashry, 1979). The Nile Delta as a petroliferous province is bordered from the south by latitude 30ºN, the Rosetta branch to the west, and the isobath of approximately 50 meters to the north and the Damietta branch to the east (Hamouda and Abdel Salam, 2010).

Tectonics has played a dominant role in the location and in the structural and depositional history of the Nile Delta (Fig.2). The Nile Delta occupies a key position within the plate tectonic development of the eastern Mediterranean and the Levant (EGPC, 1994).

The structural trends of the Nile Delta were recognized by four major groups of faulted trends northeast-southwest trend (Rosetta trend, pelusium trend, Qattara-Eratosthenes line), northwest-southeast trend (Temsah trend and Bardawil line), E-W Coastal fault trend (Tethyan trend and hinge zone) and minor fault trend dividing the Nile Delta into provinces; The South Delta province, The North Delta province, The Nile cone and Western and Eastern Delta province (Zaghloul, 2001: Sestini, 1995: Said, 1990: Sarhan and Hemdan, 1994). Temsah trend separates the Eastern sub-basin from the central sub- basin. This study is focusing on Wakar Formation which is assigned in the eastern sub basin Port Fouad Marine field where the four reactivated fault system (qattara-Eratosthenes line, temsah trend, pelusium trend and hinge zone) are dominant.

Lithostratigraphy of the Delta area is much different from that adopted for the outcrops around it (Fig.3). Wakar Formation which is the focusing of this study in eastern basin of Nile Delta is of Late Miocene (Tortonian) age. Its upper boundary unconformably underlies the evaporitic facies of the Rosetta Formation while its lower boundary unconformably overlies the shaly facies of the Sidi Salem Formation. (Kamel et al, 1998: Nabawy and Shehata, 2015). Wakar Formation contains level S-1, level S-2 and level S-3 in Port Fouad Field,that is composed mainly of shale with minor sandstone and siltstone streaks.

DATA AND METHODOLOGY

The wells studied are: PFM-1, PFM-2 and PFMSE-1and PFM-3. The available well logs data of the four studied wells include density, neutron, gamma ray, resistivity, and composite logs, courtesy of petrobel Petroleum Company.

The interpretation of lithology of the Waker was undertaken using all the logs registered through a systematic approach, and lithology was determined from logs using some types of cross plots (neutron-density cross plot). The well log evaluation has been achieved by using Interactive Petrophysics software (IP). The reservoir parameters of Waker reservoirs extracted from the well logging data include the distribution of total thickness, total porosity, effective porosity, water saturation, shale volume, net sand thickness, net to gross and net pay thickness, hydrocarbon saturation, residual hydrocarbon saturation and movable residual hydrocarbon saturation. For the net pay cut-off , the reservoirs were defined by the porosity greater than 10 % and shale volume less than 35%., if the water saturation within the reservoir is less than 65%, it is considered to contain hydrocarbon. The parameters distribution represented horizontally through a number of maps and vertically through the lithosaturation cross plots.

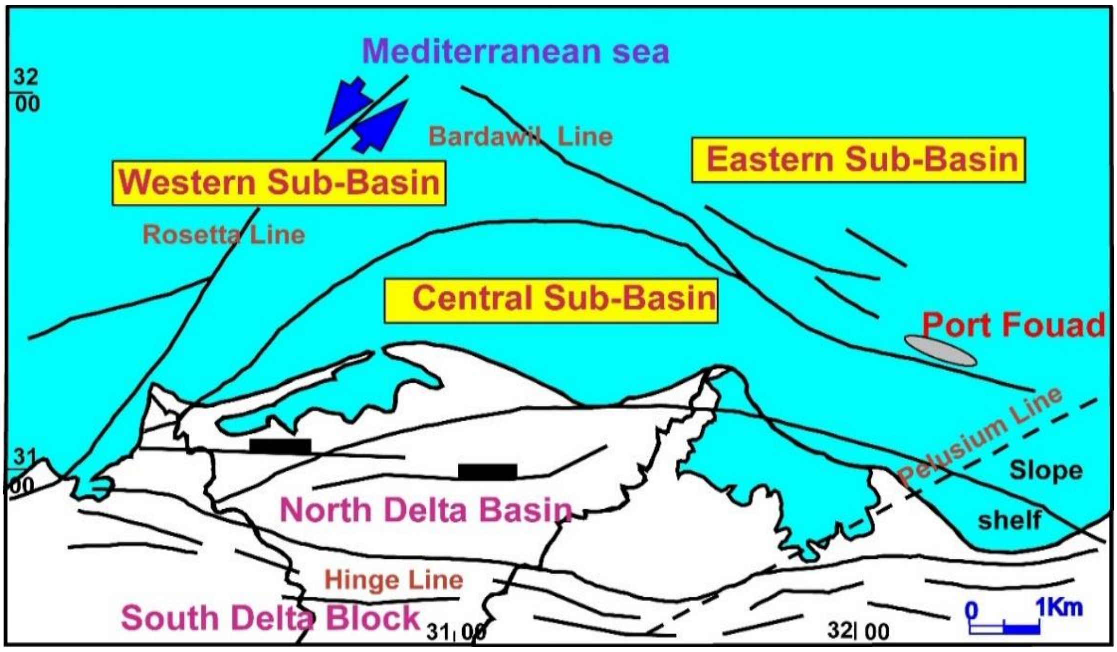

Fig. 2: Major structural features in the Nile Delta (Hemdan et al 2002).

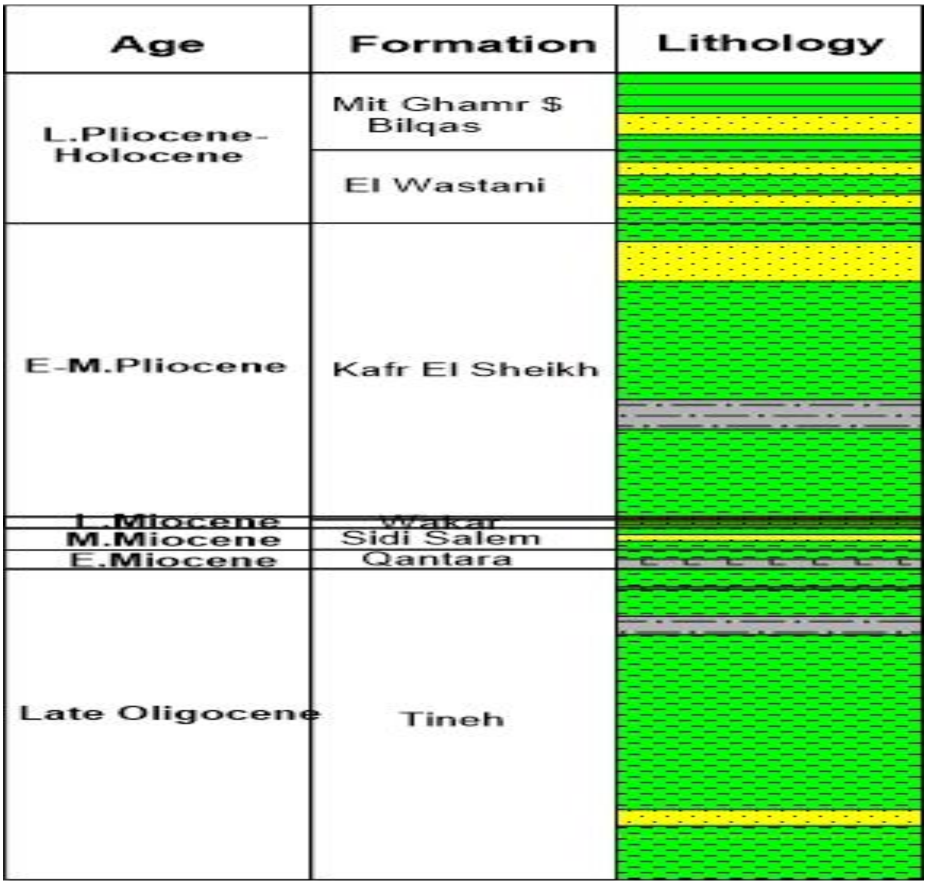

Fig. 3: Lithostratigraphic column of the Nile Delta (EGPC 1994).

RESULTS AND DISCUSSION

1 Determination of lithology and porosity from Neutron-Density crossplots

The cross plots used in this work are the Neutron-density crossplots. The Neutron- Density cross plots are commonly used to determine the lithology (using the neutron and density logs) and accurately evaluate the matrix porosity of carbonate rocks. The effect of light hydrocarbons (gas) can be observed on the cross plot, where the plotted data tend to shift north-westerly from the limestone line, since this effect increases porosity determinations from density log and decreases neutron porosity. Also, the effect of shale can be observed on the cross plot, where the shale effects tend to be in the southeast quadrant of the cross plot (Poupon and Leveaux ,1971). Neutron Porosity versus bulk density in the four wells through Wakar Formation, reflect that the plotted points are scattered in between sandstone and limestone with porosity ranging from10% to 30%. The majority of points are scattered downward through 2 dolomite line due to the effect of shale. This indicates the presence of shale lithology mixed with sandstone, limestone and dolomite streaks (Fig. 5).

2 Vertical distribution of Wakar reservoir

The main results of the petrophysical analysis are represented in table.1 and figures (6-7).based on these results in PFMSE-1 well there is one gas-bearing zone and two water-bearing zones. Gas-bearing zone is wakar LevelS-1 which is covered interval 3128.5 m to 3155m with thickness 26.5m, with 4.05 m gross sand and 3.45 net pay, it reflects a good pay with average 24.9% effective porosity, average 5.6 %volume of shale and 27.9% water saturation. The other two water-bearing zones are Level S-2 and S-3; level S-2 is covered interval 3198.5 m to 3235m with thickness 36.5, with 0.75m gross, average 12.4% porosity average 5.1 %volume of shale and 100% water saturation, level-3 with interval from 3249.5 to 3255.5 m with thickness 6m, with 3.45m gross sand completely saturated with water with average porosity 18.5% and with average 9.7% volume of shale. In PFM -3 Level S-1 gas-bearing zone with 16m thickness from 3048m to 3064m, with 8.5m gross sand and 1.4m net pay, it is a good pay with average porosity 21.1%, average volume of shale 9.7% and average water saturation 53.6%. The top of Level S-2 is 3105m with 11m thickness, 1.8 gross sand and 0.3 net pay, it reflects good pay with average porosity 21.8%, average volume of shale 0.7% and average water saturation 63.8%. S-3 is water-bearing zone covers interval from 3141m to3145m with 4m thickness, 1.3 gross sand completely saturated with water, average porosity 19.2% and average volume of shale 6.5%, it is not detected as pay zone. In PFM-2 well all levels are water bearing. level S-1 with interval from 2987 to 3017 m with thickness 30m, 1m gross sand which is completely saturated with water with average porosity 14.7% and average 5.6%volume of shale, it is not detected as pay zone.

The top of level S-2 is 3072m with thickness 5.8m, 0.5m gross sand which is 100% saturated with water with average porosity 15.4% and average volume of shale 8.8%. Level S-3 is covered interval from 3191 to 3220 with 29m thickness, gross sand 3.2m completely saturated with water with average porosity 18% and average volume of shale 18.7, also not detected as pay zone.so PFM-2 well is 100% water saturation so this well was plugged and abandoned . in PFM-1well only level S-1is appeared, which covers interval from 3010.5 m to 3043 m with 32.5 m thickness, 16.9 m gross sand and 11.58 m net pay with average effective porosity 18.8%, average volume of shale 17.2% and average water saturation 44.2% all reflecting a good pay .There is no wire line data are available for level S-2 and level S-3.

From all above the main reservoir in the study area is Wakar level S-1which is productive in all wells except PFM-2 well, Level S-2 is productive in PFM-3 well only, and level S-3 is not productive in all wells.

3 lateral distribution (Iso-Parametric maps)

3.1 isopach map

The thickness of Wakar level S-1 ranges from 16m in PFM-3 to 32.5 in PFM-01 well,This thickness increases toward the north west direction of studied area where PFM-01 well (Fig.8.a) Thickness of level S-2 ranges from 5.8m PFM-2 to 36.5m PFMSE-1,this thickness level decreases from south east where PFMSE-1 to north west where PFM-2 and pfm-1(Fig.10.a).

3.2 Gross sand map

Gross sand of Wakar level S-1 ranges from 1.07m in PFM-2 well to 16.9m in PFM-01 well, Its distribution map shows that the thickness of sandstone increase from south east to north west where the maximum thickness in PFM-1 well except in PFM-2(Fig.8.b) .

In Wakar level S-2 gross sand thickness varies from 0.45m in PFM-2 well to 1.8m in PFM-3 well, Gross sand distribution map of S-2 shows the gross sand decreases from south east where PFMSE-1 and north west where PFM-3 to the center where PFM-2(Fig.10.b).

3.3 Net pay map

The net pay distribution map of Wakar level S-1 show that the net pay thickness disappear in the center of study area and increase in two direction south east and north west reaching to maximum value in north west direction in PFM-1well equal 11.58m (Fig.8.c) .

The net pay distribution mapof S-2 level reveals that the net pay appears in north west where PFM-3 and disappear in south east where PFMSE-1(Fig.10.c).

3.4 Porosity map

The average effective porosity of Wakar level S-1 varies from 24.9% in PFMSE-1 to 14.7% in PFM-2,its distribution map of show that effective porosity increases in south east where

PFSE-1 well reaching 24.9% and decrease in north direction where PFM-2 well reaching 14.7% (Fig.8.d) .

Effective porosity of S-2 ranges of12.4% in PFMSE-1 well to highest value in PFM-3 21.8%,its distribution map reveals that the effective porosity increases from south east where PFMSE-1 (12.4%) passing through PFM-2(15.4%) to north west where PFM-3 21.8% (Fig.10.d).

3.5 Shale volume map

Shale volume distribution map of level S-1 reveals the shale content increase from south east of study area where PFMSE-1 equaling 5.6% to north where PFM-1 well reaching the maximum value equal 17.2% in then decrease in north west direction equaling 9.7 % in PFM-3 (Fig.9.e).

Shale volumes of S-2 ranges from 0.7% in PFM-3 well to PFM-2 (8.8%), Its lateral distribution map shows the shale volume increases from south east where PFMSE-1 and north west where PFM-3 to the center where PFM-2 (Fig.11.e).

3.6 Water saturation and hydrocarbon saturation map

The water saturation of Wakar level S-1 ranges from 27.9% in PFMSE-1 to 100% in PFM-2 well,its distribution map (Fig.9.f) shows the increasing toward the central part of study area where PFM-2 well and decreasing in all direction equaling 44.2% PFM-1 and 53.6% PFM-3 in north west direction, 27.9% PFMSE-1 in south east direction. Vice versa hydrocarbon saturation decreasing from North West equaling 55.8% PFM-1 and 46.4% PFM-3, and south east equaling 72.1% toward the center equal 0% in PFM-2(Fig.9.g).

S-2 level shows different Water saturation from well to another ranges from 63.8%in PFM-3 to 100% in PFM-2 and PFMSE-1, its distribution map shows the increasing in south east where PFMSE-1and in center where PFM-2 and decreases in north west where PFM-3(Fig.11.f).Vice versa hydrocarbon saturation ranges from 36.2% inPFM-3 to zero in PFMSE-1 and PFM-2, Its hydrocarbon saturation distribution map shows the increasing from south east and center to north west PFM-3(Fig.11.g). The main factor controlling (S-1) and (S-2) reservoirs quality is volume of shale as the shale volume increase, the effective porosity and hydrocarbon saturation decrease.

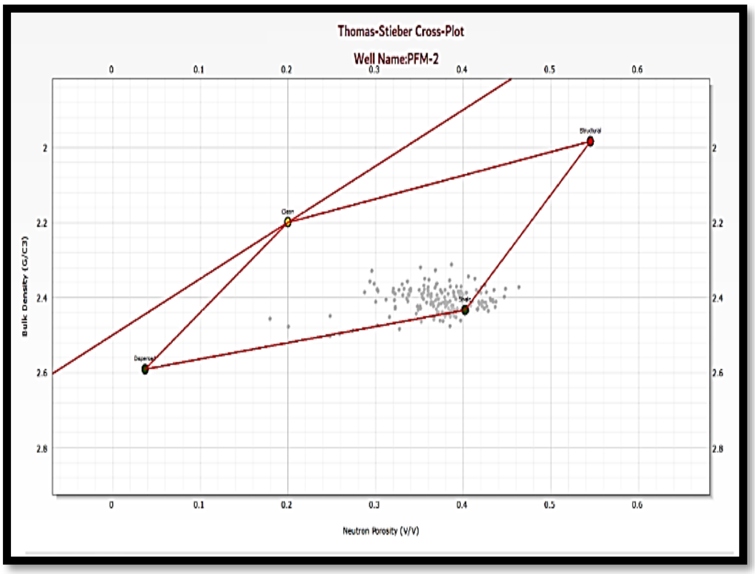

Fig. 4: Thomas Stieber cross plot of PFM-2 well

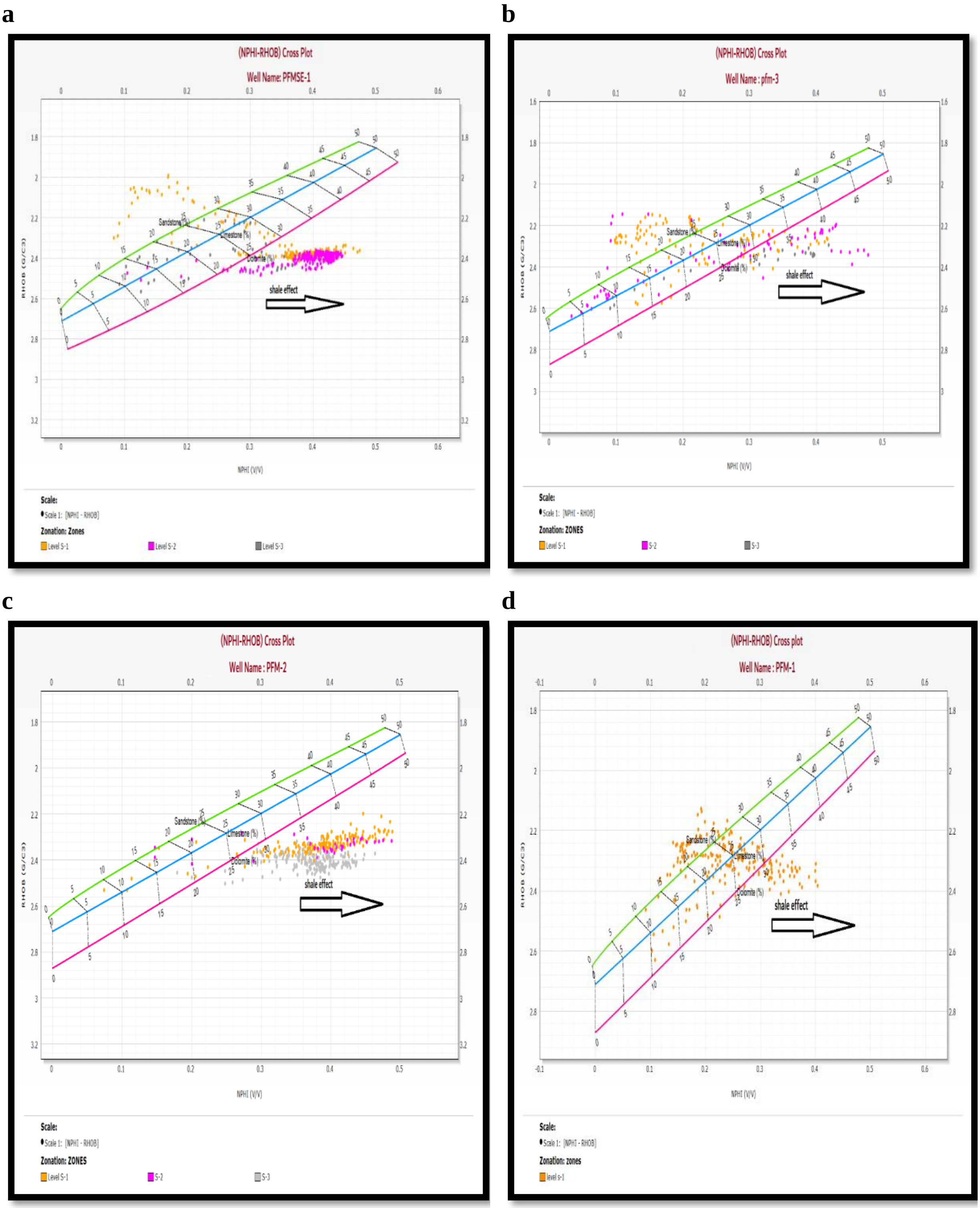

Fig. 5: Neutron-Density cross plot of PFMSE-1 well (a), PFM-3 well (b), PFM-2 well (c) and PFM-1 well (d).

a b

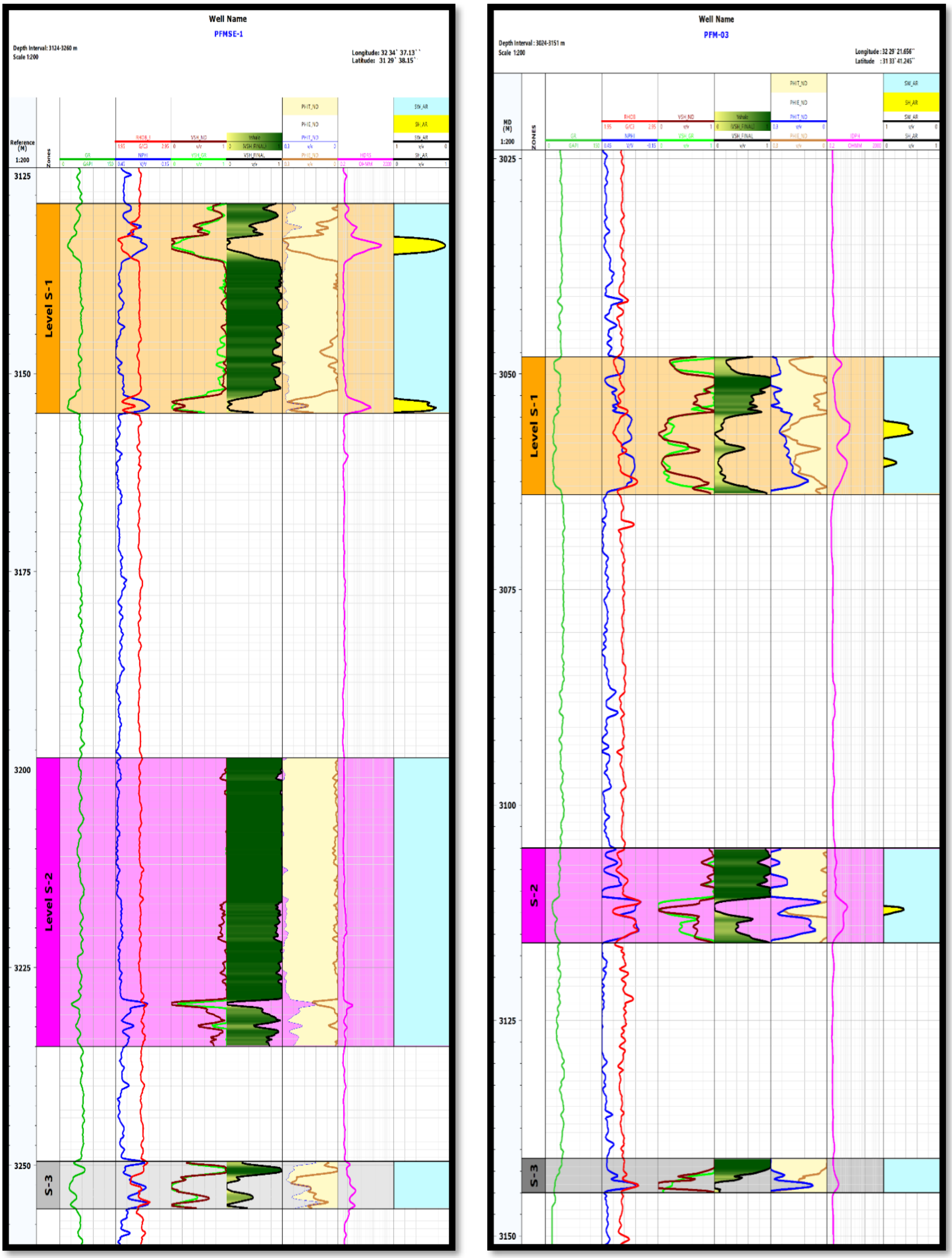

Fig. 6: The presentation of log interpretation of PFMSE-1 well (a) and PFM-3 well (b).

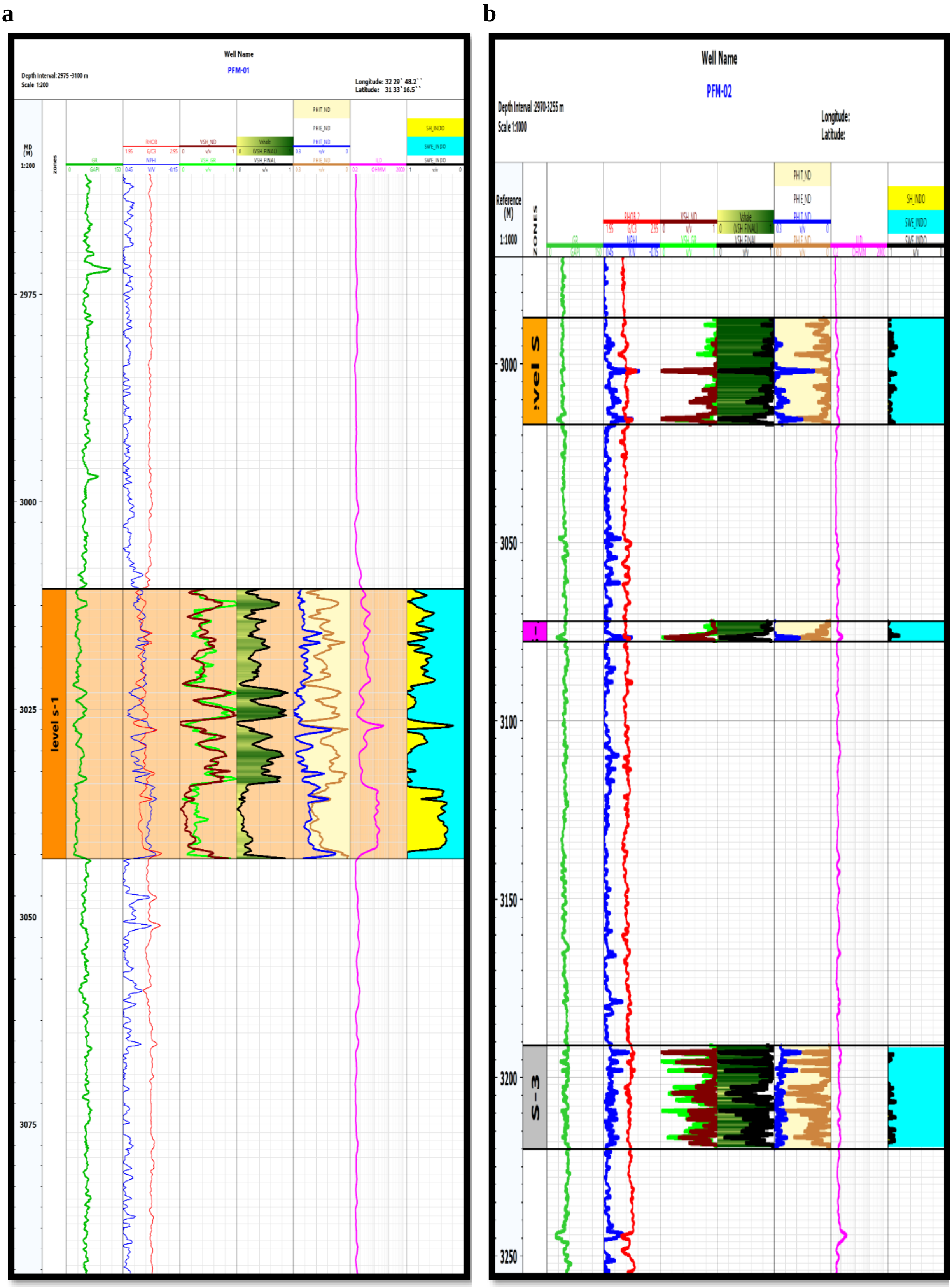

Fig. 7: The presentation of log interpretation of PFM-1 well (a)and PFM-2 well(b).

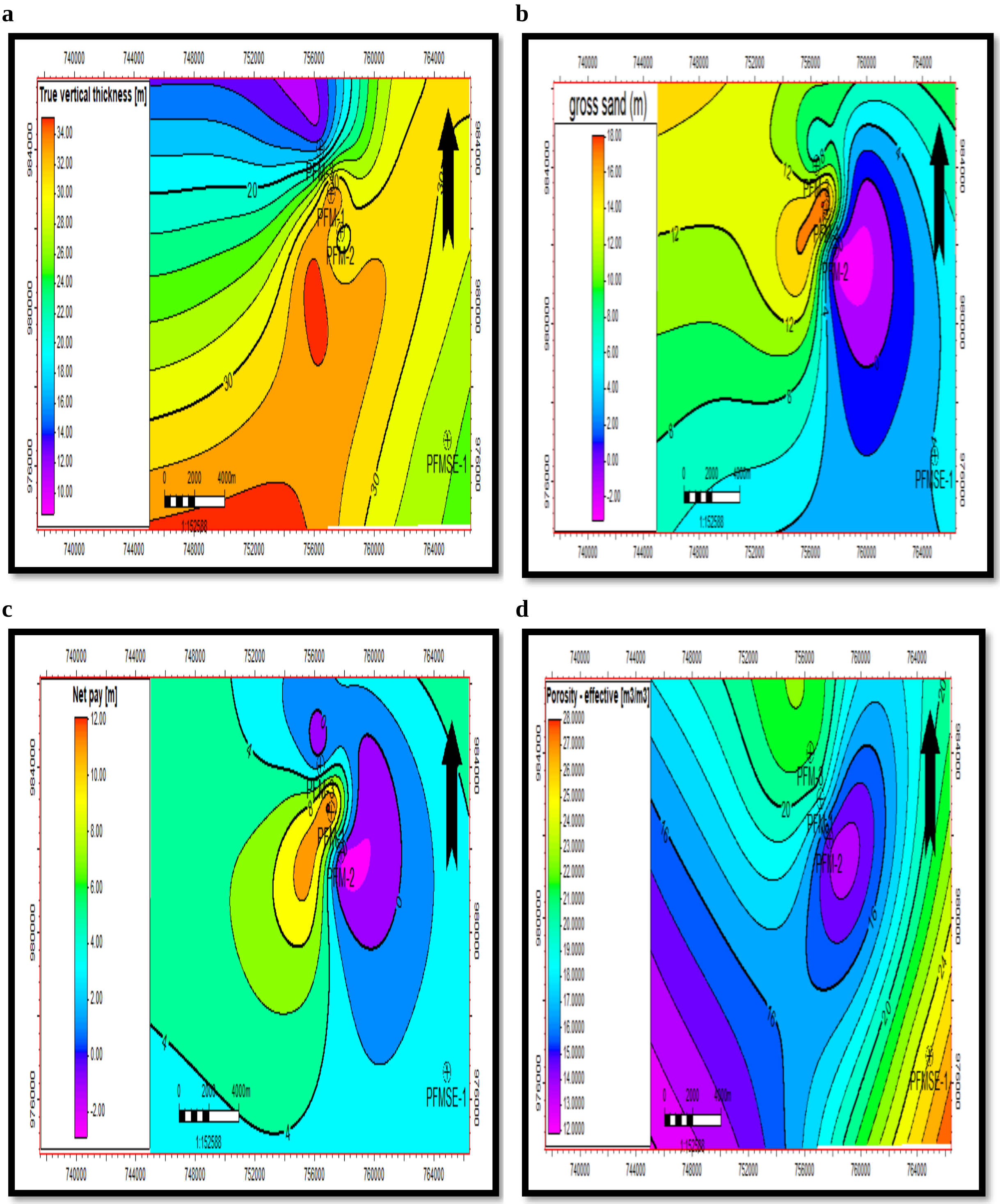

Fig. 8: Maps showing Isopach map (a), gross sand map (b), net pay map(c) and average effective porosity map (d) of Wakar level S-1 reservoir.

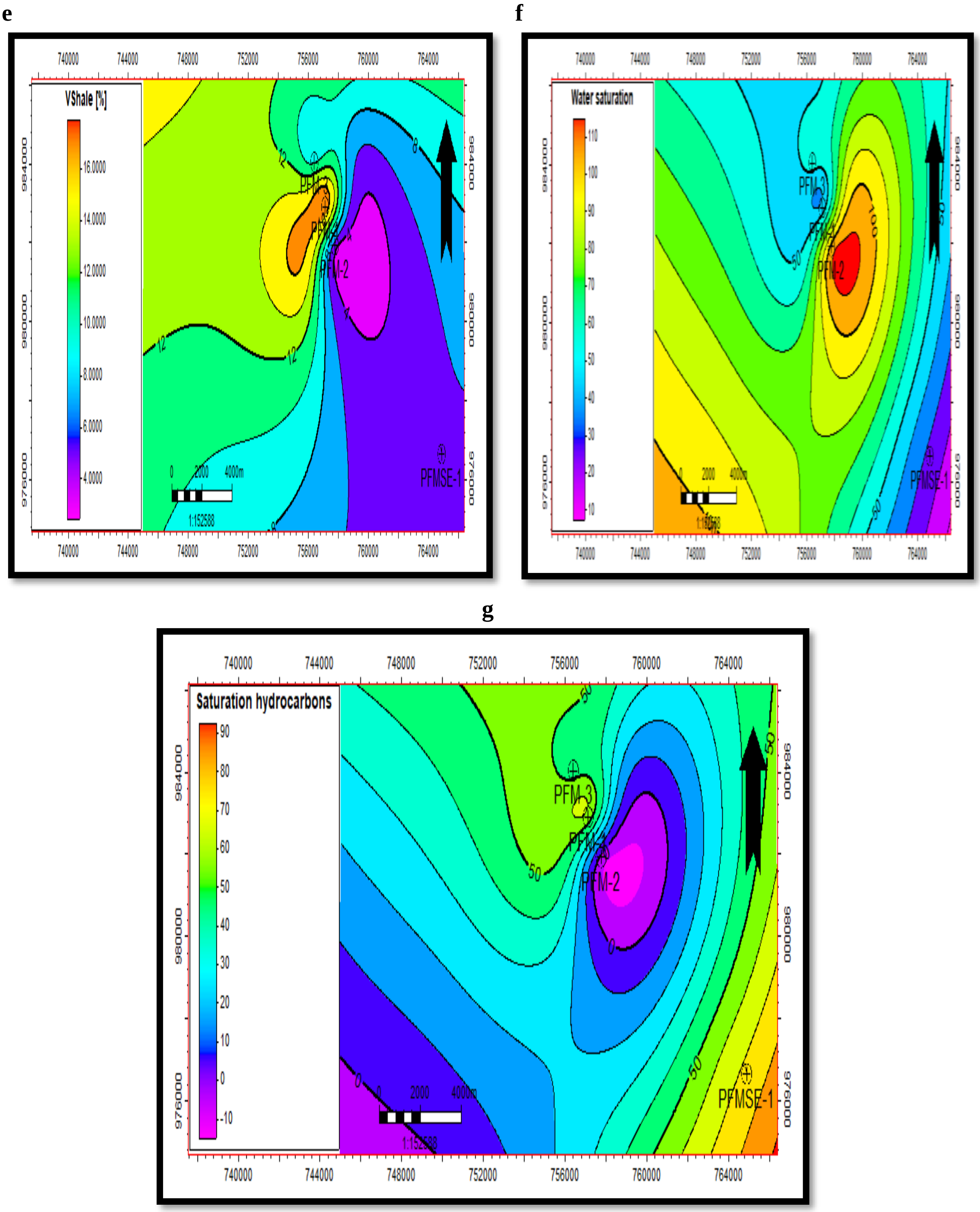

Fig. 9: Maps showing average shale volume map (e), average water saturation map (f) and average hydrocarbon saturation map (g) of wakar level S-1 reservoir.

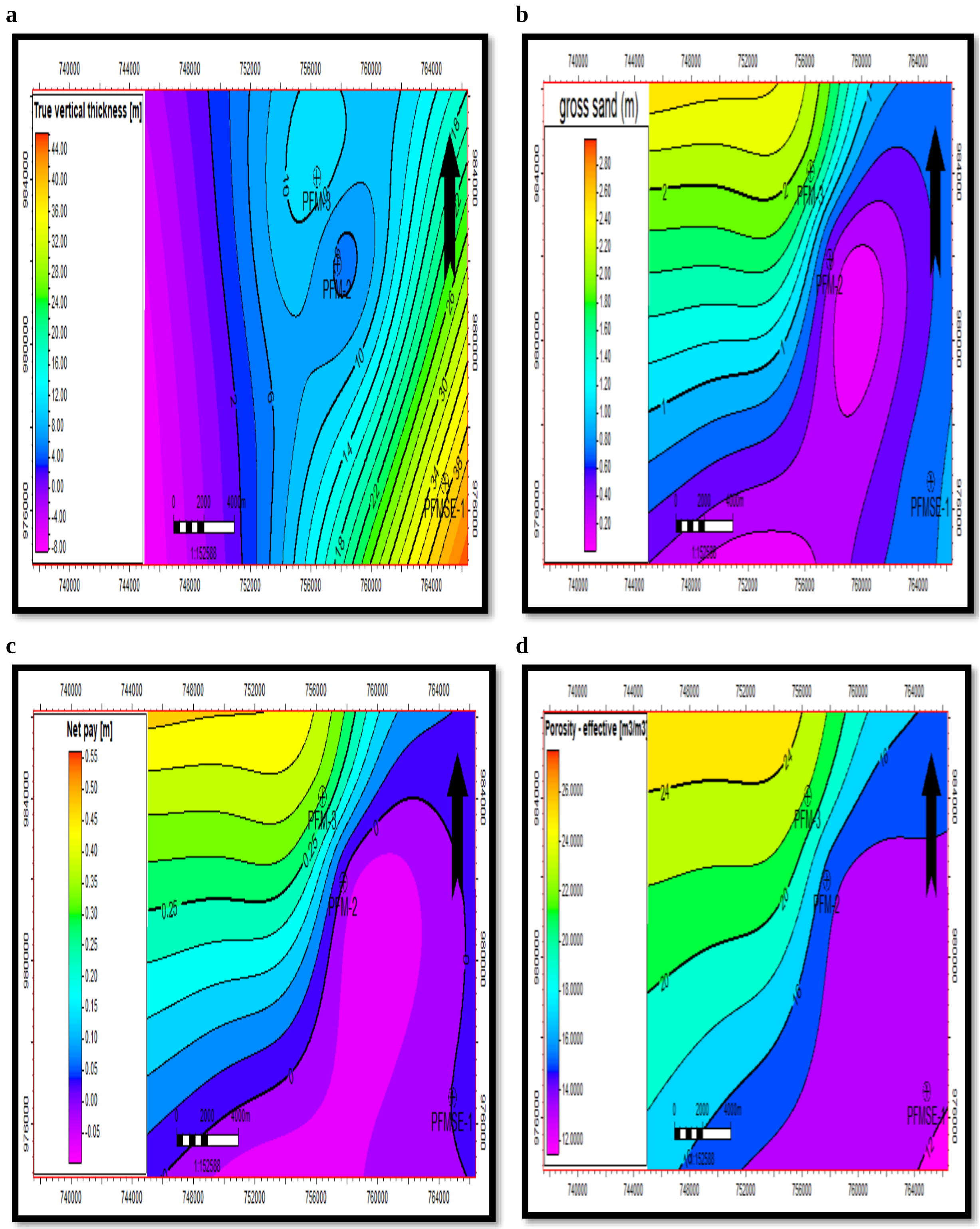

Fig. 10: Maps showing Isopach map (a), gross sand map (b), net pay map(c) and average effective porosity map (d) of Wakar level S-2 reservoir.

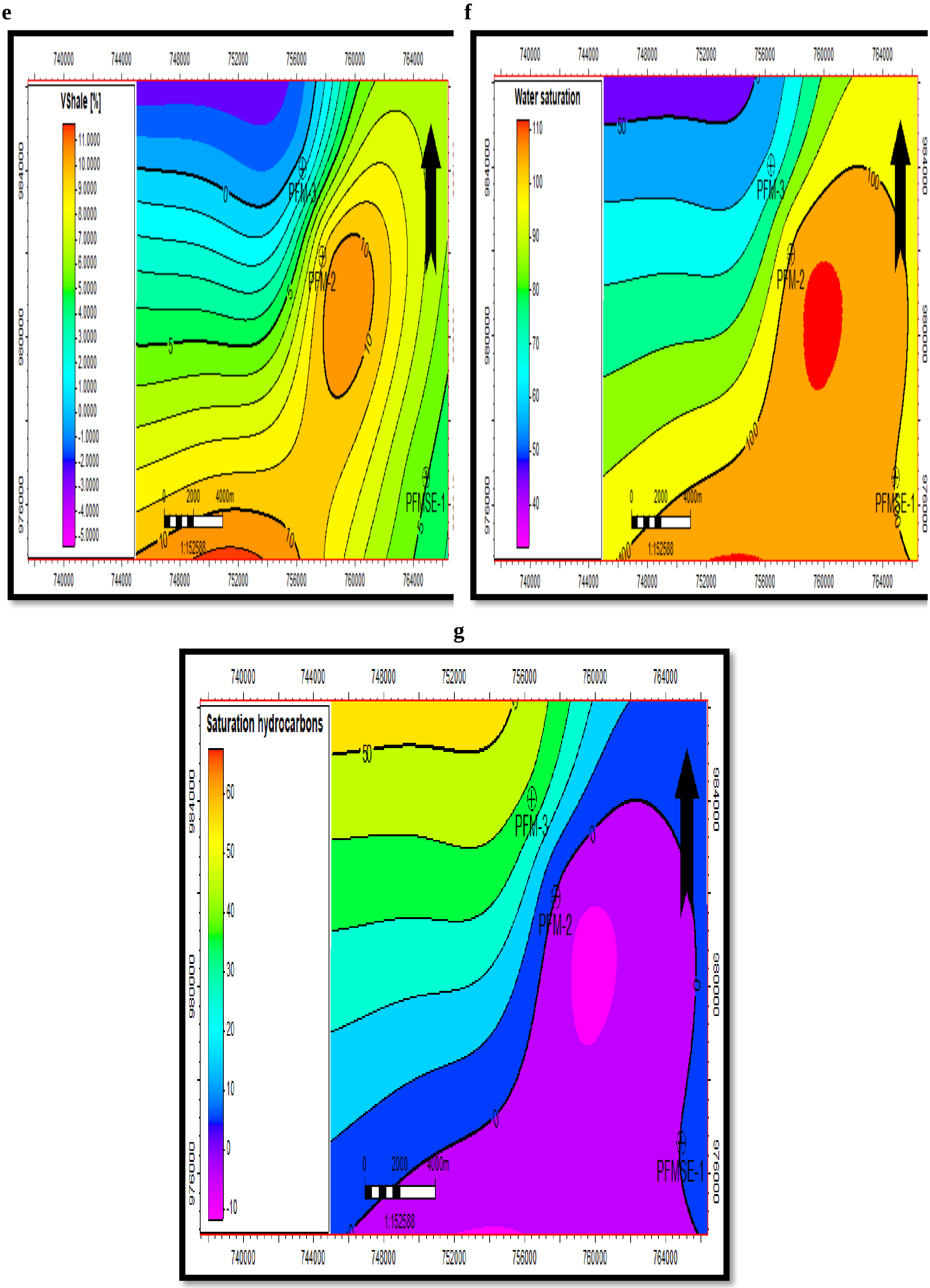

Fig. 11: Maps showing average shale volume map (e), average water saturation map (f) and average hydrocarbon saturation map (g) of wakar level S-2 reservoir.

Table 1: Petrophysical parameters of Wakar levels of S-1, S-2and S-3 in the studied wells.

Well name	Zones	Top m	Bottom m	Thickness m	Gross Sand	Reservoir thickness	Net Pay	Ave. Vsh.	Ave. Ø	Ave. SW	Ave. SH
PFM-3	S-1	3048	3064	16	8.5	7.5	1.4	9.7	21.1	53.6	46.4
	S-2	3105	3116	11	1.8	1.2	0.3	0.7	21.8	63.8	36.2
	S-3	3141	3145	4	1.3	0.84	0	6.5	19.2	100	0
PFMSE-1	S-1	3128.5	3155	26.5	4.05	4.05	3.45	5.6	24.9	27.9	72.1
	S-2	3198.5	3235	36.5	0.75	0.6	0	5.1	12.4	100	0
	S-3	3249.5	3255.5	6	3.45	2.7	0	9.7	18.5	100	0
PFM-2	S-1	2987	3017	30	1.07	0.76	0	5.6	14.7	100	0
	S-2	3072	3077.8	5.8	0.46	0.46	0	8.8	15.4	100	0
	S-3	3191	3220	29	3.2	3.2	0	18.7	18	100	0
PFM-01	S-1	3010.5	3043	32.5	16.9	16.76	11.58	17.2	18.8	44.2	55.8

CONCLUSION

Wakar reservoir in the Port Fouad Marine field is the focus of this study which is located in eastern basin of Nile Delta is divided into three levels Wakar level S-1, Wakar level S-2 and Wakar level S-3.

By using Schlumberger techlog, (2015.3) software we detected petrophysical parameters of the three levels and lithology components from well logging data wells (Gamma ray log – neutron log -density log -Resistivity log-etc) of four studied well(PFM-01,PFM-2,PFM-3 and PFMSE-1) . The lithology detecting by the cross plot (neutron-density) that suggests the Wakar reservoir composed of mainly shale with some sand. Shale is laminated detected from Thomas-Stieber cross plot.

From the petrophysical analysis data log; in PFM-SE-1 a potential gas accumulation is Wakar level S-1, both S-2 and S-3 is water bearing zones. In PFM-3 two potential gas accumulation is Wakar level S-1 and S-2 but S-3 is water bearing zone. In PFM-1 one potential gas accumulation Wakar level S-1. in PFM-2 all levels are water bearing so this well was plugged and abandoned. So the potential reservoirs in this field levels (S-1) and (S-2), level (S-1) is productive in all wells except PFM-2 that drilled outside the sand channel of level (S-1) .Level (S-2) is productive only in PFM-3 and not productive in other all wells due to low porosity,high shale content and high water saturation . Level(S-3) is not productive in all wells. So (S-1) and (S-2) levels are evaluated using the distribution contour maps showing the lateral various distribution of petrophysical parameters (thickness,gross sand, net pay,shale volume, total and effective porosity, water saturation and hydrocarbon saturation) .

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