Scientific Journal for Damietta Faculty of Science **14**(1) 2024, 76-83
doi: 10.21608/sjdfs.2024.233476.1133
ISSN Print 2314-8594
ISSN Online 2314-8616

https://sjdfs.journals.ekb.eg/

Assessment of Reservoir Petrophysical Parameters using Well Logs for the Abu Madi Formation, Level III, in Baltim North Field, Nile Delta, Egypt; A Case Study on BN-2 well

Ahmad, M. K. Basal[1], Mohamed, A. Omran[1] and Esraa El-Twargy[*1]

[1] Geology Department, Faculty of Science, Damietta University, New Damietta City, Egypt

Received: 17 September 2023 /Accepted: 04 March 2024

[*]Corresponding author's E-mail: esraaeltwargy@gmail.com

Abstract

The Nile Delta basin represents a main gas production province in Egypt including Baltim Field. The current study is focused on the evaluation of Abu Madi Formation (level III) in BN-2 well, Baltim North field, Nile Delta Basin, Egypt. The qualitative and quantitative well logging evaluation techniques are used to detect the causes of low hydrocarbon potentiality and high water production from BN-2 well. The calculated water saturation values is about 40%, porosity reaches up to 16.5%, and high values of Bulk Volume of Water above 0.08. The lithology identification cross plots for this formation confirmed shaly sandstones. The grain size is detected as very fine grained using PHIE- SW cross plot. The pressure gradient gave a fluid density of about 1.12 g/c^3 which confirmed the water content. The outcome of this study may be used as a useful tool in studying dry and water productive wells in the hydrocarbon productive fields.

Keywords: Abu Madi Level III, Baltim North Field, Nile Delta, Buckle plot, graphical formation evaluation.

Introduction

East Mediterranean area is considered as an important province for exploration and hydrocarbon production in the Nile Delta basin. Hydrocarbon fields in that province encompass one of the oil and gas production in Egypt. The Nile Delta basin is considered as an important province for exploration and hydrocarbon production in the East Mediterranean. Abu Madi Formation (Upper Messinian) contains the main hydrocarbon producing reservoirs. The stratigraphic traps (Oligocene-Pliocene-Pleistocene) are dominated. This formation is deposited as a fluvial paleo-valley infill. It is characterized by fluvio-deltaic sandstones and shales that have onlap termination with the landward to the south direction and to the valley margins alongside the unconformity erosional truncation surface, that cut through Qawasim and Sidi Salem Formations (Eni, 1999). According to Abdel-Fattah (2014), the Abu Madi Formation level III which belongs to Baltim North (BN) field in the offshore Nile

Delta and encompasses stock accumulations of gas explored in the northern part of the Abu Madi Paleo channel area.

Abu Madi Formation (Level III) in the studied (BN-2) well (Figure1) was tested as dry and were produced well on the contrary to the nearby wells. Accordingly, the presented work deals with deduction of the different petrophysical parameters through interpretation of the available well log data to find explanations and causes for such unexpected fluid production.

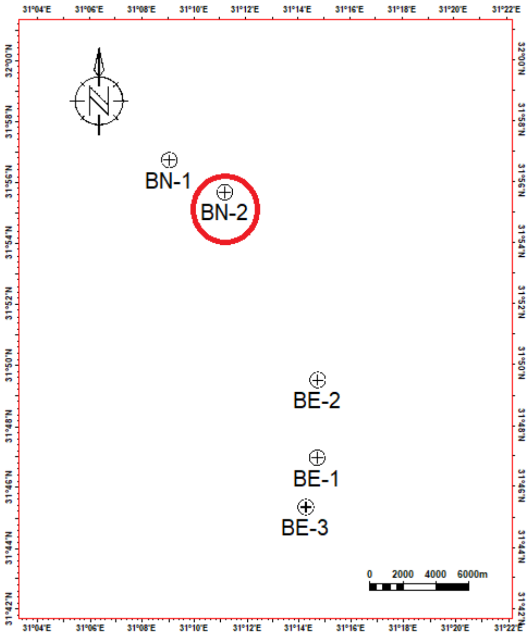

Figure 1: Location map for BN-2 well, Baltim North Field, Nile Delta, Egypt

Geologic Setting

Baltim field is one of the numerous prolific fields located in the offshore Nile Delta cone that is characterized by thick Tertiary sedimentary succession formed mainly of clastic rocks (Figure2). The Nile Delta Basin was exposed to a major regression in sea level, as the rest of the Mediterranean Sea, through the late Miocene (Missinian crises), that lead to deposition of fluvial to marginal marine facies in the deep cut channels of Abu Madi Formation (Kadi et.al., 2020). The Abu Madi Formation is simply subdivided into three levels, known as (I, II and III) (Figure2). Level (I) is mainly shale, while level (II) consists of intercalation of sandstones and/or siltstones with shale streaks and level (III) represents the main reservoir in Baltim Field and consists mainly of sandstone and is considered the thickest level of Abu Madi Formation and further is subdivided into Upper, Middle and Lower (Mahmoud et.al.,2017).

According to Abdel Aal et al. (1994, 2000), the Nile Delta is structurally affected by many tectonic phases, giving rise to major fault patterns. These tectonic phases extended from Late Palaeozoic to the Recent. The created fault patterns show four major trends (Figure3), the E-W (the hinge zone), NE-SW (Rosetta), NW-SE (El- Temsah) that represents Pliocene wrench fault activity, and the Baltim North - South. These fault trends affected the Nile Delta province, controlling the reservoir trapping conditions with other minor faults.

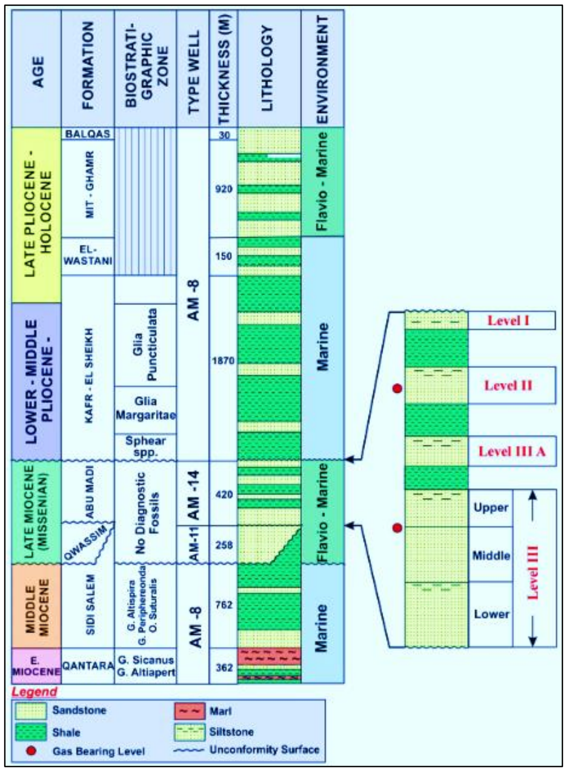

Figure 2: Schematic stratigraphic column of Baltim Field, Nile Delta. (after El Heiny, et.al, 1990)

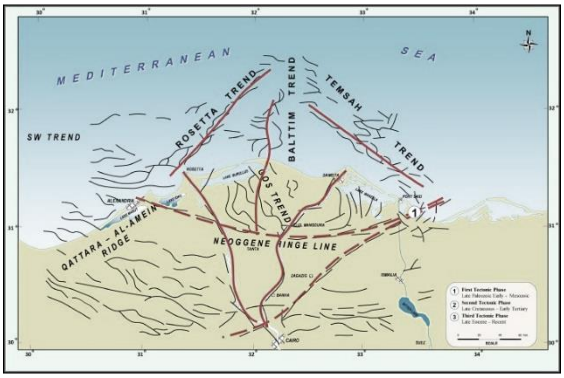

Figure 3: Nile Delta created tectonic fault trends (Hing zone, Rosetta, El-Temsah and Baltim) map (after Abdel Aal et. al, 1994).

Data and Techniques

Well log suite data available for Abu Madi Formation Level III in BN-2 well are gamma ray (GR), density (RHOB), neutron (NPHI), Photo electric (PEF) ,Array Induction resistivity Tool(A010, A030 and AT90) in addition to Repeat Formation Tester (RFT) Pressure data. The Interactive Petrophysics (IP) program software was used to facilitate and accelerate the computation and graphical presentations for deducing the various petrophysical parameters for the studied formation. The evaluated parameters are porosity (Φ), matrix content, shale volume (Vsh), water saturation (SW) and Bulk Volume Water (BVW). Two main phases of interpretation were conducted for Abu Madi Formation, Level III in BN-2 well. The first phase is a qualitative (quick Look) interpretation for the different well log curve shapes and their response for different matrices, fluid contents and discrimination between reservoir and non-reservoir intervals. The second phase represents quantitative interpretation through applications of different techniques to calculate the important petrophysical parameters.

Results and interpretation.

Well log data qualitative interpretation

The analog form for the available well log data for Abu Madi Level III sand in BN-2 well is presented as seven tracks (Figure4). The hole conditions (CALI) for the entire interval is good and the gamma ray (GR) is relatively moderate (Track 4) reflecting the shaly nature of this sand. The three resistivity curves (AO10, AO30 and AT90) in (Track5) show low readings indicating very low permeability which may be due to the very fine grain nature of this sand. The Photo Electric Factor (PEF) for this sandstone is higher than clean quartz of 1.98 which averages 4 (Track 6) the Neutron (NPHI) and Density (RHOB) are also presented in this track. The upper level is characterized by little Neutron-Density separation indicating presence of shale intercalations with high porosity (21%) (as read on the neutron porosity scale). The lower level possesses typical configuration of shale with large Neutron-Density negative separation (Neutron on the left of Density), 5 PEF and high gamma ray (45 API). According to the above log analysis the entire interval looks non-productive. Detailed and quantitative analysis are required to confirm the wet nature of Level III in this well as described in phase two below.

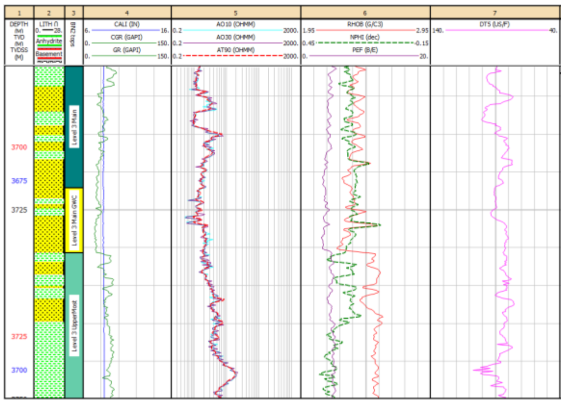

Figure 4: Well Log Data analog format displayed on the IP program for Abu Madi level III, BN-2 well, Baltim North field, offshore Nile Delta.

Quantitative well log interpretation

Graphical presentation among the different log readings in the form of cross-plots were been constructed. The chosen cross-plots can help to describe and evaluate the reservoir matrix, saturations in addition to its fluid type. Neutron-Density (NPHI-RHOB), Resistivity-Porosity (AT90-PHIE), Porosity-Saturation (PHIE-SW) and Pressure-Depth cross-plots were constructed for level III and will be described in details in the following sections. Finally, the obtained results are presented as litho-saturation cross-plot to integrate and correlate all the reservoir petrophysical parameters in one track depth wise.

Neutron-Density (NPHI-RHOB) cross-plot.

The neutron-density cross-plot for Level III in the study well is presented in Figure 4. The most important point which can be noticed is that the plotted points are clustered on and around the limestone line (i.e. below the sandstone line) although this level is described on the mud log report as very fine sand grading to silt. The presence of silt and shale led the points to migrate downward. Most of the plotted points have moderate gamma ray readings ranging between 15 and 30 API (aqua color) with some points located on the limestone line having gamma ray values in the range between 30 and 45 AP (fucsia color). This confirms the shaly nature of the sand of Level III as described earlier qualitative interpretation section. Also, on this plot, the points occupy the area between 20 and 25 % lines correlating reasonably well with about 21% porosity as deduced qualitatively on neutron-density overlay (Figure 5).

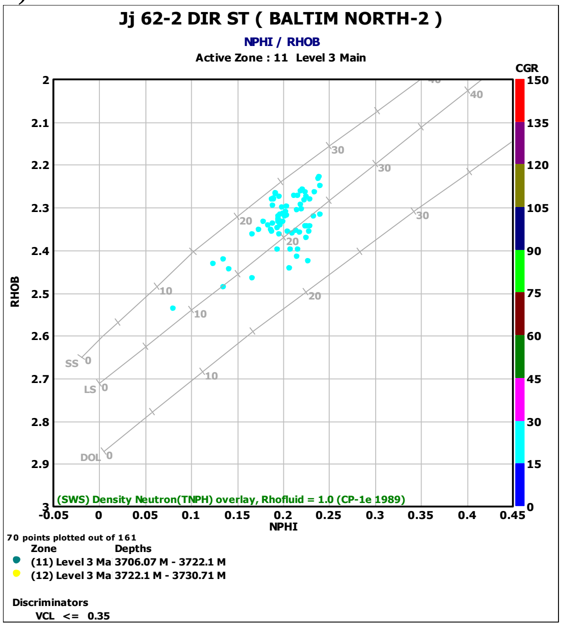

Figure 5: Neutron density x-plot for Abu Madi level 3, BN-2 well, Baltim North Field, offshore Nile Delta, Egypt.

Resistivity-Porosity (AT90-PHIE) cross-plot

This type of cross-plot is well known as Pickett plot (1972). This technique can be considered as a modification of Archie (1942) equation in the form of logarithmic presentation. On this graph a number of different parallel water saturation lines can be obtained. The most important enhancement of this plot is that, many vital petrophysical parameters can be detected rather than assuming them. These parameters are cementation exponent (m) and brine water resistivity (aRw) as they appear in the Archie equation ($sw = \sqrt{\frac{aRw}{\emptyset^m.RT}}$) . The slope of the water saturation lines represents exponent (m), while the intersection of the 100%| SW line with 100% porosity represents aRW (read on the resistivity scale). The constructed pickett cross-plot for Level II in BN-2 well (Figure6) shows that exponent (m) equals 2 and Rw equals 0.03 Ωm^2/m. These values correlate well with those obtained for offset wells for Level III in the same field. It is also noted that the plotted points are populated below 50% water saturation line towards 100% water saturation one. This confirms the expected water production as mentioned above.

Porosity saturation cross plots

Two types of porosity versus water saturation cross-plots are constructed. Figure (7) displays the first one which represents the relation between effective porosity (PHIE) on logarithmic scale versus water saturation (SW) on a linear scale (i.e. semi log) (Asquith and Gibson, 1982)**.** On this plot the effect of grain size can be detected where two definite lines separate between three regions namely Coarse Grain (CG), Fine-Medium Grain (F-MG) and Very Fine (VFG). The Level III sand in BN-2 well is mainly very fine grain sized as the plotted points occupy the area of VFG. This is compatible with the mud log report which described this sand as very fine grading to silt.

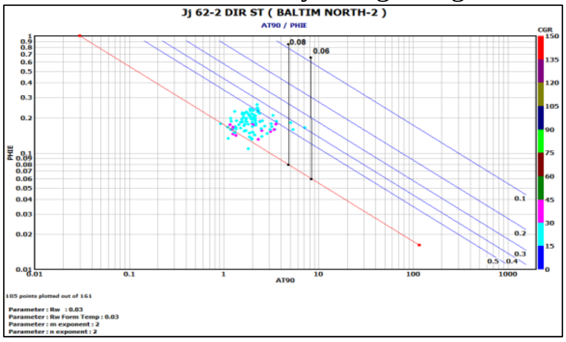

Figure 6: Picket plot for Abu Madi level 3, BN-2 well, Baltim North Field, offshore Nile Delta, Egypt.

The second type of cross-plot is introduced by Buckle (1965) where both effective porosity (PHIE) and water saturation (SW) are cross-plotted as linear scale (Figure8). This plot is displayed as a number of hyperbolic curves that represent different Bulk Volume Water (BVW) which is the product of porosity times water saturation (Φ x Sw). In case when the plotted points follow the same hyperbolic line it can be expected that the reservoir is at irreducible state (i.e. produce free water hydrocarbon). If the plotted points are scattered, the production is only water. It is of prime importance to mention that, BVW cutoff values for clastic rock depend on grain size (Asquith and Gibson, 1982). Accordingly, as Level III sand in BN-2 well is interpreted through Figure (7) as very fine, the BVW cutoff value ranging between 0.05 and 0.07 will be applied. This means that, points with BVW values more than 0.07 will be considered water. Most of the plotted points (Figure8) are scattered above 0.08 hyperbola which indicate that, Level III in that present well will produce only water.

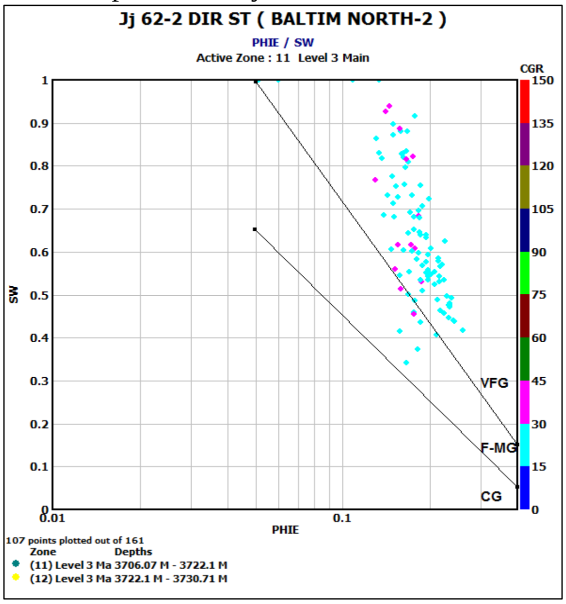

Figure 7: Grain size distribution deduced from PHIE-SW cross plot for Abu Madi level 3, BN-2 well, Baltim North Field, offshore Nile Delta.

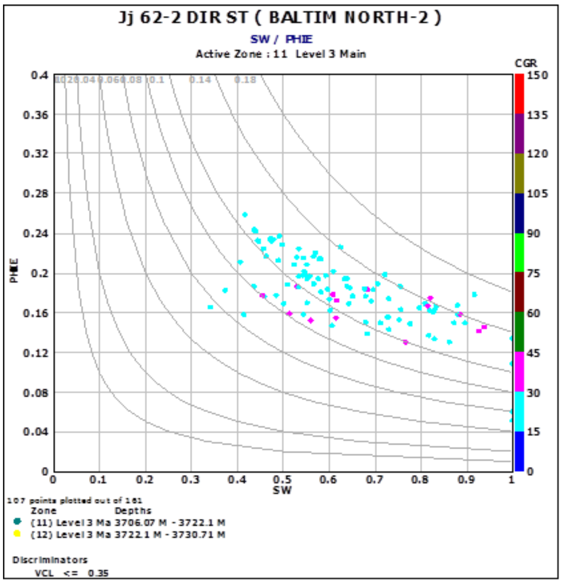

Figure 8: Buckle plot for Abu Madi level III sand in BN-2 well, Baltim North Field, offshore Nile Delta, Egypt showing the dominated BVW values above 0.8

Pressure-Depth (P-D) Cross-Plot

Pressure data represent very important source for locating fluids contacts and densities. This can be achieved by constructing pressure versus depth (P-D) plots. On this plot any group of points lining up along the same gradient trend indicate that they are related to the same fluid type (water, oil or gas) according to the density.

The Repeat Formation Tester (RFT) log tool was run in the study well. This tool allows measuring multiple pressure readings at different depth locations in one run. Accordingly, the (P-D) plot for Level III in BN-2 well was constructed (Figure9).

The plotted pressure points are all exactly aligned on one trend line (Figure9). This means that, Level III in that well contains one fluid. The slope (Pressure/Depth) of this line (λ) is directly giving the fluid density. The slope of the trend line (λ) is 1.6 psi/m (0.11bar/m) which corresponding to water with density of 1.122 g/cc . The interpretation of RFT pressure data is compatible with that of the above interpreted graphical technique which indicated that the water saturations (SW) is higher than 50% and BVW more than 0.8 which all reflect that Level III in BN-2 well is wet.

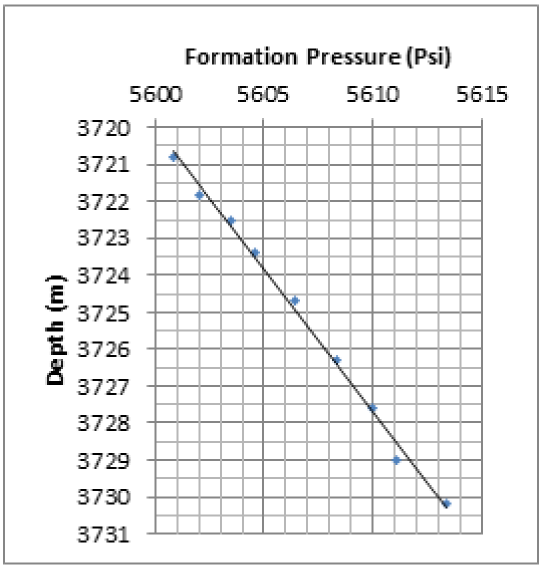

Figure 9: showing the fluid pressure of Abu (Madi Level III), BN-2 well, Baltim North field, Nile Delta, Egypt.

Results Integration

Through the above sections, the deduced interpretation was made individually without depth notifications. The litho-saturation cross-plot (Figure10) represents a means of displaying all results depth wise in correlation manner. This visual graphical type, facilitate making decision about the type of the fluids which the well may produce. The litho-saturation plot for Abu Madi Formation Level III (Figure10) comprises five tracks. The input matrix model (track3) is sand (VSAD), silt (VSILT) and clay (VCL) based on the neutron-density cross-plot (Figure5) and is confirmed by mud log report. The volume of sand decreases downward (i.e coarsening upward) with sharp upper contact, where both clay and silt increase.

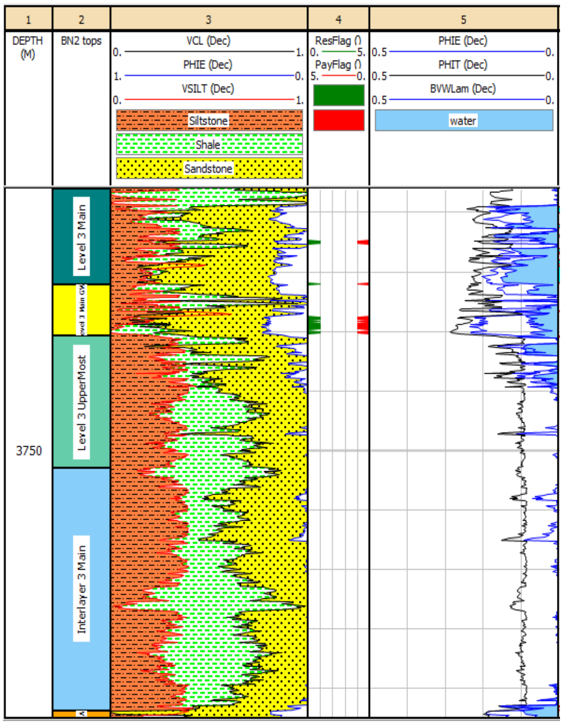

Figure 10: The litho-saturation cross-plot for forAbu Madi level 3, BN-2 well, Baltim North Field, offshore Nile Delta.

There is a clear difference between the effective (PHIE) and total calculated porosity (PHIT) due to the shale content. The correlation between BVW (Track4) and that of SW (Track4) clearly indicates that the entire interval is wet. This is evidenced by higher BVW (>0.06) for fine grain sandstone (Asquith and Gibson, 1982) coupling with higher Sw values (>50%) with very thin pay zone in track4.

The lithosaturation plot for Abu Madi Level III in BN-1 well is displayed in Figure 11. There is an increase in the shale volume upward in the studied section as a fining upward succession. The gas saturation exceeds 80%. The shale volume reached about 20% while the BVW values varied from 0.02 to 0.04 in the pay zone. The average values of the calculated reservoir parameters showed porosity of 18% and net pay of 31 meters in contrary with BN-2 well.

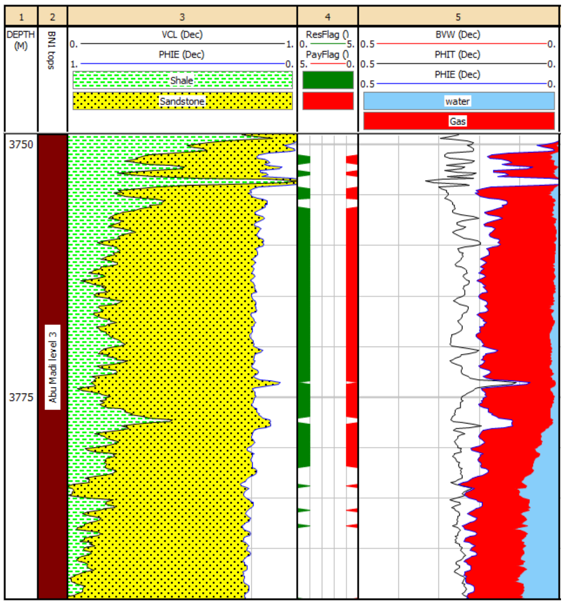

Figure 11: The litho-saturation cross-plot for forAbu Madi level 3, BN-1 well, Baltim North Field, offshore Nile Delta.

Conclusions

Abu Madi Level III in BN-2 well composed mainly of shaly sandstone.The calculated shale volume content average reached about 20 %. The calculated water saturation (Sw) ranges higher than 40%. The estimated bulk volume water (BVW) values ranged from about 0.06 to 0.14. The average porosity varied with a maximum value of 16 %. The calculated fluid density is about 1.122 g/cc from the pressure depth plot, which reveals water production from the studied well. BN-1, BE-1, BE-2 and BE-3 wells are gas productive wells on contrary with BN-2 well which is wet and is water productive. The shale volume increases northward, this may due to facies changes. The reservoir thickness, porosity and gas saturation increases southward this means gas accumulation in the southern parts of the channel. Development wells are recommended in the southern parts of the field.

Discussion

The Nile Delta basin represents a main gas producing province in Egypt. Baltim fields are located in Abu Madi paleo channel as a Messenian stratigraphic trap for gas accumulations. The mechanism of trapping is characterized by pinch out in the sides of the Abu Madi paleo-channel **(Sarhan etal, 2022).**

BN-2 well is located near to the flanks of the valley not at the central portion of it according to **(Kadi etal, 2020)**. The present study is concerned mainly with the causes of the low hydrocarbon potentiality of BN-2 well. Abu Madi Level III in BN-2 well composed mainly of shaly sandstone. Heterogeneity of the sand bodies controls the quality of the reservoir. The presence of clays decreases gas saturation and porosity in the sandstone reservoir especially along the margins of the palaeo channel and in the northern area **(Abdel-Fattah 2014)**. The grain size ranges from very fine sandstone to siltstone. (**El Sayed *et al,* 2019**) concluded that In BN-2 Well, sand units are quite fine grained and moderately sorted. The log shapes indicate a general coarsening upward in a highly serrated funnel curve shape type. **Zein El Din et al. (2016)** concluded that the reservoir rock quality for both two reservoir levels (III Main and III Lower) is decreasing towards the North. The Abu Madi formation is commonly dipping northward, as the depth to the formation top increases towards north (**Kadi et.al, 2020),** that reveals the hydrocarbon accumulated in the southern parts according to the buoyancy.

Acknowledgment

The authors are grateful to the Egyptian General Petroleum Corporation and Belayim Petroleum Company (PETROBEL) for providing the data set for the current case study.

Data availability

The data that has been used is confidential

References

Abdel Aal, A., El Barkooky, A., Gerrits, M., Meyer, H., Schwander, M., & Zaki, H. (2000). Tectonic evolution of the Eastern Mediterranean Basin and its significance for hydrocarbon prospectivity in the ultradeepwater of the Nile Delta. The leading edge, 19(10), 1086-1102.

Abdel Aal, A., Price, R. J., Vaitl, J. D., & Shrallow, J. A. (1994). Tectonic evolution of the Nile Delta, its impact on sedimentation and hydrocarbon potential. In EGPC 12th exploration and production conference (Vol. 1, pp. 19-34).

Abdel-Fattah, M. I. (2014). Petrophysical characteristics of the Messinian Abu Madi Formation in the Baltim east and North fields, Offshore Nile delta, Egypt. Journal of Petroleum Geology, 37(2), 183-195.

Abdel-Fattah, M. I., & Slatt, R. M. (2013). Sequence stratigraphic controls on reservoir characterization and architecture: case study of the Messinian Abu Madi incised-valley fill, Egypt. Central European Journal of Geosciences, 5, 497-507.

Archie, G. E. (1942). The electrical resistivity log as an aid in determining some reservoir characteristics. Transactions of the AIME, 146(01), 54-62.

Asquith, G. B., Krygowski, D., & Gibson, C. R. (2004). Basic well log analysis (Vol. 16). Tulsa: American Association of Petroleum Geologists.

Asquith, G. B., & Gibson, C. R. (1982). Basic Well Log Analysis for Geologists, Basic relationships of well log interpretation: Chapter I, P1-27.

Buckles, R. S. (1965). Correlating and averaging connate water saturation data. Journal of Canadian Petroleum Technology, 4(01), 42-52.

Dalla, S., Harby, H., & Serazzi, M. (1997): Hydrocarbon exploration in a complex incised valley fill: an example from the late Messinian Abu Madi Formation (Nile Delta Basin, Egypt). The Leading Edge, 16(12), 1819-1826.

EI Heiny, I, Rizk R, Hassan M. (1990): Sedimentological model for Abu Madi reservoir sands, Abu Madi Field, Nile Delta, Egypt. Proceedings 13th Petroleum Exploration and Production Conference, Cairo: EGPC. p. 1–37.

El Sayed, A. M. A., El Sayed, N. A., Lala, A., & Metwally, M. (2019). Reservoir Rock Genetic Types Using Log Curve Shapes: Abu-Madi Formation, Offshore Nile Delta-Baltim Gas Field, Egypt. In IOP Conference Series: Earth and Environmental Science (Vol. 221, No. 1, p. 012045). IOP Publishing.

Enter Nazionale Idrocarburi (ENI) (1999): Egypt, Baltim concession and leases; Stratigraphic/Sedimentological study of the Miocene Sequence, Rome, Italy. p. 155.

Kadi, H. H. E., Shebl, S., Ghorab, M., Azab, A., and Salama, M. (2020): Evaluation of Abu Madi Formation in Baltim North & East gas fields, Egypt, using seismic interpretation and well log analysis. NRIAG Journal of Astronomy and Geophysics, 9(1), 449-458.

Mahmoud, M., Ghorab, M., Shazly, T., Shibl, A., and Abuhagaza, A. A. (2017): Reservoir characterization utilizing the well logging analysis of Abu Madi Formation, Nile Delta, Egypt. Egyptian journal of petroleum, 26(3), 649-659.

Pickett, G. R. (1972): Practical formation evaluation.

GR Pickett. Inc, Golden, Colorado.

Sarhan, M. A., Hassan, T., & Ali, A. S. (2022). 3D static reservoir modelling of Abu Madi paleo-valley in Baltim Field, Offshore Nile Delta Basin, Egypt. Petroleum Research, 7(4), 473-485.

Zein El Din., Salah, A. S., & Islam, H. A. (2016). Effect of the mineralogical composition on the reservoir rock quality of the Abu Madi Formation in Baltim gas field, Nile Delta, Egypt. ENI. 10p.

الملخص العربي

عنوان البحث: تقييم المعاملات البتروفيزيائية للمكمن باستخدام سجلات الآبار لتكوين أبو ماضي، المستوى الثالث ، حقل شمال بلطيم ، دلتا النيل ، مصر؛ دراسة حاله على بئر BN-2

أحمد محمد كمال بصل[١]، محمد أحمد عمران[١]، إسراء التوارجي[١]

[١، ٢] قسم الجيولوجيا – كلية العلوم – جامعة دمياط – مصر

يمثل حوض دلتا النيل الاقليم الاساسي لإنتاج الغاز في مصر. حقول بلطيم من حقول الغاز الرئيسية في الاقليم. ركزت الدراسة الحالية على تقييم متكون أبو ماضي في بئر BN-2 ، حقل بلطيم الشمالي ، حوض دلتا النيل ، مصر. تم استخدام تقنيات تقييم تسجيلات الابار النوعية والكمية للكشف عن أسباب انخفاض كميات الهيدروكربونات وإنتاج المياه من بئر BN-2. النتائج اوضحت تفاوت قيم تشبع الماء المحسوبة من حوالي ٤٠٪ ، وتراوحت قيم المسامية حتى ١٦,٥٪ ، وتراوحت القيم العالية لحجم الماء السائب اكثر من٠,٠٨ . تم تأكيد نوعية صخور المتكون على أنه حجر رملي باستخدام العلاقات البيانيه. تم الكشف عن حجم الحبيبات على أنها حبيبات دقيقة جدًا باستخدام العلاقه بين PHIEوSW. اكدت علاقة التغيرفي الضغط مع العمق كثافة المائع حوالي ١,١٢ جم / سم مكعب محتوى الماء. الدراسة الحالية هي أداة للتعرف على الآبار الجافة و المنتجة للمياه في الحقول المنتجه للهيدروكربون.