DJS Vol. 43(1) (2021) 65-79 ISSN: 1012-5965

Delta Journal of Science

Available online at **https://djs.journals.ekb.eg/**

Research Article

GEOLOGY

Evaluation of Hydrocarbon Potentiality of the Lower Safa Reservoir, Pepi Field, Shushan Basin, North Western Desert, Egypt

Sara R. El ghareeb[1]*, Mohamed A. Elbastawesy[2] , Mohamed S. El-Sadek[2], Abdelaziz L. Abdeldayem[1] and Shadia A. Mohamed[1]

**Corresponding author e-mail:* sararagab246@gmail.com

[1] Geology Department, Faculty of Science, Tanta University, 31527 Tanta, Egypt

[2] Khalda Petroleum Company, New Maadi, P.O Box 560, Maadi, Cairo, Egypt

KEY WORDS

Evaluation, Lower Safa reservoir, "Pepi" field, Shushan Basin, North western desert, Egypt.

ABSTRACT

The Middle Jurassic Lower Safa Member serves as a hydrocarbon reservoir in Shushan Basin, North Western Desert, Egypt. The present work deals with studying the subsurface setting and reservoir properties of this member to assess its hydrocarbon potentiality in the Pepi field. Seismic interpretation of thirty 2D seismic sections was used to determine the geometry and the detailed structural properties affecting this member. Well-log data available from five well-logs (Pepi-1X, Pepi-2, Pepi-5, Pepi-6, and Pepi-8) was utilized to determine the various reservoir parameters distinguishing the pay zone to highlight the promising locations for further exploration and development. Interpretation of the seismic data showed two master faults (F1 and F2) forming a half-graben block that trends NW-SE and NE-SW, respectively. These faults reflect the structural control of hydrocarbon accumulation in the Pepi field. Results of neutron-density cross-plots showed that the lithology of the studied Lower Safa reservoir is mainly sandstone with some calcareous cement. Vertical demonstration of the petrophysical data via Litho- Saturation cross-plots and lateral layout through the iso-parametric maps helped identifying the lateral variation of petrophysical parameters, reservoir thickness and to define the most suitable place for locating new productive wells. The estimated petrophysical parameters of the reservoir throughout the study area ranges from about 7.6 % to 11.3 % for effective porosity, from 1.8 % to 8.3 % for shale volume and from 47.3 % to 85.1 % for hydrocarbon saturation. These results revealed that good reservoir parameters distinguish the Pepi field. Analysis of the reservoir pressure was utilized to define the reservoir fluid type and degree of connectivity of hydrocarbon in sand-bearing parts. Integrating obtained results indicates that the Lower Safa Member of Pepi field contains commercial hydrocarbon accumulation with a good chance to increase productivity through the drilling of extra exploratory and development wells.

1. Introduction

Latest gas and oil discoveries have indicated that the northern Western Desert of Egypt has a large hydrocarbon potential **(Dolson *et al.* 2001)** and may contain some 80% of the undiscovered gas reserves and 90% of the undiscovered oil reserves in Egypt **(Zein El-Din *et al.* 2001).** The Pepi field, the target of the present study, which lies in the Shushan Basin, North Western Desert, Egypt (Fig. 1), has gained the attention of many researchers and oil companies. It is bounded by latitudes 21° 25' 36"- 21° 26' 08"N and longitudes 26° 06' 56"- 26° 07' 44"E.

2. Geological Setting

The North Western Desert comprises many sedimentary basins that received a thick succession of Mesozoic deposits. The general stratigraphic section in the north Western Desert varies from Paleozoic to Recent as summarized in figure 2. The post-Paleozoic succession in this region includes four sedimentary cycles: Lower to Upper Jurassic, Lower Cretaceous, Upper Cretaceous, and Eocene- Miocene **(Sultan and Halim, 1988).**

The Shushan Basin, which is the biggest of the coastal basins, is a half-graben system with a maximum thickness of 7.5 km of Jurassic, Cretaceous, and Paleogene deposits **(El-Shazly, 1977 and Hantar, 1990)**. The Shushan Basin witnessed Jurassic and Early Cretaceous extension followed by Late Cretaceous early Tertiary inversion **(El Awdan *et al*., 2002).**

Khatatba Formation is divided into four members Lower Safa, Kabrit, Upper Safa, and Zahra Member **(Khalda, 2001).** The Lower Safa member, the target of this study, comprises sandstone, shale, siltstone, and limestone streaks.

Abu Shady (2003) assessed the sandstones of the Khatatba Formation (Middle Jurassic) through the studying of its depositional environment and petrophysical properties. It consists of dark shale containing TOC varying from 3.60 to 4.20 wt %, representing an excellent source rock **(Peters and Cassa, 1994).** On the other hand, the depositional environment was determined to be of fluviatile type **(Khalda, 2001).**

The Middle Jurassic Khatatba Formation comprises both sandy reservoir intervals and organic-rich shales with source rock potential. Potential seals comprise the large carbonates of the Upper Jurassic Masajid Formation **(EGPC, 1992).** The shales and limestone units in the Shushan basin act as a source rock for oil generation on the central site of the basin (**Al sharhan and Abd El-Gawad, 2008**).

3. Results and Interpretation

3.1 Seismic Data

The interpretation of thirty seismic lines (Fig. 3) covering the entire studied area has led to determining the most important seismic reflectors and structural elements throughout the Lower Safa Member. The quality of seismic data was good enough to be used to pick to the Lower Safa horizon in the part of area that isn't covered by well data.

3.1.1 Horizon Interpretation

Figure 4 illustrates the interpreted seismic line (inline- 11296). This line trends from the north to the south direction of the study area. It reveals presence of horsts and half grabens and grabens delineated by normal faults. This line illustrates one interpreted horizon; the Lower Safa Member crossed by five normal faults (F1, F2, F3, F6, and F13) where F1 and F2 forms half graben that represent the major structural trap in this area. The 2D interpreted seismic line (xline-5750) is represented in figure (5). This line trends from the east to the west direction of the study area. A group of normal faults were observed along this line. F2 fault delineate a half graben with a good reservoir potentiality.

3.1.2 Structural Interpretation

A. Lower Safa depth map

Figure 6 demonstrates the structural elements using a depth map instead of the time map. The time and velocity calculation are used to convert the reflection time to depths, for constructing the structure depth map. The depth value of Lower Safa ranges from -12228.9 to -15550 ft (TVDSS) and reaches its maximum value toward the northern, central, and southeastern parts of the study area, while the minimum value occurs in the east, south, and southwestern parts of the study area. Two identified master faults seem to form the Pepi field half-graben block. The master fault (F1) has NE-SW direction resulting from Jurassic rifting movement in North Africa, while the antiseptic master fault (F2) trends NW-SE resulting from Cretaceous rifting movement in North Africa **(Said, 1990; EPGC, 1992).** F1 and F2 represent a three-way deep closure.

3.2 Reservoir Petrophysics

3.2.1 Neutron-Density cross-plot

The Neutron-density cross-plots are usually utilized to identify the lithology and accurately define the matrix porosity of carbonate rocks **(Poupon and Leveaux, 1971).**

The neutron-density cross-plots of the Lower Safa reservoir (Figs 7, 8, 9, 10, 11) shows that the porosity ranges from 5 to 15%, where most points are scattered close to the sandstone line, while the remaining points lie between the sandstone and limestone lines, indicating sandstone reservoir with calcareous cement.

3.2.2 Vertical Variation of Petrophysical properties

The vertical distribution of petrophysical parameters was accomplished by constructing the litho-saturation cross-plots for each well in the study area to demonstrate the distribution of porosity, water saturation, the volume of shale, and the corresponding calculated hydrocarbon saturation. Figures (12-16) show that the Lower Safa reservoir has a good hydrocarbon saturation potentiality in all studied wells.

3.2.3 Horizontal Variation of Petrophysical Parameters

Many iso-parametric maps, which are the net pay, shale content, effective porosity, water saturation, and hydrocarbon saturation maps, were constructed for the Lower Safa reservoir in the Pepi field to trace the lateral variation of petrophysical characteristics.

Reservoir maps

The total thickness distribution map of Lower Safa (Fig. 17) shows its increase towards the central and southeast parts of the study area; it reaches the maximum value of 208 ft at Pepi-2 (Table 1). However, the total thickness decreases towards the northeastern part, where it reaches a minimum value of 135.5 ft at Pepi-5 well.

The effective porosity distribution (Fig. 18) attains 7.6 % at Pepi-1X and reaches 11.3 % at Pepi-8 well (Table 1). It shows an increase in the central part of the study area and toward the southeast direction while decreases in the northeast direction.

The water saturation distribution map of the Lower Safa reservoir (Fig. 19) increases in the northeast direction and decreases in the central and southeast parts. It reaches its maximum value of 52.7 % at the Pepi-6 well and the minimum value of 14.9 % at Pepi-5 well.

The shale volume content (Fig. 20) increases in the southeast direction reaching its highest value of 8.3% at Pepi-1X well, while it decreases toward the central and northeastern parts where it reaches the minimum value of 1.8 % at Pepi-8.

The gross sand thickness (Fig. 21) attains its lowest values of 37 ft at Pepi -5 wells and its highest value of 184 ft at Pepi -2 well. It increases in the central part of the study area and toward the southeastern direction.

The net pay thickness (Fig. 22) attains its lowest values of 10.5 ft at Pepi -8 well and its highest value of 67.5 ft at Pepi-2 well. It increases in the central part of the study area and toward the southeastern direction.

Figure (23) shows that the hydrocarbon saturation increases in the central part and toward the southeastern direction and decreases toward the northeastern direction. It attains its maximum value of 85.1 % at Pepi-5 well and the minimum value of 47.3 % at Pepi-6 well.

3.2.4 Reservoir Pressure Measurement

The repeat formation tester (RFT) is a tool capable of estimating the formation permeability via the interpretation of the pretest pressure data record during drawdown and buildup **(Stewart and Wittmann, 1979).**

Analysis of pressure data for Lower Safa reservoir in Pepi-1X; Pepi-6 and Pepi-8 wells are represented in figures (24-26). Pressure analysis at Pepi-1X well shows an average pressure reading of 6251.2 psi, and an oil gradient of 0.33 psi/ft, and a water gradient of 0.7 psi/ft (Fig. 24). Such values indicate a probable oil-water contact at a depth of 14189 ft (measured depth). Pressure reading plots at Pepi-6 and Pepi-8 wells are scattered and could not be used to establish oil gradient and oil-water contacts. This is probably due to the depletion of pressure after a period of high production (Figs.25 and 26).

Summary and Conclusion

Analysis of available seismic lines for the Lower Safa reservoir in the Pepi filed, Shushan Basin, north Western Desert, indicates the presence of a three-way deep closure structural trap that was successfully charged by hydrocarbons. Well logs analysis, on the other hand, enabled the construction of continuous accurate lithological column of this member that is regarded as a promising reservoir with high hydrocarbon potentiality. This is clearly demonstrated through the obtained high structural position, good porosity (from 7.6% to 11.3%), high gross sand (from 37 ft to 184 ft), low shale volume (from 1.8 ft to 8.3 ft), low water saturation (from 14.9 %to 52.7 %) and a high percentage of hydrocarbon saturation (from 47.3% to 85.1%). Therefore, we recommend the drilling of extra development and exploratory wells, particularly in the central and southeastern parts of the area to enhance the productivity rate from the Pepi filed.

Acknowledgements

The authors are very indebted to the authorities of the Egyptian General Petroleum Corporation (EGPC), Cairo, Egypt for their permission to obtain the well-log data used in this study. They are also grateful to the Khalda Petroleum Company, Cairo, for their kind help in providing the used well-log and seismic data used in this study.

REFERENCES

1 Abu Shady, A.N., 2003. "Sedimentary Environments and Petrophysical Characteristics of the Khatatba Formation (Middle Jurassic), North Western Desert, Egypt", Ph.D. Thesis. Geo. Dep. Tanta Univ., Egypt, 133 p.

2 Al Sharhan, A. S. and Abd El Gawad, E.A., 2008. "Geochemical Characterization of Potential Jurassic / Cretaceous Source Rocks in the Shushan Basin, North Western Desert, Egypt". Journal of Petroleum Geology 31, p 191-212.

3 Dolson, J.C., Shann, M. V., Matbouly, S., Harwood, C., Rashed, R. and Hammouda, H., 2001. "The Petroleum Potential of Egypt", in W. A. Morgan. ed., Petroleum Provinces of the 21st Century, V. Memoir 74, Tulsa, Oklahoma, America.

4 EGPC (Egyptian General Petroleum Corporation), 1992. "Western Desert, oil and gas fields, a comprehensive overview". EGPC, 11th Petrol. Expl. Prod. Conf., Cairo, 431p.

5 El Awdan, F. Youssef, and A.R. Moustafa., 2002. "Effect of Mesozoic and Tertiary Deformations on Hydrocarbon Exploration in the Northern Western Desert, Egypt". In Am. Assoc. Petrol. Geol. Int. Meeting, (Abstract).

6 El Shazly, E.M., 1977. "The geology of the Egyptian region". In: A. E. M. Nair, W. H. Kanes & F. G. Stehli, "The ocean basins and margins".
Plenum press, V. 4 (A), p 379-444.

7 Khalda Petroleum Company Internal Report, 2001. "Paleontological Studies for Qasr Field", PP.3-22.

8 Hantar, G., 1990. "North Western Desert". In: Said, R. (Eds.). "The geology of Egypt". A. A. Balkema, Rotterdam, Netherlands. P 293–319.

9 Peters, K. E. and Cassa, M. R., 1994. "Applied Source Rock Geochemistry". In: Magoon, L.B., Dow, W.G. (eds.) "the Petroleum System-From Source to Trap". American Association of Petro. Geologists, Memoir 60, PP. 93-120.

10 Poupon, A. and Leveaux, J., 1971. "Evaluation of water saturation in shaly parts of Northern Egypt". AAPG, 60 (1) Abstract.

11 Said, R., 1990. The geology of Egypt. Rotterdam, Netherlands, A.A. Balkema Publishers, 734 p.

12 Stewart, G. and Wittmann, M.J., 1979. "Interpretation of pressure response of the repeat formation tester", SPE, fall meetings in Las Vegas, 8362 p.

13 Sultan, N., and Halim, M.A., 1988. "Tectonic framework of northern Western Desert, Egypt and its effect on hydrocarbon accumulations". Proc. 9 EGPC. Petrol. Explor. Prod. Conf., 2, p 1-22.

14 Zein El Din, M. Y., Abd El-Gwad, E. A., El Shayb, H. M. and Haddad, I. A., 2001. "Geological Studies and Hydrocarbons Potentialities of Mesozoic rocks in Ras Kanayis Onshore area, North Western Desert, Egypt". The Annals of the Geological Survey of Egypt, Vol. 12, p 325-337.

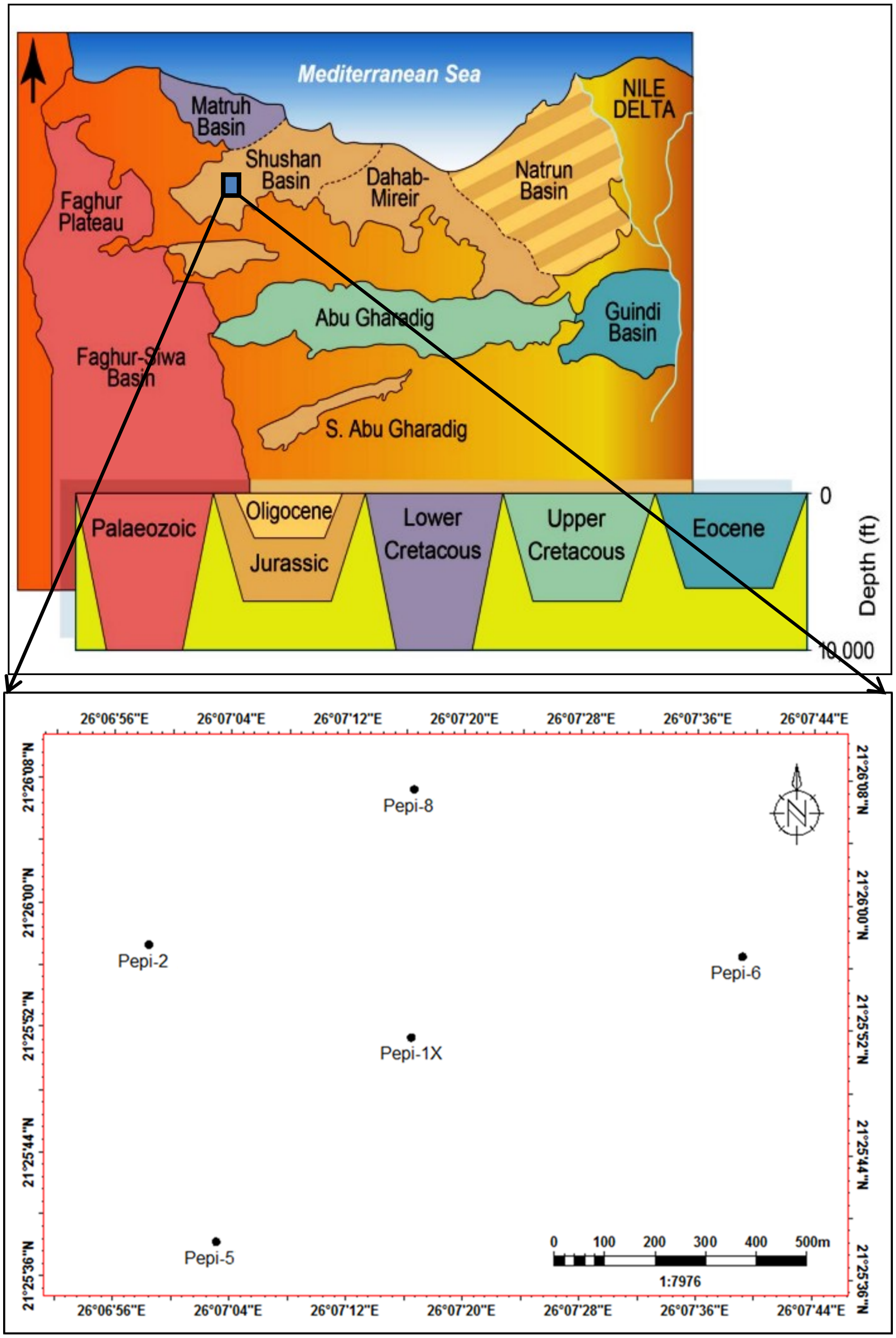

Fig 1: Location map of the studied area illustrating the location of the five wells in Pepi field, North Western Desert, Egypt.

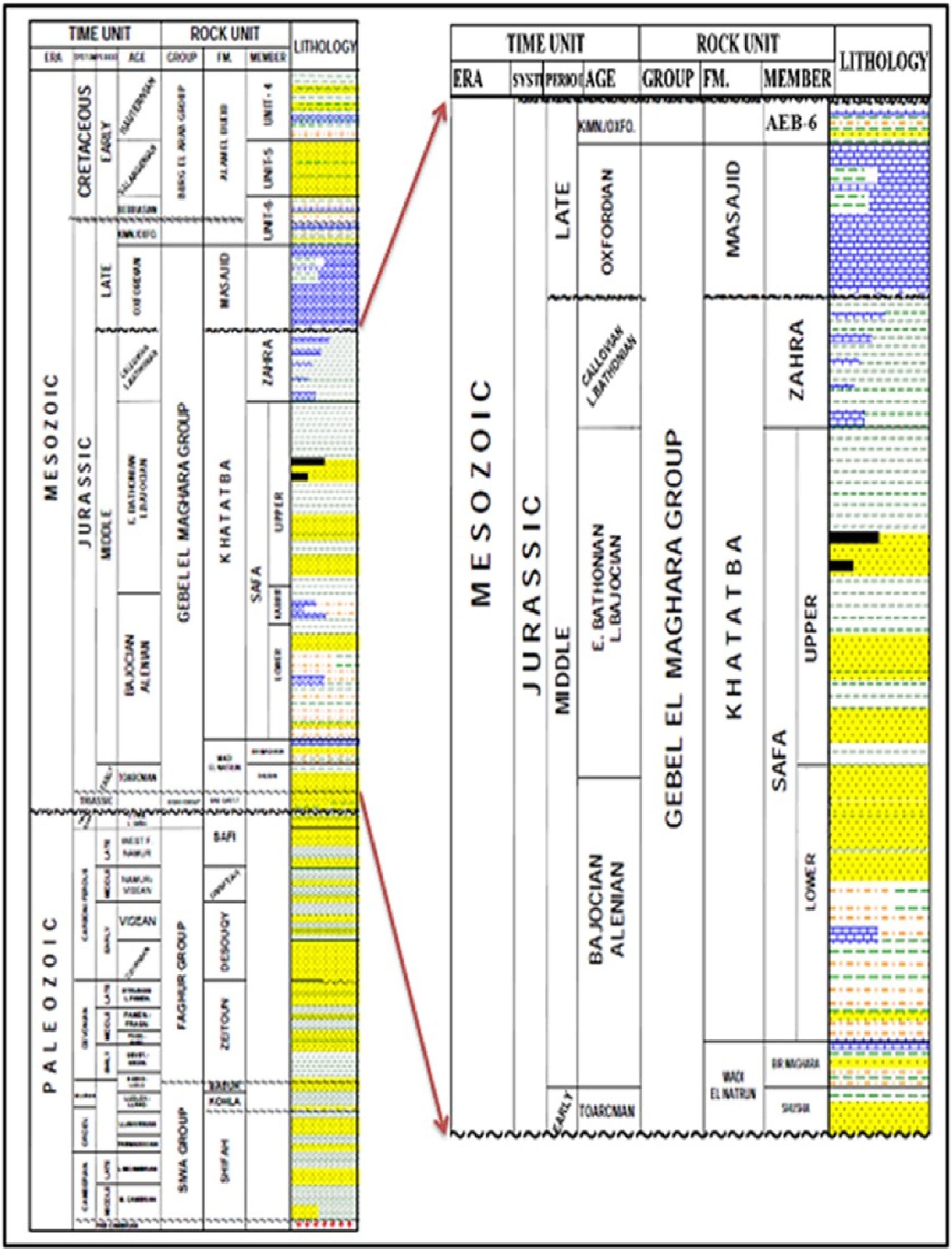

Fig. 2: A generalized stratigraphic column of the North Western Desert **(Khalda, 2001*)*.**

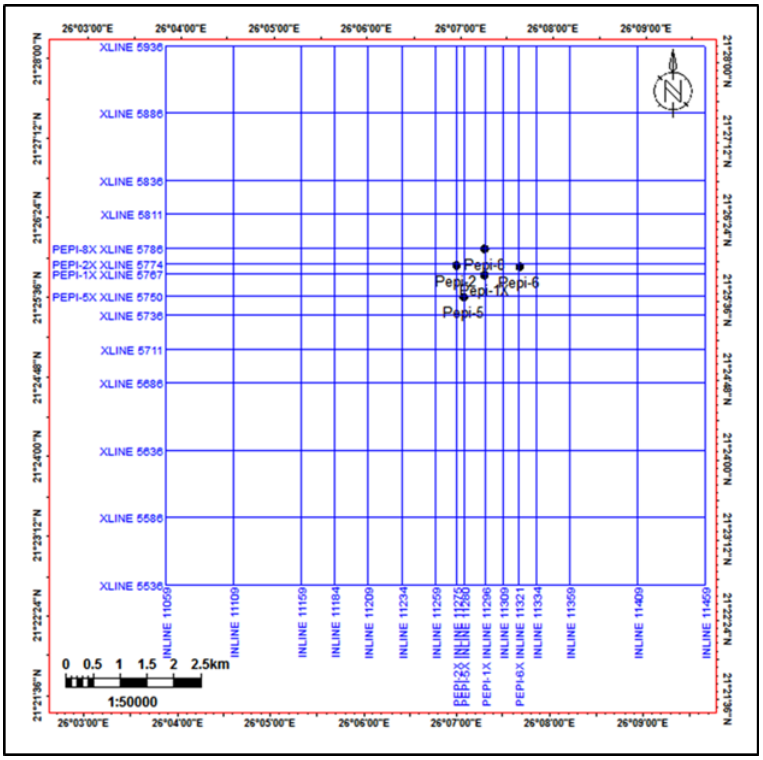

Fig. 3: Location map of the available seismic sections and wells.

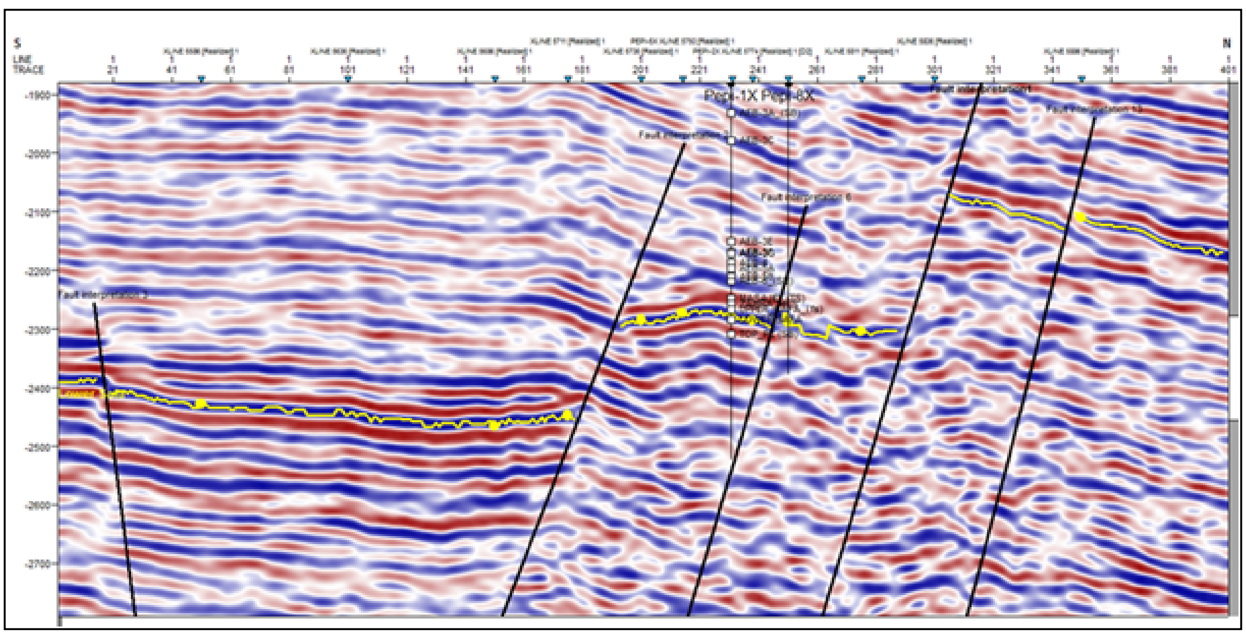

Fig. 4: Seismic line (in-line 11296) passing through the two studied wells showing the Lower Safa member and the faults crossing it.

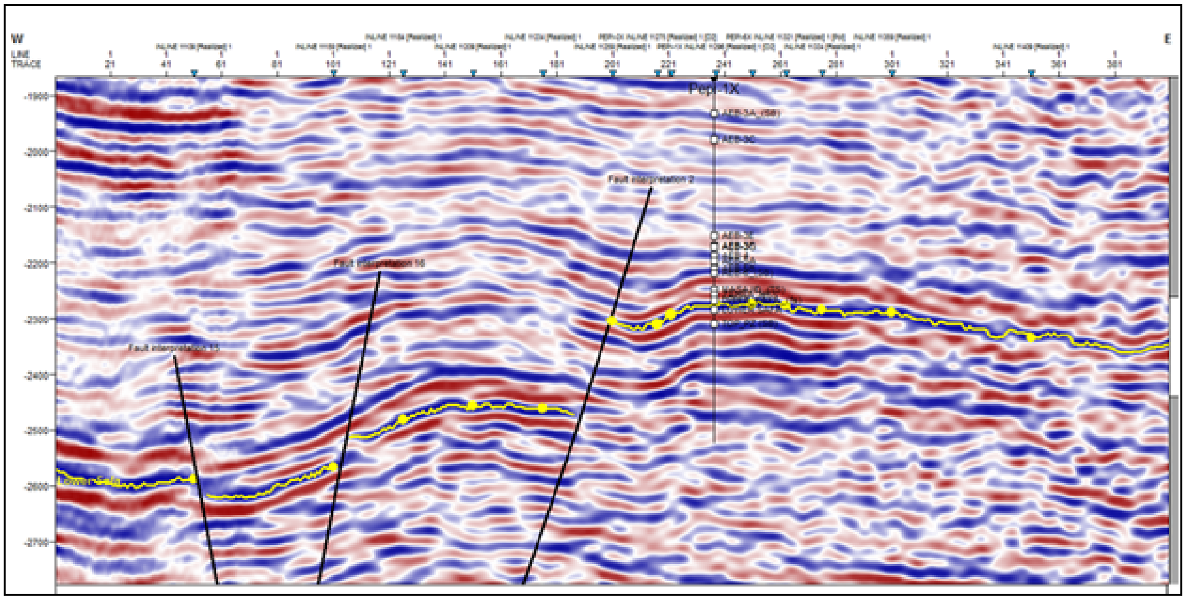

Fig. 5: Seismic line (x-line 5750) passing through the one studied wells showing the Lower Safa member and the faults crossing it.

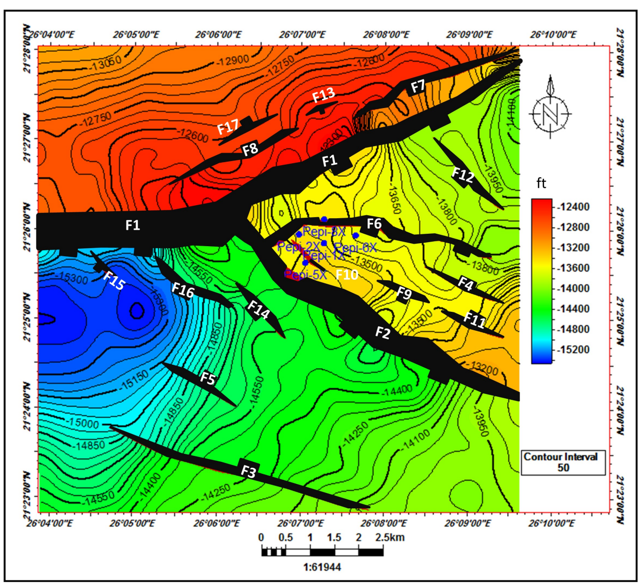

Fig. 6: Depth structure map of the Lower Safa member.

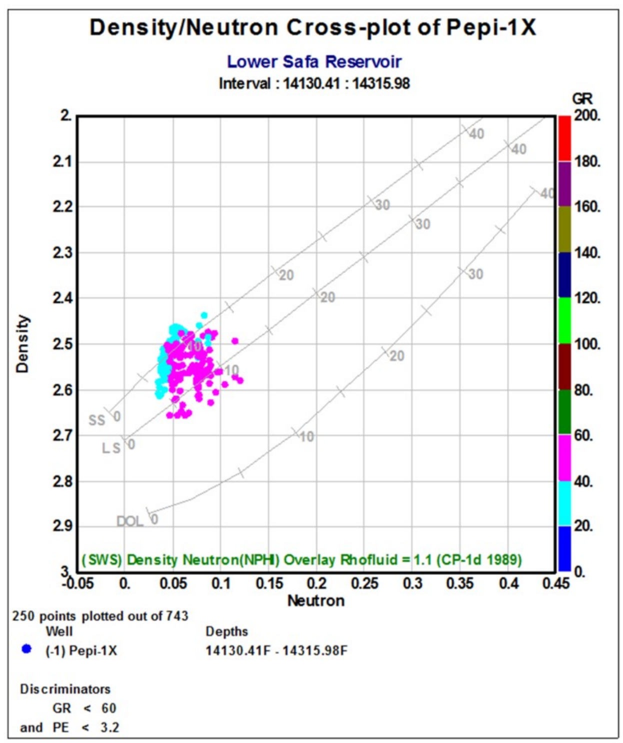

Fig. 7: Density/neutron cross-plot of the Lower Safa reservoir in Pepi-1X well.

.

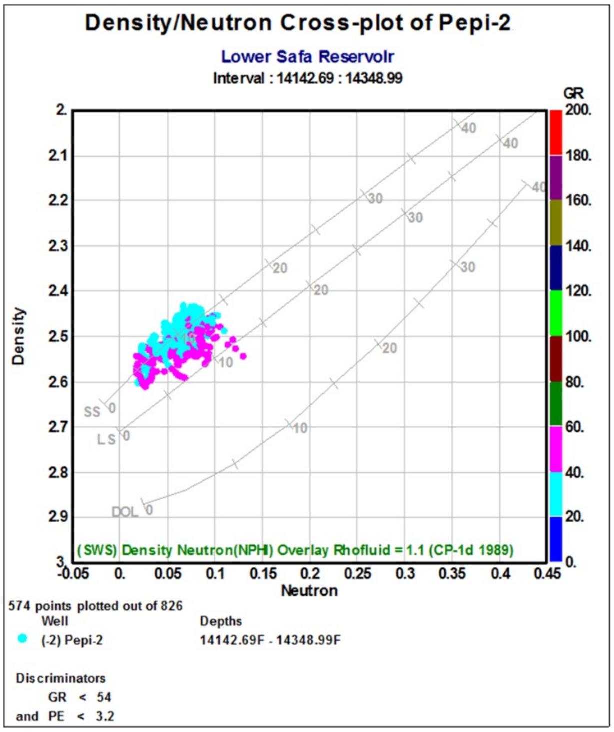

Fig. 8: Density/neutron cross-plot of the Lower Safa reservoir in Pepi-2 well.

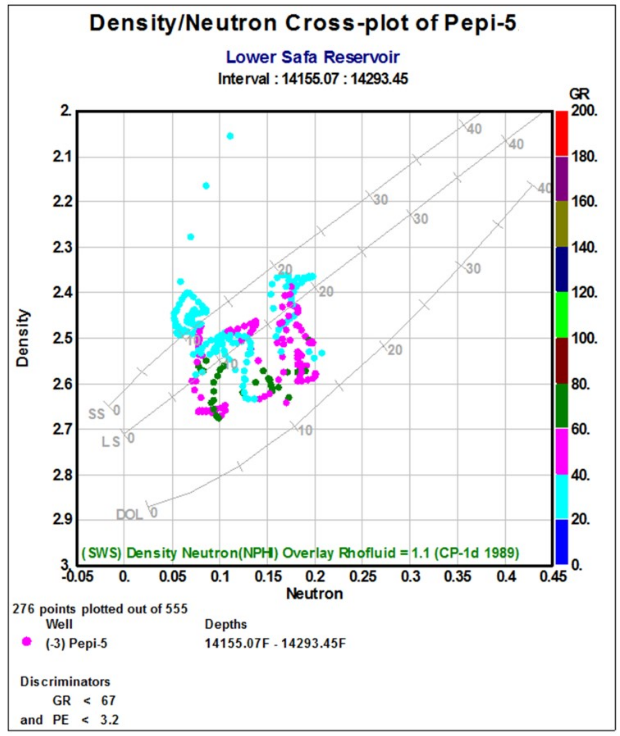

Fig. 9: Density/neutron cross-plot of the Lower Safa reservoir in Pepi-5 well.

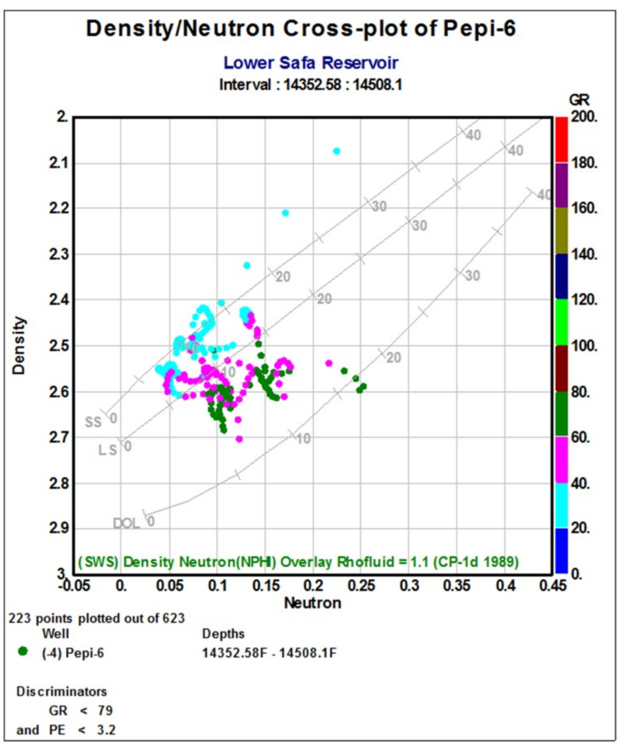

Fig. 10: Density/neutron cross-plot of the Lower Safa reservoir in Pepi-6 well.

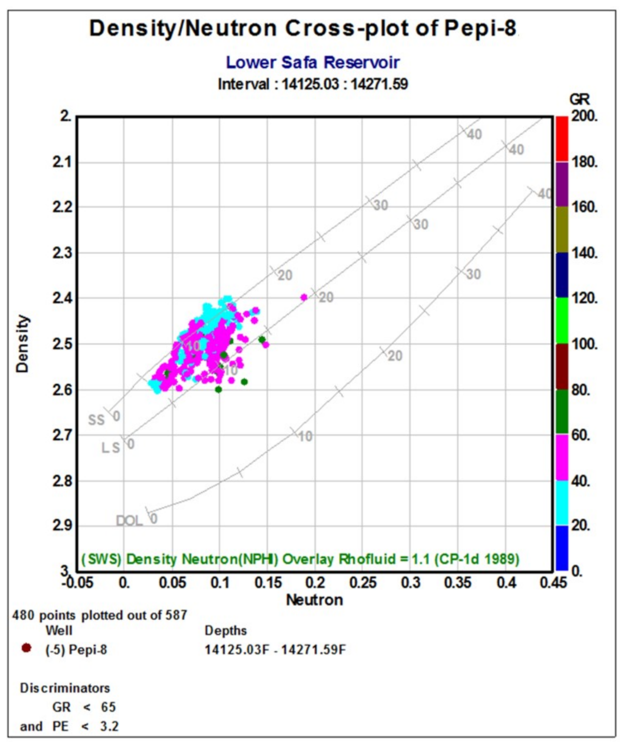

Fig. 11: Density/neutron cross-plot of the Lower Safa reservoir in Pepi-8 well.

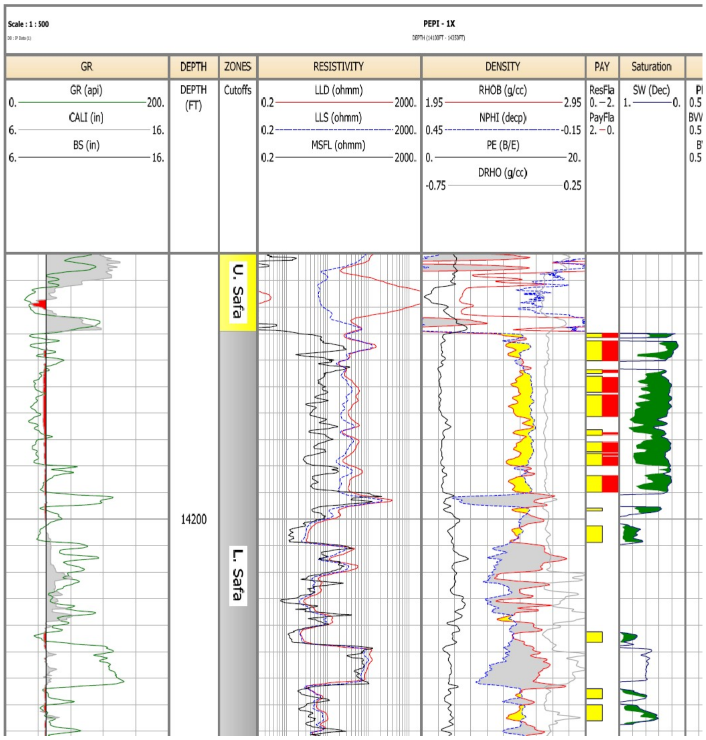

Fig. 12: Vertical distribution of Petrophysical parameters and lithology results of Lower Safa Member in Pepi-1X.

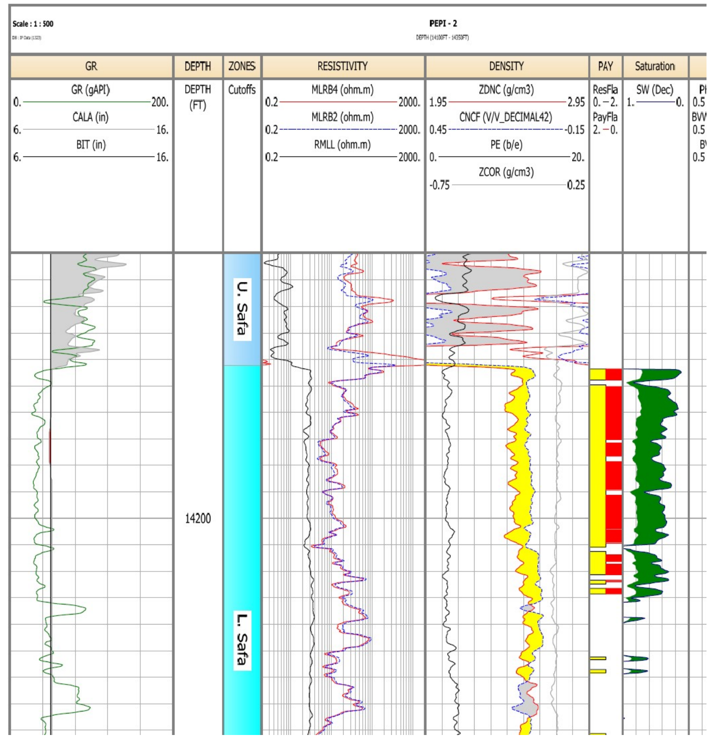

Fig. 13: Vertical distribution of Petrophysical parameters and lithology results of Lower Safa Member in Pepi-2.

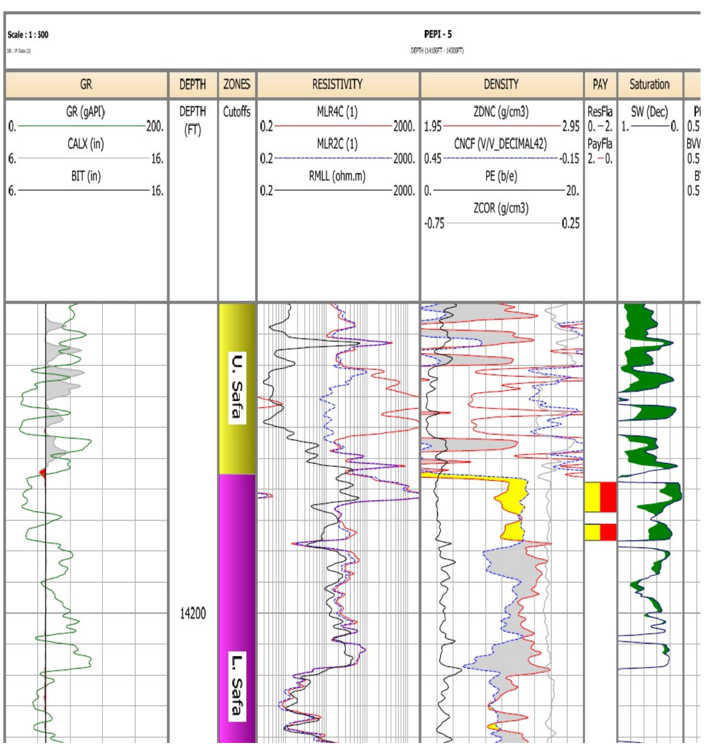

Fig. 14: Vertical distribution of Petrophysical parameters and lithology results of Lower Safa Member in Pepi-5.

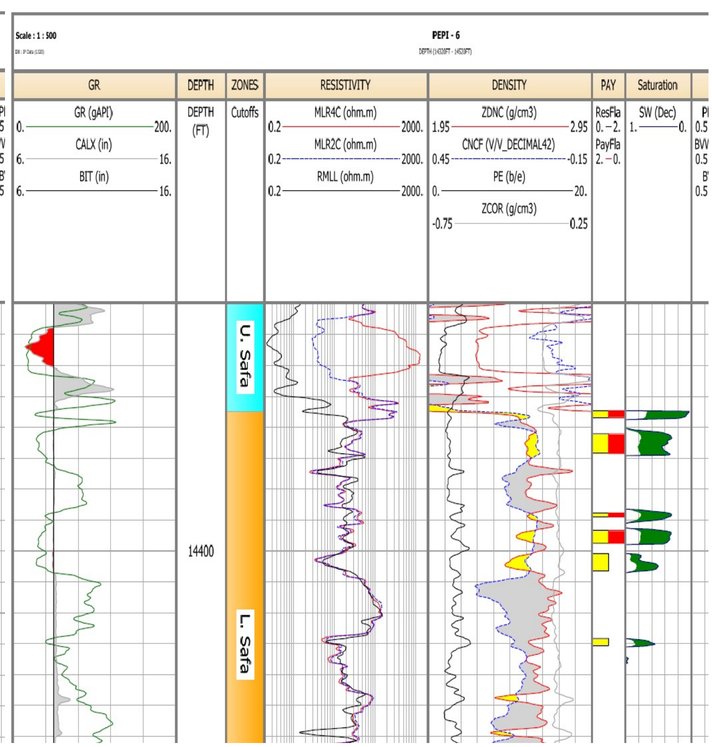

Fig. 15: Vertical distribution of Petrophysical parameters and lithology results of Lower Safa Member in Pepi-6.

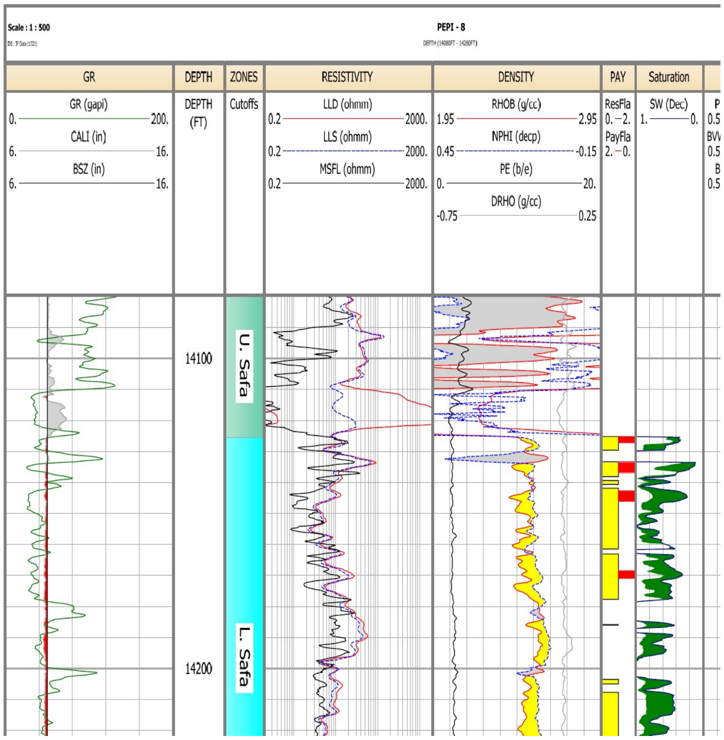

Fig. 16: Vertical distribution of Petrophysical parameters and lithology results of Lower Safa Member in Pepi-8.

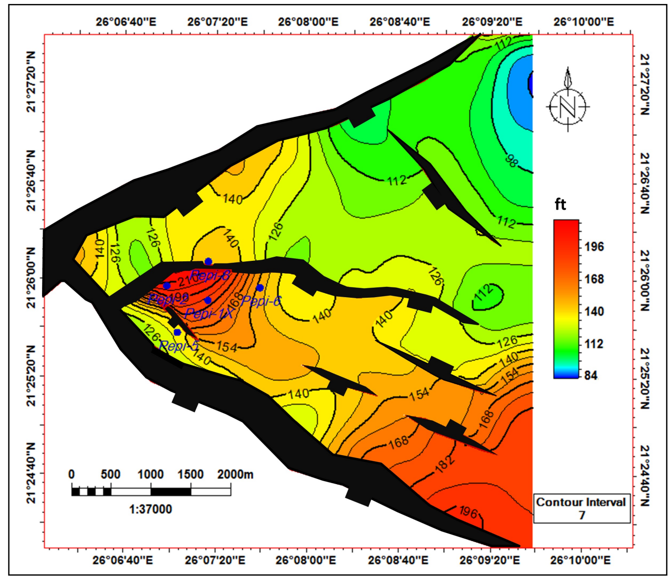

Fig. 17: Total thickness map of Lower Safa reservoir.

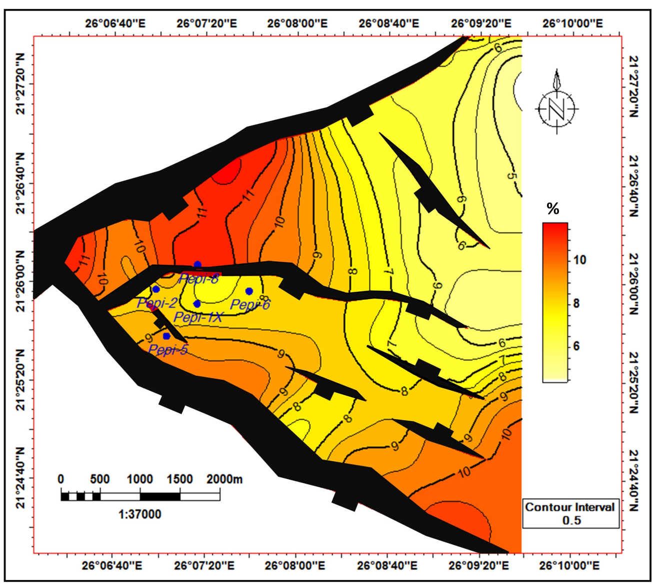

Fig. 18: Effective porosity map of Lower Safa reservoir.

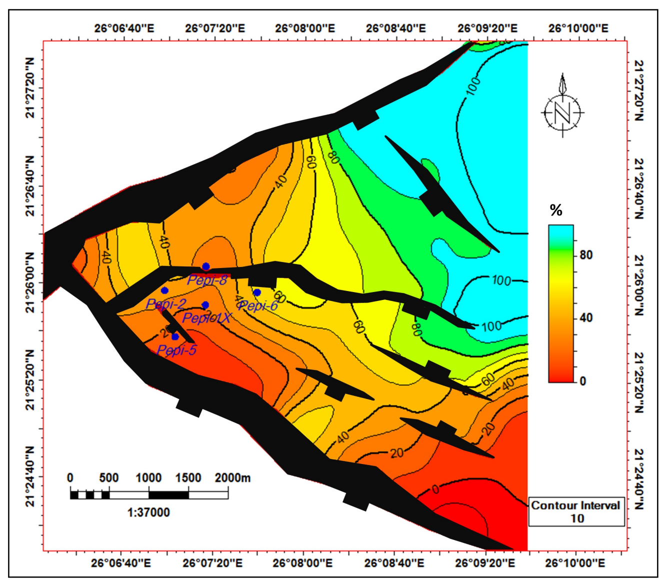

Fig. 19: Water saturation map of Lower Safa reservoir.

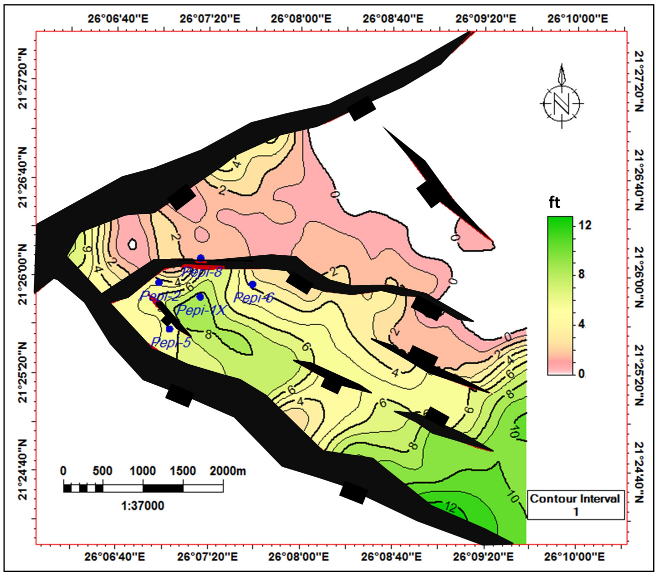

Fig. 20: Shale volume map of Lower Safa reservoir.

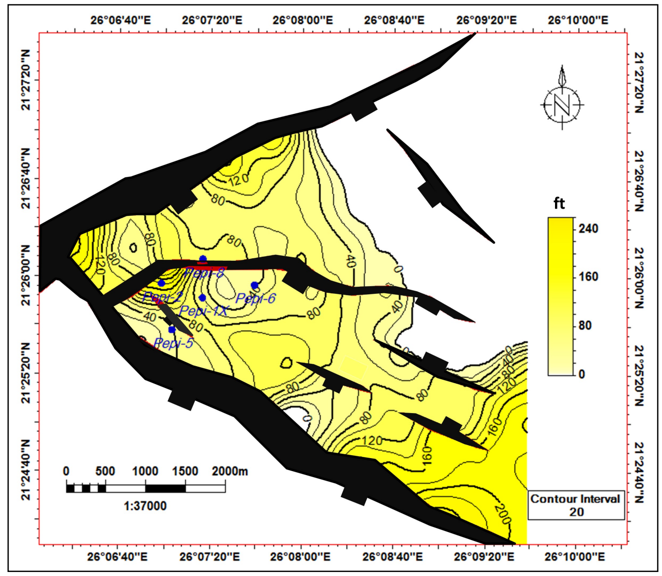

Fig. 21: Gross sand map of Lower Safa reservoir.

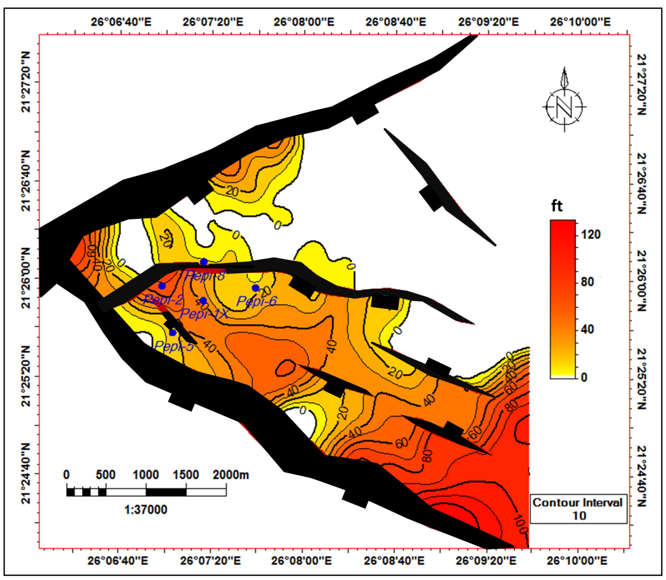

Fig. 22: Net pay map of Lower Safa reservoir.

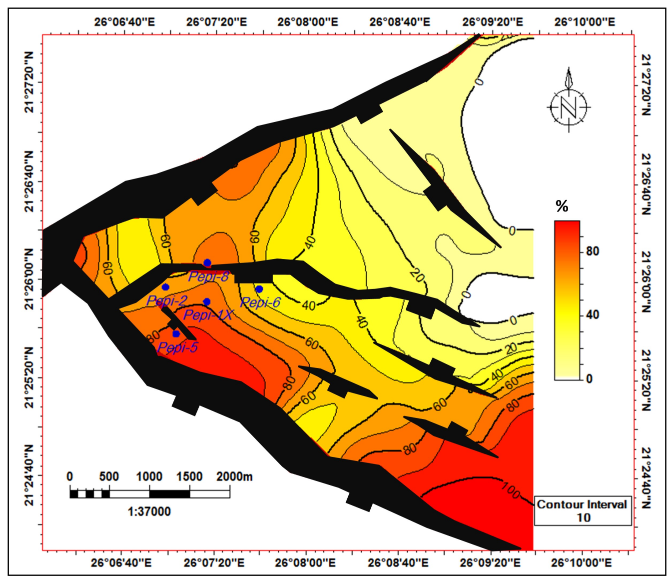

Fig. 23: Hydrocarbon map of Lower Safa reservoir.

Table 1: Summary of petrophysical results of Lower Safa reservoir for Pepi Field.

Well	Reservoir	Total Thickness (ft)	Effective Porosity (%)	Shale Volume (Vsh, %)	Gross Sand (ft)	Net pay (ft)	Water Saturation (Sw, %)	Hydrocarbon Saturation (Sh, %)
Pepi-1X	Lower Safa	187	7.6	8.3	61.5	38	22.6	77.4
Pepi-2		208	8.2	4.5	184	67.5	35.1	64.9
Pepi-5		135.5	9.2	5.4	37	15	14.9	85.1
Pepi-6		151.5	7.8	3.6	37.5	14	52.7	47.3
Pepi-8		142.5	11.3	1.8	92	10.5	27.4	72.6

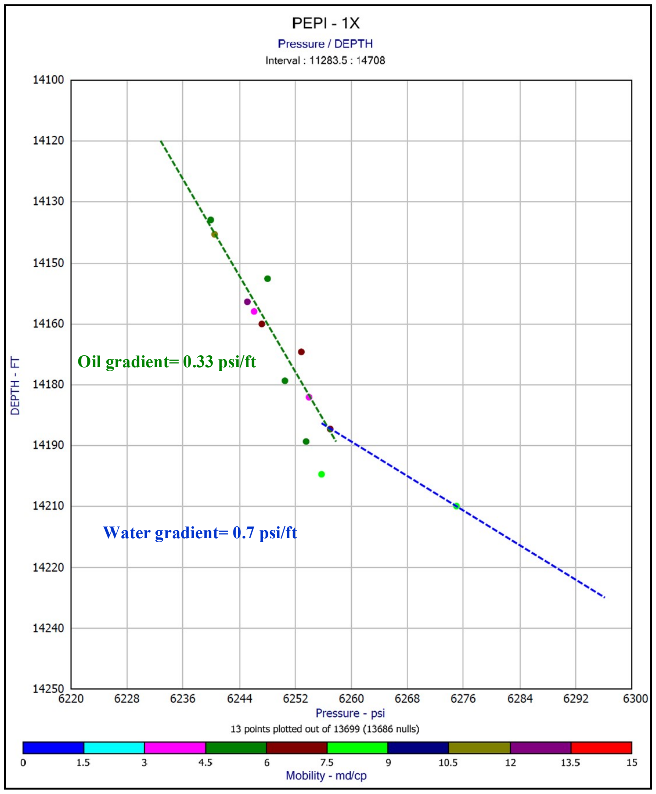

Fig. 24: Analysis of the Lower Safa reservoir Pressure data (RFT) in Pepi-1X well.

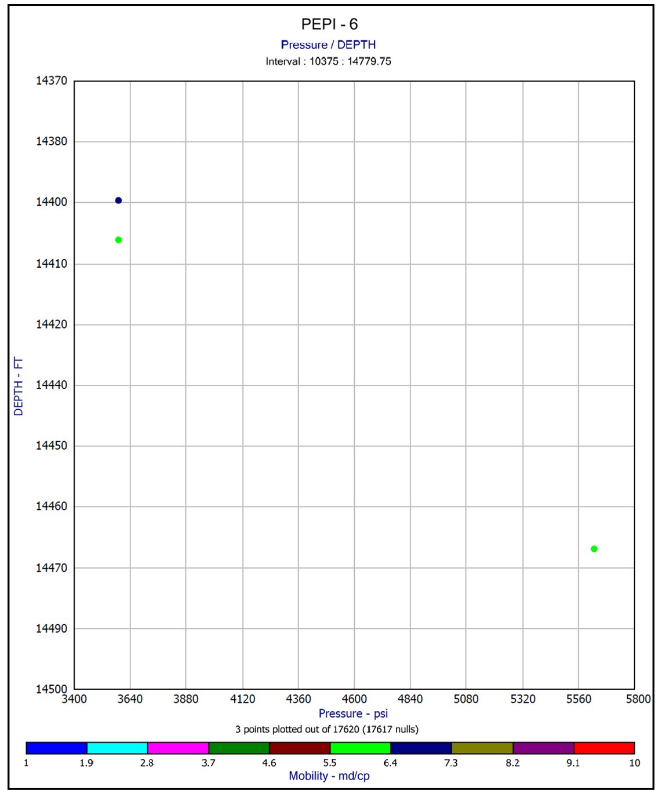

Fig. 25: Analysis of the Lower Safa reservoir pressure data (RFT) in Pepi-6 well.

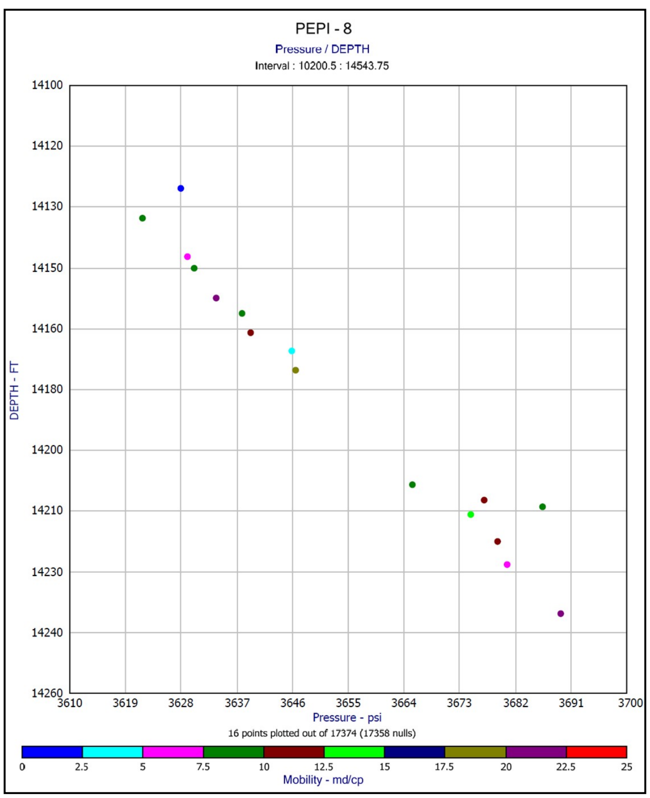

Fig. 26: Analysis of the Lower Safa reservoir pressure data (RFT) in Pepi-8 well.

تقييم القدرة الهيدروكربونية لخزان الصفا السفلي ، حقل بيبي ، حوض شوشان ، الصحراء الشمالية الغربية ، مصر

سارة رجب ابراهيم الغريب [1]، محمد ابراهيم البسطويسى[2] ، محمد صبحى الصادق[2] ،

عبد العزيز لطفى عبد الدايم[1]، شادية محمد عبد الرحيم[1]

1- قسم الجيولوجيا - كلية علوم - جامعة طنطا
2- شركة خالدة للبترول – المعادى – القاهرة - مصر

يعمل عضو الصفا السفلي من العصر الجوراسي الأوسط كمستودع للمواد الهيدروكربونية في حوض شوشان ، الصحراء الشمالية الغربية ، مصر. تم تخصيص العمل الحالي لدراسة الإعداد تحت السطحي وخصائص الخزان لهذا العضو لتقييم إمكاناته الهيدروكربونية في حقل بيبى ؛ تم استخدام التفسير السيزمى لثلاثين قطاع سيزمى ثنائي الأبعاد لتحديد الوضع التركيبى والخصائص التركيبيه التفصيلية التي تؤثر على هذا العضو من حيث الأزمنة والأعماق ذات الاتجاهين. تم استخدام بيانات سجل الآبار المتاحة من خمسة سجلات آبار (بيبى-1اكس و بيبى-2 و بيبى-5 و بيبى-6 و بيبى-8) لتحديد المعاملات البترفيزيائيه لصخر الخزان التي تساهم في تحديد مواقع واعدة لمزيد من الاستكشاف والتطوير. أظهر تفسير المقاطع السيزميه فالقين رئيسيين (فالق1وفالق 2) يشكلان تركيب نصف منخفض فى الأتجاه الشمال الشرقى-الجنوب الغربى و الشمال الغربى-الجنوب الشرقى، على التوالي. تساهم هذه الصدوع اهميه لتراكم الهيدروكربونات في حقل بيبى. كما أظهرت نتائج المخططات التبادلية للسجلات البئريه مثل الكثافة والنيوترونية أن الصخور لخزان الصفا السفلي المدروسة تتكون أساسًا من الحجر الرملي مع بعض الأسمنت الجيري. ساعد التخطيط الرأسي للبيانات البتروفيزيائية عبر التشبع اوالليثولوجى ..الخ وخرائط توزيع معلمات البتروفيزيائية مثل سمك الخزان المساميه لتحديد المكان الأنسب لحفر آبار منتجة جديدة. تتراوح المعلمات البتروفيزيائية المقدرة للخزان في منطقة الدراسة من حوالي 7,6٪ إلى 11,3٪ للمسامية الفعالة ، و من 1,8٪ إلى 8,3٪ لحجم الصخر الصخري ومن 47,3٪ إلى 85,1٪ للتشبع الهيدروكربوني. أظهرت النتائج أن حقل بيبى يتميز بمعايير مكمن جيدة. كما تم استخدام تحليل ضغط المكمن لتحديد نوع سائل المكمن ودرجة اتصال الهيدروكربونات في الأجزاء الحاملة للرمل. حيث يشير دمج النتائج التي تم الحصول عليها إلى أن عضو الصفا السفلي في حقل بيبى يحتوي على تراكم هيدروكربوني اقتصادى مع فرصة جيدة لزيادة معدل الإنتاجية من خلال حفر آبار استكشافية ووتطويريه اضافيه .