Essa et al. Iraqi Journal of Science, 2023, Vol. 64, No. 8, pp: 3948- 3962
DOI: 10.24996/ijs.2023.64.8.21

ISSN: 0067-2904

Field, Western Desert, Egypt

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Received: 9/5/2022 Accepted: 17/9/2022 Published: 30/8/2023

Abstract

This study aims to overcome the unexpected hydrocarbon non-potentiality detected in the upper Alam El-Bueib (I to IIIE) and justify the hydrocarbon accumulation within Alam El-Bueib (IIIG) at the Emry oil field, also, it is important to highlight the importance of fault seal analysis and the impact of Matruh canyon as a seal. Seismic interpretation and 3D structural framework are carried out using the fault-seal analysis technique for fault no.1 (F1). To assess the fault zone's capacity to be defined as either seal or leakage. Litho-facies juxtaposition diagram (Allan diagram) and Shale Gouge Ratio (SGR) were generated. It is concluded that the possible reason for the dry reservoir of the upper part of Alam El Bueib (Alam El Bueib I to IIIE) due to the leakage of the fault (F1). On the other hand, the seal mechanism for Alam El Bueib IIIG is mainly related to increasing the thickness of the Matruh shale and Matruh Canyon act as a seal rock. SGR for Alam El Bueib IIIG is around 80%, which confirms the presence of the shale in Matruh Canyon is the reason for accumulating the hydrocarbon at Alam El Bueib IIIG.

Keywords: Canyon, Seal, Shale Gouge Ratio, Juxtaposition, Emry Oil Field.

تحليل تأثير وجود الصدع ووادي مطروح علي طبيعة توزيع النفط تكوين علم البويب في حقل امري النفطي، الصحراء الغربية، مصر

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الخلاصة

تهدف هذه الدراسة إلى التغلب على مشكلة الإمكانات الهيدروكربونية غير المتوقعة للجزء العلوي لعلم البويب (I to IIIE) وتبرير التجمع الهيدروكربوني داخل علم البويب (IIIG) في حقل إمري النفطي وأيضا تسليط الضوء على أهمية تحليل ممانعة الصدع لهجرة الزيت وتأثير وادي مطروح كممانع لهجرة الزيت في منطقة إمري. ولتحقيق هذا الهدف تم عمل محاكاة للبيانات السيزمية وعمل نمذجة هيكلية ثلاثية الابعاد. ثم تم استخدام تقنية تحليل تأثير وجود الصدع لتحليل مدى قدرة منطقة الصدع على ممانعة هجرة الزيت بطريقتين، الأولى هي

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باستخدام السحن الذي يتم تفسيره بواسطة خريطة مواجهة النطاقات عبر على جانبى الصدع (شكل ألن) والطريقة الثانية نسبة الصخر الطيني (SGR) الملامسة للصدع.
يعتقد أن السبب المحتمل للخزان الجاف للجزء العلوي لعلم البويب (الأول إلى الثالث) هو تسريب الصدع (F1). من ناحية أخرى، ترتبط آلية الممانعة الخاصة بعلم البويب IIIG بشكل أساسي بزيادة سمك الصخر الطيني داخل وادي مطروح ويعمل وادي مطروح الطيني كمانع لهجرة الزيت من علم البويب IIIG، نسبة SGR حول طبقة علم البويب IIIG ‎80٪‏ وهو ما يؤكد أن وادي مطروح الطيني المسبب لتجميع النفط في طبقة لعلم البويب IIIG.

1. Introduction

Fault seal analysis is an important element of the petroleum system; another four key elements are necessary for the petroleum system [1]. These fundamental elements are the source rock, the reservoir rock, the trap and finally, the migration of the hydrocarbon [1]. The sealing mechanism can result from juxtaposing permeable rocks (reservoir) occur against impermeable (Non-reservoir) rocks through a fault plane. It may also form when the reservoir is juxtaposed against another reservoir, but in this case, the materials inside the fault zone itself act as barriers to hydrocarbon migration [2]. The North Western Desert (NWD) of Egypt contains most of the hydrocarbon fields, and the Emry oil field is one of these fields.

The study area lies SW of Matruh city, sited between latitudes 30° 03' and 30° 54' N and longitudes 27° 00' and 27° 18' E (Figure 1). Emry oil field occupies an area among Shushan and Matruh Basins.

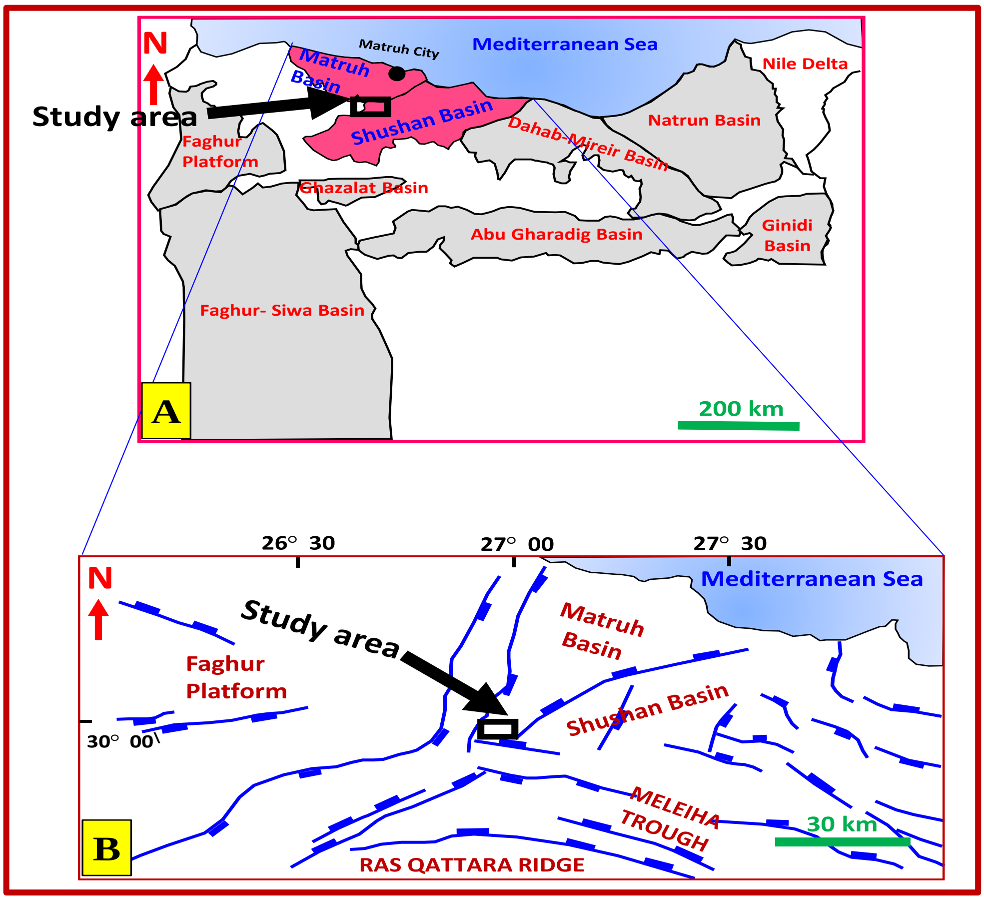

Figure 1: A. Emry oil field located between Matruh-Shushan basins and **B**. normal faults affected the study area **Error! Reference source not found.** [3].

The area of interest is affected by the erosion of the Matruh canyon and filled by shale within Alam El Bueib IIIG member (Lower Cretaceous). Emry Deep_01X has been explored with the hydrocarbon column is about 76 meters at Alam El Bueib IIIG. Alam El Bueib IIIG is one of the main oil-bearing in Alam El Bueib Member in the Emry area [4]. The entrapment is a combination trap with fault assisted at Emry oil field. The fault seal analysis was introduced and illustrated by several authors, such as [5] [6] [7] [8].

Alam El Bueib (AEB) Member of several areas in the Northwestern Desert of Egypt, is one of the main reservoirs [9] [10] [11] [12] [13]. In order to produce a 3D litho-facies model and generate Shale Gouge Ratio (SGR) model, a 3D modelling technique had been created. The 3D model is mandatory to investigate the structural characteristics of reservoirs [14] [15] [16] [17]**Error! Reference source not found.**. This work clarifies the importance of seal analysis for the hydrocarbon potentiality of Alam El Bueib IIIG (part of Alam El Bueib Member) and highlights Matruh Canyon's importance for hydrocarbon accumulation.

2. Geological settings

The age of Alam El Bueib Member is Cretaceous; the facies is predominantly sandstone with siltstone and gray shale, with small carbonate beds in most areas. Matruh Shale is a marine shale with thin sandy, and calcareous interbeds. It is laterally equivalent to Alam EI Bueib Member in the South and the East**Error! Reference source not found.**. Matruh shale may consider a good lateral seal. The average thickness of Alam El Bueib IIIF is around 10 meters to 60 meters with shaly to silty facies. In Matruh basin, the thickness of the Matruh Shale increases to around 400 meters due to Matruh shale [18] [19].

[20] said that the sedimentary basins of the northern WD were structurally controlled, leading to several rock facies to be deposited**.** The northern WD is controlled by faults, mainly determined from seismic and well data. The majority of these faults are controlled by faults NW to NNW-SE [21] **(**Figure 1).

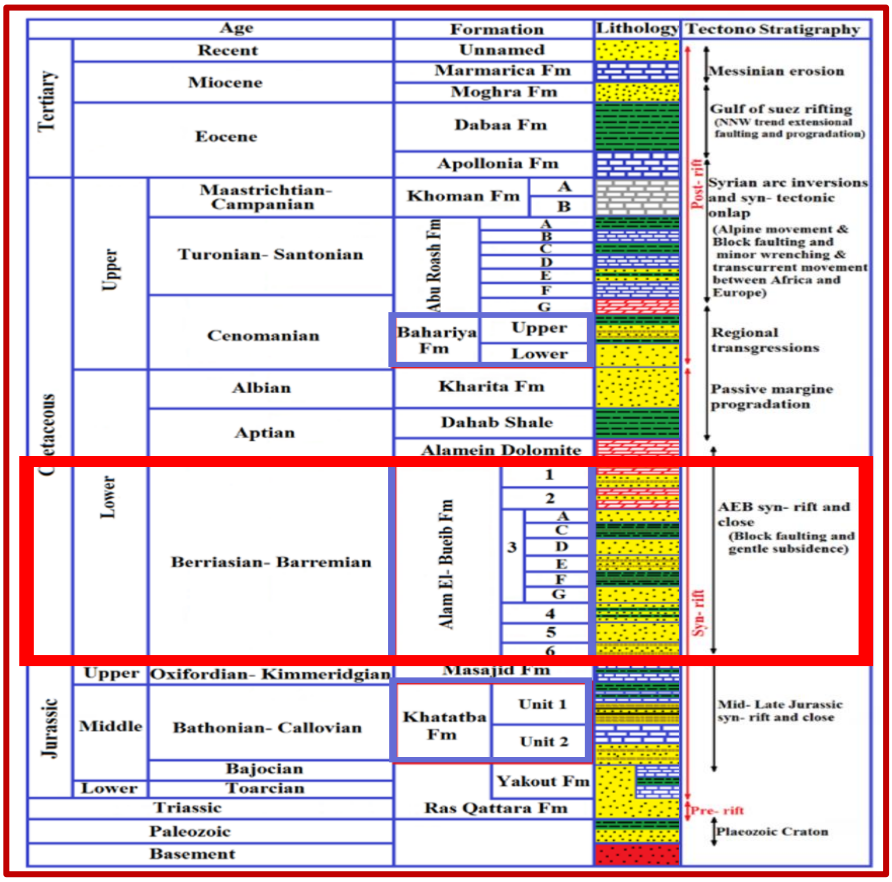

Figure 2: Generalized stratigraphic geological column for North Western Desert of Egypt [22], highlighted with the rift boundaries**Error! Reference source not found.** [23].

Alam El Bueib Members' rocks act as sources, cap and reservoirs in several basins in the Western Desert. Alam El Bueib Member is divided into several units as follow (I, IIA, IIB, IIIA, IIIB, IIIC, IIID, IIIE, IIIF, IIIG, IV, V and VI) (Figure 2).

3. Materials and methodology

The geometry of the seismic survey is orthogonal. The receiver lines were running in a north-south direction while the source lines were running in an east-west direction. The spacing for both the receiver and source lines spacing is 250 m. The sources were vibrosis, while the receivers were the geophones. The frequency ranged between 6-72 HZ, while the seismic polarity is SEG polarity. A package of 2D seismic sections extracted from 3D survey with five wells with their E-logs**,** the proposal is to produce fault seal analysis (Figure 3). To achieve the aim of the study through several steps such as well correlation, seismic interpretation [24], V_{sh} analysis for the wells, 3D modelling of the reservoir, and finally, fault seal analysis.

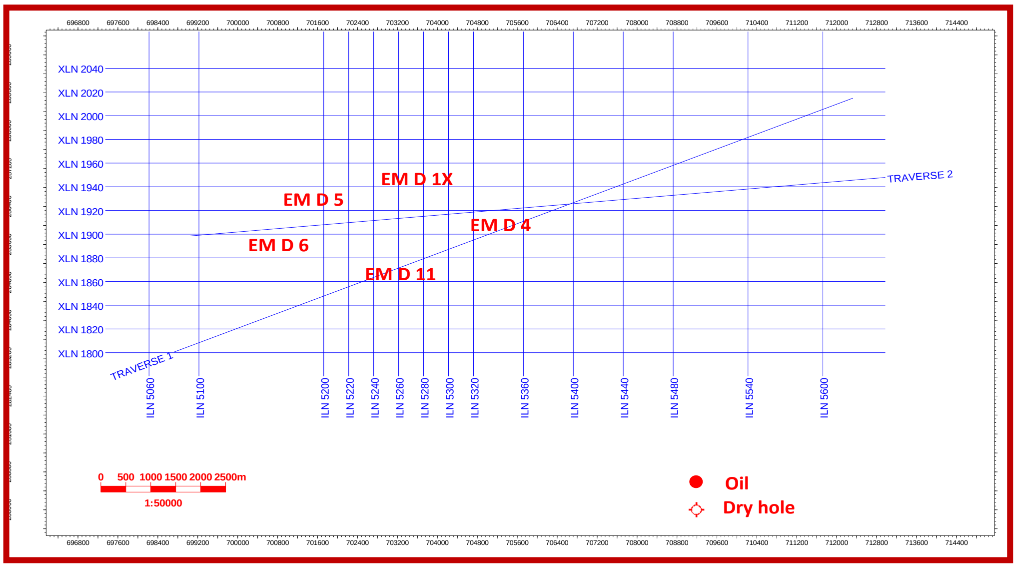

Figure 3: Base map including the available seismic sections and the location of five wells.

The current research divides the fault-seal analysis technique into two techniques. The first technique is based on the concepts of juxtaposition (Allan diagram) [25], which utilizes the fault-seal lithology to test the fault capacity of either sealing or non-sealing of the interesting fault. The second technique is quantitative seal analysis, which utilizes Shale Gouge Ratio (SGR) Eq. (1). SGR [26] is based on Vsh and the thickness of each zone. The Vsh was calculated based on [27]. [28] said that the values of SGR from (15 to 20 %) are defined as leakage fault, and the values around 20 to 60 % are associated with weak seal to be a moderate seal. Finally, the values of SGR above (60 %) are identified as a sealing fault [28].

$$SGR = \sum(Vsh * \Delta z) / fault\ throw * 100\% \quad (1)$$

Where, Vsh = Shale volume fraction at each zone, Δz = Thickness of each discrete lithology

4. Results and discussion

The study's objective highlights the importance of lateral seal analysis.

4.1. Well correlation and formation evaluation

Ten markers were interpreted between the five wells (Figure 3). The markers are Alamein Formation, Alam El Bueib I, IIA, IIB, IIIA, IIIB, IIIC, IIID, IIIE, IIIF and IIIG. Alam El Bueib IIIG was eroded by Matruh Canyon and substituted by Matruh shale. The thickness of Matruh shale exceeds in Emry Deep_04, Emry Deep_05 and Emry Deep_11.

Figure 4 reveals that all the reservoirs are dry except Alam El Bueib IIIG. The hydrocarbon is found in the wells which are away from erosion.

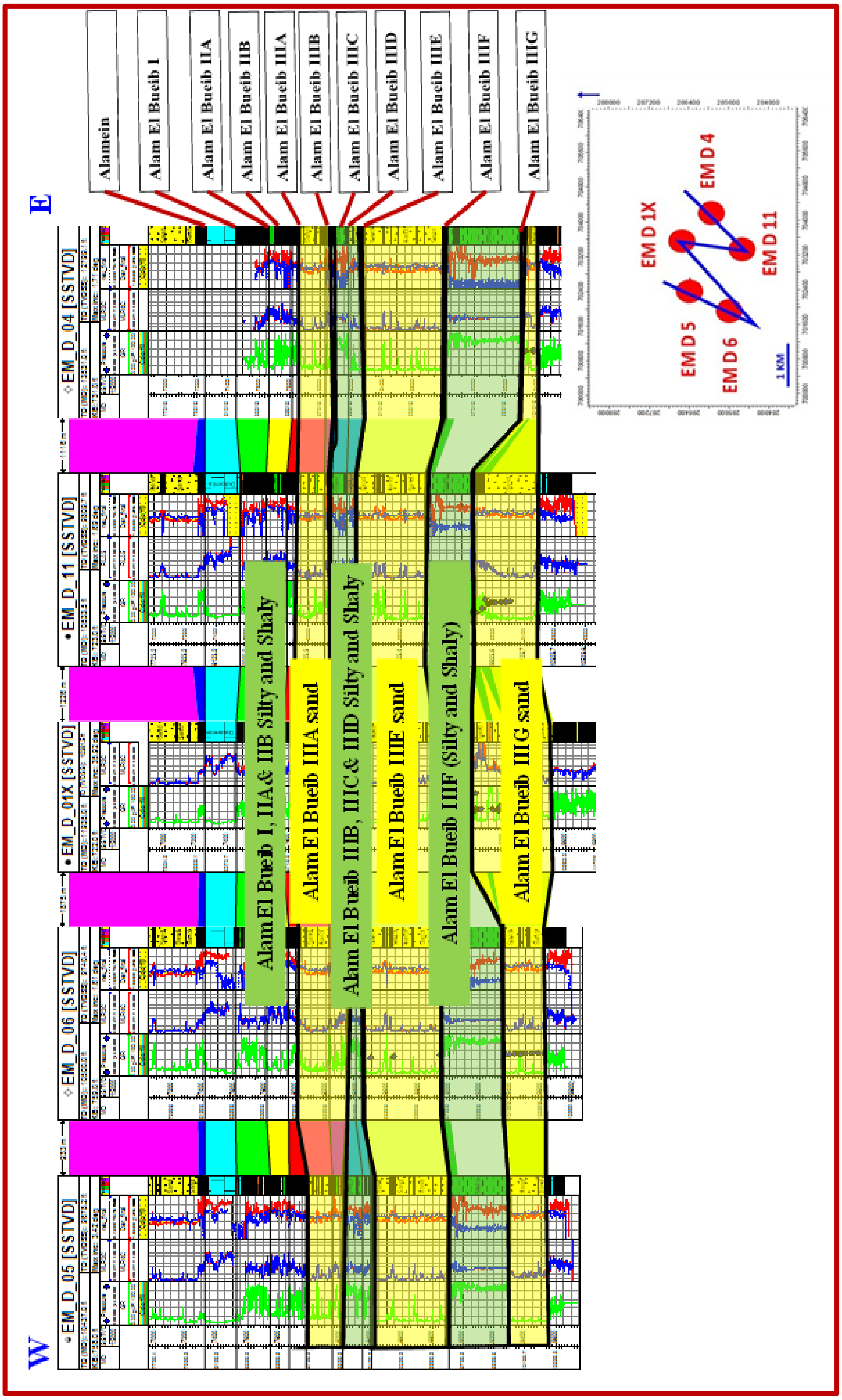

Figure 4: Regional correlation for Alam El Bueib Member between Emry Deep 05, Emry Deep 06, Emry Deep 11, Emry Deep 1X and Emry Deep 04 shows the erosion of Matruh Canyon.

The zonation divides Alam El Bueib into reservoirs and non-reservoir based on their lithology (Figure 4). The reservoirs are Alam El Bueib IIIA, IIIE and IIIG, while Alam El Bueib

I, IIA, IIB, IIIB, IIIC and IIIF were represented as impermeable zones (Figure 4), the thickness of Alam El Bueib IIIF increases due to the infill of the shale inside Matruh Canyon. Based on the correlation panel, the thickness of Alam El Bueib IIIG decreases to the East and the West due to the effect of the Matruh Canyon.

4.2. Seismic interpretation

The N-S inline 5320 seismic section shows the faults that dissect Alam El Bueib (Figure 5). The E-W crossline 1920 illustrates a smaller number of faults, it is the main line to detect Matruh Canyon (Figure 5).

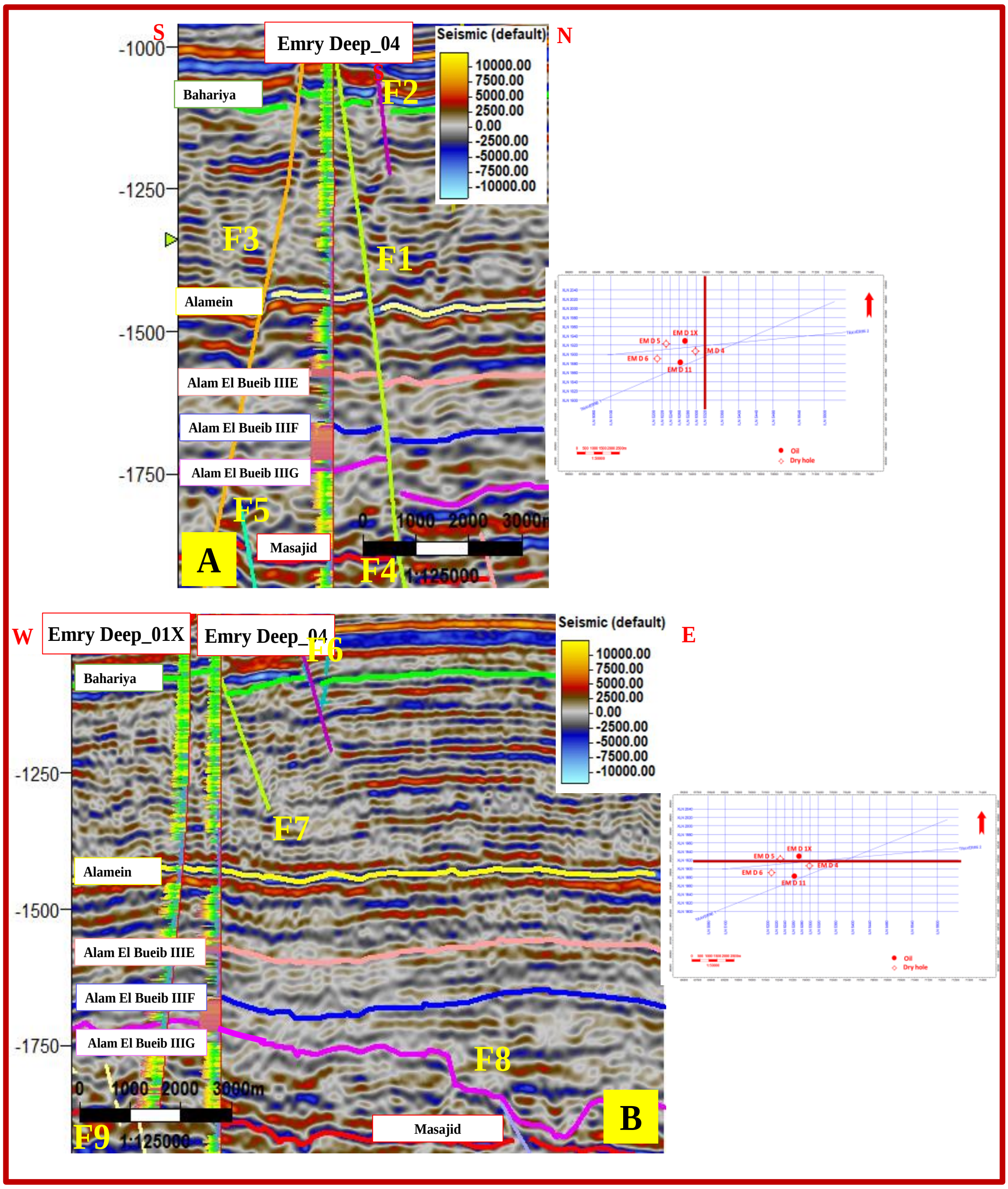

Figure 5: Reveals the Seismic lines for A. Iln 5320 and B. Xln 1920 with interpreted horizons and normal faults (F1) controlling the structure.

Thirty 2D seismic lines were used to interpret the area. The faults in the Emry area are trended as NW-SE and ENE-WSW. The area of interest is bounded by two faults, F1 and F19, from the north and the south, respectively.

4.3. Horizon mapping

The trap definition for Alam El Bueib IIIE is a structure trap bounded from the North by F1. The spill point is around -2542 m tvd subsea (Figure 6A). The structure geometry is a three-way dip closure. The entrapment for Alam El Bueib IIIG sand III is a combination trap. The faults system is Jurassic, and later the impact of the stratigraphic event (Matruh Canyon) eroded Alam El Bueib IIIG from the north, east and west, and the shale of Matruh Canyon covered Alam El Bueib IIIG from all directions (Figure 6B).

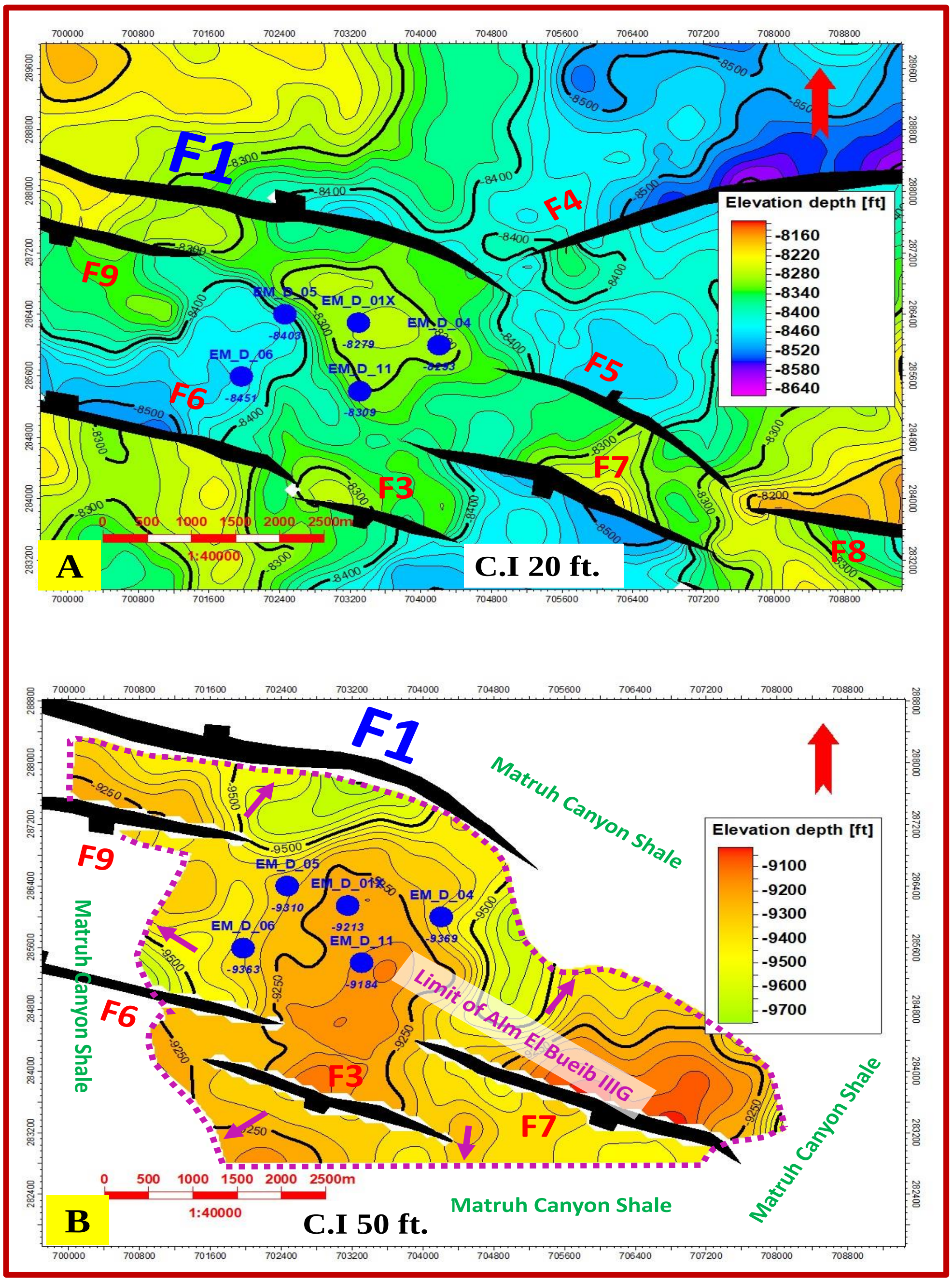

Figure 6: A and B. display the map of top Alam El Bueib IIIE and Alam El Bueib IIIG, respectively, and highlight around target fault (F1).

4.4. Volume of shale

The Vsh logs are mandatory to create the shale gouge ratio displaying the Vsh, which presented two shaly zones (seal) in blue while the sandy zones in yellow (Figure 7).
The values of Vsh increase with the presence of the shale, the maximum calculated values within Matruh canyon and the minimum values within Alam El Bueib IIIE and IIIG.

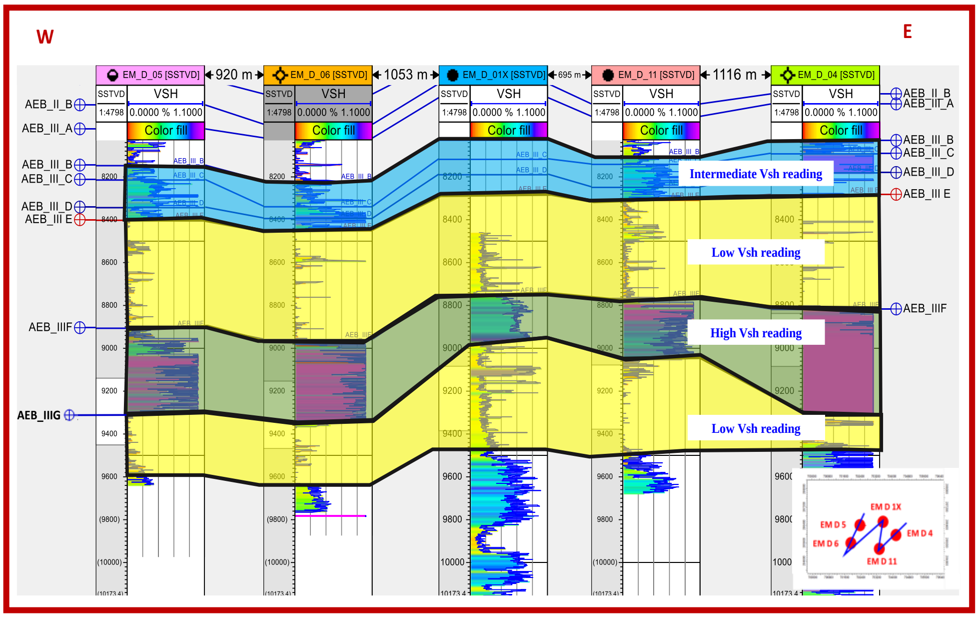

Figure 7: Representing Vsh logs for the Emry Deep_01X, Emry Deep_04, Emry Deep_05, Emry Deep_06 and Emry Deep_11.

4.5. 3D model creation

The first step is to build a fault model. The area is bounded by main fault F1 (Figure 8). Two different models were initialized from Alamein Formation to Alam El Bueib IIIE (Figure 9A) and from Alam El Bueib IIIF to Alam El Bueib IIIG (Figure 9B).

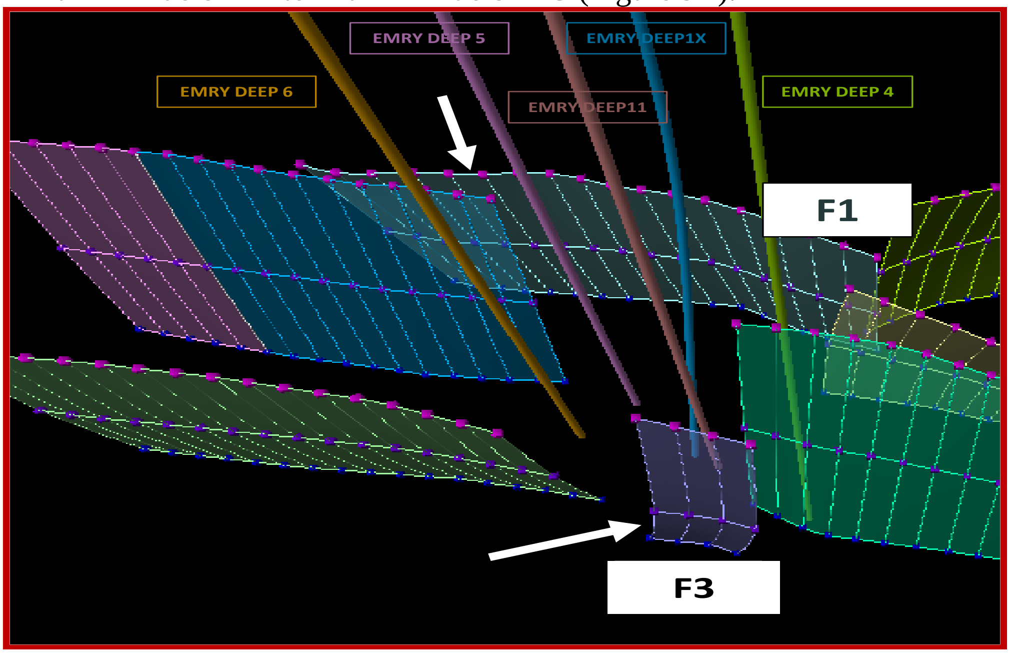

Figure 8: 3D fault modelling at Emry oil field.

The second step is to model the horizons inside the model. The two input grids are Alam El Bueib IIIE to Alam El Bueib IIIG Sand IIII. It was then upscaling the facies logs and Vsh logs. The last stage is to populate the properties inside the model.

Figure 9A displays the structure depth map for the interpreted Alam El Bueib IIIE with the related spill point, Alam El Bueib IIIA is the modelled horizon, and the fault (F1) is penetrated all Alam El Bueib layers. Figure 9B is a 3D view of Alam El Bueib IIIG with the spill point.

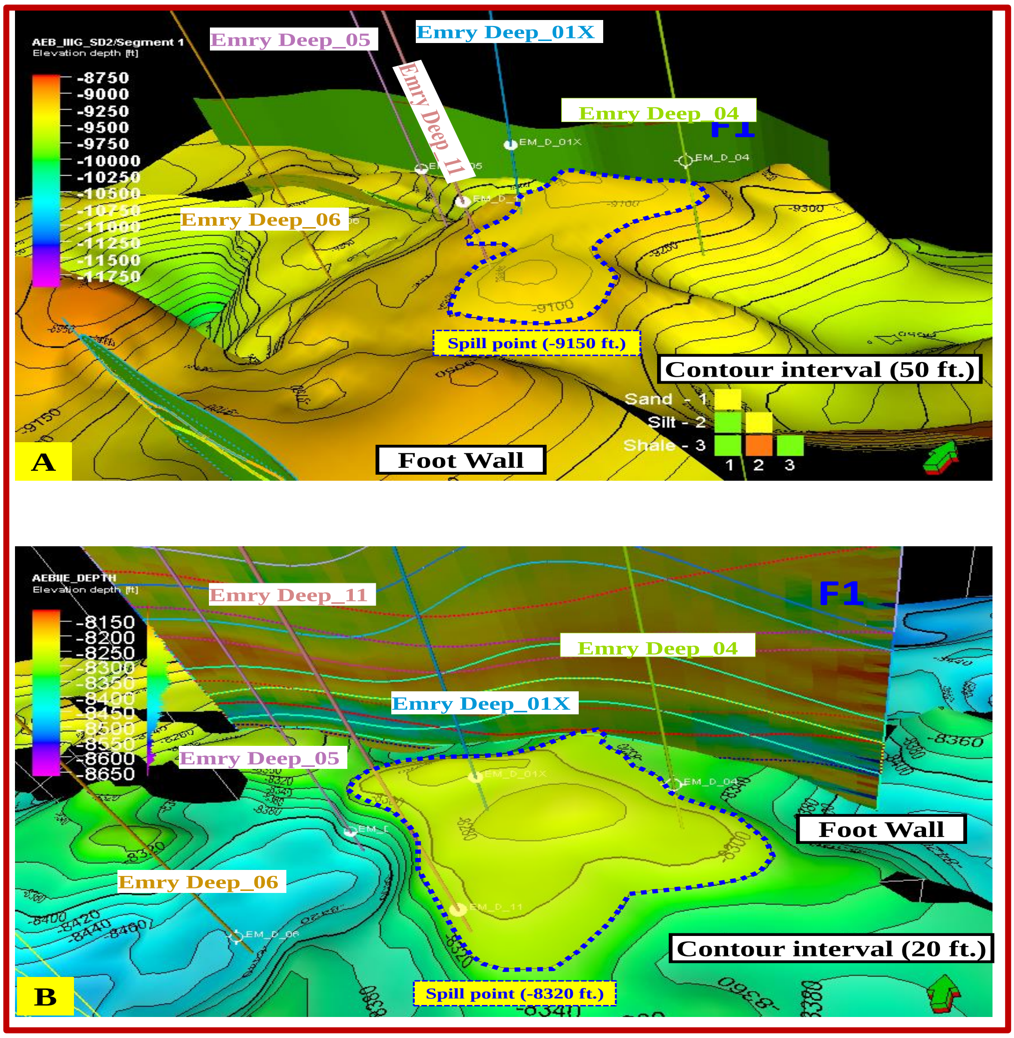

Figure 9: A. Delineating Alam El Bueib IIIE and B. Alam El Bueib IIIG structure depth maps with the spill point intersecting with the fault surface (F1).

4.6. Fault seal analysis from Alamein Formation to Alam El Bueib IIIE

Identifying the leakage of fault segments is an important and critical geometric component that connects the across-fault flow. Hydrocarbon trapping by fault sealing denotes a vital indefinite aspect in risk analysis associated with strategies of hydrocarbon exploration. In addition, fault sealing is a vital factor that controls reservoir behavior during production. The cross-section explains qualitative juxtaposed fault seal analysis by litho-facies, and Vsh (Figure 10 A-B) explains Alam El Bueib IIIA and IIIE (reservoir) are juxtaposed against the sandy layers of Alam El Bueib Member in the downthrown, which is possible leakage.

Allen diagram (Figure 11-A) reveals the fault surface map between Alamein Formation and Alam El Bueib IIIE at (F1). The juxtaposed sand to sand presents in yellow color, while sand to shale displays in green color and silt to silt exposes in orange color, Alam El Bueib IIIA and IIIE are the reservoirs. Figure 10-A introduces the litho-facies model for Alam El Bueib IIIA and IIIE. It is sand to the sand case across the fault plane and most probably represents leakage zones. Based on the Shale Gouge Ratio of Alamein Formation to Alam El Bueib IIIE**,** the values at the main reservoirs Alam El Bueib IIIA and IIIE are around 5% to 25%, so these values inferred these reservoirs are possible leakage (Figure 11B).

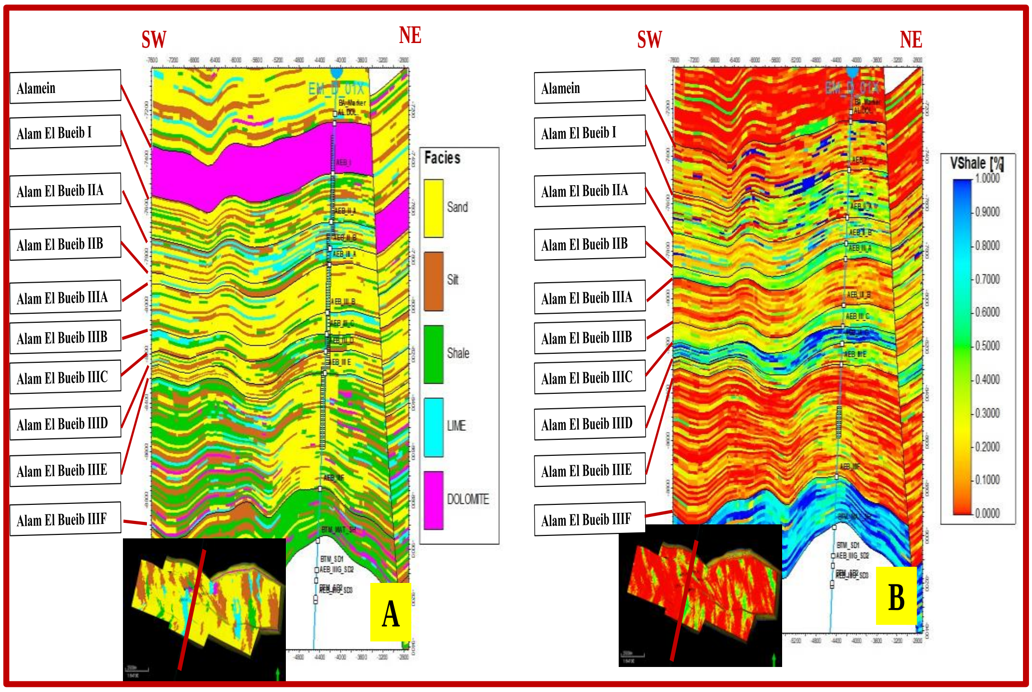

Figure 10: Cross section for (Litho-facies) and (Vsh) of the Alamein Formation to Alam El Bueib IIIE target fault No. 1 (F1).

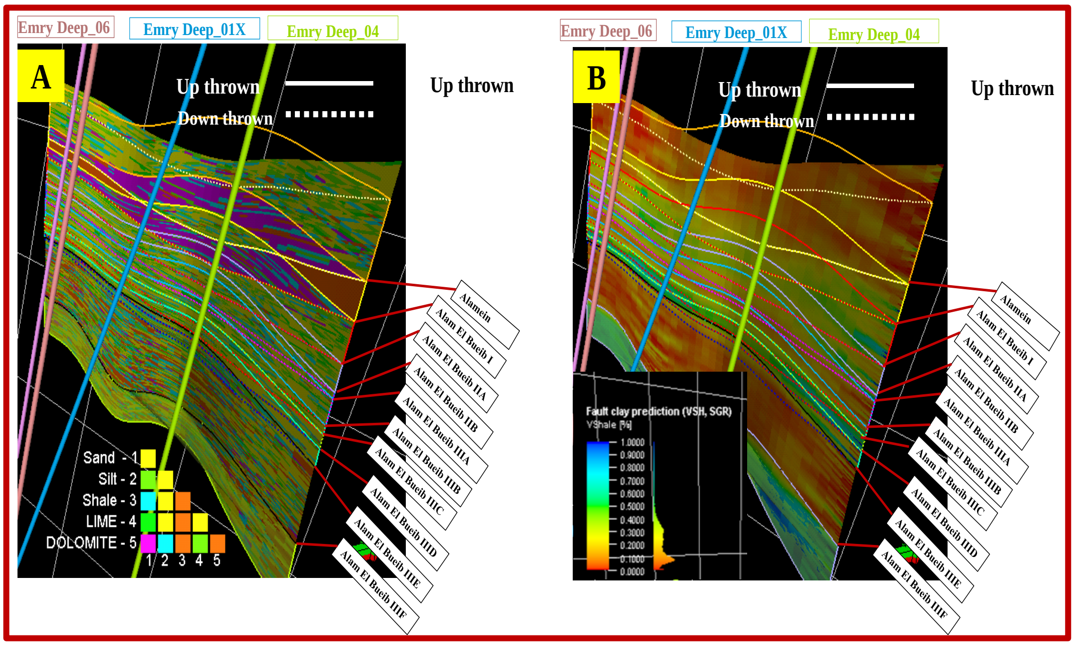

Figure 11: Juxtaposition (Litho- Facies) and Shale Gouge Ratio (SGR) diagrams for (F1) for (F1), from Alamein Formation to Alam El Bueib IIIE member.

*4.7. Fault seal analysis from Alam El Bueib IIIF to Alam El Bueib IIIG***.**

Figures 12A-B indicate the litho-facies and Vsh section for Alam El Bueib IIIG juxtaposed against Alam El Bueib IIIF and Matruh, indicating a possible seal.

The Allen diagram for the fault seal analysis for (F1) explains that Alam El Bueib IIIG is the reservoir while Alam El Bueib IIIF and Matruh Shale are the seals (Figure 12 A). In the Emry area, the shale thickness increases due to the Matruh Canyon being filled with shale. Matruh Shale blanketed Alam El Bueib IIIG from all directions, which is why the hydrocarbon accumulates in Alam El Bueib IIIG. Figure 13B illustrates the Shale Gouge Ratio for around (F1). The values of SGR are around 80%, indicating a possible lateral seal (Figure 13 B).

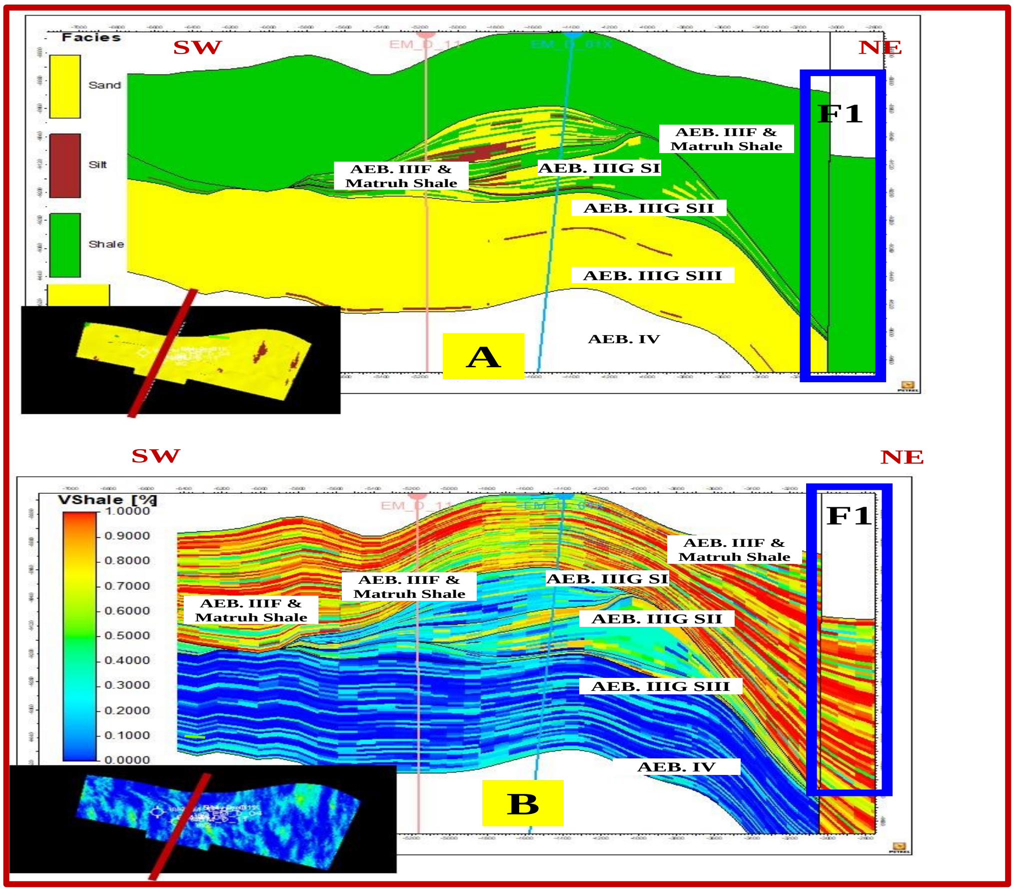

Figure 12: Cross section for (Litho-facies) and (Vsh) of the Alamein Formation to Alam El Bueib IIIE target fault No. 1 (F1).

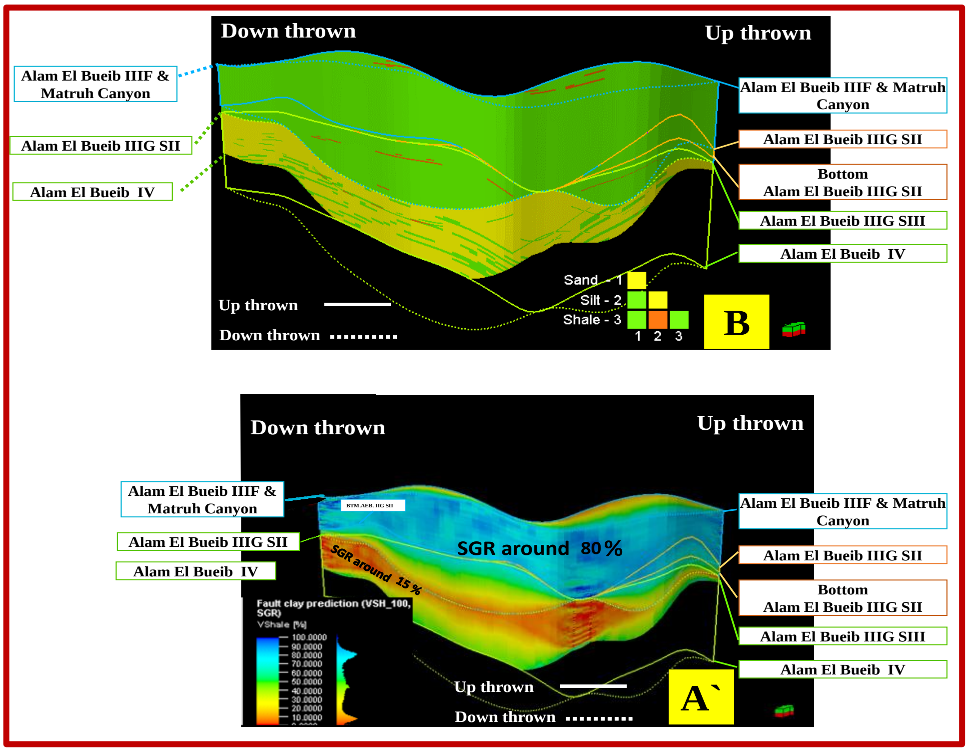

Figure 13: Juxtaposition (Litho- Facies) and Shale Gouge Ratio (SGR) diagrams for (F1) from Alam El Bueib IIIF to Alam El Bueib IIIG.

As a result of the above, the lateral seal analysis shows that thickness of Matruh Shale increased and covered Alam El Bueib IIIG from all directions. This may be why the entrapment at the Emry oil field within Alam El Bueib IIIG.

5. Conclusion

It is found that the normal fault (F1) in the study area, which is trending NW-SE and ENE-WSW, affects the Alam El Bueib Formation as a seal for oil in different degrees ranging from good, medium, to poor.

Finally, the possible reason for a wet reservoir at the upper part of Alam El Bueib (Alam El Bueib I Alam to El Bueib IIIE) in the Emry area may occur due to fault leakage (F1). Based on the litho-facies model, Alam El Bueib IIIA, IIIB, IIID, and IIIE are sand to the sand case across the fault plane and most probably represent leakage, and SGR confirms these results. The values ranged from 5% to 25%. The seal mechanism for Alam El Bueib IIIG is mainly related to increasing the thickness of the shale around (F1). The Allen diagram for Alam El Bueib IIIG sand is juxtaposed against Alam El Bueib IIIF, and Matruh Shale, which means a possible seal due to Alam El Bueib IIIF and Matruh Shale covering Alam El Bueib IIIG vertically and laterally along the target fault (F1). The Shale Gouge Ratio (SGR) values at Alam El Bueib IIIG are around 80%, confirming an effective lateral seal for (F1). So, Matruh shale thickness may be the main reason for trapping the hydrocarbon at the Emry oil field at Alam El Bueib IIIG.

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