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Reservoir Characterization and Reservoir Modeling Of Amal Formation in the Northern East Sirte Basin, Amal Oil Field

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Abstract
The Amal Reservoir of Pre-Upper Cretaceous Sandstone is a significant hydrocarbon reservoir in Concession 12, North-East Sirte Basin. The reservoir is unconformably overlaid by the Maragh Formation and unconformably underlain by a granitic basement. Eight wells have been studied in this project to build 3D structural and petrophysical models (porosity model, water saturation model, volume of shale model) represented by a 3D static geological model. Petrophysical analysis results revealed an average porosity of about 8.1–11.9%, a volume of shale of about 18%, water saturation of about 27.5%, and an average net pay thickness of about 15% of the gross thickness. Based on the log analysis, the analyzed wells' reservoir rock quality is fair to good in the area of the north-west and fair-poor in the south-east. Cross-sections of the porosity model show Water Saturation and Volume of Shale Models were built to illustrate the vertical and horizontal distribution of petrophysical properties in Amal Reservoir in Concession 12 of the Amal oil field.
Key words: Amal Reservoir, Static Geological Model, Reservoir Rock Quality.

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توصيف ونمذجة الخزان النفطي لتكوين آمال في شمال شرق حوضa سرت ، حقل الآمال النفطي

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الملخص

يتناول الملخص خزان الجوفي او مكمن أمال وهو موجد في العصر قبل العصر الطباشيري، والذي يعتبر خزان هيدروكربوني كبير في الامتياز رقم 12 في حوض سرت الشمالي الشرقي. يحد الخزان بشكل غير متماثل بتكوين مرغة من الاعلى ويتم تحديده من الأسفل بقاعدة جرانيتيه. تم دراسة تسعة آبار في هذا المشروع لبناء نماذج ثلاثية الأبعاد تمثل الخصائص الجيولوجية للخزان، مثل المسامية وتشبع المياه ونسبة الطين. أظهرت نتائج التحليل الطبيعي متوسط مسامية تتراوح بين 8.1٪ و11.9٪، ونسبة الطين حوالي 18٪، وتشبع المياه حوالي 27.5٪، ومتوسط سمك الطبقة الصافية لإنتاج حوالي 15٪ من السمك الكلي. وبناءً على تحليل السجلات، تبين أن نوعية صخور الخزان في الآبار كانت جيدة إلى متوسطة في منطقة شمال غرب الحقل ومتوسطة إلى ضعيفة في الجنوب الشرقي. تم بناء قطاعات عرضية لنماذج المسامية وتشبع المياه ونسبة الطين لعرض التوزيع الرأسي والأفقي للخصائص الطبيعية في خزان أمال في الامتياز رقم 12 من حقل أمال للنفط.

الكلمات المفتاحية: الخزان الجوفي أمال، نموذج جيولوجي، التوزيع الرأسي والأفقي للخصائص الطبيعية.

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1.0 Introduction

This study is evaluation of reservoir characteristics of Amal Reservoir in the Amal Oil Field, B - Pool by building 3D Statistic Geological Model Including Petrophysical Model for Amal Reservoir [1]. The Amal Formation is one of the main hydrocarbon bearing uints in Sirte Basin. The Reservoir is a thick sequence primarily composed of quartz Subarkose Sandstone of medium to coarse grained, poorly to moderately sorted, sub-angular to sub-rounded grains. The study area contains a mixture of minerals, including illite, mixed-layer illite, mectite, and chlorite as well as quartz, feldspar (orthoclase), muscovite (mica), plagioclase, calcite, dolomite, and siderite. The Amal Field in eastern part of Sirte Basin has been discovered by the drilling of the exploration well B1-12 in 1959.

1.1 Location of Study Area:

The Amal Field; located on Amal High and Maragh Low. It lies in the northeast flank of Sirte Basin in the northern part of the Concession 12, between coordinates of Latitudes 29°19' 04" and 29° 41' 47" North and Longitudes 21° 01' 05" and 21° 14' 35" East, Figure 1.

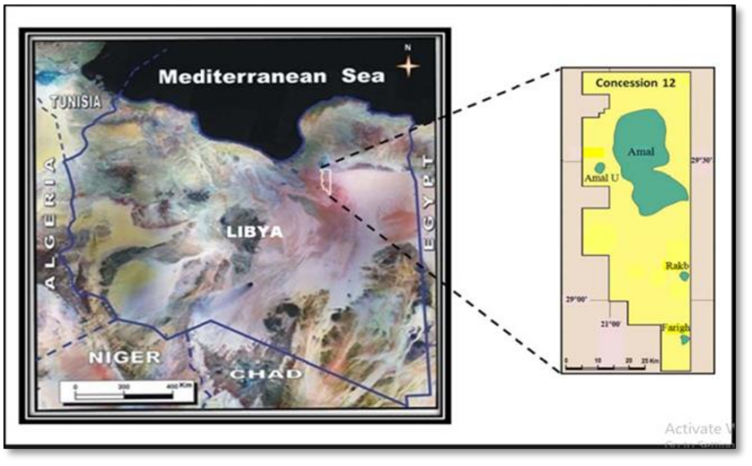

Figure. 0 illustrate Location map of the concession 12, Libya [2].

1.2 Objectives of this Study:

The objectives are to determine Amal Reservoir Petrophysical properties including evaluation of the reservoir porosity, Volume of Shale, water saturation, permeability and net pay thickness. Results of this study are used to define potentiality of Amal Reservoir.

Build the 3D static geological model for Amal Reservoir using Schlumberger Petrel & amp؛ Techlog software based on geological data to build a reservoir geometry and property modeling of the study area.

2. Literature review

2.1.Tectonic evolution of Northern Africa and the Mediterranean during the Phanerozoic.

The Sirte Basin is a large sedimentary basin located in central north Libya that has produced significant oil and gas resources over several decades [3]. Formed during the Late Paleozoic to Mesozoic breakup of the supercontinent Pangaea, the basin transitioned from an extensional rift setting to a passive margin as the African plate migrated northwards relative to Eurasia [4].It now contains a sedimentary fill exceeding 12km in thickness that records the poly phase tectonic evolution of northern Africa [5]. Fundamental basement structures across North Africa were established by the Pan-African Orogeny (~650-500 Ma), a period of crustal deformation and metamorphism that sutured the West African and Congo-São Francisco cratons together along the northern edge of Gondwana [6];[7]. Continued orogenic activity through the Late Paleozoic led to the Variscan Orogeny (~345-290 Ma), representing the final amalgamation of Pangaea through crustal interactions between proto-Africa, North America, and Eurasia [8];[9]. As Pangaea began rifting in the Triassic, extensional forces driving the separation of Africa from Europe and North America initiated subsidence of proto-rift basins like the Proto-Sirte within the northern African craton [8];[6]. Rifting accelerated during seafloor spreading in the Jurassic as new oceanic crust formed along nascent mid-ocean ridge systems [10];[11].

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2.2. Geology of the Sirte Basin:

The Sirte Basin is a major intracratonic rift system in central Libya. The sedimentary succession within the basin reflects its tectonic and structural evolution, which is closely related to the opening of the Atlantic Ocean and the opening and subsequent closure of the Tethys Oceans in Mesozoic and Tertiary times [12]. In general, the sedimentary sequence of the Sirte Basin overlies Precambrian igneous and metamorphic basement rocks and comprises sporadically distributed and poorly dated Lower Paleozoic clastics which are unconformably overlain by a thick Lower Cretaceous and Tertiary clastic and carbonate sequence.

2.2.1. Stratigraphy and petroleum system:

A general Stratigraphic column for the Sirte Basin is shown in Figure 2.

Basement lithologies comprise metamorphosed igneous and sedimentary Proterozoic complexes overlain by shallower marine Paleozoic carbonates and siliciclastics deposited as the supercontinent assembled [13];[14]. Red beds indicating initial continental rifting infilled Triassic depocenters [14]. Extensive marine Jurassic mudrocks and carbonates accumulated during a period of sea floor spreading across expanding rift grabens [15]. Important hydrocarbon source rocks, such as the hydrocarbon-prone shales of the Lower Cretaceous Arak Formation, were deposited under anoxic marine conditions atop developing passive continental margins [16]. Widespread Upper Cretaceous carbonates host significant oil reservoirs currently producing from large fields across the basin [17]. Paleogene stratigraphy reflects the transition to a stable, thermally-subsiding passive margin setting and includes economically important Eocene limestone reservoirs [18];[19]. Younger Miocene to Pleistocene terrestrial clastics onlap older units as the final phases of continental breakup shaped the modern North African coastline [20].

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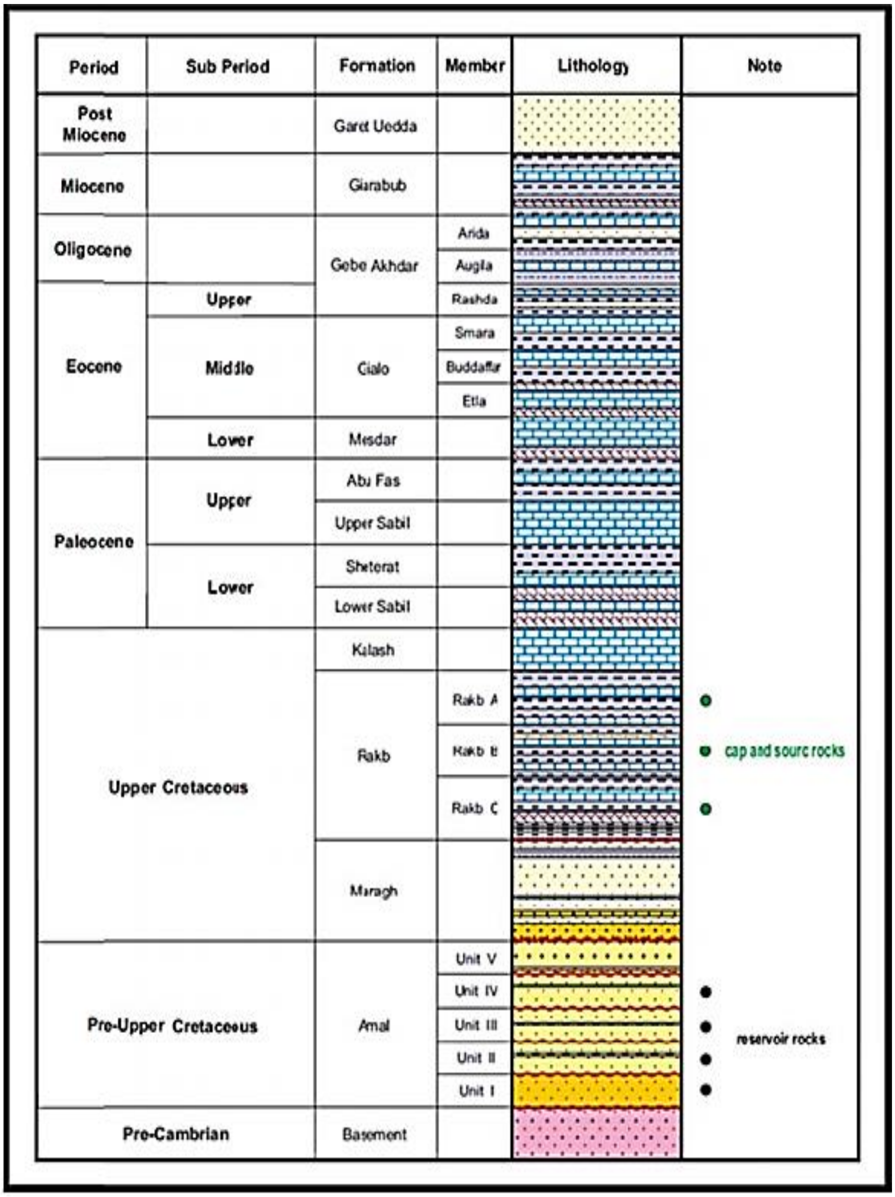

Figure 2. Stratigraphic column section penetrated sequence in the study area [23].

2.2.2 Structure of Sirte Basin :

The first-order structural grain of the Sirte Basin parallels the ancient northern Gondwana margin with prominent NW-SE trending lineaments inherited from the Pan-African basement fabric [1]. Early Triassic rifting partitioned the area into asymmetric sub-basins bounded by major border fault zones, such as the prolific Raguba, Sirt and Misurata depocenters that now contain multi-billion barrel oil and gas fields [21]. Post-rift inversion folding and reactivation of basement structures during the Cretaceous contributed additional structural complexity targeted by hydrocarbon exploration [22].

2.2.3 Amal Formation:

The Amal High forms the southwestern margin of the Cyrenaica Platform and the northeast the margin of Sirte Basin and is situated at the intersection between E-W (Hameimat Trough) and NNW-SSE (Sirte) basement fault trends. Amal High appears to have a shared tectonic history with the Cyrenaica Platform and the bounding fault to the west, with Ajdabiya Trough maybe a major crustal tectonic feature. **extensional faults and to the south by the E-W to ESE-WNW trending g extensional faults marking the northern edge of Hameimat Trough as shown in Figure 3.**

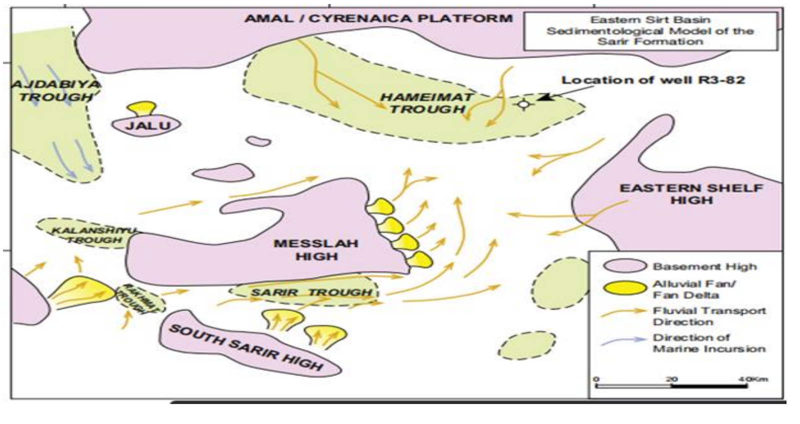

Figure 3 Postulated Petroleum Migration Pathways For Oil Sourced From Upper Cretaceous Shales, (Regional Seal) In Sarir Arm Area Of Eastern Sirte Basin [24].

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3. Materials and Methods of Study.

3.1. Wireline Logs Data

The logs relate to 8 wells of Amal Reservoir (Amal B Pool) drilled between 1959 and 2011 that will be used in this study Figure 4. These wirelines well logs including, spontaneous potential, gamma ray, resistivity, Sonic logs have been used in this study for correlation scheme of strata and for Construction of maps, and cross-sections. Formation tops depths obtained from these logs is used to construct.

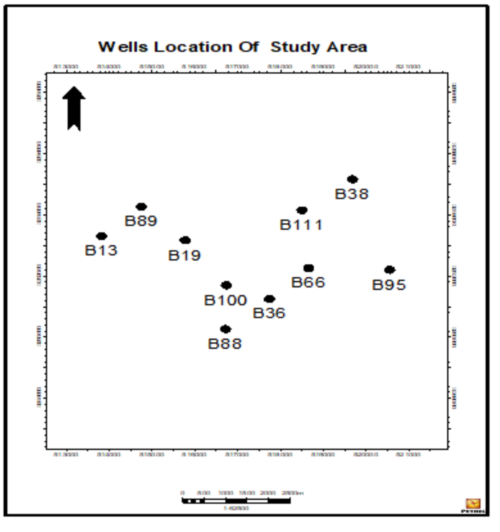

Figure 4 Shows well location map for the wells used in the study.

depths across **foot 0.5** character values have been read and Analyzed at each-These logs properties such as gross and net pay Petrophysical the reservoir to determine the interval, porosity, and water saturation, volume of shale and hydrocarbon volume calculation.

3.2. Software Package

The sequence of the techniques and phases is illustrated in Figure 5. as schematic diagram shows the materials and methods used in this study.

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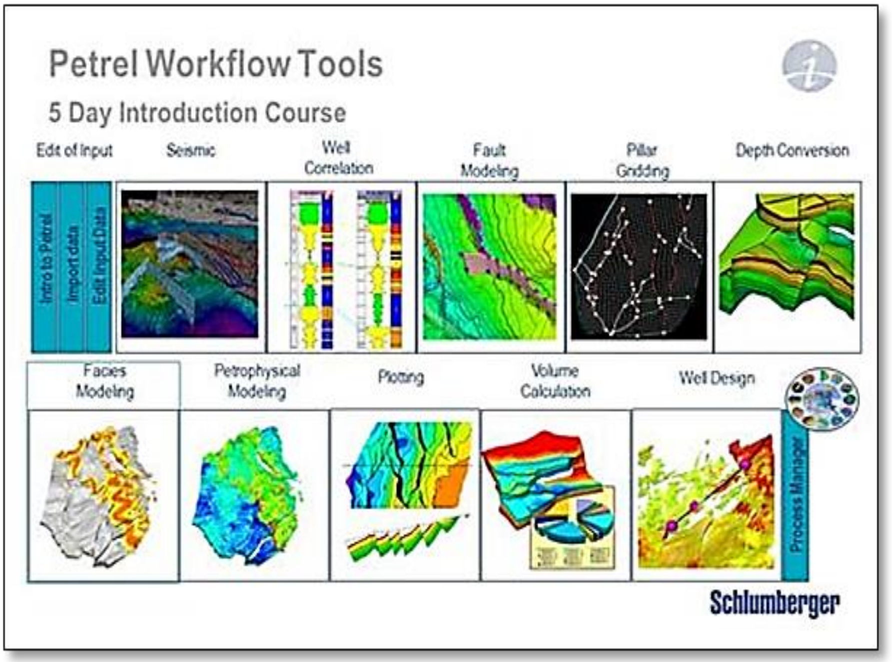

Figure 5 Techniques and phases used for Amal Reservoir assessment and the materials and methods used in this study.

4.0 Results discussion

4.1. 3D Geological Model

Based on workflow application for subsurface interpretation and modeling, data preparation is the basis for geologic model the data prepare for this 3D-Geological model are well heads, well tops, well logs [23].

1-Well head: include the position of each well in 3-dimentions, and the measured depth.

2-Well tops: Markers representing significant points (well picks) along the well path, normally a change in Stratigraphy.

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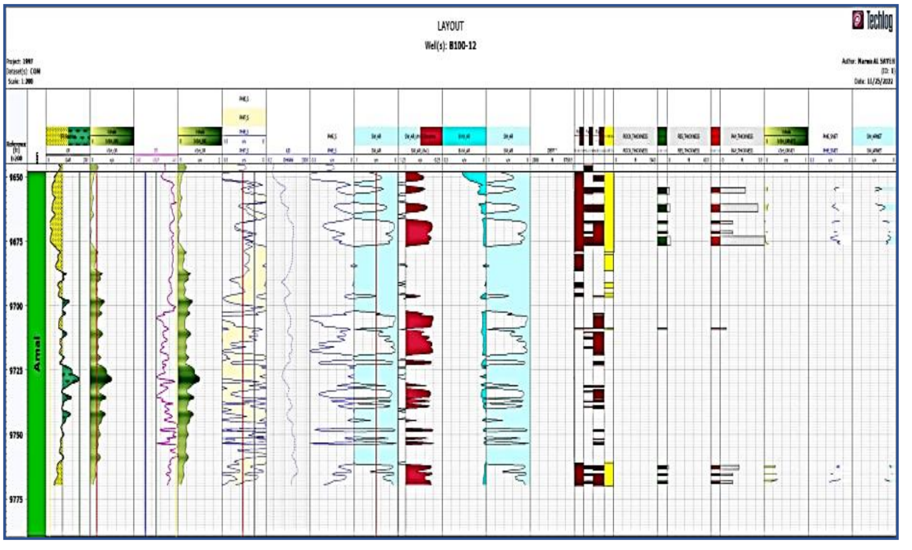

Figure 6. Petrophysical results wells in study area.

4.2. Well correlation

In this study, well correlation applied as a relatively easy method to give an idea and allow simple visualization of the changes in the thickness within Amal Reservoir, Figure [7].

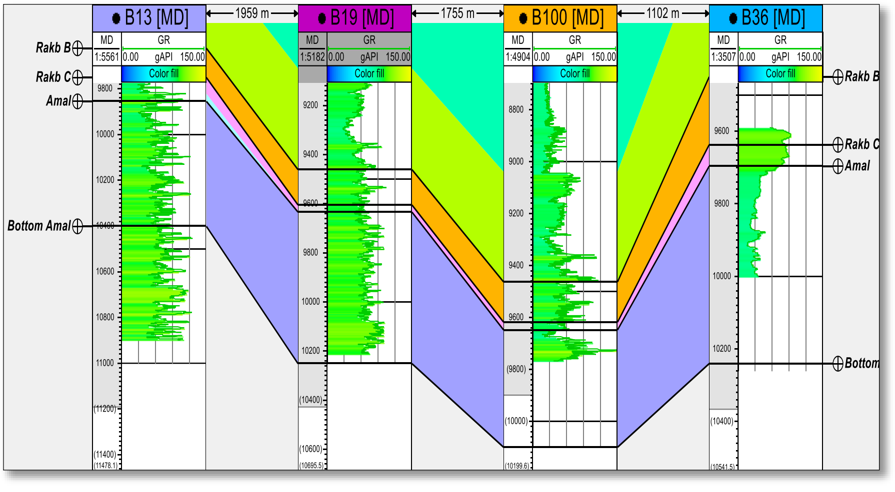

Figure 7. Well correlations between wells in study area

4.3. Structural Modelling:

The mapping techniques to be discussed are equally applicable in surface and subsurface interpretation. 3D Structural maps built for top of Amal reservoir from Well Tops Figures (8&9) represents 3D structural modeling for the Amal reservoir. This model shows that Amal reservoir structure [8].

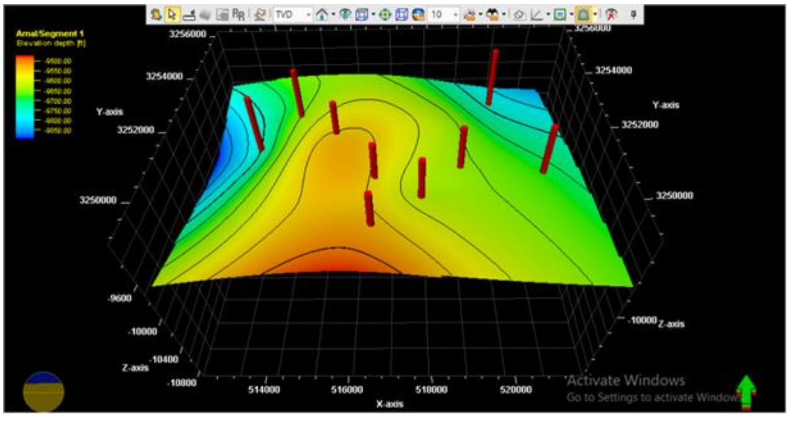

Figure .8. showing structure map of top Amal Reservoir in study area

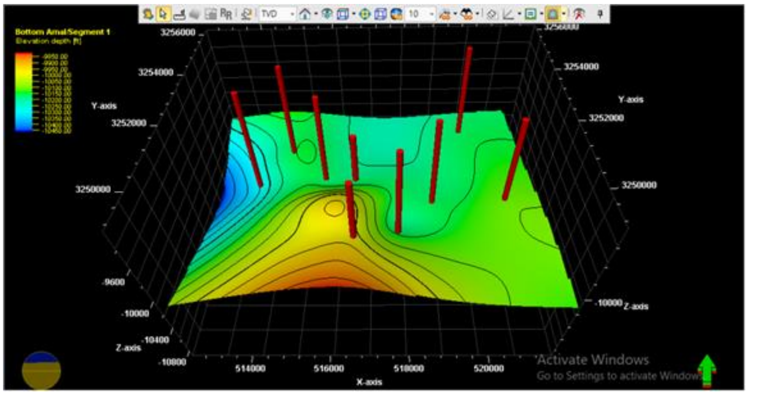

Figure 9. Structure map of bottom Amal reservoir in study area

Structural modeling is to insert the Stratigraphic horizons into the pillar grid, honoring the grid increment and the faults. Make horizons process step used in defining the vertical layering of the 3D grid in Petrel. This present a true 3D approach in the generation

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of 2D surface, which was gridded in the same process, taking the relationships between the surfaces into account Figure 10. represents horizons of the main reservoir.

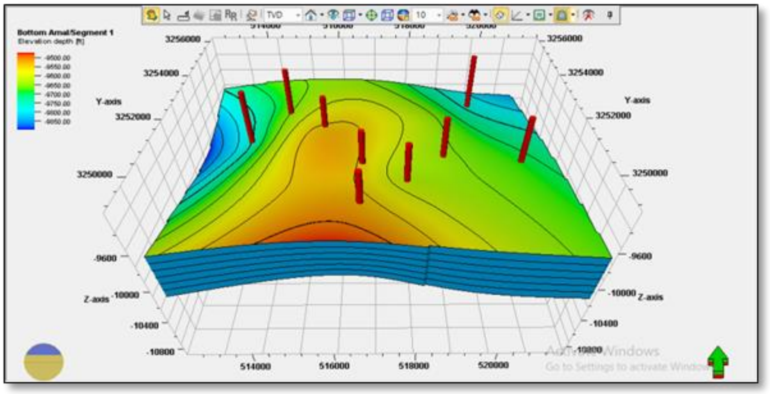

Figure 10 3D. structural modeling of Amal reservoir in Amal oil field

The zone consists of six layers in the uppermost of the formation. The Scale up well logs process Figure 11. averages the values to the cells in the 3D grid that penetrated by the wells. Each cell gets one value per up scaled log. These cells later used as a starting point for property modeling [8].

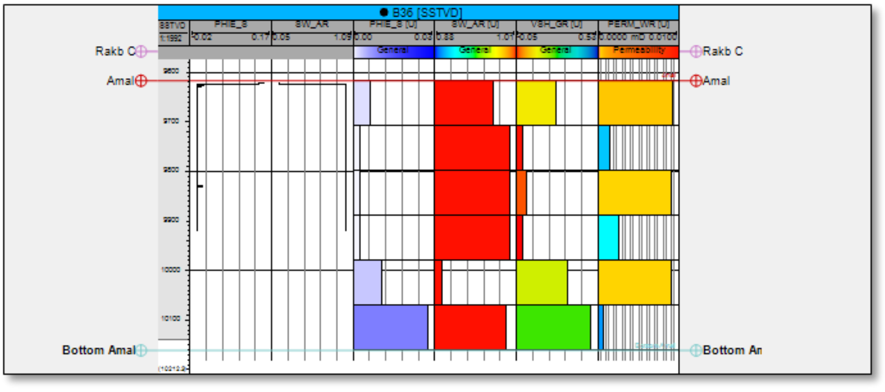

Figure 11. Scale up of porosity, Volume of shale, water saturation and permeability for B36.

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In petrophysical modeling, a 3D grid cell structure represents the volume of the zone. Well logs are scaled up to match the grid's resolution using statistical methods like arithmetic averaging. Figure 11.shows the scaled-up porosity and water saturation for the B13-12 well in the Amal reservoir model.

4.4. Petrophysical modeling process.

Porosity and water saturation models were built depending on the results of porosity and water saturation values, which have been corrected and interpreted in the Techlog software. Sequential Gaussian.The porosity model of the Amal reservoir as shown in Figure 12. is characterized by high porosity values in all wells in North part of the area and reach about 11.9 % ,but the southern parts the area this show porosity decreases to reach 8.1 %. The porosity values in Amal Reservoir range from (9-12 %).

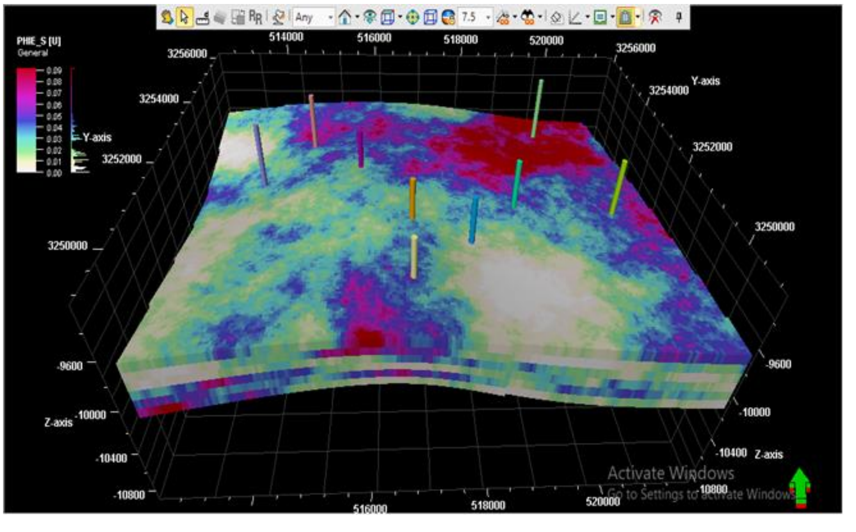

Figure 12. Final Porosity Model for Amal Reservoir.

From figure 13. Water saturation model for Amal reservoir indicate water saturation values that range from (0-10%), but in the south part water saturation values reached to 100%, the zone is represented as having no reservoir unit in Southwest and Southeast the area.

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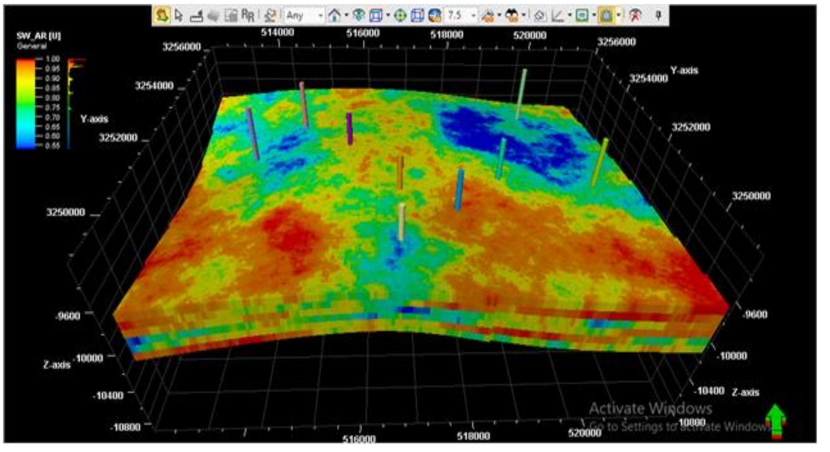

Figure 13. Final Water Saturation Model for Amal Reservoir.

The Volume of Shale model of the Amal reservoir as shown in Figure 14. is characterized by high values in all wells in Southwest and Northeast parts of the area and reach about 17.7 % in well B66-12, but the Northwestern parts and the center of the area this show Volume of Shale decreases to reach 0 % in well B36-12 and 2.6% in well B100-12. The Volume of Shale values in Amal Reservoir range from (0-18 %).

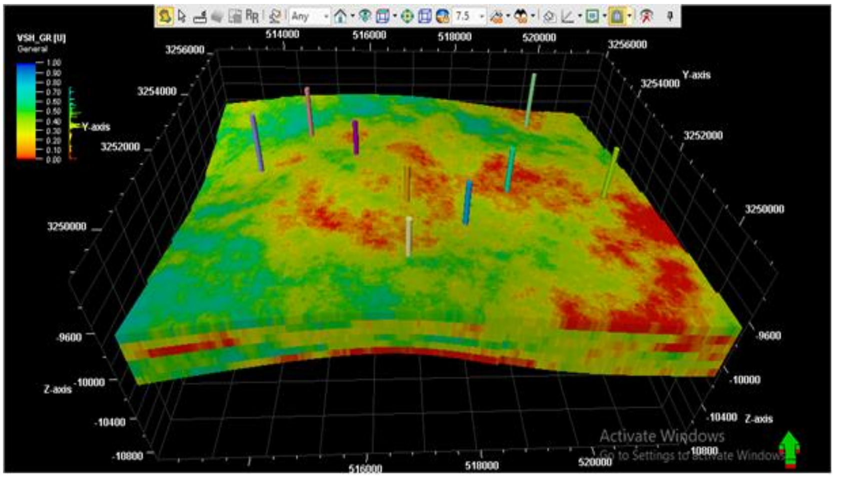

Figure 14. Final Volume of shale Model for Amal Reservoir .

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5. Conclusion

- The average porosity and water saturation in the study area, according to the well log analysis, are about 12% and 41%, respectively and net pay thickness is about 15 feet.
- The Amal reservoirs' log analysis reveals medium to good quality.
- The Amal reservoirs' structural model depicts an anticlinal fold with two domes at its northern and southern ends.
- Petrophysical model (Volume of shale, porosity and water saturation) for Amal reservoir was built using a statistical method after scale up the Petrophysical results. This model shows that the high porosity and low water saturation are placed in the north-west and Northeast and High Volume of shale occurs in the South part of the Amal Oil Field.
- Cross sections Volume of Shale, porosity and Water Saturation Models ware constructed in E-W direction show that the best location characterized by good reservoir properties is around the wells B89-12 and gradually these properties decrease toward wells B95-12 and B36-12.

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