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# Petrophysical analysis of Mabruk Reservoir in West Mabruk oil Field, (Sirt Basin, Libya)

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**Keywords:**
Petrophysical analysis
Reservoir rock
porosity
permeability
water saturation
net pay

**ABSTRACT**

The Sirt Basin in the north-central part of Libya is one of the youngest sedimentary basins on the African craton. Sedimentation controlled by tectonic and eustatic influences, locally inducing high sedimentation rates with the distribution of the various lithology is being governed by ridge-and-trough paleotopography. The carbonate intervals of the Heira formation which including the Mabruk Member, The upper Mabruk unit which represent the main reservoir producing oil in the Mabruk oil Field (Block C17). The objective of this study is evaluate the carbonate reservoir (Mabruk member) quality by analysis the petrophysical properties, for five selected wells drilled in the study area (B1-17 , B2-17 , B3-17 , B4-17, B5-17 ) .The Upper Mabruk member with gross thickness is ranging from 70 to 90 feet, while the net pay thickness ranging from 14 to 46 feet. The analysis results reveled good reservoir quality content average porosity ranging from 14 to 23%, average permeability ranging from 19 to 309 MD, average water saturation variations with some wells reached 34%, and increasing toward south reached 71%, which located at the edge of oil water contact. the lateral facies evolution creates petrophysical variations The heterogeneities are big impact in carbonate reservoir quality, although this study used only five wells with short distances between the wells but clear lateral variation encountered as in well B4-17 and B5-17, heterogeneities can enhance petrophysical properties such as permeability as it was in B4-17 and B5-17(19 and 191 md).

## التحليل البتروفيزيائي لخزان مبروك في حقل نفط غرب المبروك (حوض سرت، ليبيا)

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**الكلمات المفتاحية:**
التحليل البتر وفيزيائي
صخور المكمن
المسامية
النفاذية
التشبع بالماء
صافي السمك

**الملخص**

يعتبر حوض سرت الواقع في الجزء الشمالي الأوسط من ليبيا أحد أحدث الأحواض الرسوبية في منطقة الرسخ الأفريقي. تم التحكم في الترسيب من خلال الحركات التكتونية وارتفاع مستوي البحر مما أدى إلى معدلات ترسيب عالية محليًا مع توزيع مختلف للوصف الصخري التي تحكمها التلال والأحواض الصغيرة. المسافات الكربونية لتكوين الهيرة والتي تشمل عضو مبروك، وحدة مبروك العليا التي تمثل الخزان الرئيسي المنتج للنفط في حقل مبروك النفطي (C17)، الهدف من هذه الدراسة هو تقييم جودة مكمن الكربونات (عضو مبروك) من خلال تحليل الخصائص البتروفيزيائية لخمسة آبار مختارة تم حفرها في منطقة الدراسة (B1-17، B2-17، B3-17، B4-17، B5-17) ويتراوح سمك عضو مبروك العلوي من 70 إلى 90 قدمًا، بينما تتراوح صافي السمك من 14 إلى 46 قدمًا. أظهرت نتائج التحاليل عن جودة جيدة لمحتوى الخزان متوسط المسامية يتراوح من 14 إلى 23٪، ومتوسط نفاذية تتراوح من 19 إلى 309 مللي دارسي، ومتوسط تشبع المياه في بعض الآبار وصل إلى 34٪، والزيادة

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باتجاه الجنوب وصلت إلى 71٪ التي تقع على الحافة. من ملامسة الزيت بالماء. ينتج عن تتغير السحنات الجانبية اختلافات الخصائص البتروفيزيائية لها تأثيرًا كبيرًا في جودة مكامن الكربونات، على الرغم من أن هذه الدراسة استخدمت خمسة آبار فقط بمسافات قصيرة بين الآبار ولكن التباين الجانبي الواضح الذي تم تحديده في البئر B4-17 و B5-17، يمكن أن تعزز التغيرات الخصائص البتروفيزيائية مثل النفاذية كما كانت في B4-17 و B5-17 (19 و 191 مللي دارسي).

## 1. Introduction

Mabruk Field is an onshore field located about 170 kilometers to the south of Sirt town (Middle Eastern Libya). It discovered in 1959. The Western part of Sirt Basin in the Zallah Trough. The reservoirs are located over three horizons Mabruk, Dahra and Gharian Formations, and further divided into several structures (West Mabruk, North Mabruk, East Central Mabruk, Dahra North, Dahra South East and Gharian), Western Mabruk Field as in (Fig.1), The West Mabruk Oil Field can be subdivided into three paleogeographic areas; 1) Northern area where per-reef deposits prevails. 2) Central area dominated by (lagoon) deposits. 3) Southern [area of dolomitized inner platform deposits the [1], [2], [3].

Well logging analysis is an important tool to evaluate the petrophysical properties of the reservoir. Well logging is the practice of making a detailed record of the geologic formations penetrated by a borehole. The log may be based either on visual inspection of samples brought to the surface (geological logs) or on physical measurements made by instruments lowered into the whole (geophysical logs). Some types of geophysical well logs can be done during any phase of a well's history: drilling, completing, producing, or abandoning. Well logging performed in boreholes drilled for the oil and gas, groundwater, mineral and geothermal exploration, as well as part of environmental and geotechnical studies.

The petroleum studies of fluid flow in pores media had its beginnings in 1927 when the Schlumberger brothers introduced the first electrical wireline logs [4]. These early developments led to rapid improvements of equipment, in upstream and downstream sector, as trustable tool of formation evaluation. The well logging technology is an extensive area in the petroleum industry and it has many types of logging tools, each one has its use and measurement to interpret petrophysical property depending on a specific physical mechanism. The main logs are Gamma Ray (GR), Spontaneous Potential (SP), resistivity log and porosity logs) Neutron-Density-Sonic). [5] To understand the reservoir conditions such as fluid flow in porous media, estimation reserve, hydraulic fracture design, etc., estimation of the petrophysical and mechanical rock properties using well logging data one of important sector of reservoir engineering.

Routine core analysis best method to check the quality of logs results, to approve the results that will obtained from the well logging data and for estimating the reservoir rock properties. The main aim of this study evaluate the reservoir quality (upper Mabruk Limestone Member) within selected area. All the data collected, sorted and loaded into one of software used for determined physical properties (Techlog 2015 software) than draw a maps to shown the distribution in the area, geological cross-section generated through the study area, to show the topography of the member and the structure, by using another software (Petrel 2017).

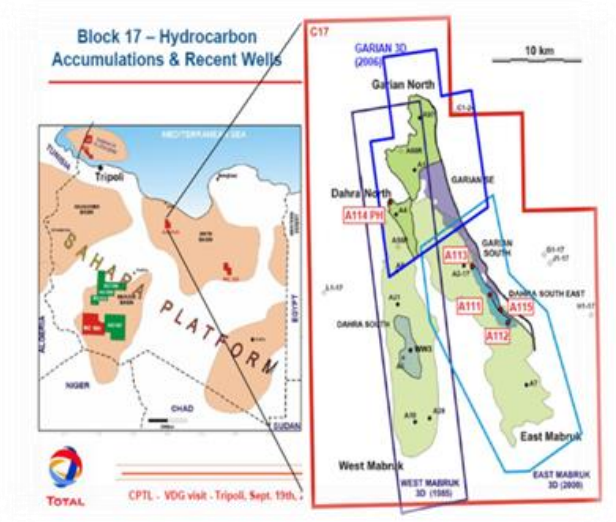


**Fig1.** The Block 17 content West Mabruk, North Mabruk, East Central Mabruk, Dahra North, Dahra South East and Gharian Fields [1]

## STRATIGRAPHY

The West Mabruk oil Field, producing from carbonate reservoir Paleocene age as shown in (Fig.2), consists of an upper limestone unit (productive oil zone) and a lower limestone unit. An intermediate shale layer separates these two limestone units. The upper Mabruk unit with variable thickness, ranging from 20 to 100 feet; an intermediate shale unit

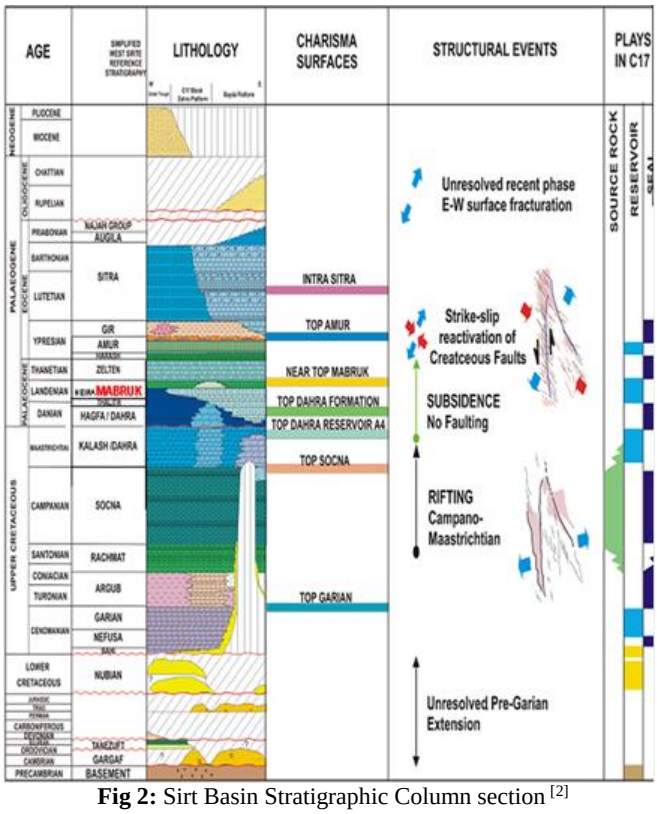


**Fig 2:** Sirt Basin Stratigraphic Column section [2]

**Methodology**

The study divided to three stages as following:

Stage I: Collecting data. The goal of this stage is collect all the available Geological, Geophysical, Petrophysical, and reports, review the quality of data. The electrical wireline Log used to include (GR, RHOB, NBHI, DT, ILD, MSFL).

Stage II: Load and Quality Control the data.

Loaded all the Geological, Geophysical and petrophysical data into a project generated by using Techlog software. Techlog 2015 software give us the ability to design our own petrophysical workflow to generate meaningful quick-look interpretations based on local expertise and the application of industry standard methods for lithology, porosity, saturation, and permeability. All common data formats start from various tools, vendors, and data vintages are easily loaded through a powerful drag and drop interface into the Techlog platform.

Stage III: Analysis the Electrical wireline logs. The major application of petrophysical analysis is studying reservoirs properties. The layout of the petrophysical analysis, (Quanti Elan), to compute all discussed Petrophysical results in the area of study.

**Results and Discussion.**

The Petrophysical analysis applied for five wells located at West Mabruk Field, starting by loading the electrical well logs and formation tops, cut off physical parameters, calculations the physical properties results carried out as layouts and tables, the following shown the process:

**A) Well B1-17**

This well drilled in 1998 at southwest part of the field, with total depth 4,160 feet the objective (upper Mabruk) encountered at depth 3,795 feet, with gross tackiness of 77 feet. The analysis of electrical wireline logs shown average net pay zone with 36.5 feet from 77 feet as gross the net pay reservoir has average effective porosity, average vertical permeability and water saturation respectively 19.4%, 125 md and 71%. As shown in the layout in (Fig.3), average volume of shale within the upper Mabruk unit were low as it reached 9.4%. The (Table 1). Content the Petrophysical analysis results of the B1-17, the results shown that reservoir unit in this well has good reservoir quality.

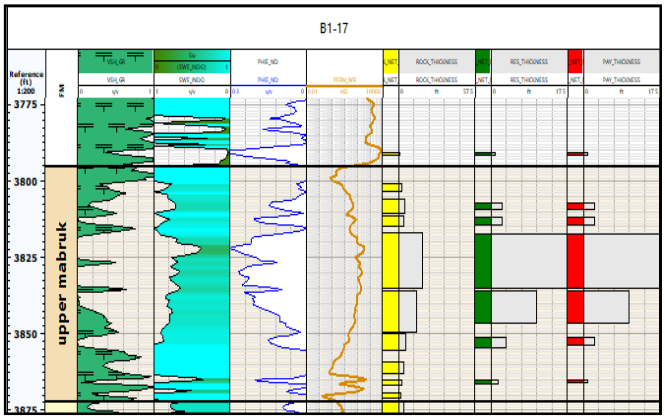


**Fig.3:** Petrophysical analysis layout results. B1-17.

**Table.1: Petrophysical analysis results well B17**

| Well | B1-17 | B1-17 | B1-17 |
|---|---|---|---|
| Zones | upper mabruk | upper mabruk | upper mabruk |
| Flag Name | ROCK | RES | PAY |
| Top | 3795.000 | 3795.000 | 3795.000 |
| Bottom | 3872.000 | 3872.000 | 3872.000 |
| Gross | 77.000 | 77.000 | 77.000 |
| Net | 55.000 | 38.000 | 36.500 |
| Net to Gross | 0.714 | 0.494 | 0.474 |
| Av_Effective Porosity | 0.144 | 0.191 | 0.194 |
| Av_Effective Water Saturation | 0.731 | 0.718 | 0.710 |
| Av_Shale Volume | 0.180 | 0.091 | 0.094 |
| Av_Permeability | 88.730 | 120.560 | 125.123 |

**B) Well B2-17**

The well drilled in 2008 by (NWD RIG#9) for Mabruk oil field, with total depth 3,962 feet the upper Mabruk reservoir encountered at depth interval from 3,626.5 to 3698.5 feet. With gross tackiness of 71 feet and net pay zone calculated reached 37 feet, consist average effective porosity 22%, average vertical permeability 165 MD and 70% of water saturation, as shown in (Fig.4), the percentage of volume of shale within the upper Mabruk Member is very low reached (2.7%) which reflect on porosity. The (Table .2) content Petrophysical analysis results.

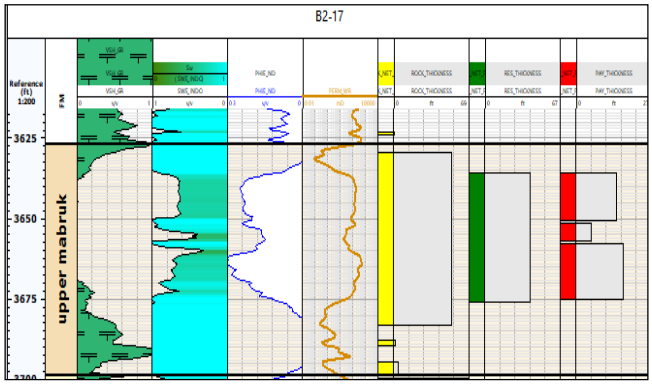


**Fig4:** Petrophysical analysis layout results B2-17.

**Table 2: Petrophysical analysis results well B2-17.**

| Well | B2-17 | B2-17 | B2-17 |
|---|---|---|---|
| Zones | upper mabruk | upper mabruk | upper mabruk |
| Flag Name | ROCK | RES | PAY |
| Top | 3626.500 | 3626.500 | 3626.500 |
| Bottom | 3698.500 | 3698.500 | 3698.500 |
| Gross | 72.000 | 72.000 | 72.000 |
| Net | 59.000 | 40.000 | 37.000 |
| Net to Gross | 0.819 | 0.556 | 0.514 |
| Av_Effective Porosity | 0.156 | 0.219 | 0.224 |
| Av_Effective Water Saturation | 0.729 | 0.716 | 0.699 |
| Av_Shale Volume | 0.103 | 0.028 | 0.027 |
| Av_Permeability | 106.927 | 157.107 | 165.802 |

**C) Well B3-17:**

This well drilled in 1998 in Mabruk Field located in Center part of the field, with total depth 3,790 feet. The reservoir (upper Mabruk unit) encountered at depth of 3,410 feet with gross tackiness of 81 feet, the upper Mabruk unit analysis show net pay zone of 36.5 feet, average effective porosity 22.7%, average vertical permeability reached 309 MD and water saturation 34%, as shown in the layout (Fig.5), the average volume of shale within the formation increasing reached 14.9%. The (Table .3) content Petrophysical analysis results.7

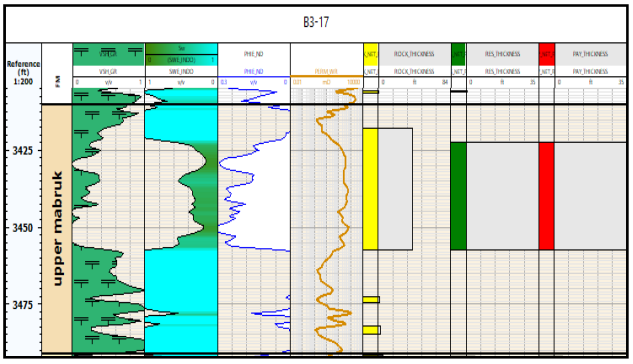


**Fig.5:** Petrophysical analysis layout results. B3-17.

**Table.3: Petrophysical analysis results well B3-17.**

| Well | B3-17 | B3-17 | B3-17 |
|---|---|---|---|
| Zones | upper mabruk | upper mabruk | upper mabruk |
| Flag Name | ROCK | RES | PAY |
| Top | 3410.000 | 3410.000 | 3410.000 |
| Bottom | 3491.000 | 3491.000 | 3491.000 |
| Gross | 81.000 | 81.000 | 81.000 |
| Net | 44.500 | 35.000 | 35.000 |
| Net to Gross | 0.549 | 0.432 | 0.432 |
| Av_Effective Porosity | 0.182 | 0.227 | 0.227 |
| Av_Effective Water Saturation | 0.352 | 0.340 | 0.340 |
| Av_Shale Volume | 0.193 | 0.149 | 0.149 |
| Av_Permeability | 246.358 | 309.494 | 309.494 |

**D) Well B4-17**

This well drilled in 1997 in Mabruk Field located in Northeast, with total depth 3,847 feet; the well encountered the upper Mabruk unit at interval from 3482 to 3570 feet with gross tackiness of 88 feet. Due to non-presences of neutron and density logs, we used the sonic to calculate the effective porosity in this well. The net pays zone 14 feet, content average effective porosity 20.3%, permeability 19 MD and water saturation 63.8%, as shown in the layout (Figure. 6), the average volume of shale within the formation were very low as it reached1.3%.

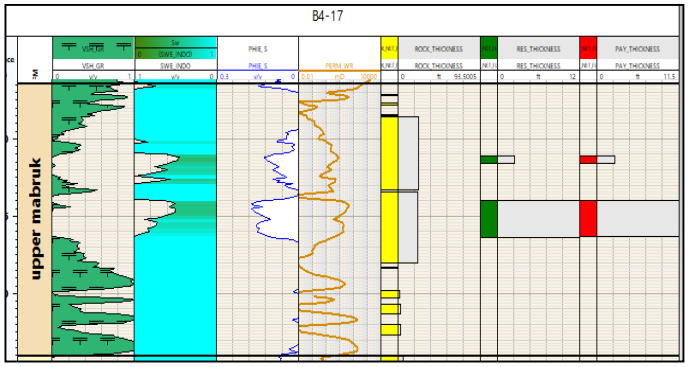


**Fig.6:** Petrophysical analysis layout results B4-17.

**Table.4: Petrophysical analysis results well B4-17.**

| Well | B4-17 | B4-17 | B4-17 |
|---|---|---|---|
| Zones | upper mabruk | upper mabruk | upper mabruk |
| Flag Name | ROCK | RES | PAY |
| Top | 3482.000 | 3482.000 | 3482.000 |
| Bottom | 3570.000 | 3570.000 | 3570.000 |
| Gross | 88.000 | 88.000 | 88.000 |
| Net | 57.500 | 14.500 | 14.000 |
| Net to Gross | 0.653 | 0.165 | 0.159 |
| Av_Effective Porosity | 0.052 | 0.138 | 0.139 |
| Av_Effective Water Saturation | 0.705 | 0.648 | 0.638 |
| Av_Shale Volume | 0.173 | 0.013 | 0.013 |
| Av_Permeability | 5.530 | 18.540 | 19.024 |

**E) Well B5-17**

This well drilled in 1997 in Mabruk Field located in the North of the field, with total depth 3,820 feet, encountered the upper Mabruk unit at depth 3,469 feet, with gross tackiness of 87 feet. The upper Mabruk unit content average net pays zone 46.5 feet, with average effective porosity 20.3%, permeability 191 MD and water saturation 38%, as shown in the layout (Figure .7), the percentage volume of shale within the formation increasing to reach 13.9%. The rest of petrophysical analysis results write down in (Table.5).

**Table.5: Petrophysical analysis results well B5-17**

| Well | B5-17 | B5-17 | B5-17 |
|---|---|---|---|
| Zones | upper mabruk | upper mabruk | upper mabruk |
| Flag Name | ROCK | RES | PAY |
| Top | 3382.000 | 3382.000 | 3382.000 |
| Bottom | 3469.000 | 3469.000 | 3469.000 |
| Gross | 87.000 | 87.000 | 87.000 |
| Net | 57.500 | 46.500 | 46.500 |
| Net to Gross | 0.661 | 0.534 | 0.534 |
| Av_Effective Porosity | 0.171 | 0.203 | 0.203 |
| Av_Effective Water Saturation | 0.407 | 0.382 | 0.382 |
| Av_Shale Volume | 0.175 | 0.139 | 0.139 |
| Av_Permeability | 157.615 | 191.724 | 191.724 |

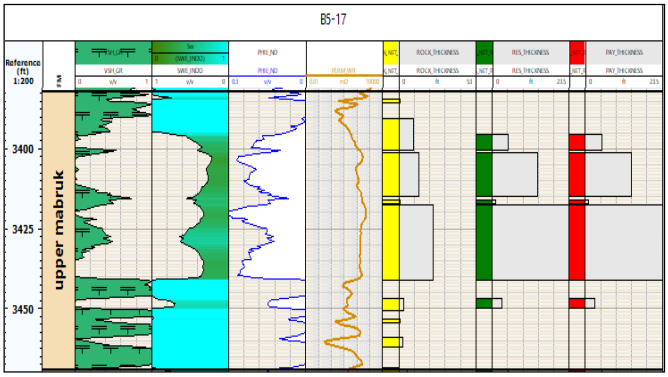


**Fig.7:** Petrophysical analysis layout results B5-17.

Table.6 content. Petrophysical analysis results of upper Mabruk unit for the selected wells, these results used to generate maps for net pay, porosity, permeability, volume of shale and water saturation for the study area.

**Table.6: The upper Mabruk unit analysis results**

| UPPER MABRUK MEMBER | | | | | |
|---|---|---|---|---|---|
| Well | Net pay (feet) | Porosity % | Permeability (md) | Vsh % | Sw % |
| B1-17 | 36.5 | 19 | 125 | 9.4 | 71 |
| B2-17 | 37 | 22 | 165 | 2.7 | 70 |
| B3-17 | 35 | 22.7 | 309 | 15 | 34 |
| B4-17 | 14 | 14 | 19 | 1.3 | 63 |
| B5-17 | 46.5 | 20 | 191 | 14 | 38 |

**PHYSICAL PROPERTIES MPS**

In order to have more information about the distribution of the physical properties within the area which are reveled the quality variation of the reservoir, we use the data to generated maps of net pay, percentage of volume of shale, porosity, permeability and water saturation of the South West Mabruk Field as following:

The information from Mabruk Oil Company inform that the gross thickness of upper Mabruk unit ranging from 20 to 100 feet in the Field and the information from the selected well the Petrophysical analysis showed that. Gross thickness reached 88 feet by using Techlog 2015 to calculate the net pay thickness, which were ranging from 14 to 46.5 feet, the thickness controlled by topography of the structure as the wells B1-17, B2-17, B3-17, located within faulted block and deeper than the wells B5-17 and B4-17. Which are shallower that represent the excellent environment to developed carbonate, the net pay in B5-17 reached 46.5 feet, note that the B4-17 has just 14 feet as net pay probable drilled at the edge of carbonate developed (Figure .8).

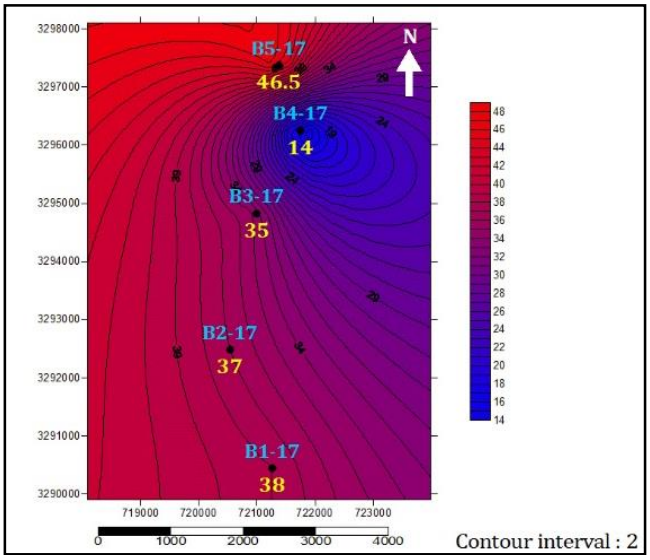


**Fig.8:** Net pay thickness map of upper Mabruk

From previous study information, this area [5], [6], [1], has been affect by secondary dolomitisation that can affect all primary facies deposits. So, it is major points enhance significantly the reservoir potential of the Southern area (Study Area), which are reflected in effective porosity results as in well B1-17 is 19.1%, in well B2-17 is 22.4%, in well B3-17 is 22.7%, in well B4-17 is 14.1%, and in well B5-17 is 20.3% (Fig .9).

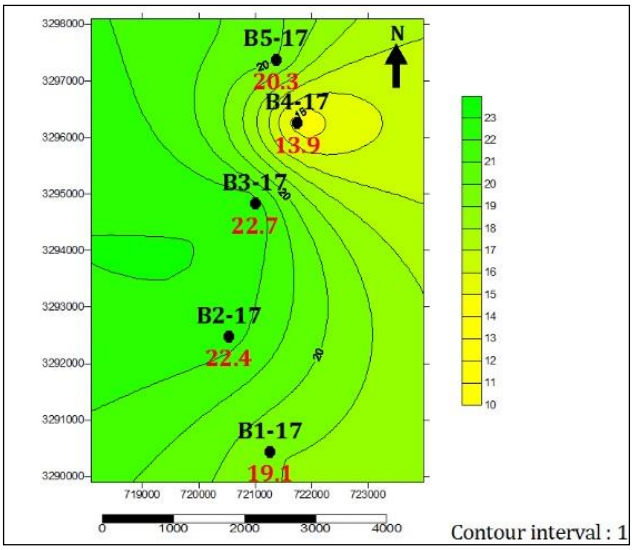


**Fig.9:** Effective porosity map of upper Mabruk unit

The south area presents numerous heterogeneities that can enhance intra- and inter-layer permeability. As shown in the wells (B1, B2, B3 and B5) respectively 120, 165, 309 and 191MD, as shown in (Figure.10) the only decreasing in permeability determined in B4-17 which is may bay as results of early digenesis processes, which may lead to porosity preservation, but they may also result in a sharp decrease in permeability as in B4-17.

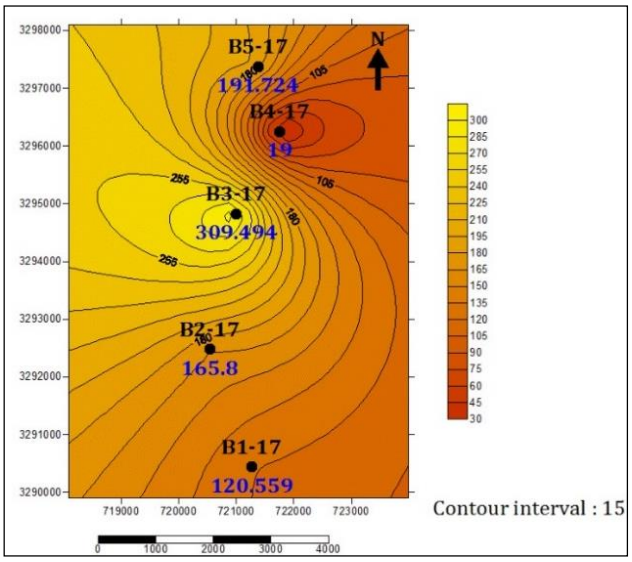


**Fig.10:** Permeability map of upper Mabruk unit

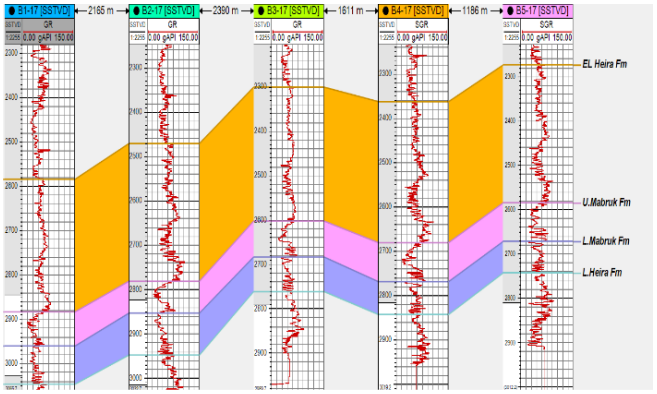


**Figure.11:** A A′ Geological cross section, by using gamma ray log, generated by (Petrel 2014)

**Conclusion**

The carbonate intervals of the Heira Formation which including the Mabruk member, the upper Mabruk member which represent the main reservoir producing oil in the Mabruk oil field in (Block C17), with gross thickness, ranging from 70 to 90 feet, The petrophysical study Determined the average Net pay thickness from 14 to 46.5 feet.

The Petrophysical analysis results show average porosity ranging from 14 to 23%, average permeability from 19 to 309 MD, the water saturation with some well 34% but increasing toward south reached 71 in the well B1-17. We conclude that the carbonate reservoir (upper Mabruk) has good quality, which may effected by heterogeneities-diageneses process, although this study used only five wells with short distances between the wells which is the minimum for this area. However, we recognized changes in petrophysical analysis results as encountered in well B4-17 and B5-17 as heterogeneities could enhance physical properties such as permeability as show in B4-17 and B5-17(19 and 191 md) and the porosity from 14 to 20 %. Therefore, the results reveled lateral variation of upper Mabruk unit, so the depositional of the unit could by controlled by digenesis process and tectonic.

**Recommendation:**

We recommend more sedimentology study to get more information about the depositional environment, also more 3D seismic work needed to identified the structure configuration

- New set of logging technique should be used to get more information about the reservoir, such as image logs, spectral Gamma ray logs.

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