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Reservoir Characteristics from Well Logging Records of Mamuniyat Formation, M Oil Field, NC115 Concession, NW Murzuq Basin, SW Libya

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ABSTRACT

This study is concerned with Reservoir characteristics at M field, concession NC-115 in Murzuq basin sw of Libya. Mamuniyat formation is considered the first reservoir in the studied field M-NC115, sourced and sealed by Tanezzuft formation.Well recording operations have developed at the present time to become an essential and important part of drilling conclusions in addition to productive probing operations, which give us information about the well's productivity. Twelve wells were identified for this work scattered in the study area. A petrophysical assessment was achieved with interactive petrophysics software 2018. The results showed that the study Formation consists of sandstones with a small percentage of shale. The results also showed that the upper part of the studied reservoir at ((zones I and II)) is of higher quality than the lower part (zones IV). The reservoir thickness is about 960 ft in the north flank of the study area, and it is completely absent in the southwest flank of the study area. The results also illustrated that the average water saturation is 40%, the porosity is 12%, and the reservoir thickness is 560 ft.

Keywords: Mamuniyat formation, M field, well logging, petro-physical parameters.

الخصائص الخزانية من سجلات تسجيل الآبار لتكوين المامونيات، حقل النفط M، منطقة امتياز CN 115، حوض مرزق الشمالي الغربي، جنوب غرب ليبيا

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ملخـــــــص البحـــــــث

تهتم هذه الدراسة بخصائص المكمن في الحقل M بامتياز NC-115 في حوض مرزق جنوب ليبيا. يعتبر تكوين المأمونيات الخزان الأول في حقل الدراسة M-NC115، ويعتبر تكوين تانزوفت هو صخر مصدر وغطاء لهذا الخزان. وقد تطورت عمليات تسجيل الآبار في الوقت الحاضر لتصبح جزء أساسياً وهاماً من استنتاجات الحفر بالإضافة إلى عمليات الإنتاج التي تعطي لنا معلومات حول إنتاجية البئر. وقد تم تحديد اثني عشر بئراً لهذه الدراسة منتشرة في منطقة الدراسة. تم إجراء

تقييم بتروفيزيائي باستخدام برنامج البتر وفيزياء **IP 2018**. وأظهرت النتائج أن تكوين الدراسة يتكون من الصخور الرملية مع نسبة صغيرة من الطين. كما أظهرت النتائج أن الجزء العلوي من الخزان المدروس في ((المنطقة الأولى والثانية)) أعلى جودة من الجزء السفلي (المنطقة الرابعة). ويبلغ سمك الخزان حوالي 960 قدماً في الجانب الشمالي من منطقة الدراسة، ويغيب تماماً في الجانب الجنوبي الغربي من منطقة الدراسة. كما أوضحت النتائج أن متوسط التشبع المائي 40%، والمسامية 12%، وسمك الخزان 560 قدم.

الكلمات الدالة: تكوين المأمونيات، الحقل M، تسجيل الآبار، المعلمات البتروفيزيائية.

1. Introduction

The Murzuq Basin located on SW Libya forms one of several intracratonic sag basins located on the north African Platform Figure **1**, covers an area of some 350,000 km², extending southwards into Niger [1]. The basin borders are defined by erosion resulting from multiphase tectonic uplifts. The Murzuq basin can be considered more accurately as the erosional remnant of a much larger Palaeozoic and Mesozoic sedimentary basin which originally extended over much of North Africa [2]. Its borders consist of Tihemboka high in the west, the Tibesti high to the SE, and the Gargaf and Atshan highs to the north and NW. Most of These uplifts were formed by tectonic events of different ages ranging from middle Palaeozoic to Tertiary times, but the main periods of uplift took place during Middle Cretaceous to Early Tertiary Alpine movements.

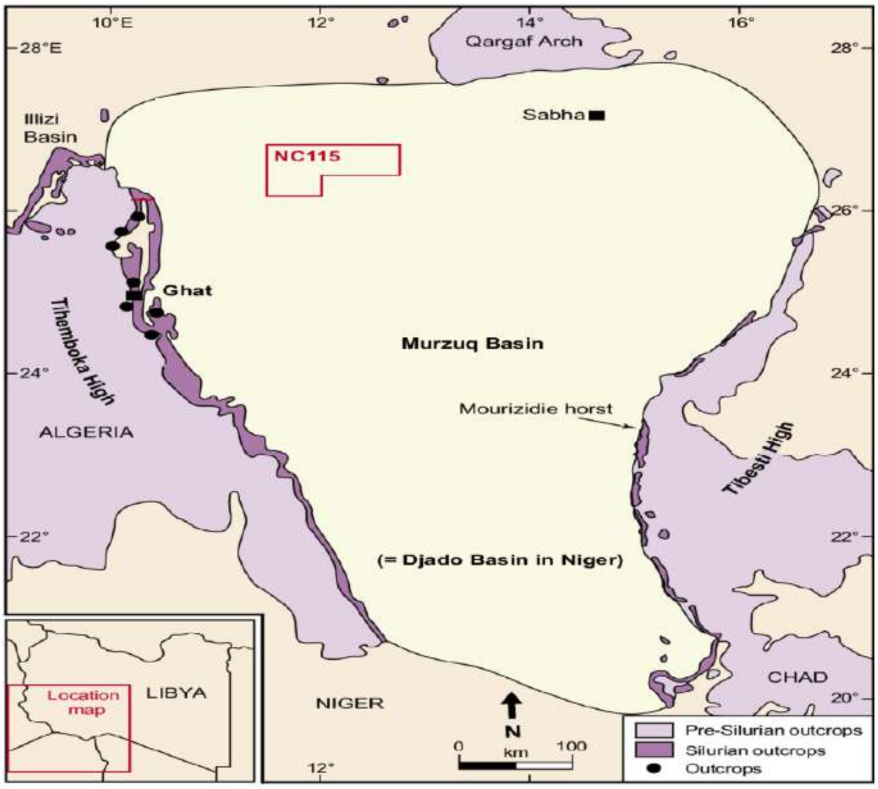

Figure 1 – Geological map of Murzuq Basin showing the location of NC115 Concession [4].

M field is considered one of the oil fields in the NC186 Concession, which contains several exploratory and development wells, distributed in the field on the north and western side of the Murzuq basin, southwest part of Libya Figure **2**. It has been affected by the structural and tectonic movements of

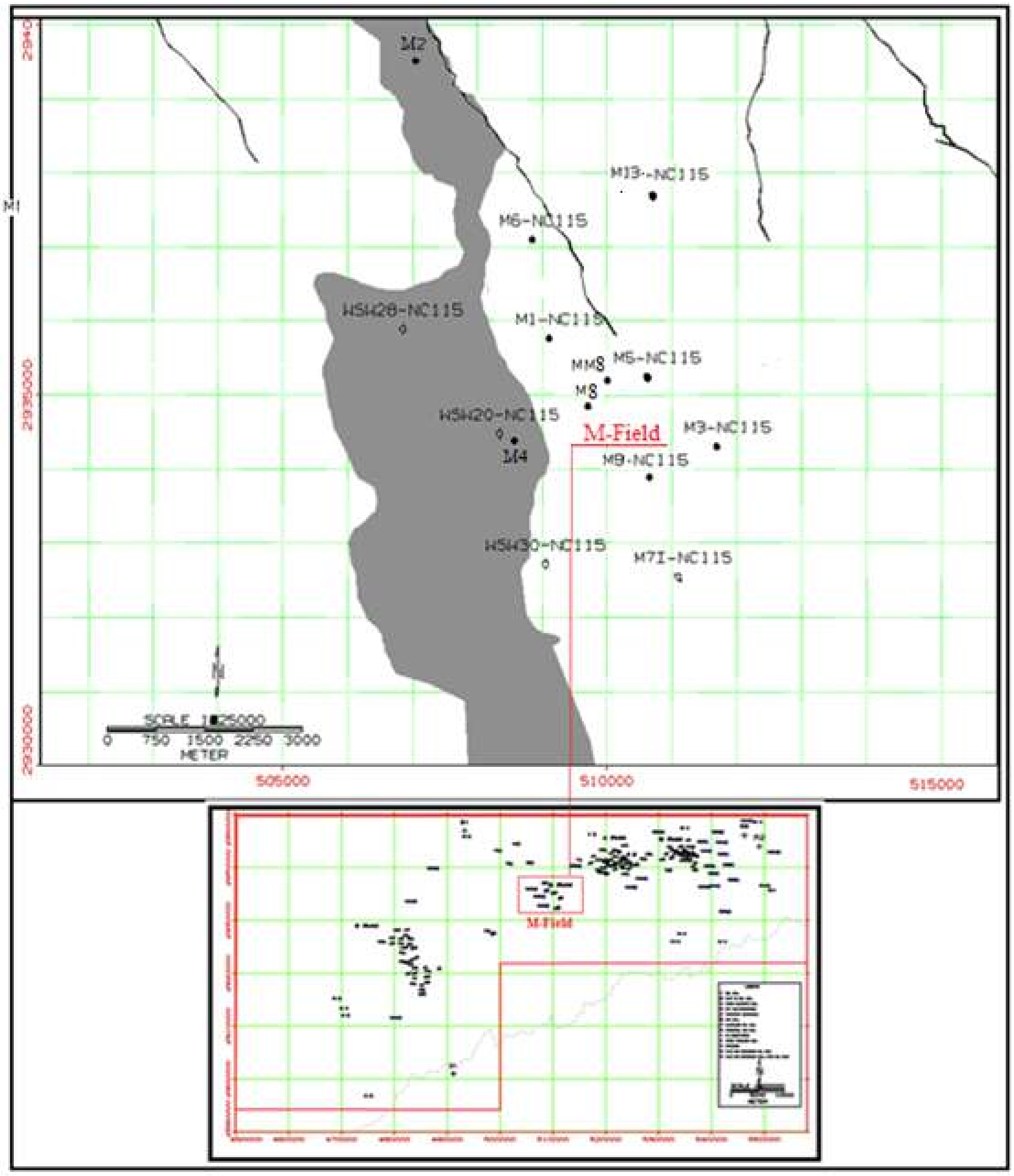

Figure 2 – Location map of M field, Concession 115, Murzuq Basin, Libya.

Murzuq Basin and created paleo-high during the post-Mamuniyat erosional events. This feature of paleo high is clearly represented in the 2-D seismic line shown in Figure **3** by Akakus Oil Operation [3] represented in the area of study. On the other hand, structure contour maps have been carried out for M field and illustrates the same structural feature of paleo-high Figure **4**.

The investigated M oil field lies between the latitudes 26º 10'and 26º 40'N and longitudes 11º 10' and 12º 50' E.

Generally, the petroleum system is represented by structural Mamuniyat paleo-high created during the post Mamuniyat erosional event. The basal Silurian Tanezzuft hot shale member acts as seal and source rock in the area of study.

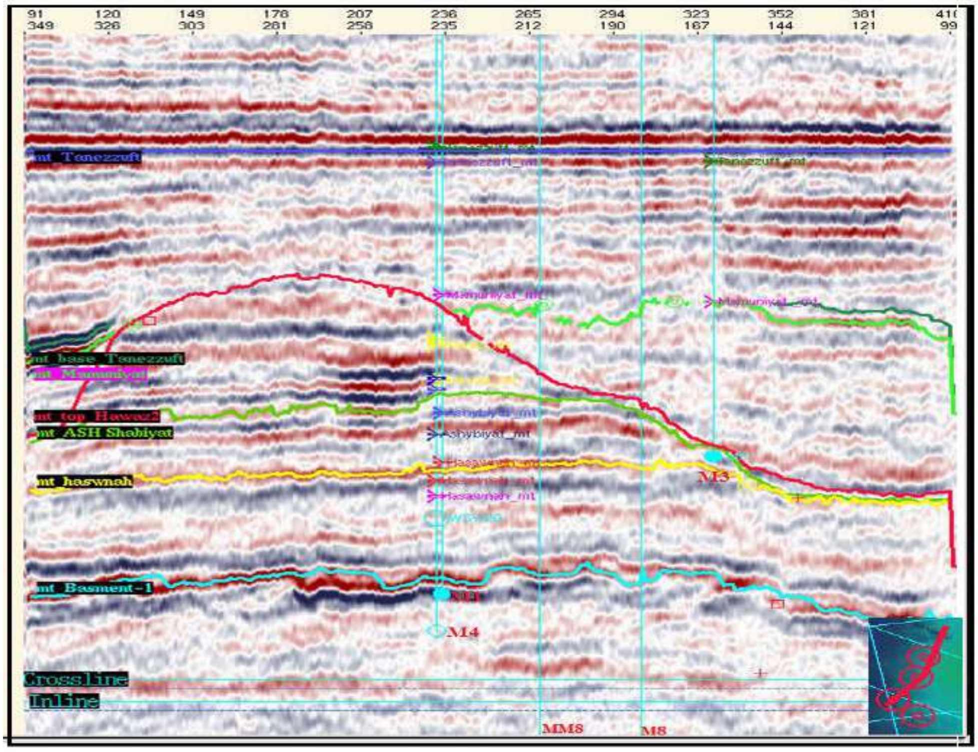

Figure 3 – 2-D seismic line for M1, M4, MM8, M8 and M3, M-field NC115 wells, Murzuq Basin[3].

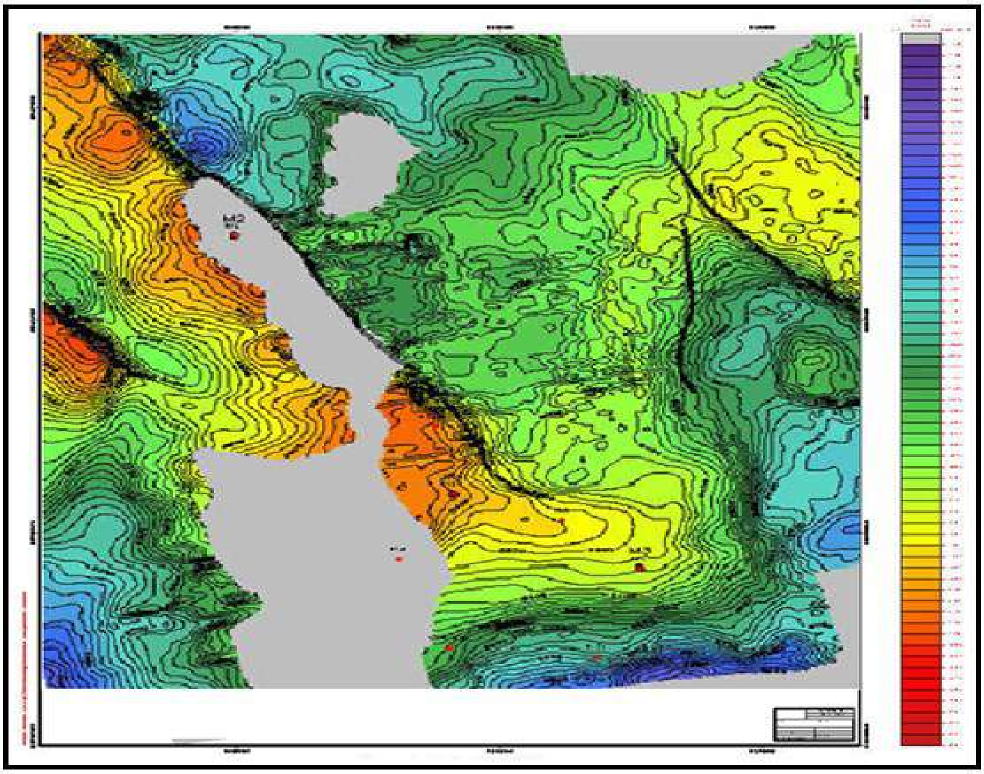

Figure 4 – Structure contour map for Mamuniyat reservoir in M field [3].

This paper is devoted to study the hydrocarbon potentialities of Mamuniyat Formation in M oil field through analysis of the available well log data. A comprehensive analytical formation evaluation has been applied using interactive petro-physics (IP 2018) software parameters [5]. The well records available for this study include the following: resistivity, sonic, neutron, density, nuclear magnetic resonance, spontaneous potential, caliper, gamma ray and natural gamma ray spectrometry logs.

This research paper is carried out as an extension to the previous studies [6],[7] to analyze the petrophysical characteristics of Mamuniyat formation in M oil field, but here we will be interested in this research mainly on the quick look analysis of log curves and plotting crossplots between the petrophysical parameters.

2. General Geologic and Structural Settings

Murzuq Basin is one of the several intracratonic sag basins located on the sw Libya The structural fabric imparted to the North African continental lithosphere during the late Proterozoic, the structural and stratigraphic evolution of the basin was controlled subsequent by Pan-African event. A series of NNW trending arches and sub-basins across North Africa created during the Early Palaeozoic tectonics, which filled with clastic continental and shallow marine deposits and transgressive open marine facies. Early Palaeozoic tectonism effectively controlled the distribution of late Ordovician reservoirs and distribution of Silurian "Hot Shale" which onlap early- formed fault blocks [8],[9].

The structure of the Murzuq basin is quite simple. The horizontal or gently dipping strata is faulted and the faults are most frequently parallel to the axis. Tectonic movements affected the basin to a greater or lesser degree from middle Palaeozoic (Caledonian) to Post- Oligocene (Alpine) times [9]. Caledonian, Hercynian and Alpine tectonic events affected this basin evolution, especially Caledonian and Hercynian orogenies [9]. Several regions in the south of the Ghadames Basin, Murzuq basin and also in the Kufra basin indicate that the Caledonian orogeny started in the Upper Silurian and persisted through the Lower Devonian.

The stratigraphic column of Murzuq basin started from the Pre-Cambrian to the Pleistocene Figure **5**. The maximum thickness in the basin center doesn't exceed 4000 m. The Mamuniyat Formation was defined by Massa and Colombo (1960) after Jabal Al Mamuniyat (West of Qarqaf) [10]. It has been described by [11]. This formation is composed entirely of sandstones, which makes it very prominent and easy to recognize throughout the area. The composition of the Mamuniyat Formation is relatively simple and monotonous. It consists mainly of medium- to coarse-grained and conglomeratic sandstones locally showing high percentages of kaolinitic matrix, with thick-bedded to massive, and less frequently thin bedded quartz sandstones, characterized by a regressive cross-bedded, sandstone unit.

The upper part of the Mamuniyat comprises medium- to coarse-grained sandstone with well-developed wavy cross-bedding[10]. The Mamuniyat formation is characterized by a wide spread under the surface, and its thickness ranges between 20-180 m. It was also noted that it has a regional overlap in the direction of the Qarqaf high [9].

The top part of the Mamuniyat Formation is normally transitional with the transgressive Silurian shales [12]. On the geological map of Libya this formation is included in the "Cambrian and Ordovician rock". In the Murzuq Basin, the main producing reservoir lies in the Mamuniyat quartzitic sandstones. The overall Ordovician sandstone reservoir quality of the Mamuniyat Formation varies greatly. However, porosity as high as 20% has been noted. The clastic deposits of this formation provide the best reservoirs in the northwestern flank of the Murzuq Basin [13],[14].

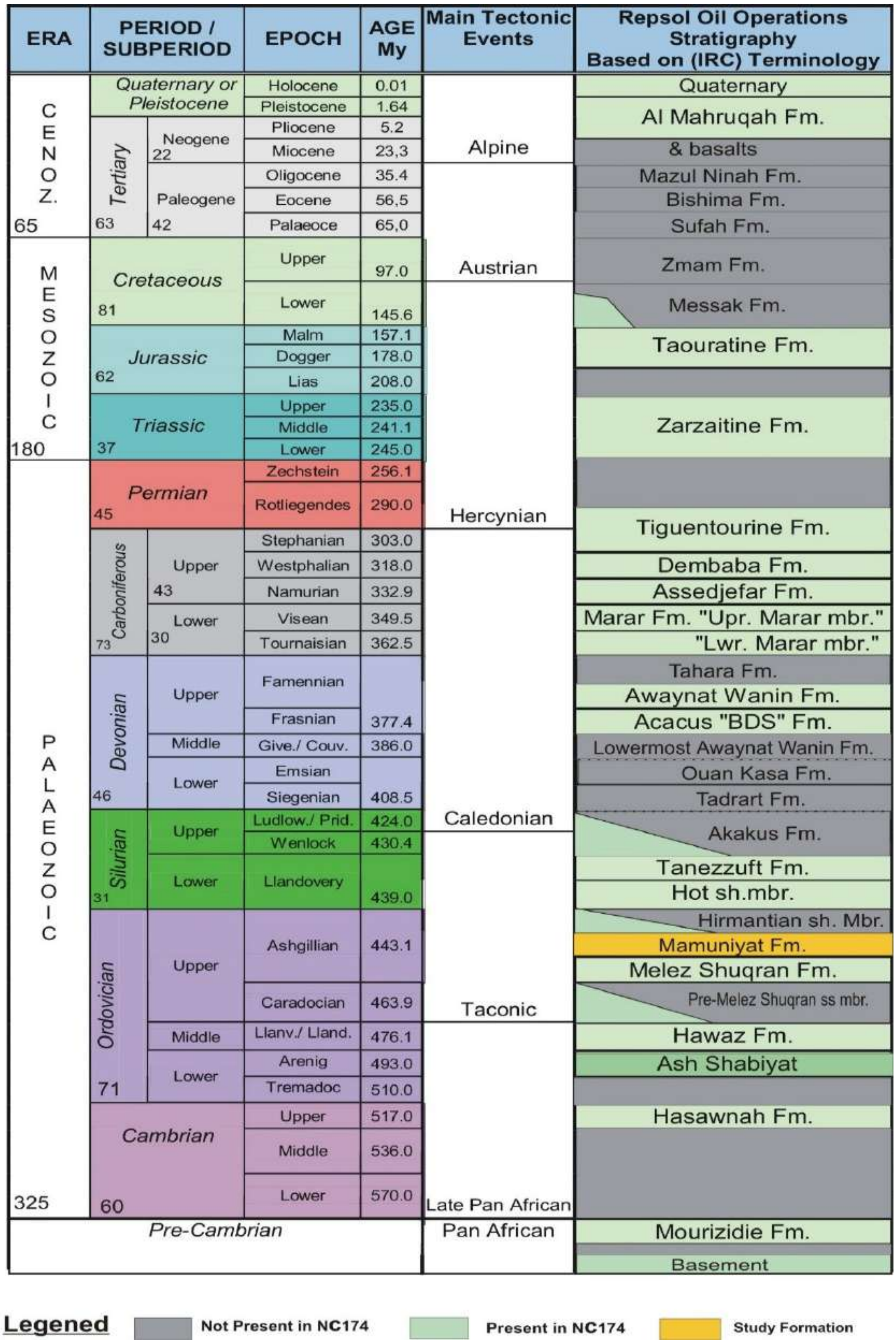

Figure 5- Stratigraphic column of the Palaeozoic, Mesezoic and Cenozoic successions in NC186, NW Murzuq basin, SW Libya, [15].

3. Well Logging Data Analysis Technique

The processing of the well logging data in this study has been carried out utilizing constructing two cross-plots for deriving formation water resistivity (*Rw*), cementation factor (*m*) and matrix parameters (*Pma*). These parameters were used as input parameters for the interactive petrophysics software to evaluate Mamuniyat reservoir. The pay flag was computed using Vshale cut-off 40%, Porosity cut off 10% and Sw cut-off 50%. These cut-off percent were determined from the inspection of the logs and cross plots of the porosity versus Vshale. The output results are presented in the form of litho-saturation cross plots parameters [5].

4. Results and Discussion

Initially, the well recording data was corrected from different borehole environments. Then these data with core samples recorded have been carried out utilizing quick log interpretation and analytical crossplots for evaluating the petrophysical characteristics of Mamuniyat reservoir.

4.1 Pickett crossplot

The Pickett plot, devised by Pickett [16], represents one of the simplest and most effective methods in use. It solved Archie's equation carefully and plotted deep resistivity and porosity, both on logarithmic scales. The saturation lines are parallel in a Pickett plot. Archie equation solution for water saturation has been replaced and rearranging the relationship becomes:

$$\log\Phi = \log Rt - m\log Sw + \log(aRw) \quad (1)$$

Figure **6** below, represents Pickett plot for M3-NC115. Points (green, red and brown spheres) represent zone I, II and upper part of zone III plotted on 25% sw line indicating high oil saturation. Blue spheres of zone IV horizons are plotted between 50% and 100% Sw lines. The slope of the parallel (Sw) lines equals (-1.9) which means that, cementation factor (m) equals 1.9. Lines representing constant (ρma - ρb)(Sw) (i.e BVW) values are parallel to the Y axis, which indicate that (m) is equal to (n) as shown in the Figure. Points plotted on these straight lines denote that, the reservoir is at irreducible state [17][17].

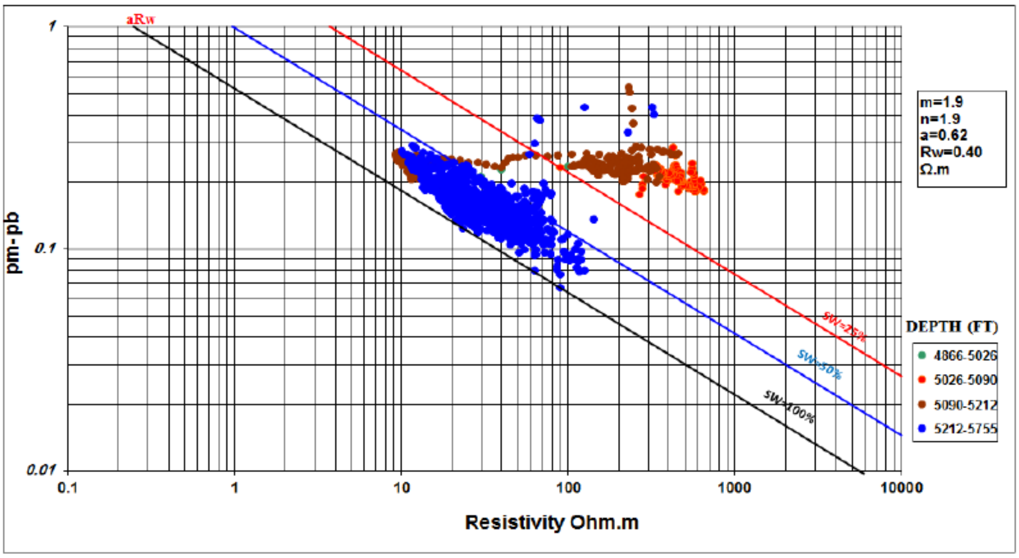

Figure 6 – Pickett plot between (ρma–ρb) versus Rt on log-log plot for M3-NC115 well.

The intercept of the R_0 line with the horizontal axis is at 0.25, which represents (aRw). Accepting the value of 0.62 for (a) gives Rw that is equal to 0.40 Ω·m.

4.2 Irreducible Water Saturation

The description estimation of Swirr can be beneficial in extracting valuable of the reservoir parameters, especially in exploratory wells, where core data are not available. It is very important to evaluating relative permeabilities to oil and water (Kro and Krw) and calculating water cut (WC). Many techniques were used to calculate this parameter. Asquith and Gibson [17] have proposed calculating Swirr for each zone depending on formation factor F:

$$Swirr = \sqrt{\frac{F}{2000}} \quad (2)$$

The authors applied the above equation for Mamuniyat formation in M3-NC115 well and displayed the results in a set of cross-plots between Sw, Swirr, and ΦN-D to give a picture of Krw, Kro, WC and grain size as follows.

4.3 Relative Permeability to Water and Oil

The relationship between Sw and Swirr can be used to evaluate graphically the relative permeability to water (Krw), as illustrated in Figure **7**. According to this plot, a set of points (green, red and brown spheres) represent zone I, II and upper part of zone III plotted on and below the zero line reflects no water production. These points reflect the irreducible state of the reservoir (i.e. Sw = Swirr). Points plotted on and below the 0.01 line (i.e. 1% water production) belongs also to the lower part of zone III. Points (blue spheres) located on a higher value line represent the deeper zone IV.

The relative permeability of oil (kro) is inversely proportioned to that of water (Krw). This is clear on Figure **8,** which represents the relation between Sw and Swirr as a function of (Kro) for M3-NC115 well. Points plotted on and below 0.01 Krw line situated also on and below 0.5 towards higher Kro values. Also points of zero Krw, (green, red and brown spheres) represent zone I, II and upper part of zone III plotted on and around 1.0 Kro line (i.e 100% relative permeability to oil and zero relative permeability to water).

The percent of water which will be produced with oil is of prime importance to describe the reservoir performance. Figure **9** represents the Water Cut (WC) lines in respect to Swirr versus Sw for M3-NC115 well. The WC% must be in correlation with the above Krw and Kro values obtained above. This obvious hence the plotted points around zero WC (green, red and brown points), which related to zone I, II and upper part of zone III, have Krw=0 and Kro=1.0. Blue points, which belong to zone IV, corresponding to very fine grain size (Fig. 10), maximum Krw >0.1, Figure **7** and Kro less than or equal 0.1 Figure **8**.

The crossplot between Sw versus ΦS for this well Figure **10** together with depth ranges represented as color coded. Points clustered below Coarse Grain (CG)line is situated in the upper part of the formation (above 5160 feet). These points represent the best reservoir quality (green, red and brown spheres) represent zone I, II and upper part of zone III. Points belong to depths lower than 5160 (lower part of zone III and zone IV) plotted around and above Very Fine (VF) line. These points related to well-known water bearing zones.

Finally, the graphical technique relating the calculated Swirr with Sw is applied to Mamuniyat formation in this well. The plotted points for this formation indicate scattering on different lines. Points (green, red and brown spheres) represent zone I, II and upper part of zone III is plotted around zero WC Figure **9**, zero Krw Figure **7** and 1 Kro Figure **8** lines confirming the upper part to be at irreducible state and will produce oil free. The lower part of zone III and zone IV) of Mamuniyat formation at depths between (5160-5755 ft) in this well have points scattered below 20% WC line and above 0.01 Krw and 0.5 Kro lines. This indicate that, the lower part of this formation has high relative permeability to water and zero relative permeability to oil and high percentage water cut or in other word it will produce only water.

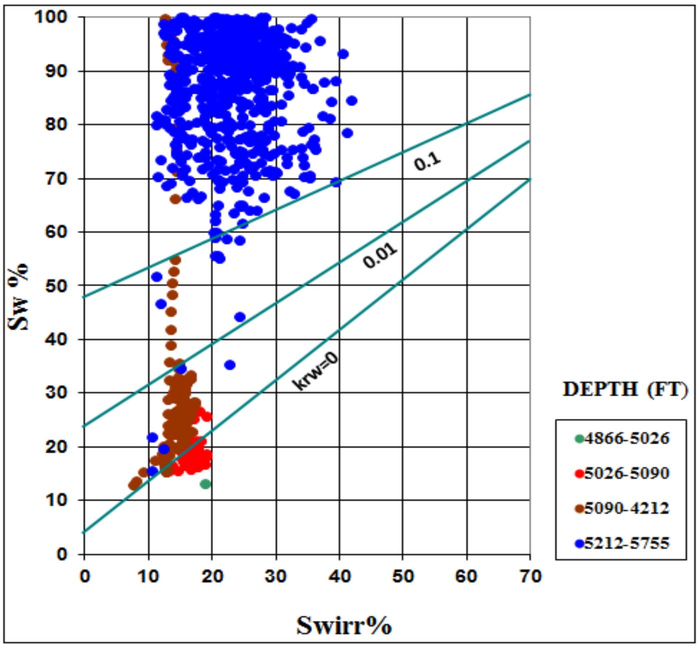

Figure 7. Crossplot between Sw versus Swirr for Mamuniyat Formation, M3-NC115 well showing relative permeability to water(Krw).

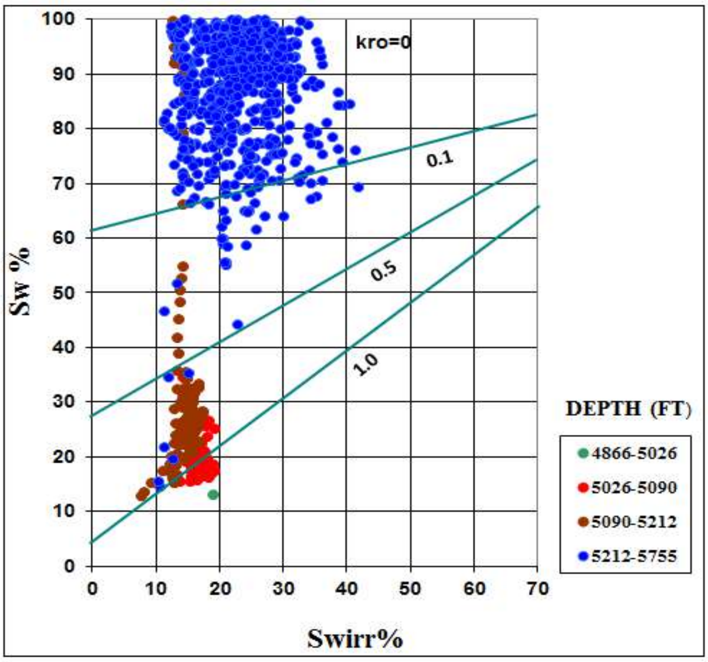

Figure 8. Crossplot between Sw versus Swirr for Mamuniyat Formation, M3-NC115 well showing relative permeability to oil (Kro).

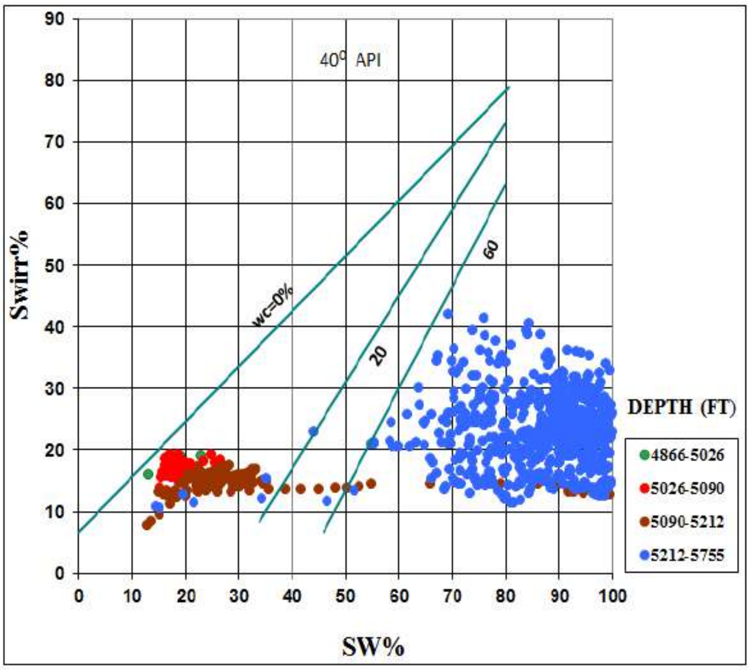

Figure 9. Crossplot between Sw and Swirr for Mamuniyat Formation, M3-NC115 well, illustrating water cut percent.

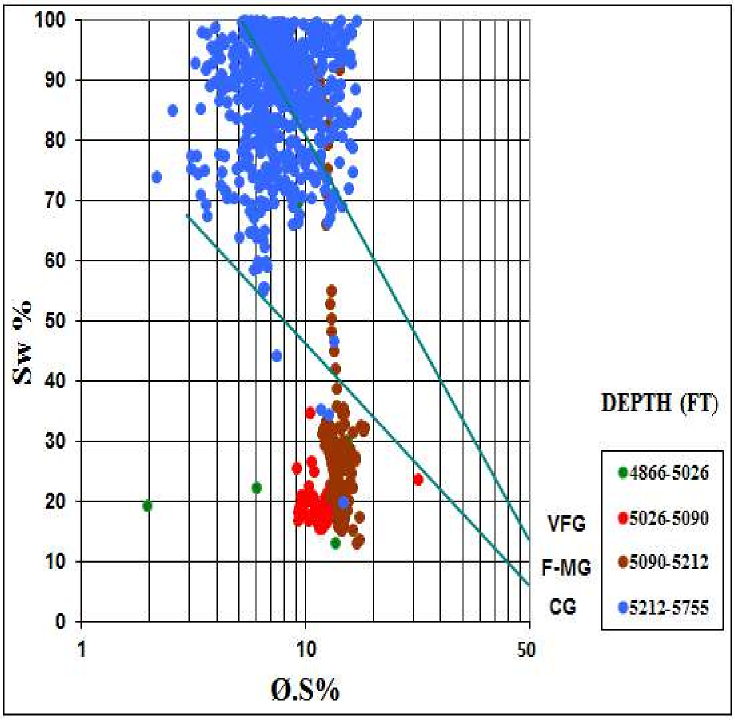

Figure 10. Water saturation vs sonic porosity showing upward coarsening sequence, for MAmuniyat Formation at M3-NC115, M oil Field

4.4 Buckles plot

Porosity-Saturation (Buckle) plot Figure **11** for the zone II (red spheres) of M3 well Mamuniyat formation indicate firmly that this zone is indeed at irreducible state and will produce free water oil as the plotted points track accurately BVW curve of 0.02. This low value, indicate oil production from well sorted and coarse grains as (i.e sorting and grain size increase towards lower BVW direction). The Sw value on this curve represents Swirr (0.11 in this case). Zone IV (blue spheres), represent the water zone thru Mamuniyat Formation in M Field when plotted on Buckle Figure **12** showed wide scattering of points. This scattering feature is characteristic for water producing zones. This zone has very fine grain connected to the presence of shale.

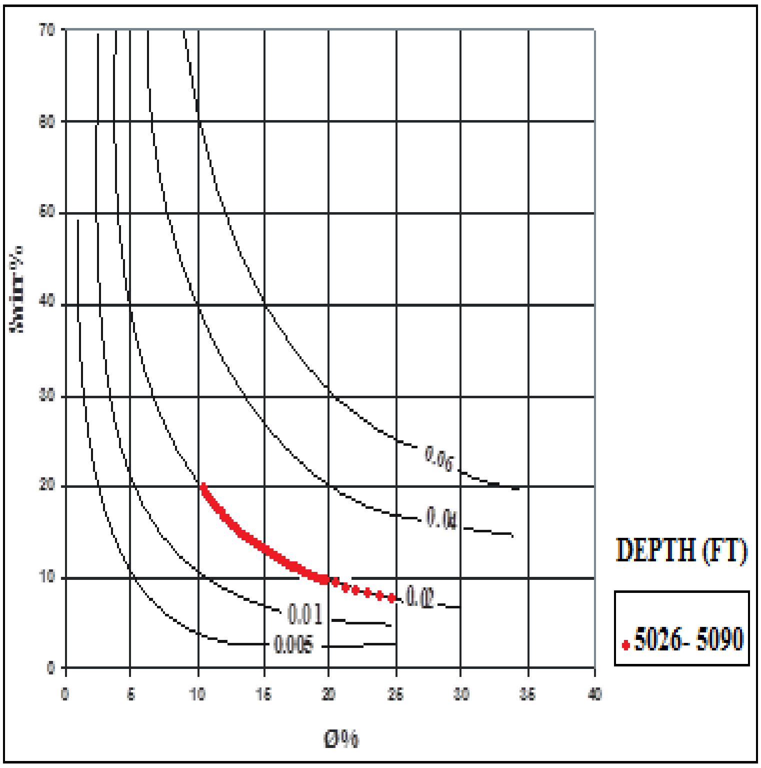

Figure 11 . Porosity Versus Water Saturation (Buckle) Cross-Plot for Mamuniyat Formation (Zone II) In M3-NC115.

4.5 Hydraulic Flow Unit (HFU)

The relation between permeability (K) and porosity (Φ) is not straight forward. Accordingly, there is no well-defined correlation between K and Φ. Different Φ - K relationships are evidence of the existence of different Hydraulic Flow Units (HFU). This situation is obvious for Mamuniyat Formation in the study area as the reservoir is clean homogeneous Sandstone. Four distinct and clear trend curves are detected between core K- Φ on a semi-log cross-plot Figure **13** suggesting the possible existence of 4 Hydraulic Flow Units corresponding to these trends.

The plot of RQI versus **Φz** on a log -log paper yields a straight line representing specific HFU. Other HFU will fall on straight parallel lines with slope unity. Figure **14** represents application of such technique to Mamuniyat Formation in M3-NC115 well. The plotted points fall on 4 parallel lines with slope unity. Each line denotes specific Hydraulic Flow Unit. Note that, these 4 lines can be correlated with 4 trends noticed on Figure **13**. Intercept of these lines with **Φz** =1 (FZI) are: 12, 18, 23 and 30 for HFU1-HFU4 respectively. All Hydraulic Flow Units in this formation with **FZI** more than one so all of these units represent good to excellent reservoir quality.

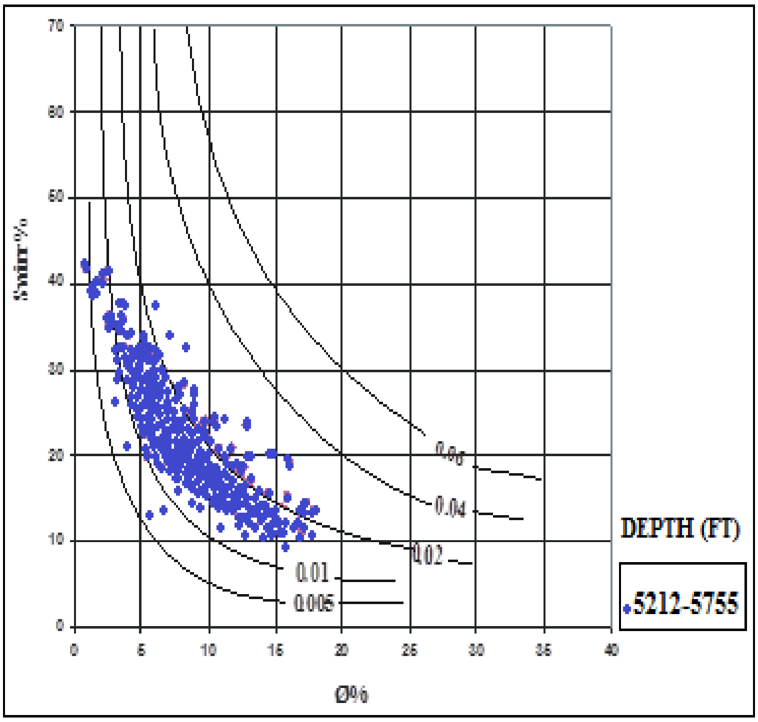

Figure 12 . Porosity Versus Water Saturation (Buckle) Cross-Plot for Mamuniyat Formation (Zone IV) In M3-NC115.

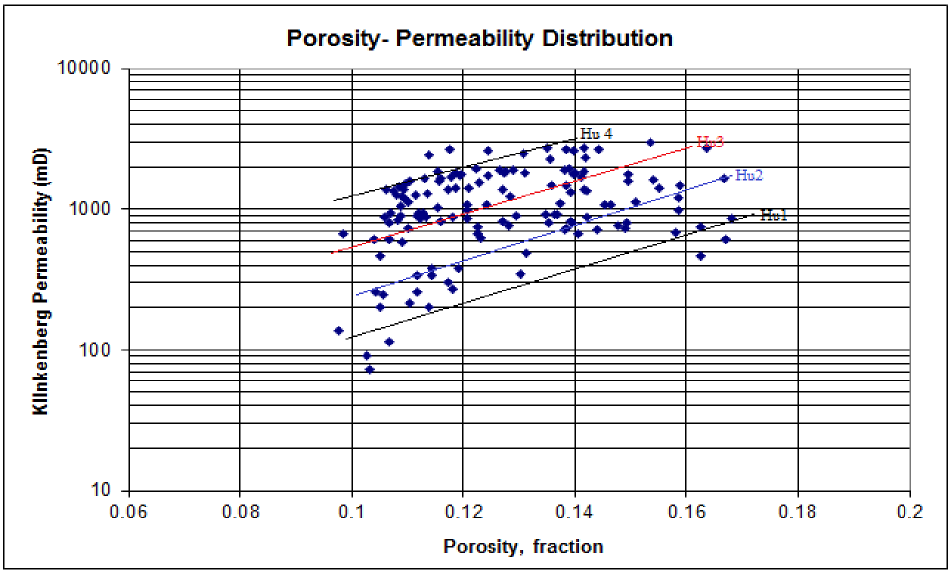

Figure 13 . Core Permeability (Kmd) Versus Porosity (Φ %) for Mamuniyat Formation, M3-NC115 well, Showing Four Distinctive Curve Trends.

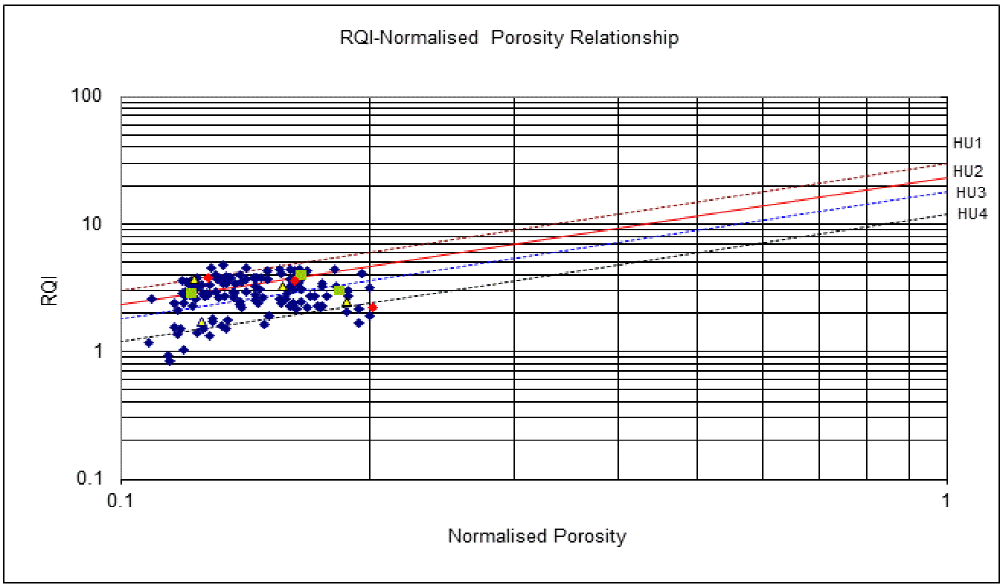

Figure 14 . Log-Log Plot of RQI versus Φz for Mamuniyat Formation in M3-NC115 Well Showing Four Parallel Lines Corresponding to Four Hydraulic Flow Units (HFU).

4.6 IP Output Results

The output results of IP-2018 were offered in the form of lithosaturation cross plots for Mamuniyat Formation in the study area. This formation was subdivided into four zones (I, II, III and IV). These zones have its own petrophysical parameters (Vsh, Sw, Sh and Φ). The calculated shale volume Vsh for Mamuniyat formation in M3-NC186 well Figure **15** ranges from 0.6% to 0.9% with average 0.7%. The effective porosity ranges from 10.2% to 12.4% with average 11.5%. Water saturation ranges from 20.5% to 93.3% with average 54.1 %. The top of Mamuniyat formation is 4866 ft with a gross thickness of 820 ft. and net pay thickness is 302 ft. It is well known that zone I, II and upper part of zone III are potentially the most productive zones.

On the other hand, the calculated shale volume of M13-NC186 well Figure **16** ranges from 0.1% to 0.3% with average 0.2%, the effective porosity ranges from 11.2% to13.3% with average 12.4%, the water saturation ranges from 21.4% to 44.3 % with average 31 %. The top of Mamuniyat formation is at 5126 ft with a gross thickness of 530 ft. and net pay thickness is 55.5 ft. Zone I is potentially the most productive zone.

4.7 Areal Distribution Of Mamuniyat Reservoir

The deduced petrophysical parameters are represented by a number of isoparameteric maps showing the lateral distribution of Mamuniyat Formation. The gross reservoir thickness contour map Figure **17** shows that the maximum recorded reservoir thickness 820 ft at M3-NC186 well, while it decreases gradually south ward recording the minimum value of 200 ft at the M7I-NC186 well.

The effective porosity contour map of the Mamuniyat reservoir shows a regular pattern of distribution with a general increasing towards North of the area Figure **18**, recording a maximum value of 12.7% at well M2-NC186. This value decreases gradually towards South of the study area recording a minimum value of 7.3% at well M4-NC186.

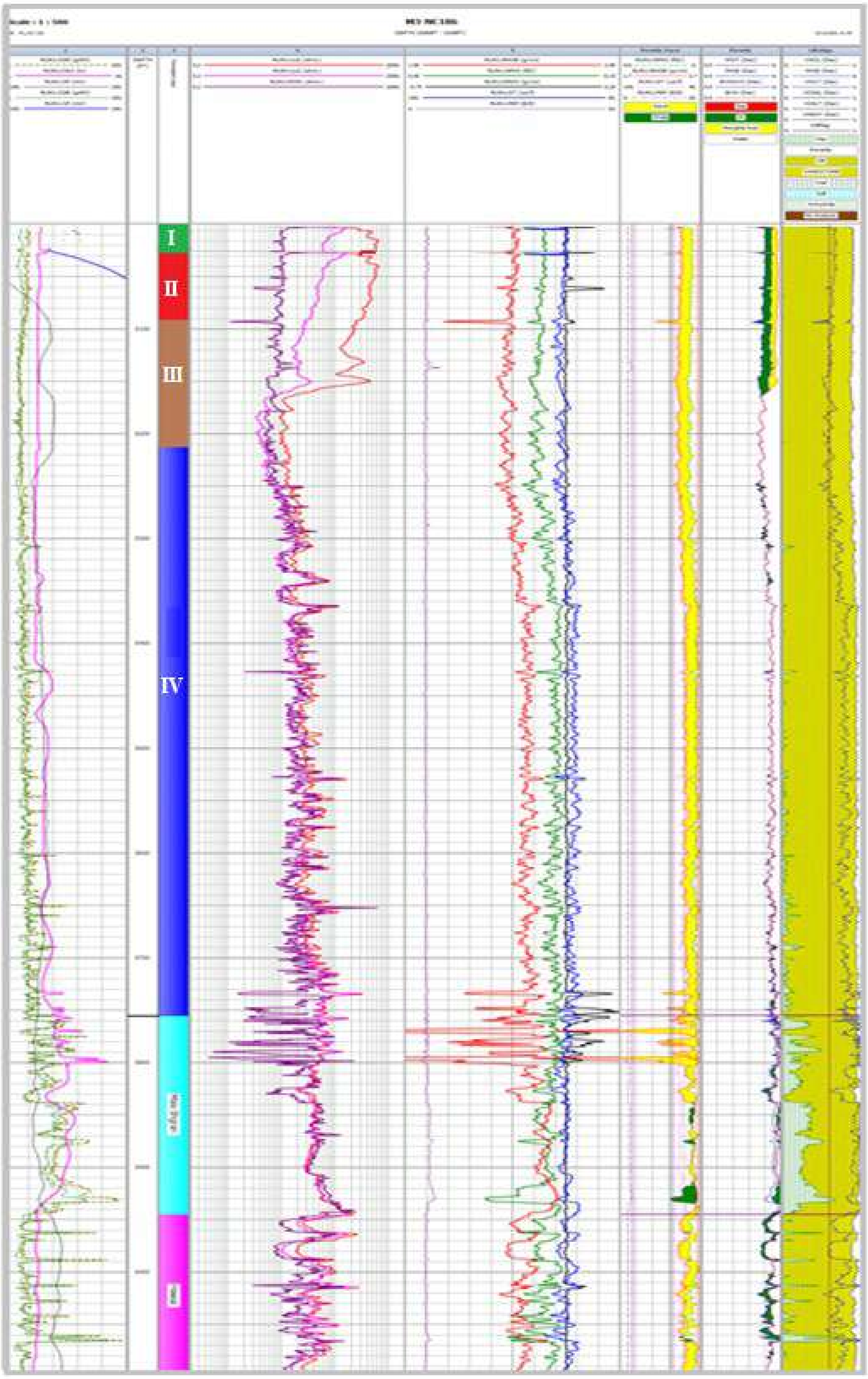

Figure 15 . Selective examples of the IP results for well M3-NC186, M Oil Field

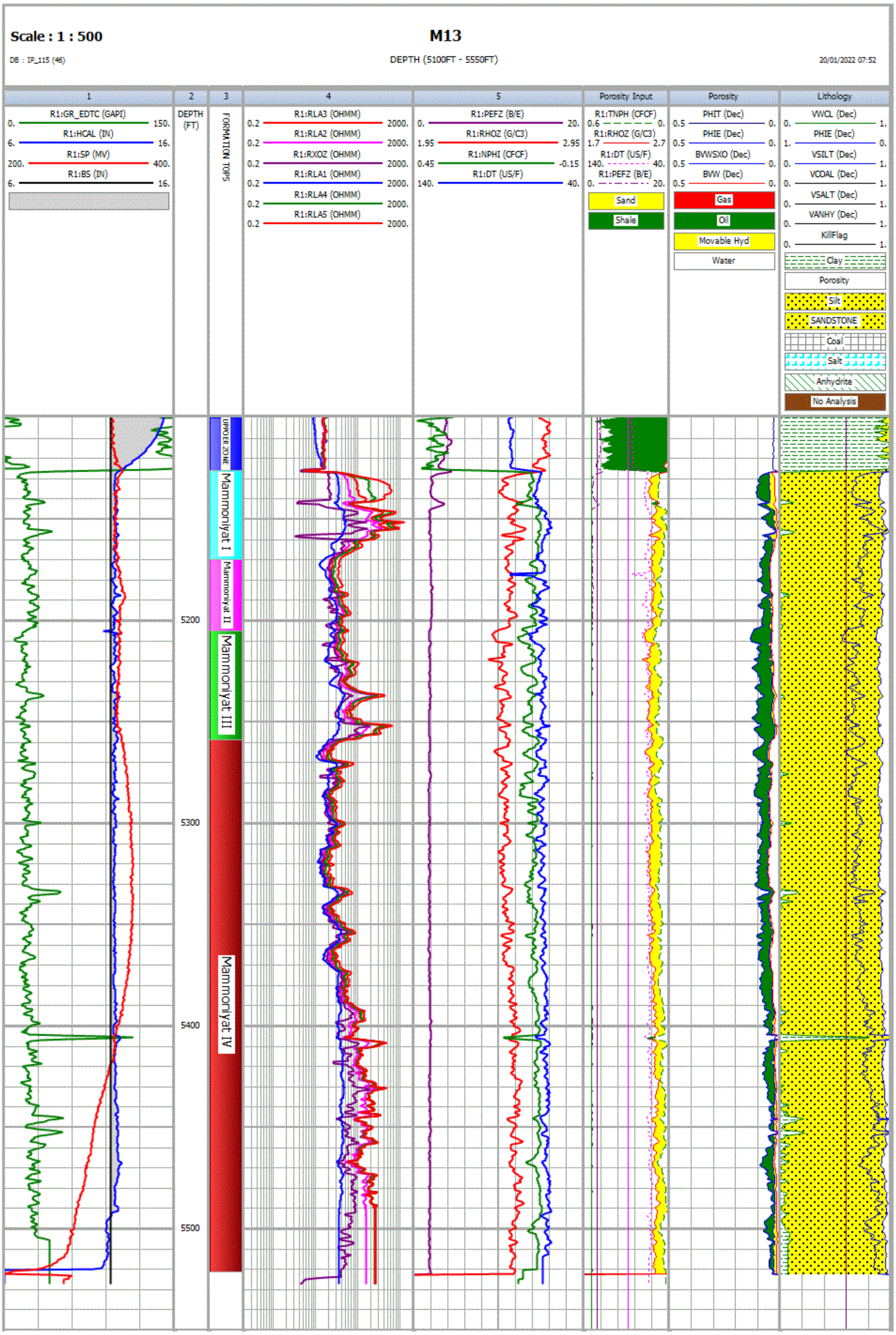

Figure 16 . IP Litho-Saturation Crossplot for M13-NC186 Well.

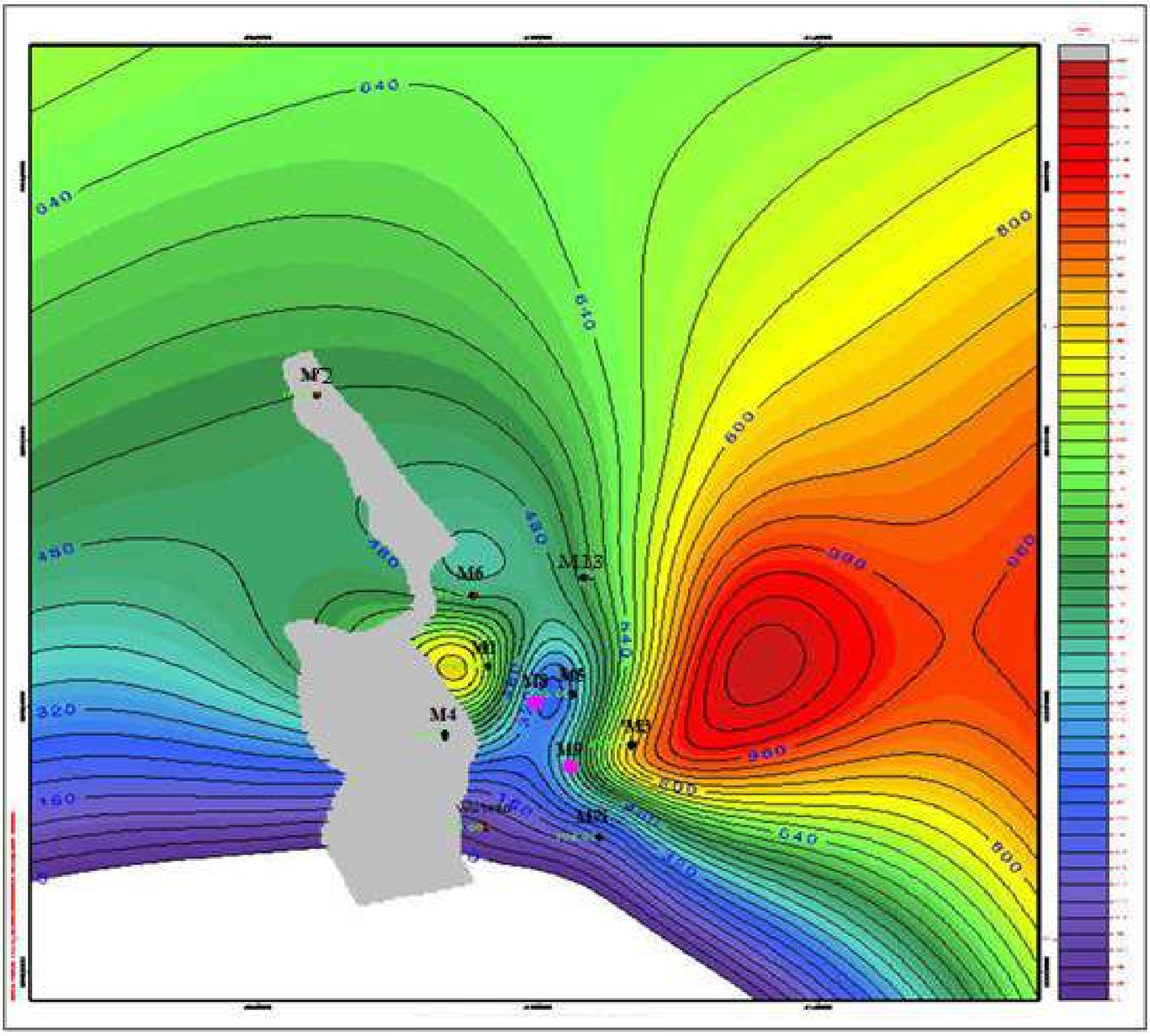

Figure 17 . Gross thickness contour map for Mamuniyat reservoir in M-NC186 Concession

5. Conclusion

The Mamuniyat Sandstone formation of Upper Ordovician age represents the main reservoir in Murzuq basin, sourced and sealed by the Silurian Tanezzuft shale formation. The Silurian Hot shale thanezzuft-upper Ordovician Mamuniyat Sandstone petroleum systems of the Murzuq basin have been studied by boote et al. (1998), Craik et al. (2001). The petroleum system is represented in this study by structural Mamuniyat paleo-high. This study is concentrated to evaluation the petro-physical parameters of Mamuniyat Formation at M oil field, Concession NC115 in Murzuq basin. The formation is informally subdivided into 4 zones, named (Mamuniyat I to IV). Each zone is characterized by its own petrophysical parameters.

The analytical and graphical formation evaluation tells that the reservoir consists mainly of clean Sandstone. This Sandstone is characterized by coarsining upward sequence from zone IV at the bottom level until zone I at the top. The results indicated that the Mamuniyat reservoir is mainly oil-bearing.

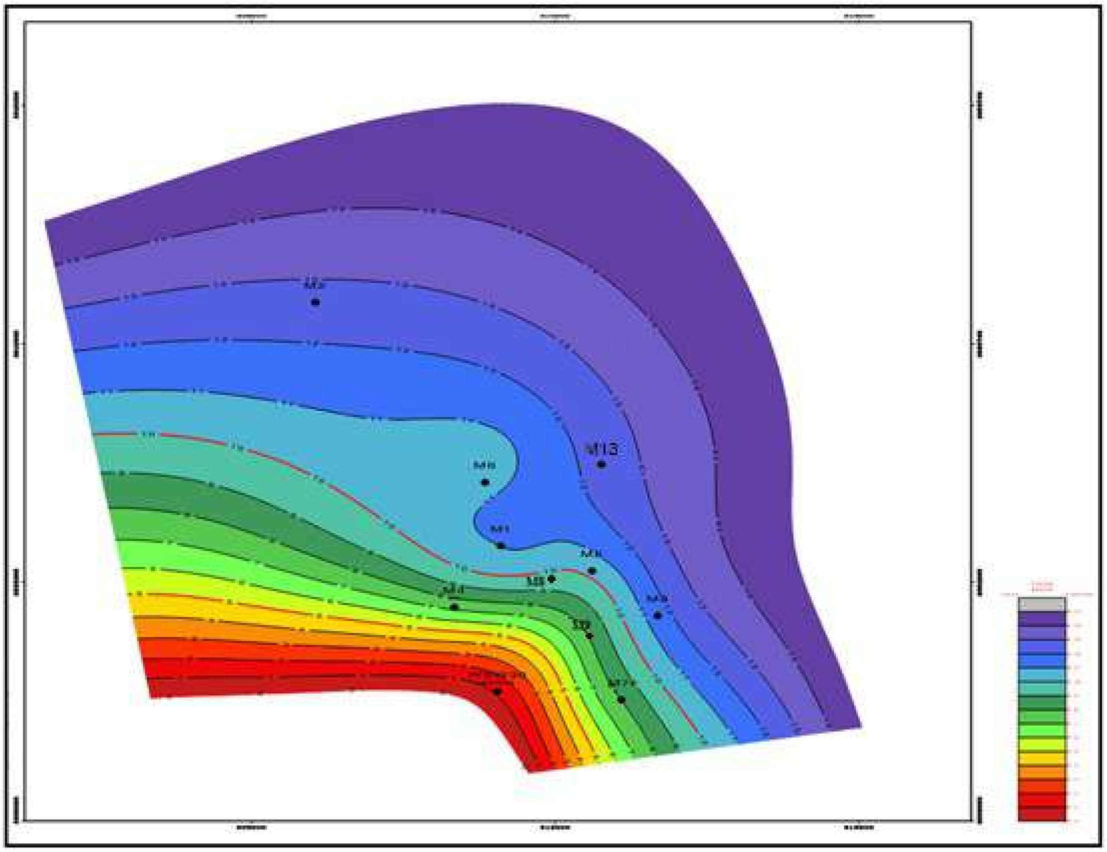

Figure 18 . Average effective porosity contour map for Mamuniyat reservoir in M-NC186 Concession.

The lithosaturation cross plots resulted through (IP -2018) program indicated that zones I and II contain the main oil reservoir. The lithosaturation crossplots and isoparameteric maps of Mamuniyat formation showing that the volume of shale is low and the porosity is relatively high as an indication of good reservoir. The relationship between core K–Φ and also Buckles crossplot suggests the presence of more than one hydraulic flow units of Mamuniyat formation represent very good to excellent reservoir quality.

6. Acknowledgment

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REFERENCES

[1] D. Thomas, Geology, Murzuk oil development could boost SW Libya prospects, Oil and Gas Journal;(United States) 93(10.(1995) (

[2] L. Davidson, S. Beswetherick, J. Craig, M. Eales, A. Fisher, A. Himmali, J. Jho, B. Mejrab, J. Smart, The structure, stratigraphy and petroleum geology of the Murzuq Basin, southwest Libya, Geological exploration in Murzuq basin, Elsevier2000, pp. 295-320.

[3] A.A. Castro, J.P. Fanjul, A. Gaaim, K. Omran, C. Gomez, Field Development Strategy Applied to a North African Field using Reservoir Simulation through an Integrated Asset Team Work, SPE Middle East Oil and Gas Show and Conference, SPE, 2009, pp. SPE-120761-MS.

[4] N. Fello, S. Lüning, P. Štorch, J. Redfern, Identification of early Llandovery (Silurian) anoxic palaeo-depressions at the western margin of the Murzuq Basin (southwest Libya), based on gamma-ray spectrometry in surface exposures, GeoArabia 11(3) (2006) 101-118.

[5] A. A Kushlaf, M. E Beneesa, Reservoir Quality Analysis of Hawaz Reservoir,(A) Oil field, Murzuq Basin, Libya.(2020) ,

[6] E.S.I. Selim, A. Kamel, A. Kashlaf, Hydrocarbon probability of middle Ordovician Hawaz formation, Murzuq basin, southwestern Libya, Arabian Journal of Geosciences 8 (2015) 5531-5560.

[7] A.K. Mohamed, A. Kashlaf, Comparative study between well logging and core analysis of Hawaz reservoir in Murzuq Basin, Libya, Egyptian Journal of Basic and Applied Sciences 3(3) (2016) 301-313.
[8] E. Klitzsch, Stratigraphic section from the type areas of Silurian and Devonian strata at western Murzuk Basin (Libya), Geology Archaeology and Prehistory of the southwestern Fezzan, Libya. Petrol. Explore. Soc. Libya, 8th Annu. Field Conf, 1969, pp. 83-101.
[9] E. Bellini, D. Massa, M. Salem, A stratigraphic contribution to the Palaeozoic of the southern basins of Libya, The geology of Libya 1 (1980) 3-56.
[10] D. Massa, G. Collomb, Observations nouvelles sur la region d'Aouinet Ouenine et du Djebel Fezzan (Libye), Proceedings of the 21st International Geological Congress, Copenhagen, Part, 1960 ,pp. 65-73.
[11] E. Pierobon, Contribution to the stratigraphy of the Murzuq Basin, SW Libya, Symposium on the Geology of Libya, 1991, pp. 1767-1783.
[12] A. Grubic, M. Dimitrijevic, M. Galecic, Z. Jakovljevic, S. Komarnicki, D. Protic, Stratigraphy of Western Fazzan (SW Libya), Symposium on the geology of Libya, 1991, pp. 1529-1564.
[13] E. Klitzsch, Comments on the geology of the central parts of southern Libya and northern Chad, South-central Libya and Northern Chad, Petrol. Explor. Soc. Libya, 8th Annu .Field Conf, 1966, pp. 1-17.
[14] D.R. Boote, D.D. Clark-Lowes, M.W. Traut, Palaeozoic petroleum systems of North Africa, Geological Society, London, Special Publications 132(1) (1998) 7-68.
[15] N. Fello, B. Turner, Provenance analysis, tectonism and shifting depositional system in the NW part of the Murzuq Basin, Libya: implication for hydrocarbon prospectivity. 21st International Association Sedimentology (IAS) meeting of Sedimentology, Abstr., Davos, Switzerland, 2001.
[16] G.R. Pickett, Practical formation evaluation, GR Pickett1972.
[17] G.B. Asquith, D. Krygowski, C.R. Gibson, Basic well log analysis, American Association of Petroleum Geologists Tulsa2004.