

Evaluation of The dynamic performance of Hawaz Formation in Murzuq Basin, Libya as inferred from the quick-look interpretation technique.

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A. A. Kushlaf

Engineering Geology Department, Faculty of Oil, Gas and Renewable
Energy Engineering, University of Zawia , Libya
a.Kushlaf@zu.edu.ly

Abstract

The evaluating of the Hawaz reservoir in the Murzuq basin based on the well recording data available for twelve exploratory were provided for this study. These records data have been examined through employing some cross-plots and use their outputs for controlling the interactive petrophysics software in order to identify the lithological constituents and fluid saturation parameters. The litho-saturation cross-plot indicated that the Hawaz Formation consists of sandstones with few shale. The Hawaz formation officially subdivided into eight horizons, namely H1–H8. Horizons (H4 and H5) are the main reservoirs in Hawaz formation as all readings indicate its high resistivity, with positive differentiation between its different curves, high porosity, and low gamma ray. BVW min technology is introduced the fast method depends on calculating the minimum total water volume so that the reservoir is considered to contain irreducible water, meaning that water will not be produced with the oil. The value of BVW min was 0.05, meaning that any range for which the product of porosity multiplied by water saturation ($\Phi.SW$) is greater than that value is excluded from any detailed calculations. Also, calculate the minimum value of electrical resistance ($R_{tmin}=140\Omega m$) for oil production zones, where zones with electrical resistivity less than that value are excluded.

Keywords: Hawaz Formation, H field of NC186, petrophysical parameters, well logging.

تقييم الأداء الديناميكي لتكوين الحواز في حوض مرزق بلبيبا كما يستدل عليه بتقنية التفسير السريع.

عادل على كشلاف

كلية هندسة النفط و الغاز والطاقة المتجددة

جامعة الزاوية- لبيبا

a.Kushlaf@zu.edu.ly

الملخص

تم تقييم خزان حواز في حوض مرزق بناءً على بيانات تسجيلات الآبار المتوفرة لاثني عشر بئرًا استكشافيًا أعدت لهذه الدراسة. تم فحص بيانات هذه السجلات من خلال استخدام بعض المخططات واستخدام مخرجاتها للتحكم في برنامج البتروفيزياء IP من أجل التعرف على المكونات الصخرية ومعدلات تشبعها بالسوائل. حيث أشارت مخططات التشبع الصخري إلى أن تكوين حواز يتكون من أحجار رملية مع القليل من الصخر الزيتي. وينقسم تكوين الحواز رسميًا إلى ثمانية آفاق، هي H1 - H8 يعتبر الآفاق H4 - H5 الخزائين الأساسيين في تكوين الحواز حيث تشير جميع القراءات إلى مقاومته العالية، مع تمايز إيجابي بين منحنياتها المختلفة، ومساميتها العالية، وأشعة جاما المنخفضة. وتم إدخال تقنية BVW min بالطريقة السريعة التي تعتمد على حساب الحد الأدنى من إجمالي حجم المياه بحيث يعتبر الخزان يحتوي على مياه غير قابلة للسحب، مما يعني أنه لن يتم إنتاج الماء مع الزيت. كانت قيمة BVW min 0.05، مما يعني أن أي نطاق يكون فيه منتج المسامية مضروبًا في تشبع الماء ($\Phi \cdot SW$) أكبر من تلك القيمة يتم استبعاده من أي حسابات تفصيلية للإنتاج. كما تم حساب القيمة الدنيا للمقاومة الكهربائية ($R_{tmin}=140\Omega m$) لنطاق إنتاج النفط، حيث يتم استبعاد الانطقة ذات المقاومة الكهربائية الأقل من هذه القيمة.

الكلمات المفتاحية: تكوين حواز، حقل H لـ NC186، العلامات البتروفيزيائية،

تسجيلات الآبار.

Introduction

Murzuq basin is one of the three major Libyan intracratonic sag basins [1]. It occupies the southern part of Libya and part of northern Niger where it is known as the Djado basin (Figure 1).

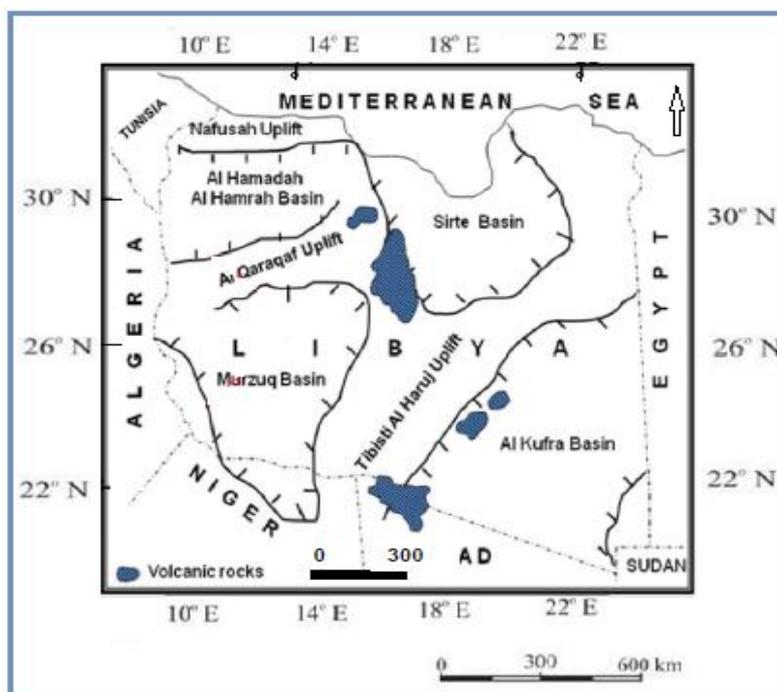


Figure 1. Location Map of the Sedimentary Basins of Libya [1].

It is located on the SW Libya and covers an area of about 350,000 km²[2] (Figure2). The basin is filled with thick Palaeozoic marine sedimentary sequences unconformably overlain by continental Mesozoic strata and Quaternary deposits, and it attains a maximum thickness of over 4000 meter in the basin center thinning to approximately 2200 to 2400 meter in along the northwest flank of the basin[2]. This Basin has different concessions containing some oil fields. Each field has some wells drilled for the evaluation of subsurface geology and hydrocarbon potentialities of the Middle-Ordovician Hawaz Formation intervals drilled by Repsol Oil Operations.

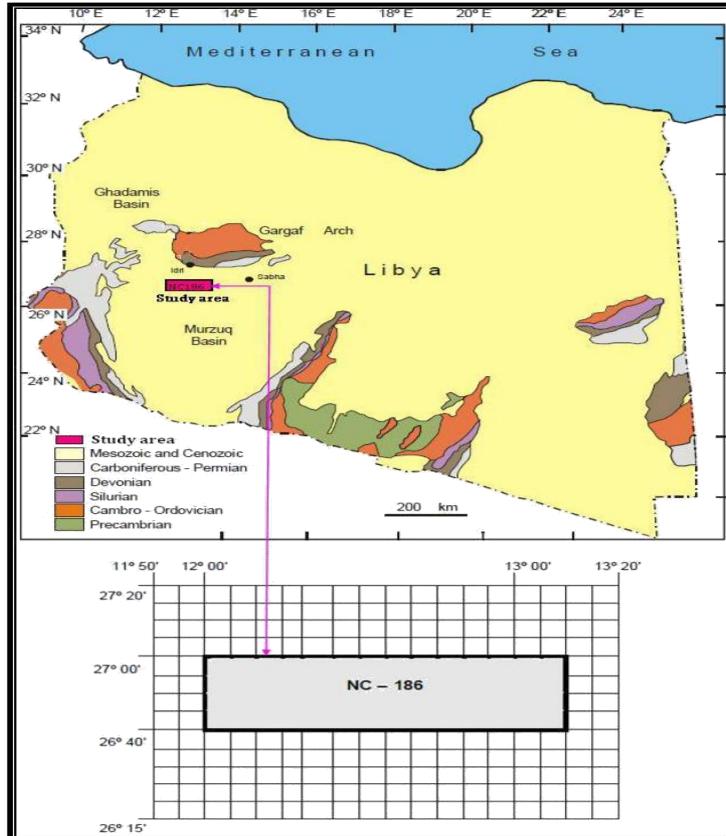


Figure 2. location map of NC186 concession, Northwest flank Murzuq Basin, SW Libya [7].

The study area was affected by the structural and tectonic movements of the Murzuq Basin, which led to the founding of paleo highlands during the erosion events that occurred after Hawaz [3]. This feature of the ptyo-high is clearly demonstrated in the two-dimensional seismic line shown in (Figure 3) from Repsol oil company [4].

Hawaz formation consists of fluvio-tidal cross bedded quartzitic sandstone and upper to lower shore face sandstones, with thin shaly intercalations and intense bioturbation (Skolithos), suggesting high-energy environment of deposition [5].

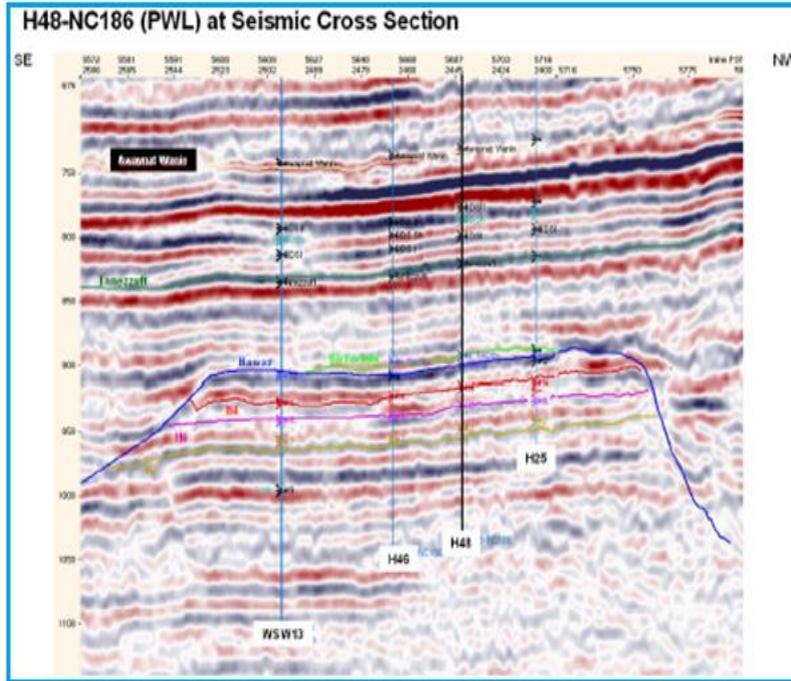


Figure 3. 2-D seismic line through wells in H oil field.
(Repsol oil operation2009)

This study is represent an extension to the previous studies [6] to analyze the petrophysical characteristics of Hawaz formation in H field (Figure 4), but here it will be concentrating mainly on the quick look interpretation of log curves and plotting cross plots between the petrophysical parameters and then liken the results with core data. This research is concerned with studying the oil potential of the Hawass Formation in H oil field by analyzing the well log data available to us, and through the IP program, the studied formation was analyzed and evaluated.

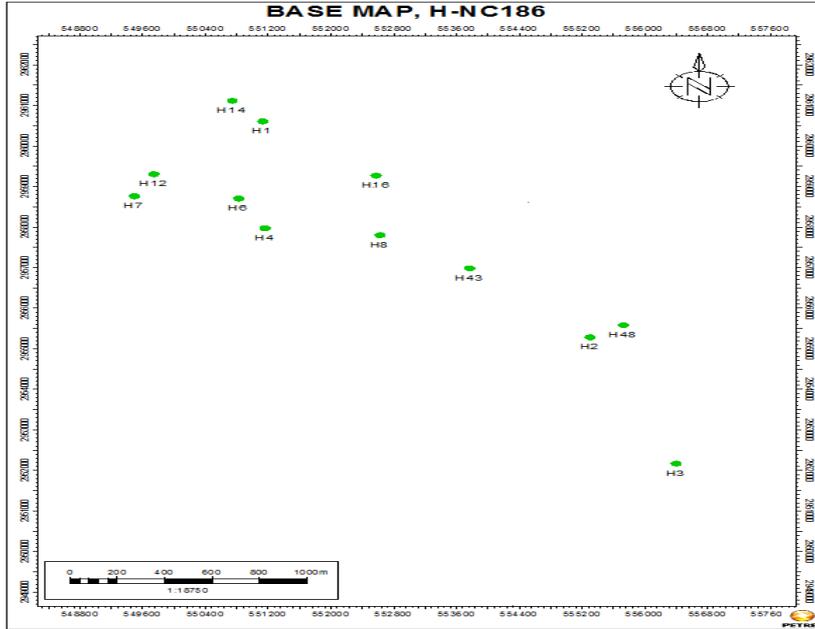


Figure 4. location map of H oil field, Concession 186, Murzuq basin.

Geological background

The Murzuk Basin is an intra-cratonic sag basin located inside East Saharan Craton on the Saharan Platform of North Africa and also is one of the three major Libyan basins [8]. It occupies the southern part of Libya, corresponding with the Gargaf Arch and part of northern Niger[8]. The basin is filled with thick Palaeozoic marine sedimentary sequences unconformably overlain by continental Mesozoic strata and Quaternary deposits [9]. The basin is bounded by the following uplifts; to the southwest by the highland of Precambrian crystalline rocks of the Hoggar massif; to the southeast by Precambrian rocks of the Tibesti massif; to the east by Al Haruj uplift; to the west, the boundary is formed by north plunging Palaeozoic rocks of Tihemboka arch; and finally to the north by the Lower Palaeozoic and Precambrian rocks of the east northeast trending Gargaf Arch[10].

The present structural framework of the basin was produced by movements related to the Caledonian (Late Silurian-Early

Devonian), Hercynian (Upper Carboniferous-Permian) and Alpine (Early Tertiary) events; the regional lineaments, NW-SE, are probably related to late Precambrian Pan-African fault systems, which largely controlled the early Palaeozoic structural evolution and deposition in the Murzuq Basin [5].The sedimentary deposits in the Murzuk Basin range from Cambrian to Quaternary in age, and can be divided into four major sedimentary cycles by [11].

The quartzitic sandstones of Cambro-Ordovician age are deposited under varying environmental conditions ranging from continental to shallow marine environments, the later resulting from the sea flooding of a large part of the Sahara platform. The Hawaz Formation represents the Middle Ordovician.

A rapid sea level rise created by the retreat and melting of glaciers from northern Africa at the end of the Ordovician resulted in the deposition of the thick blanket of Silurian shale of the Tanezzuft Formation. These shales provide excellent regional seal and oil source rock to reservoir sandstone in the basin.

The Devonian rocks have a widespread occurrence over whole the basin. They are dominantly sandstone, shale and minor amount of carbonate and are considered as an attractive target for hydrocarbon in the basal part are the Devonian sands of Acacus Formation, separated by regional shale. The Upper Devonian is represented by AwaynatWanin shale, an excellent cover for the Acacus reservoir.

Lower Carboniferous (Tournaisian-Visean) Marar Formation comprises deltaic and shallow marine shale interbedded with sandstone. Marar Formation is overlain by lagoonal mudstone and algal limestone of the Collenia Beds and these consequently by Assedjefar and Dembaba Formations. The Dembaba Formation represents the last widespread marine transgression preserved in the Murzuq Basin.

The stratigraphic column of Murzuq basin at well H48 ranges from the Pre-Cambrian to the Quaternary (table 1), and the maximum thickness in the basin center is about 3500 m.

Table 1. Stratigraphic column of the successions for H48-NC186 well. NW Murzuq basin, SW Libya [8]

| Era | Period | Age | Formation | Progn. Depths (ft) | Depth (ft) | E-logs (ft) | Lithology | |
|-----------|---------------|--------------------|------------------------|--------------------|--------------|--------------|-------------------------------|-------------------------------|
| CENOZOIC | Pleistocene | | Quaternary | Quaternary | 18 (1687) | 18 (1687) | - | Sand |
| | Tertiary | Neogene Palaeogene | | | | | | |
| | Triassic | Post-Tassilien | Tauratine | 385 (1320) | 385 (1320) | 348 | sand clay sandstone | |
| | | | Zarzitine/Tiguentourin | 755 (950) | 764 (941) | 712 | claystone limestone sandstone | |
| PALEOZOIC | Permian | | Dembaba | Dembaba | 1897 (-192) | 1853 (-148) | 1863 | limestone claystone sandstone |
| | Carboniferous | Upper | | | | | | |
| | | | Lower | Collenia Beds | Upper Marar | 2080 (-375) | 2087 (-382) | 2053 |
| | | Marar | | Lower Marar | 2923 (-1218) | 2928 (-1223) | 2903 | shale sandstone |
| | | Devonian | Aouenit-Ouenine | AwainatWanin | BDS II | 3835 (-2130) | 3837 (-2132) | 3830 |
| | BD Shale | | | | 3890 (-2185) | 3893 (-2188) | 3888 | |
| | BDS I | | | | 3965 (-2260) | 3965 (-2260) | 3958 | |
| | Silurian | Tanezzuft | Tanezzuft | 4089 (-2384) | 4072 (-2367) | 4080 | shale sandstone | |
| | Ordovician | Upper | Himantian | Hirnant.Sh.mbr | 4480 (-2775) | (-) | - | shale sandstone |
| | | Lower | Hawaz | Hawaz | 4529 (-2824) | 4532 (-2827) | 4518 | shale sandstone |
| H2 | | | | 4549 (-2844) | 4560 (-2855) | 4531 | | |
| H3 | | | | 4582 (-2877) | 4578 (-2873) | 4566 | | |
| H4 | | | | 4639 (-2934) | 4610 (-2905) | 4622 | | |
| H5 | | | | 4695 (-2990) | 4693 (-2988) | 4672 | | |
| H6 | | | | 4754 (-3049) | 4745 (-3040) | 4749 | | |
| H7 | | | | 4875 (-3170) | 4881 (-3176) | 4854 | | |
| H8 | | | | 5031 (-3326) | 4909 (-3204) | 4904 | | |
| TD | 5131 (-3426) | 5131 (-3426) | 5131 | | | | | |

Quick Look interpretation

The Quick Look technique is well known and used routinely to describe the nature of the reservoir in the form of the prevailing lithology, shaliness, porosity and the possible presence of permeability and movable hydrocarbons.

Minimum Bulk Volume water ((BVW_{min})

The amount of water a reservoir can retain (SW_{irr}) without production is constant for a particular formation. Therefore, if we calculate BVW ($\Phi.SW$) for a reservoir and it is less than or equal to Minimum Bulk Volume water ((BVW_{min}), it will produce free of water. Water-free production is obviously desirable because it costs money to produce and dispose of the unwanted water.

Since BVW components from the Archie equation, we can rearrange the equation as follows:

$$(BVW_{min})^2 = R_w/R_{t_{min}} \quad (1)$$

$$R_{t_{min}} = R_w/(BVW_{min})^2 \quad (2)$$

Where, $R_{t_{min}}$ is the minimum formation resistivity required for water-free production. If we know the formation water resistivity and (BVW_{min}, we can calculate the approximate $R_{t_{min}}$ required confirming water-free production. For a carbonate we need about 800 R_w ; 200 R_w for a slightly shaly sandstone and 400 R_w for clean sandstone [12]. Once we have identified the zones, that have enough resistivity to produce water free, we only need to discover whether the porosity is high enough This technique will be applied for the studied wells and presented in the following sections.

Figure 6 represents the log curves for H48-NC186 well. The clear positive resistivity separations are seen opposite the base of (H4a, H4b,H4c) (4622/4672') and upper H5 horizons (4672'-4725'). A clean 100% wet interval is seen at the horizon H6bon depth 4775 ft. Connate water resistivity R_w can quickly verified where R_o at this interval averaging 10 $\Omega.m^2/m$ and porosity is 0.16. The connate water resistivity (R_w) equals 0.32 $\Omega.m^2/m$ as calculated using Archie relation [13] as follows:

$$R_o = FR_w$$

$$10 = 0.62/(0.16)^{2.15} \times R_w$$

$$R_w = 0.32\Omega m$$

The most striking and embracing feature is that, the core result for this well give R_w value of 0.32 which is in close correlation with 0.32 obtained through the below described quick look technique. Also the Pickett plot (Figure 5) give value of 0.32 which also agree with the prescribed procedure.

The reservoir water saturation can then be calculated using the Archie relation (1942) and Humble model [14] for Formation Resistivity Factor $F = 0.62/\phi^{2.15}$ as follows:

$$SW = \left[\frac{(0.62 \times 0.37)}{\phi^{2.15} \times RT} \right]^{1/2} \quad (3)$$

As Hawaz reservoir in this well is almost clean sandstone as described above, the RT_{min} value for free water production is 128 $\Omega \cdot m^2/m$ (400×0.32). BVW_{min} value of 0.05 is used (Eq.1). Accordingly, only zones with R_t more than 140 and BVW less than 0.05 will be expected to produce oil with zero Water Cut (WC). The calculated results for Hawaz Formation in H48-NC186 well are presented in (Table.2) below.

TABLE 2. Calculated BVW and expected fluid type production for Hawaz Formation in H48-NC186well, Murzuq Basin, SW Libya compared with 0.05 BVWmin.

| Horizon | Depth feet | RT $\Omega \cdot m^2/m$ | Φ % | SW % | BVW Fraction | Expected fluid |
|-------------|---------------|----------------------------|-------------|---------|-----------------|-------------------|
| H4a | 4622- 4638 | 150 | 15 | 28 | 0.042 | Clean Oil |
| H4b | 4638- 4655 | 190 | 14 | 26 | 0.036 | Clean Oil |
| H4c | 4655- 4672 | 300 | 15 | 20 | 0.03 | Clean Oil |
| Upper H5 | 4672- 4730 | 250 | 11 | 30 | 0.033 | Clean Oil |
| Lower H5 | 4730- 4749 | 20 | 11 | 67 | 0.07 | water |

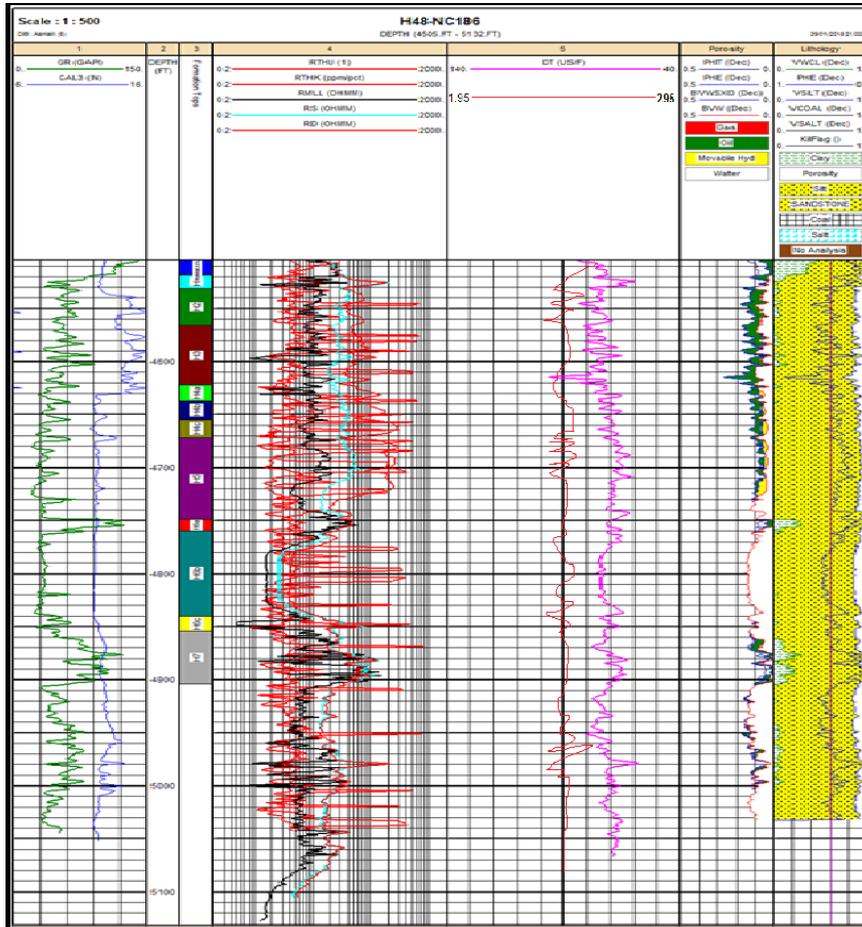


Figure 5. Well log data and IP Software output results for Hawaz Formation in H48-NC186 well.

Figure 6 represents the log curves for H43-NC186 well. Positive resistivity separations are clearly visible opposite H4a, H4b, H4c (4645-4699) and upper H5 horizons (4699-4710) with highest one exist at H4c one. Accordingly, these horizons may contain oil. A clean 100% wet interval is seen at the base of H5 horizon (4750). Table (3) summarizes the log readings and the calculated BVW and the expected fluids when compared with BVWmin values of 0.05 for clean zones.

TABLE 3. Calculated BVW and expected fluid type production for Hawaz Formation in H43-NC186well, Murzuq Basin, SW Libya compared with 0.05 BVWmin.

| Horizon | Depth feet | RT $\Omega\text{m}^2/\text{m}$ | Φ % | SW % | BVW Fraction | Expected fluid |
|-------------|---------------|-----------------------------------|-------------|---------|-----------------|-------------------|
| H4a | 4644-4662 | 110 | 11 | 45 | 0.049 | Clean Oil |
| H4b | 4662-4677 | 120 | 16 | 29 | 0.046 | Clean Oil |
| H4c | 4677-4699 | 120 | 17 | 27 | 0.046 | Clean Oil |
| Upper H5 | 4699-4710 | 150 | 18 | 23 | 0.036 | Clean Oil |

As BVW values constant over the H4b,c horizons, Water Cut (W.C) is expected to be zero. Interval 4645' – 4700' was perforated and recovered 800 BOPD. The oil is produced from layer H4 and no water with 40 API^o oil gravity (i.e light oil) (Repsol oil operation report 2009), which support the validation of the quick and visual interpretations applied.

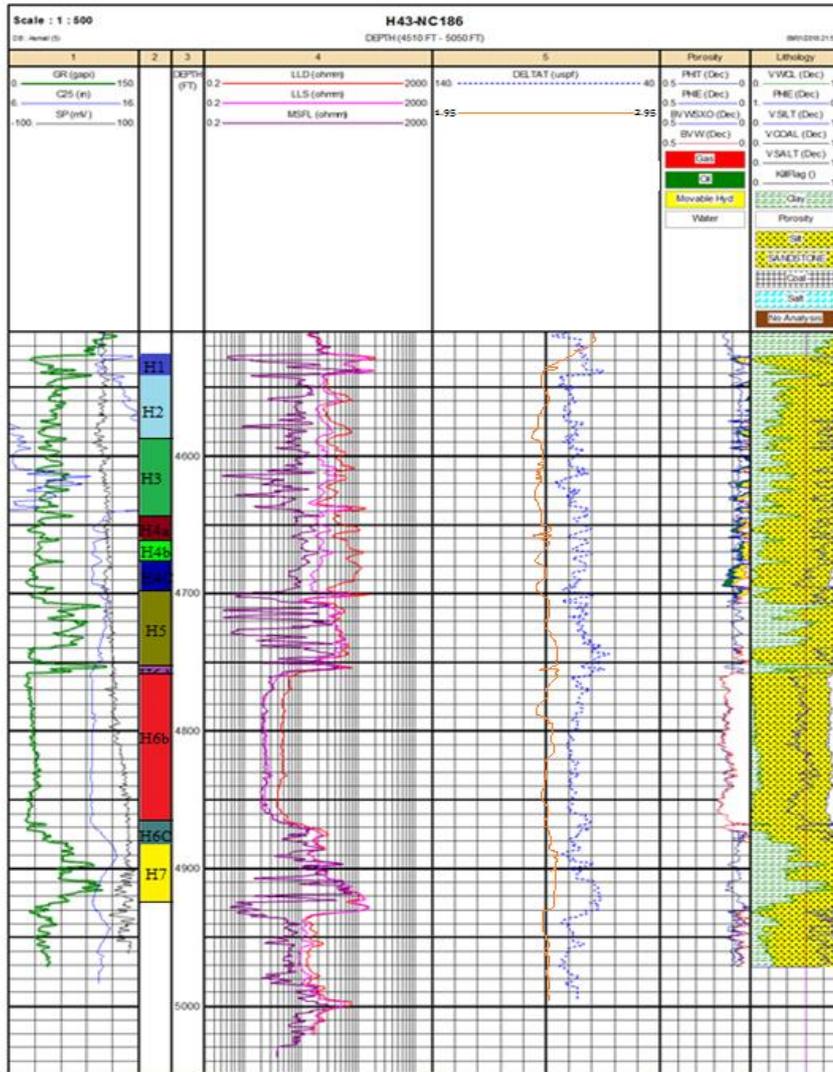


Figure 6. Well log data and IP Software output results for Hawaz Formation in H43-NC186 well.

Resistivity-Porosity Relation (Pickett Crossplot)

The Pickett plot which devised by Dick Pickett (1966) [15] represents one of the simplest and most effective in use. It solved Archie's equation in the following form:

$$\log \phi = \log Rt - m \log Sw + \log(aRw) \quad (4)$$

This technique is based on observation that true resistivity (R_t) is a function of porosity (ϕ), water saturation (Sw) and cementation factor (m). The straight line (100% water saturation) represents the wet resistivity (R_o). The slop of this line is $-1/m$. It intercepts the vertical scale, at porosity equals unity, where aRw can be read on the resistivity scale.

Figure (7) represents the Pickett plot for Hawaz Formation in H48-NC186 well. The R_o line was drawn through points representing lower H6b and H7 horizons and intersects the ($pm-pb$) line at unity, which corresponds to " aRw " equals $0.2 \Omega.m^2/m$ when considering exponent " a " equals "1" as default of Archie model. The Rw value from cross-plots equals to $0.32 \Omega m^2 m^{-1}$, which is correletable with that obtained by core sample data executed by Repsol oil operation. Instead, when applying Humble Formula with 0.62 for " a ", then Rw will be $0.32 \Omega.m^2/m$ which match very well. This confirmed the validation of Humble formula for calculating the formation factor (F).

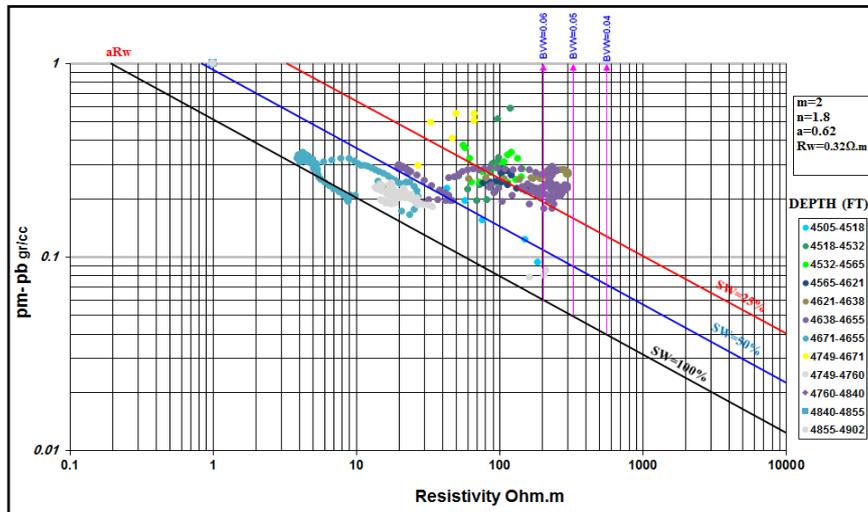


Figure 7. Pickett Plot for Hawaz Formation in H48-NC186 Well.

Figure (8) represent the Pickett plot for Hawaz Formation in H43-NC186 well. A thick clean water bearing interval (4865' – 4925') and presented as yellow circles was used to draw the R_o line for Hawaz Formation in H43-NC186 well (Figure 3 and 4). This line give “m” equals 1.9 and R_w 0.29 $\Omega.m^2/m$. The BVW lines are parallel to the vertical axis indicating that “m” equals “n”. A lot of points plotted between 50% and 25% lines but located on the left hand side of 0.06 BVW line (more than that of BVWmin), which expect to produce water. On the other hand, minor points (green colored circles) are situated below 25% S_w and followed 0.03 BVW line reflecting possible free water oil production.

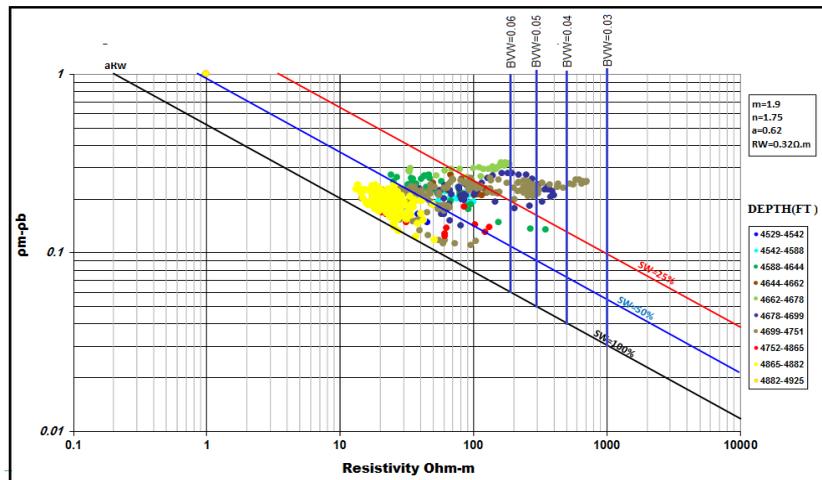


Figure 8. Pickett Plot for Hawaz Formation in H43-NC186 Well.

Buckles Plot and Irreducible Water Saturation (S_{wirr})

The irreducible state for horizons (H4a,b,c) at H48-NC186 is very clear on Buckle plot (Figure 9). This plot is very essential and must be seen as a routine analysis for extracting S_{wirr} value which is the cornerstone for any reservoir performance evaluation. For (H4a, b,c) this value is 0.11. By the same manner, H7 is water bearing as the representative points are scattered widely (Figure 10).

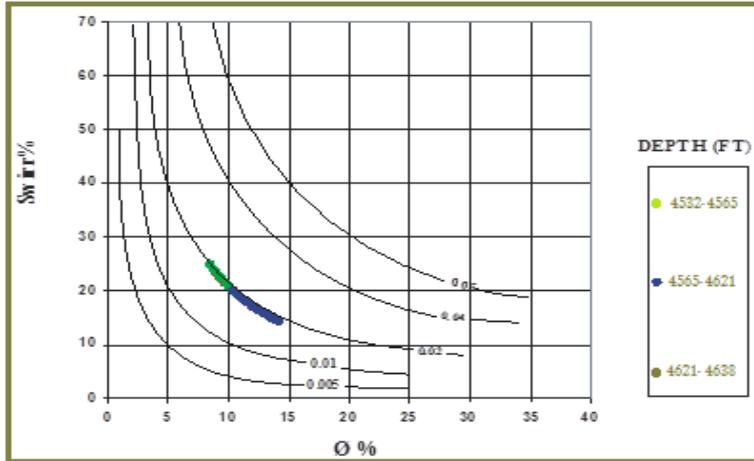


Figure 9. Porosity versus water saturation cross plot to determining bulk volume water for Hwawz Formation (horizon H4a, band c) at H48-NC186.

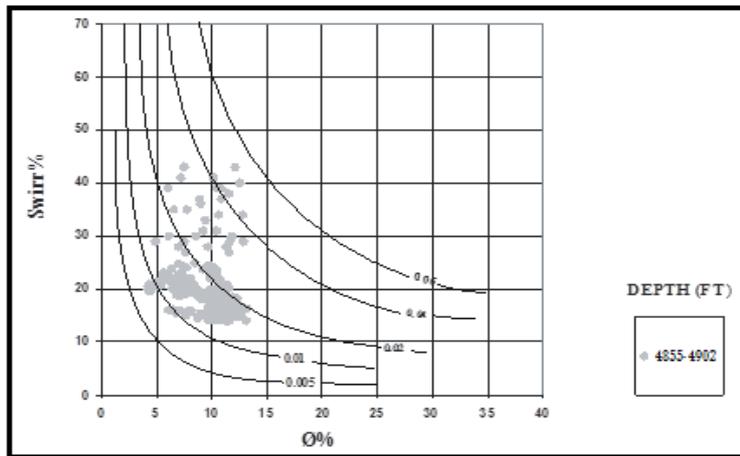


Figure 10. Porosity versus water saturation cross plot to determining bulk volume water for Hwawz Formation (horizon H7) at H48-NC186.

Porosity-Saturation (Buckle) plot (Figure 11) for horizons (H4a,b,c) at H43-NC186 well indicate firmly that these horizons is indeed at irreducible state and will produce free water oil as the plotted points track exactly 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 lowest Sw value on this curve represents Swirr (0.11 in this case). Horizon H7, which is well known water bearing throughout Hawaz Formation in H Field when plotted on Buckle (Figure 12) showed wide scattering of points. This scattering feature is characteristic for water producing horizons. This horizon has very fine grain connected to the presence of shale.

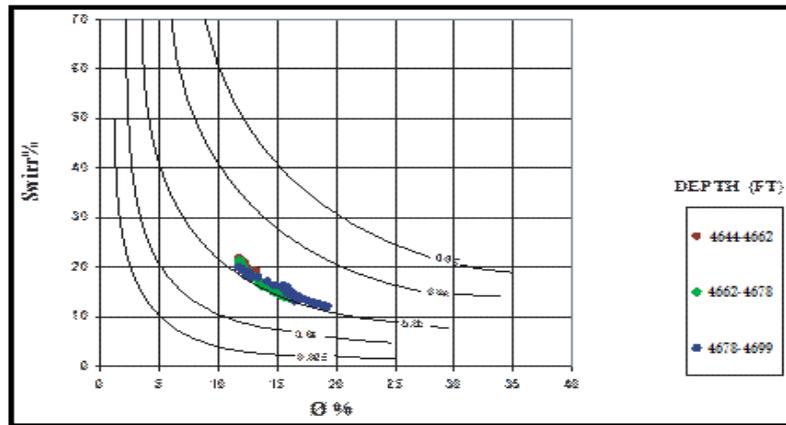


Figure 11. Porosity versus water saturation cross plot to determining bulk volume water for Hwaz Formation (horizon H4a, band c) at H43-NC186.

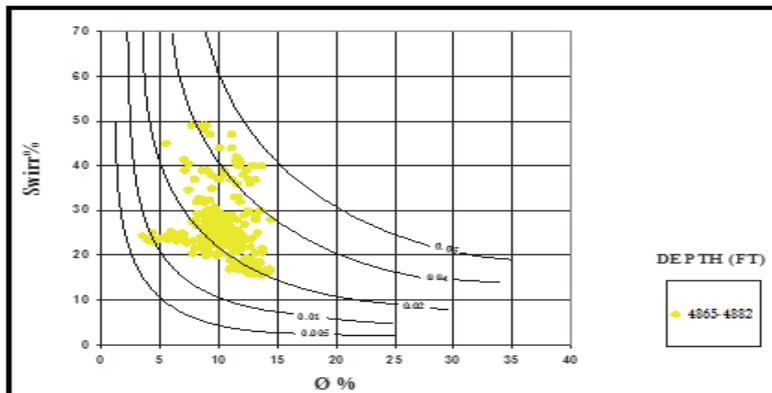


Figure 12. Porosity versus water saturation cross plot to determining bulk volume water for Hwaz Formation (horizon H7) at H43-NC186.

The iso parametric maps of Hawaz reservoir.

A number of isoperimetric maps showing the aerial distribution of the reservoir petrophysical parameters (net pay, ϕ_{eff} . And Sw) were constructed and presented in Figures 13, 14 and 15. The net pay thickness map (Figure13) indicates a general increase at the northern part of the area with maximum thickness of 210 ft at well H14NC186, while it decreases gradually from the center to the southeast. The effective porosity contour map of this reservoir (Figure 14) shows a general increasing towards NW and SW of the area recording a maximum value of 16% at well H7NC186

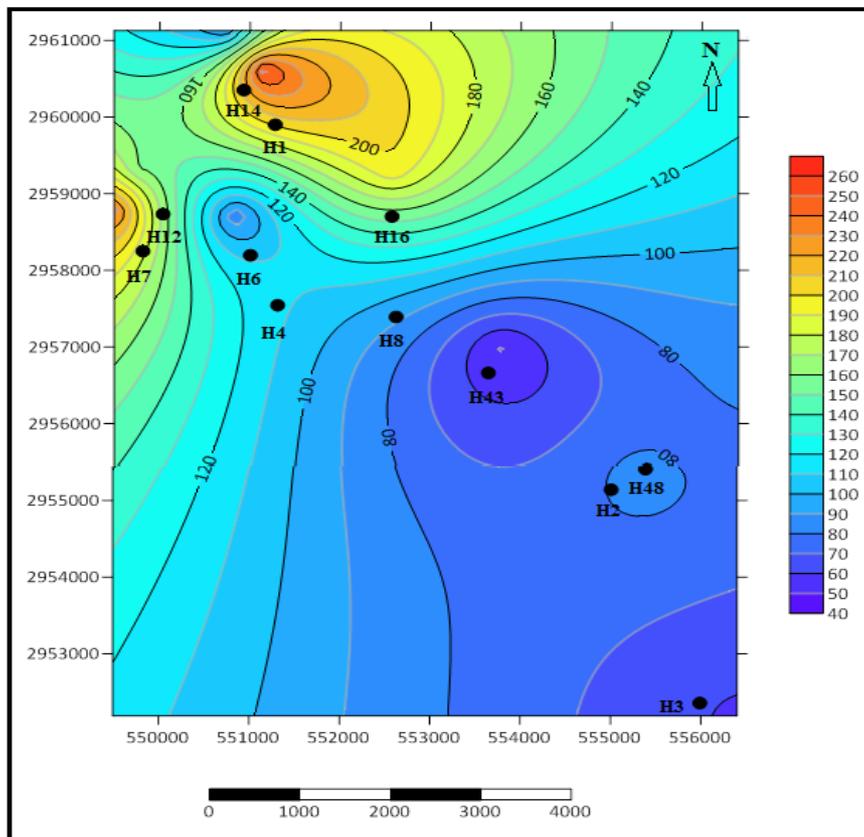


Figure 13.: Net Pay Thickness Contour Map for Hawaz Reservoir in H oil field, Concession NC186, NW Murzuq basin, SW Libya.

. The water saturation contour map (Figure 15) of the reservoir illustrates a considerable distribution pattern with a general increase towards NW ward, recording a maximum value of 45% at well H12-NC186. This value clearly decreases in the center of the study area to record 32% at the well H4-NC186. It also decreases in the northwest direction to record 32% at well H14-NC186 and in the southeast direction to record 31% at the well H48-NC186.

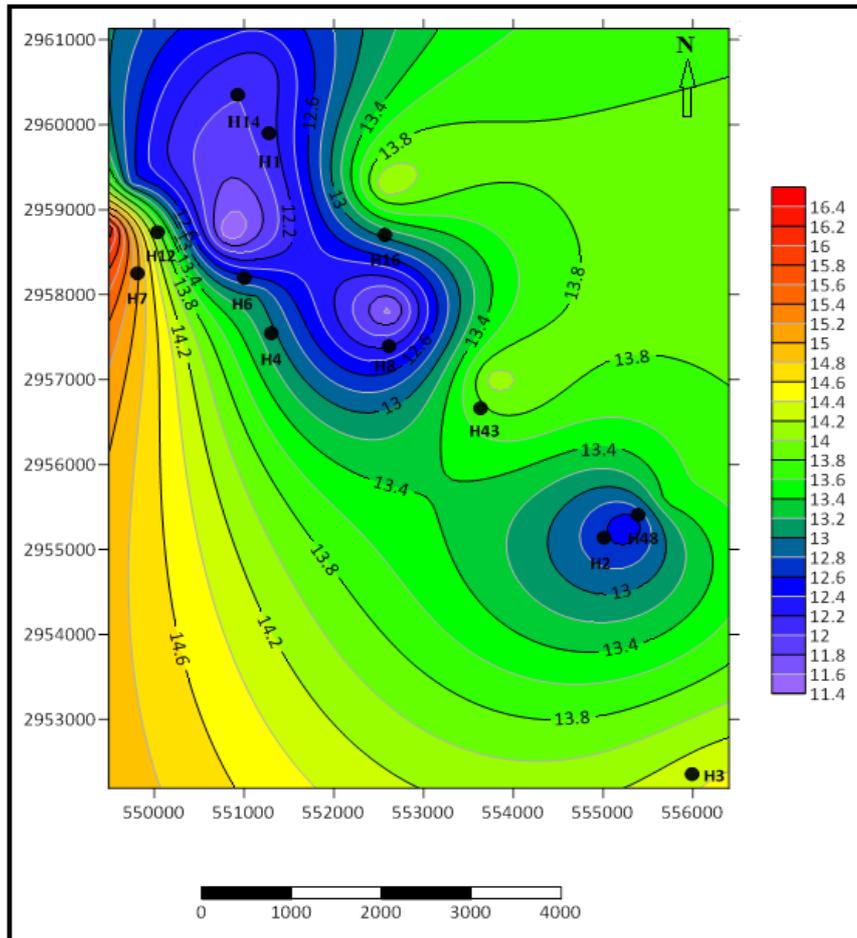


Figure 14. Average Effective Porosity Contour Map for H oil field, Concession NC186, NW Murzuq basin, SW Libya.

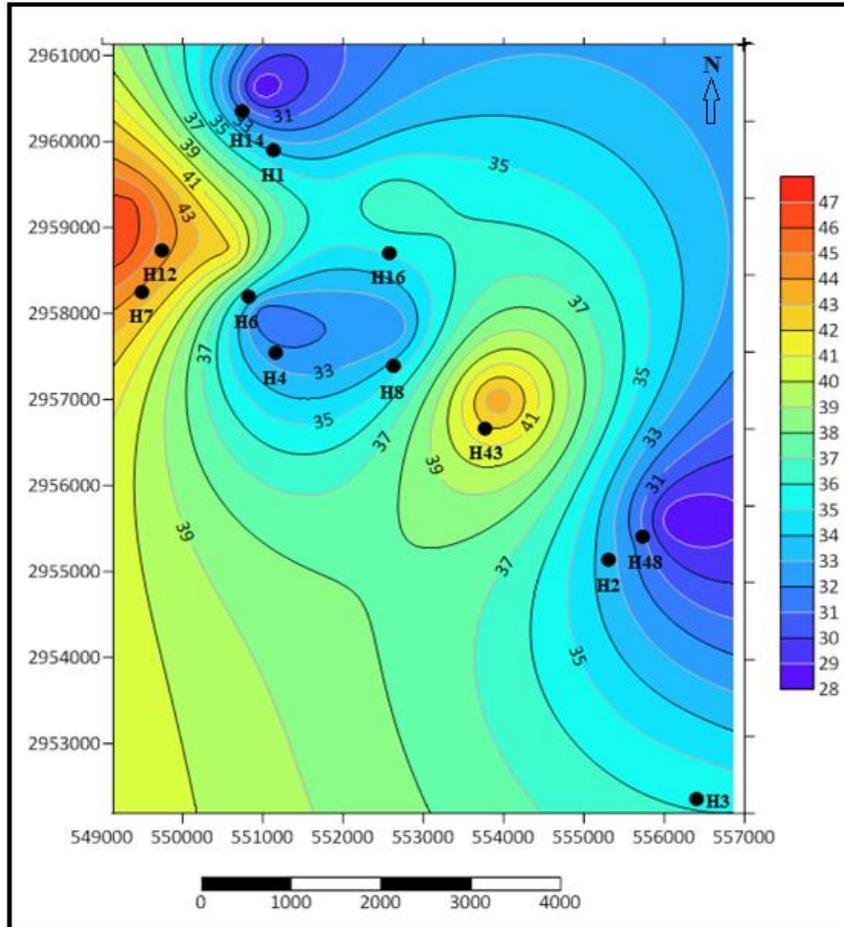


Figure 15. Average Water Saturation Contour Map for Hawaz Formation in H oil field, Concession NC186, NW Murzuq Basin, SW Libya.

SUMMARY AND CONCLUSIONS

This research paper is focused on studying the petrophysical parameters and hydrocarbon potentialities of Hawaz Formation in H oil field, Concession NC186 by use quick-look interpretation technique. The litho saturation cross plots resulted through IP program indicated that horizons H4a, b, c and H5 contain the main

oil reservoir they possess positive resistivity separation ($R_D > R_m > R_{xo}$) with mud cake (caliper less or equal to or slightly more than bit size) indicating presence of high porosity and permeability. The quick look method are important step prior any detailed and cognizance interpretations to save time and money. BVW_{min} technique is a powerful and easy to perform for quickly detect the zones of interest as confirmed through further investigations. The calculating (RT_{min} values are very useful to visually locate where the well log curve reads higher than that value indicating hydrocarbon production. Through Quick look techniques, the Minimum Bulk Volume BVW_{min} was calculated to be 0.05 through the two considered horizons in Hawaz Formation of Murzuq basin. Only zones with BVW (Φ . SW) less that value, is considered to produce clean oil (no water). Also (RT_{min} is calculated as $R_w / ((BVW_{min})^2)$. Any zone has resistivity less than (RT_{min} considered nonproducing. Archie model was used to calculate SW with Humble parameters for Formation Factor ($F = 0.62 / \Phi^{2.15}$). Connate water resistivity (R_w) was calculated at 100%. The isoperimetric maps indicated that the northern part of the study area contained the main productive wells. Mostly, it can be recommended to concentration on horizons H4 and H5 for any future drilling and detailed study should be given to these units.

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