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Petrophysical characteristics of Hawaz formation, H oil field, concession NC186, NW Murzuq basin, SW Libya

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Abstract

Petrophysical characteristics of the Hawaz Formation in H oil field, Concession NC186 of Murzuq basin have been evaluated through the analysis of well-logging data recorded for ten exploratory and development wells. These records have been analyzed through utilizing 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 results indicated that Hawaz Formation is mainly oil-bearing Horizons H4 and H5 are the main productive zones. The evaluation reveals also that the lithological facies consists mainly of sandstone. This facies is characterized by coarsing upward.

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

Introduction

Murzuq Basin is one of several intracratonic basins located on the North Africa platform that have a predominantly marine Palaeozoic clastic infill. It is located on the southwestern part of Libya and has sub-circular shape and clearly visible on satellite images. The basin covers an area of some 350,000 km², extending southwards into Niger [1]. This basin has different concessions that have some oil fields. Each field contain some wells drilled for the evaluation of subsurface geology and hydrocarbon potentialities of the Cambro-Ordovician Hawaz Formation intervals drilled by Repsol Oil Operations. H field is one of the oil fields in concession NC186 that was encountered by several exploratory and development wells, distributed in the field (H-NC186) on the northwestern flank of the Murzuq basin, southwestern part of Libya (Fig. 1 and 2). Ten of these exploratory wells have been selected for this study. These investigated wells lie between the latitudes 26º 43' and 26º46 N and longitudes 12º 32' and 12º 36' E (Fig. 3). It measures about 36 km².

Oil was discovered in H field by H1-NC186 well drilled between April 21st and May 22nd, 2004. The well was tested in the interval 4365-4608 producing 950 STBOPD of 35° API gravity

by natural flow. Subsequently, three appraisal wells (H2, H3 and H4) were drilled in order to collect the required information to evaluate the commerciality and development feasibility of the field. Generally, the petroleum system is represented by structural Hawaz paleo-high created during the post Hawaz erosional event. The main regional seal is the Silurian Tanezzuft shale Formation, and the basal Tanezzuft Hot Shale member acts as the main source rock in the area of study.

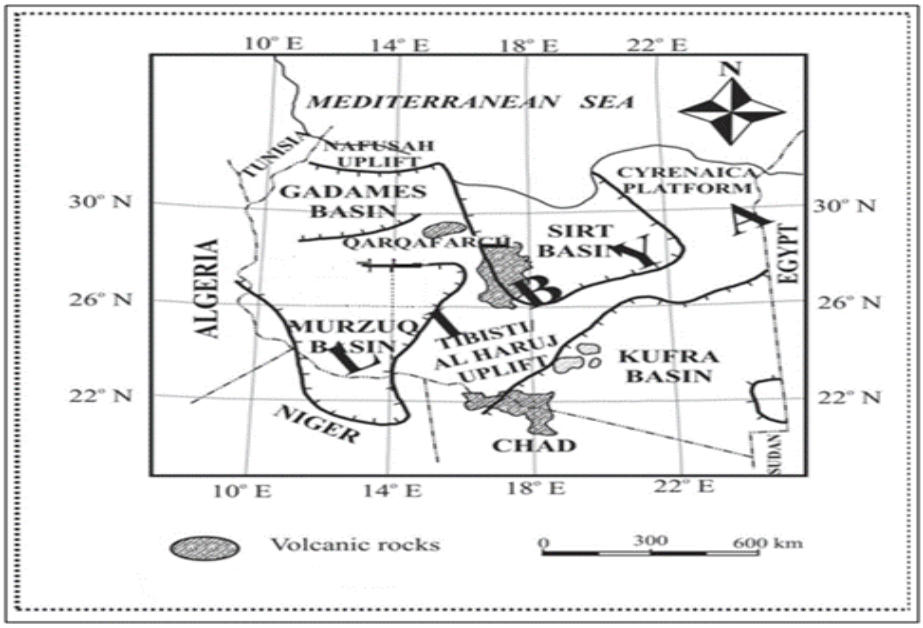

Fig. 1 Location Map of the Sedimentary Basins of Libya (After Fello [2])

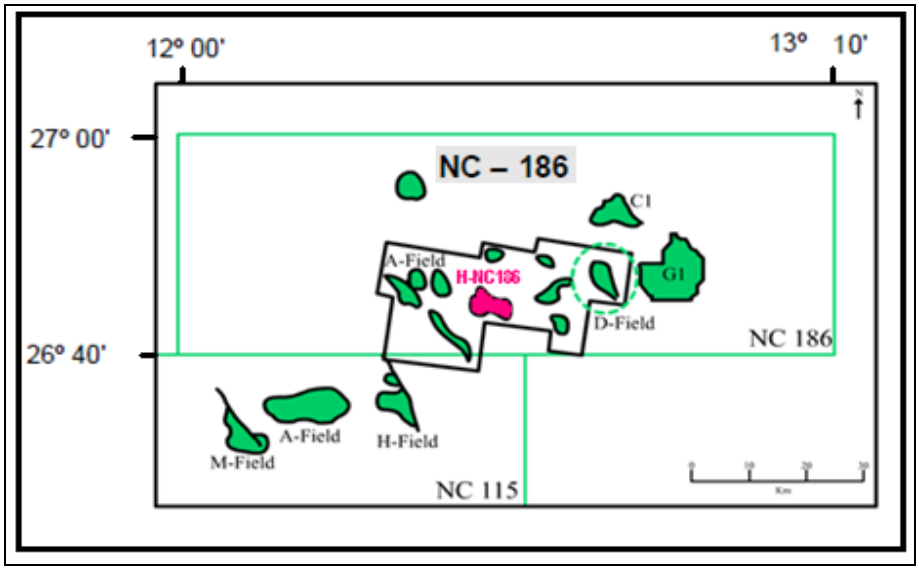

Fig. 2 Location map of H oil field, concession 186

The present paper is devoted to study the petrophysical parameters and hydrocarbon potentialities of Hawaz Formation in H oil field. A comprehensive analytical formation evaluation program has been applied on the available well log data to identify the lithological constituents, petrophysical and fluid saturation parameters using interactive petrophysics (IP) software. The hydrocarbon potentialities have been evaluated through integration of the well logging and core data in order to deduce the petrophysical parameters. The log data comprise resistivity, sonic, neutron, density, spontaneous potential, caliper, gamma ray and natural gamma ray

spectrometry logs, where the geological data are represented by composite logs.

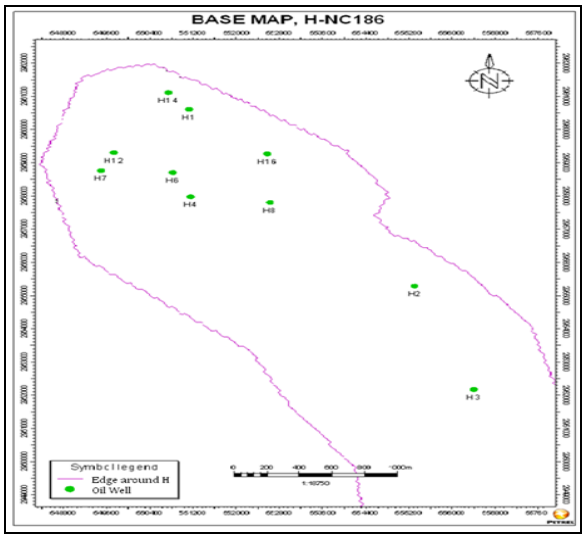

Fig. 3 location map of H oil field, concession 186, Murzuq basin

Murzuq Basin is roughly triangular in shape, narrowing towards the south from libya into Niger. The sedimentary fill is predominately marine and continental Palaeozoic, with some Mesozoic and Cenozoic sediments overlying Precambrian crystalline basement. In the central part of the basin, the total sedimentary thickness exceeds 3500 m [1]. It is separated from the Illizi Basin, Algeria, to the west by the north-south ridge of the Ghat/Tikiumit Arch [3]. It is located between three tectonic elements: the Qarqaf uplift in the north, the Tibesti/Haruj uplift in the east and the Precambrian Hogger on the west which extends into Algeria and Niger.

The whole sedimentary succession is well exposed along much of the edge of the basin, as well as on the southern flank of the Qarqaf Arch. The full sedimentary succession is present only in few outcrop areas due to regional erosion connected with the Caledonian and Hercynian orogenies, and other lesser unconformities affecting on all formations. In the core of the Qarqaf arch the crystalline basement outcrops in relatively small areas [4]. The structure of the Murzuq Basin is quite simple. The sub-horizontal or gently dipping strata is faulted. These faults are most frequently parallel to the axis. Tectonic movements have affected the basin to a greater or lesser degree from middle Palaeozoic (Caledonian) to Post-Oligocene (Alpine) times [5].

The Tectonics, Caledonian, Hercynian and Alpine tectonic events have affected Murzuq Basin evolution, specially Caledonian and Hercynian orogenies [5]. The Caledonian orogeny started in the Upper Silurian and persisted through to the lower part of the Lower Devonian, Which is for some 25 million years. This has been provided in several localities in the south of the Ghadames Basin, Murzuq Basin, and also in the Kufra Basin (Fig. 4).

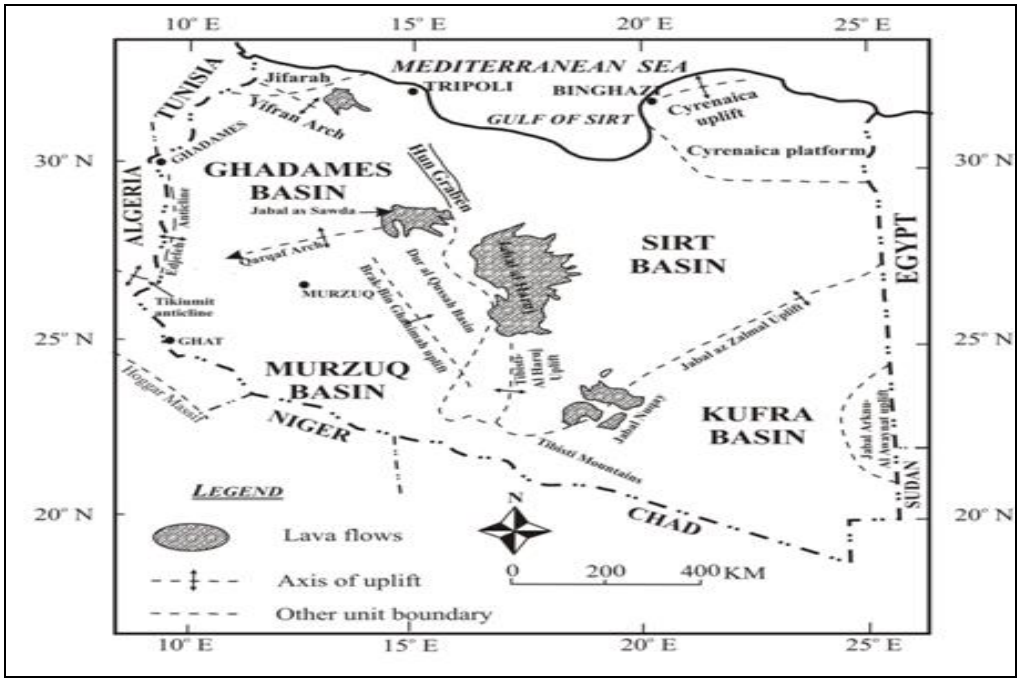

Fig. 4 Location Map showing the general tectonic framework of Libya (After Fello, [2])

The area of study has been affected by the structural and tectonic movements of Murzuq basin mentioned above and created paleo-high during the post Hawaz erosional events. Figure 5 is a selective example of stratigraphic section illustrating part of paleo-high, which is clearly represented in the corresponding 2-D seismic line shown in (Fig. 6). This paleo-high is restricted in the area between wells H1 and H3.

The stratigraphic succession of the basin in the south western part of Libya was studied by many authors [5,7,8]. They concluded that, the stratigraphic column of Murzuq basin ranges from the Pre-Cambrian to the Quaternary (Fig. 7). The maximum thickness in the basin center is about 3500 m.

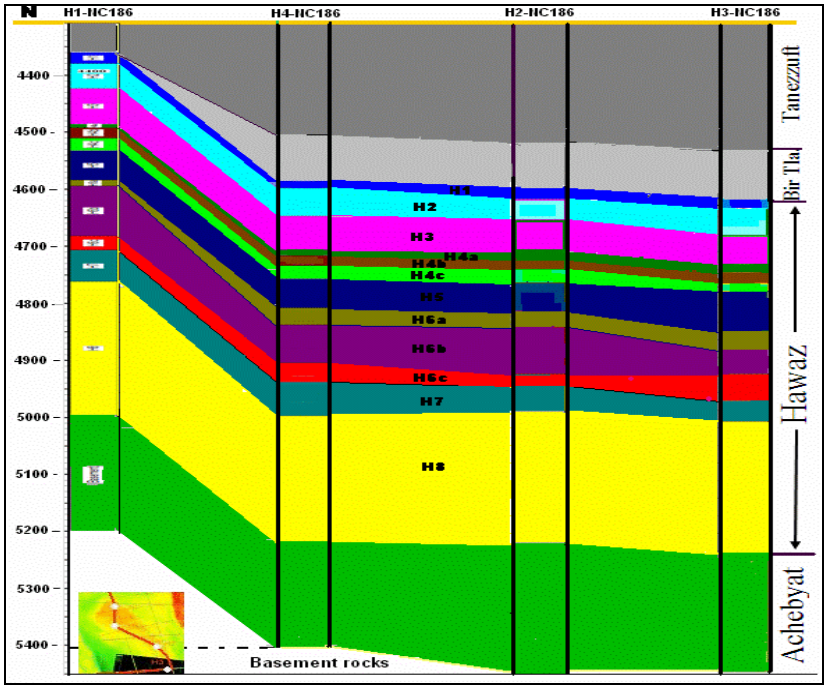

Fig. 5 stratigraphic section for correlation between wells in the study area

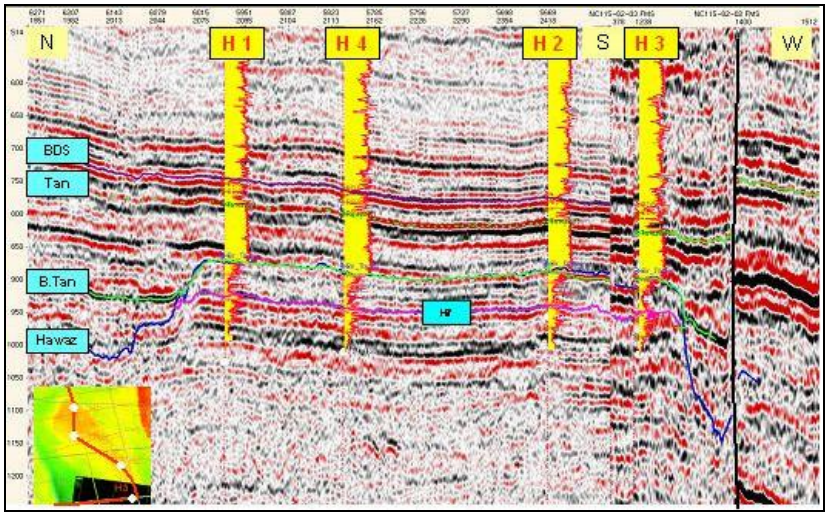

Fig. 6 2-D seismic line through wells in H oil field (Repsol oil operation [6])

Hawaz formation is one of stratigraphic sequences and it is the main reservoir in Murzuq basin in the absence of Mamuniyat formation . It has been described by Pierobon [7] as "typically consisting of cross-bedded, quartizitic sandstone with kaolinitic and thin shaley intercalations. Tigillites-bioturbated levels and ripple marks are conspicuous. Hawaz Formation is conformably overlain by Melez Shuqran Formation. The formation thickness ranges from 50 m (at Dor Al

Qussah) to 300 m (at Al Qarqaf) in outcrops, and 30 m to 230 m in the subsurface. Palynological studies of the Hawaz Formation strongly indicate a Middle Ordovician (Llanvirnian-Llandeilian) age for the whole of the Hawaz Formation, this is based on palynological data from Braspetro type well C1-NC58 [7].

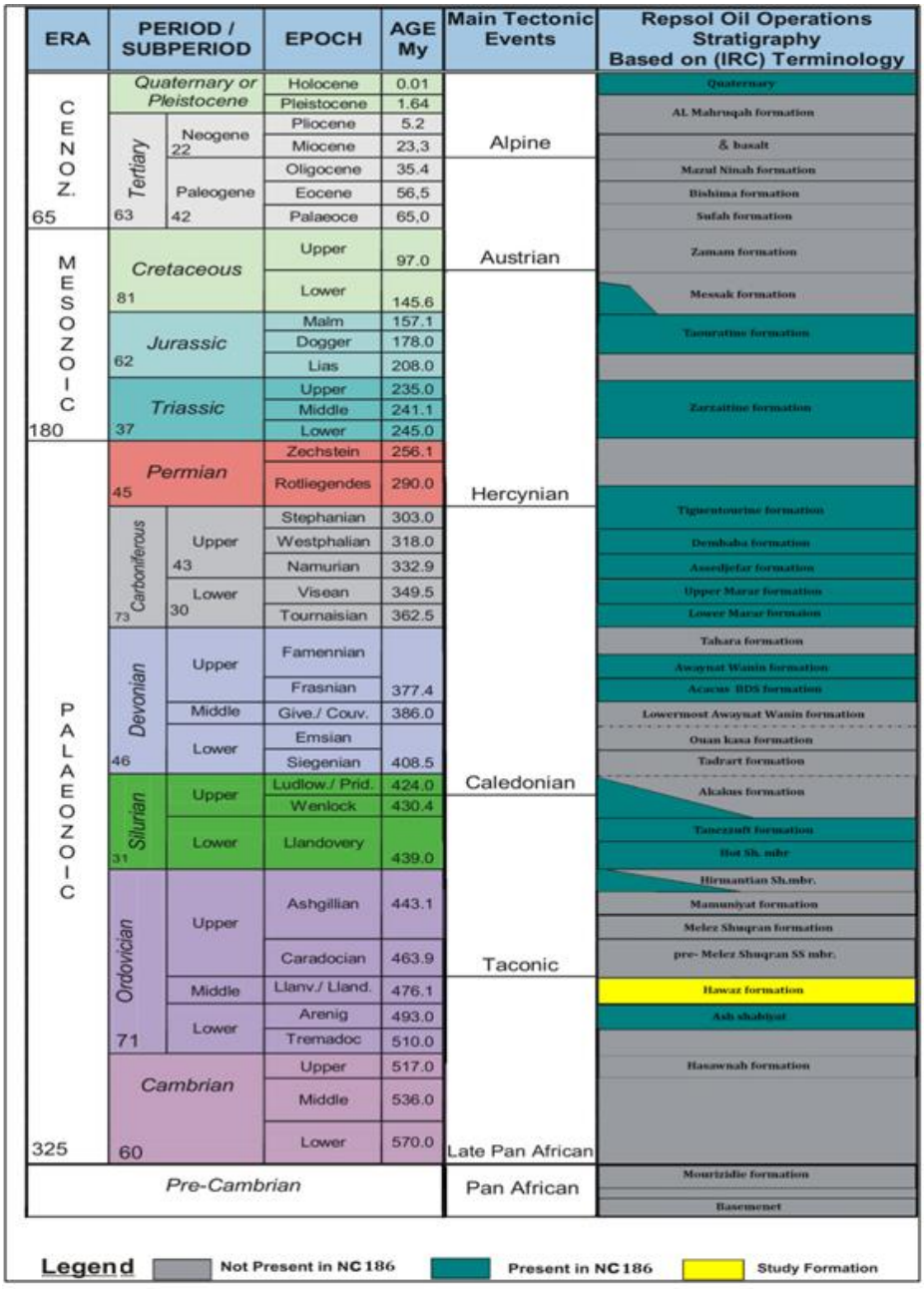

Fig. 7 Stratigraphic column of the Palaeozoic, Mesezoic and Cenozoic successions in NC186, NW Murzuq basin, SW Libya (Fello and Turner, [9])

Data analysis and processing

Several specific analysis steps are employed in the well logging data in the study area for interpretation process:

1) Filtering the raw log response data to remove and correct anomalous data points.
2) Correcting neutron, sonic, density and resistivity logs for mud filtrate invasion.
3) Normalizing logs from all selected wells to determine the appropriate ranges of porosity, clay content, water resistivity, etc.

These data are integrated to verify the following petrophysical characterization and hydrocarbon potentialities of Hawaz sandstone within the H oil field. Reservoir characterization study is based on the following components: cross-plot, log evaluation, lithology and fluid

analysis, forward modeling and rock property relationships.

The processing of the well logging data in this study has been carried out utilizing analytical cross-plots (Pickett and Hingle) for deriving formation water resistivity (R_w), cementation factor (m) and matrix parameters (ρ_{ma} , Δt_{ma}), and then use these parameters for the interactive petrophysics software (IP). The shale volume (Vsh) was calculated using the gamma ray log data. The porosity (ø) was calculated using neutron and density logs with shale correction when needed.

The sonic log (ΔT) is used for determining matrix porosity values. The water saturation (SW) was then derived using connate water resistivity (RW) derived from, Rwa, technique. The cut off petrophysical parameters used for discriminating between pay and non-pay were: Vshale ≤ 40%, Porosity ≥10% and Sw ≤ 50%.

The output results obtained from the application of IP program, are presented as litho-saturation cross plots and iso- parametric maps. This is to evaluate the hydrocarbon potentialities of the studied reservoir. This lithosaturation crossplot (Fig. 8), comprise eight tracks from left to right as follows: gamma ray, caliper, and spontaneous potential (track 1) depth and tops of horizons (tracks 2 and 3). The fourth track includes resistivity data. The porosity logs (ρb,ΦN and ΔT) are displayed in track no. 5. The output results are illustrated in tracks 6 and 7. Total porosity (ΦT), effective porosity (Φeff), flushed zone bulk volume water (BVWsxo), and bulk volume water (BVW) values are presented in track 7. Volume fraction of the deduced lithological constituents (Φ, Vcl and Vsan) are displayed in track 8.

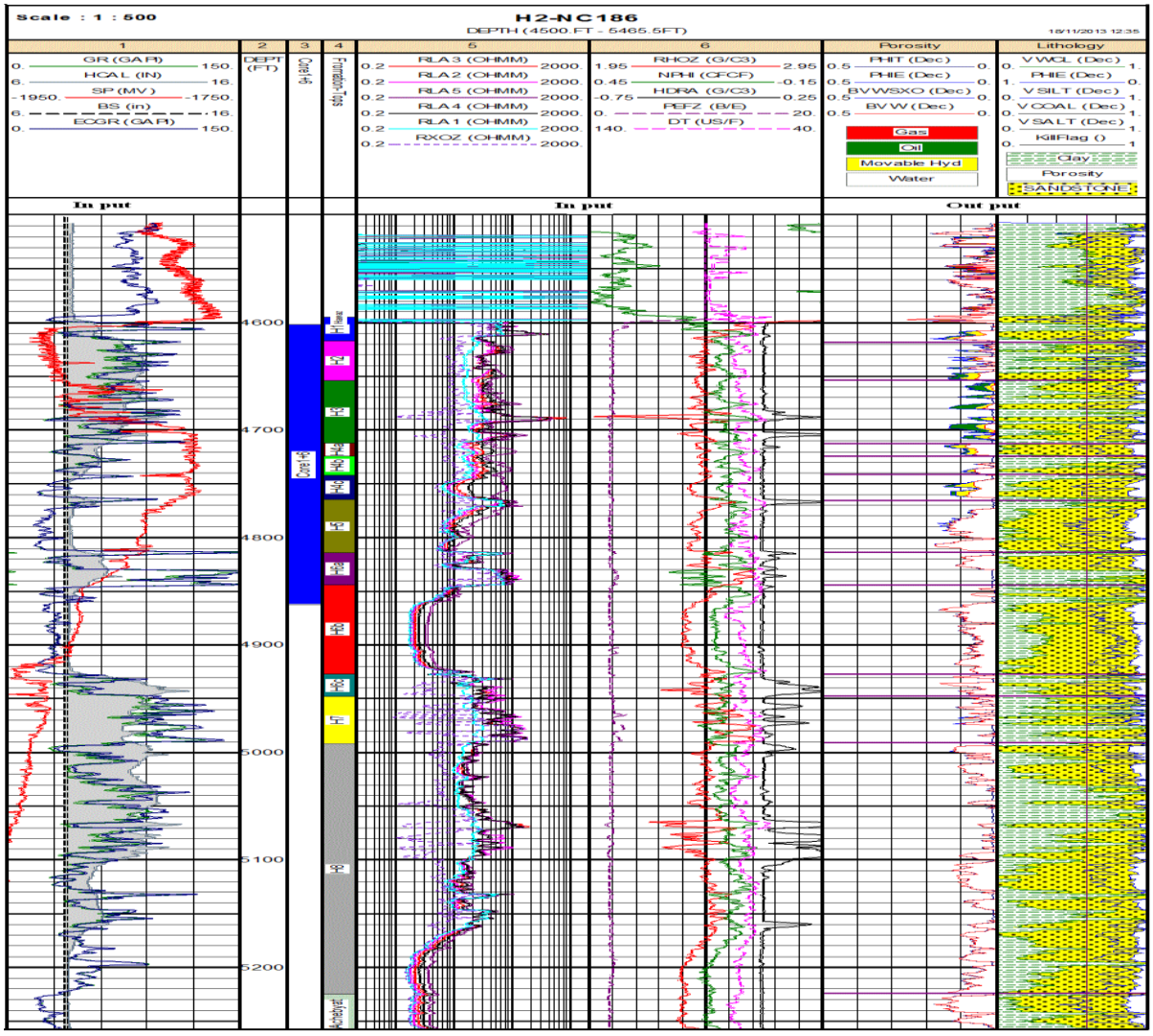

Fig. 8 Litho-saturation cross-plot for well H2-NC186

Analytical formation evaluation

The Pickett cross-plot [10] is one of the simplest and most effective technique in use. It is based on the observation that true resistivity (Rt) is a function of porosity (ø), water saturation (S_w), and cementation factor (m). It can be used for determining formation water resistivity (RW), water saturation (SW), cementation factor (m), and saturation exponent (n) through plotting effective porosity (Φeff) versus true resistivity (RT) on two-by three cycle log-log paper. On the plot, zones of 100% SW will land on a single straight line. Pickett cross-plot for wells H2-NC186 and H12NC-186 are shown in Figures 9 and 10.

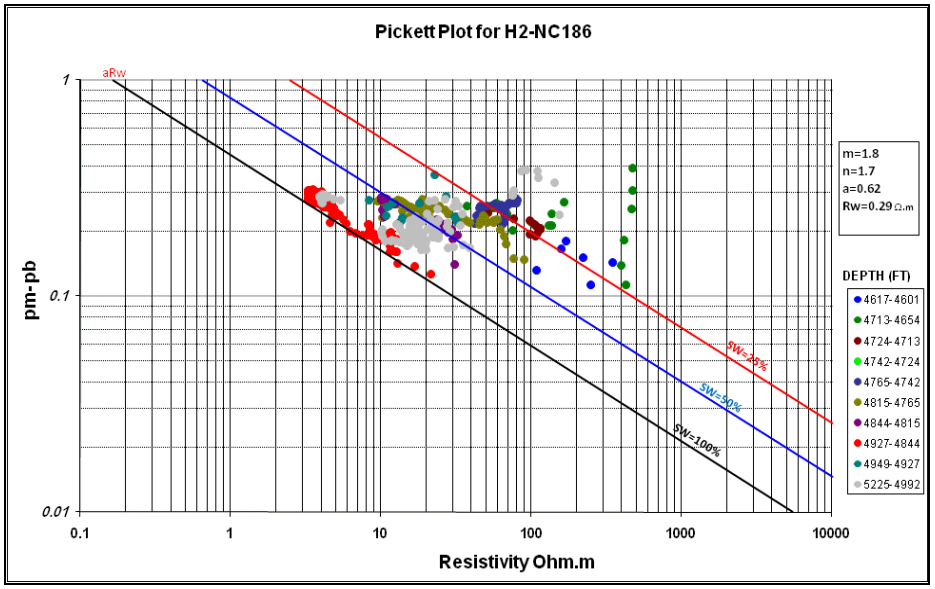

Fig. 9 Pickett plot for Hawaz Formation , H2-NC186 well

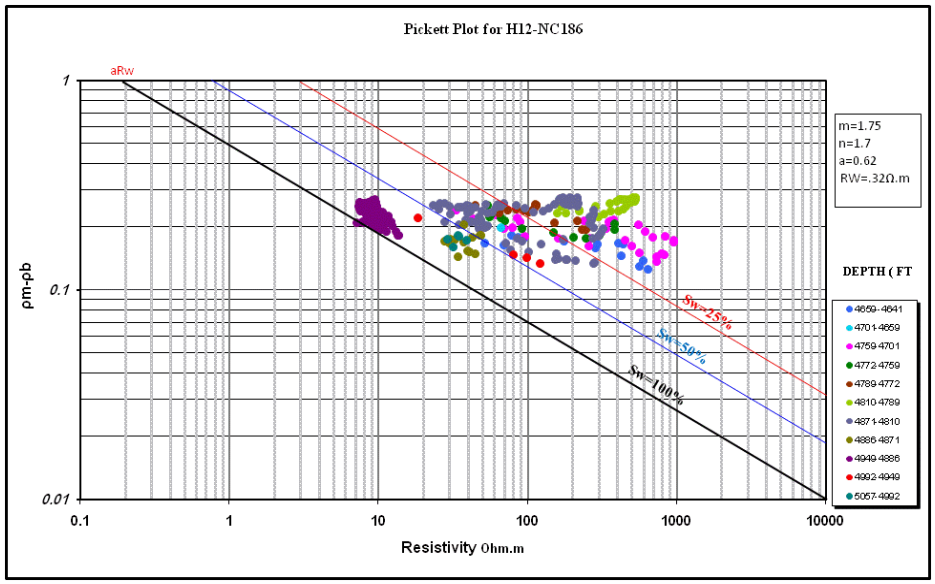

Fig. 10 Pickett plot for Hawaz Formation , H12-NC186 well

The intersection of Ro line with the horizontal axis at 100% porosity represents a*Rw. The average value of Rw equals to 0.32 Ωm^2 m^{-1} as "a" equals 0.62 for sandstone. This value is correllatable with that deduced by core analysis executed by Repsol oil operation. It was found that value -m was 1.85 (slope of 100% sw line). "n" has been taken as 1.7 as obtained from core data (Repsol oil operation). On the other hand, matrix density (ρ_{ma}) has been obtained from Hingle cross-plot, which is the oldest of the resistivity versus porosity cross-plot methods. In this study, the matrix was found to be equals 2.66

g cc^{-1} (Fig. 11 and 12) which represent the intersection of Ro line with the x-axis.

The value of 2.66 g cc^{-1} for matrix reflects the sandstone nature for this reservoir which confirmed on the ρb/Øn cross-plot for well H7-NC186 (Fig. 13). Points migrated slightly over the sandstone line reflect the low density nature for the oil encountered in this reservoir which confirmed by low gravity oil represented by 35°API [6]. The grain size can be obtained from semilog representation between porosity on logarithmic scale and water saturation (Sw) on linear one [11]. The Hawaz reservoir is characterized by coarsening upward sequence (Fig. 14). The upper part for this formation contains coarse sand with high porosity where the main reservoir is located.

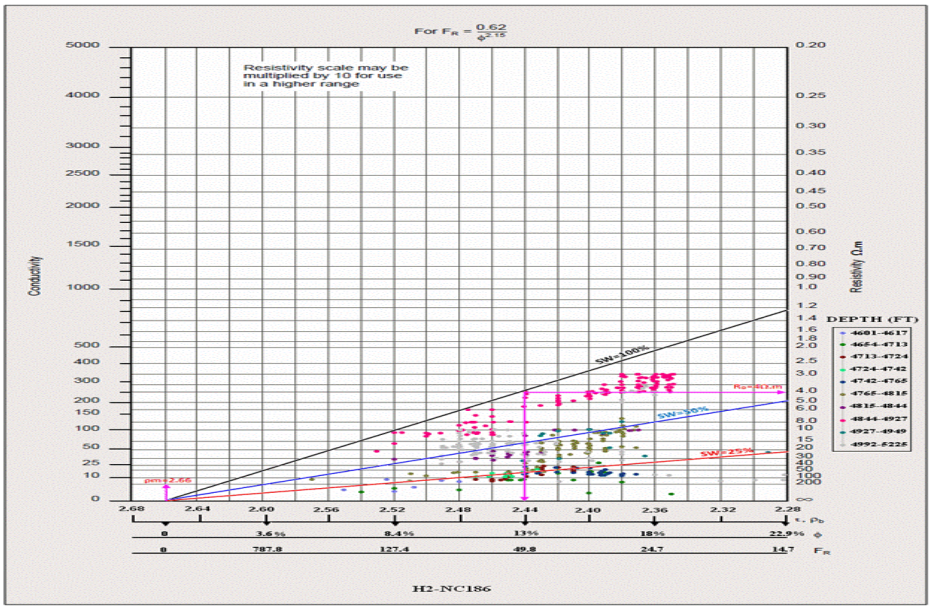

Fig. 11 Hingle cross-plot for Hawaz Formation at H2-NC186

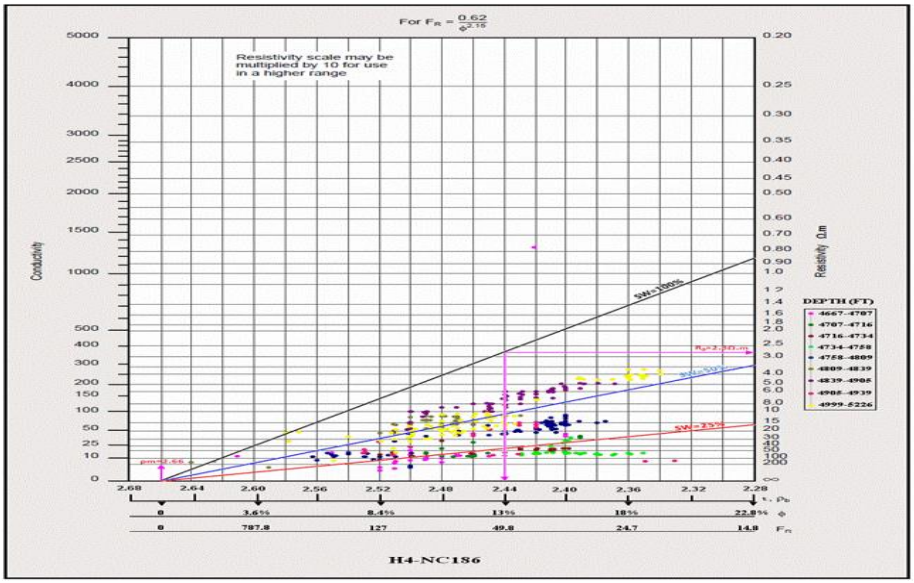

Fig. 12 Hingle cross-plot for Hawaz Formation at H4-NC186

The IP litho-saturation results of Hawaz formation

Hawaz Formation is divided into eight horizons (H1 to H8.). Each horizon represented by its own petrophysical parameters (Vsh, Φ and Sw). The following is a full interpretation for the lithosaturation crossplot for H2-NC186, H12-NC186 and H4-NC186 wells (Fig. 8, 15 and 16).

The calculated shale volume of H2-NC186 well (Fig. 8) ranges from 1% to 12.7% with average 7.4%. The effective porosity ranges from

10.3% to 15.6% with average 12.5%. Water saturation ranges from 23.7% to 99.6% with average 82%. The top of Hawaz formation is located at 4595 ft with a gross thickness of 635 ft. and net pay thickness is 114ft. The results show that horizons H3 and H4 are potentially the most productive zones, where caliper denoted reduction of hole size corresponding to the presence of mud cake and hence good permeability. Also high resistivity and effective porosity together with low Sw values confirmed productive reservoir. Also these zones have low Bulk Volume Water (BVW) indicative of high oil saturation. The high separation between flushed zone Bulk Volume water (BVWsxo) and that of BVW reflect high mobility of the encountered oil. The lithosaturation results for H12-NC186 (Fig. 15) reflect the clean nature of the reservoir where Vsh ranges from 0.1% to 5.5%. The effective porosity Φeff ranges from 6.5% to18.3% with average 12.9%., SW ranges from 3 % to 89 % with average 54.5%. The top of Hawaz formation at this well is located at 4641ft with a gross thickness of 407ft. The net pay thickness is 217 ft. Horizons H2, H3, H4 and H5 are potentially representing the main reservoir zones as shown in the lithosaturation cross-plot (Fig. 15). Zone H5 which is the cleanest zone has high content of movable oil and very low BVW. The Oil Water Contact (O.W.C) may be located at 4862 ft where the resistivity decreased and Sw increased and also BVW increased.

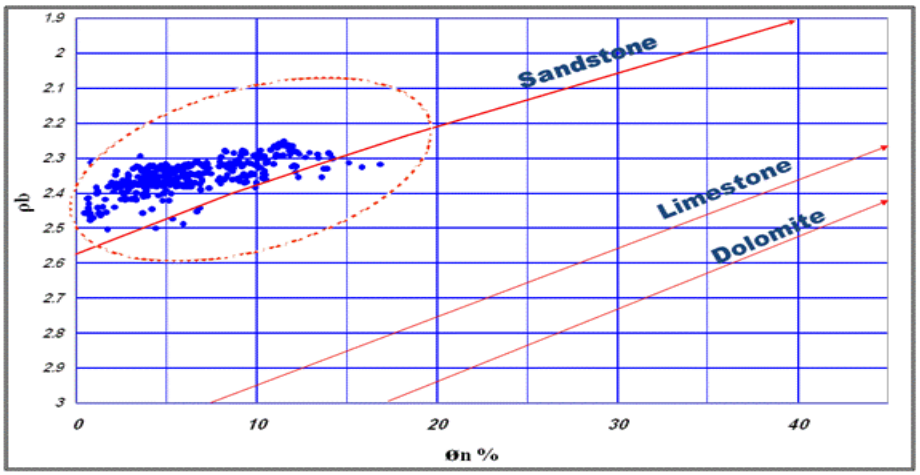

Fig. 13 ρb and vs Øn cross-plot for Hawaz Formation at H7-NC186

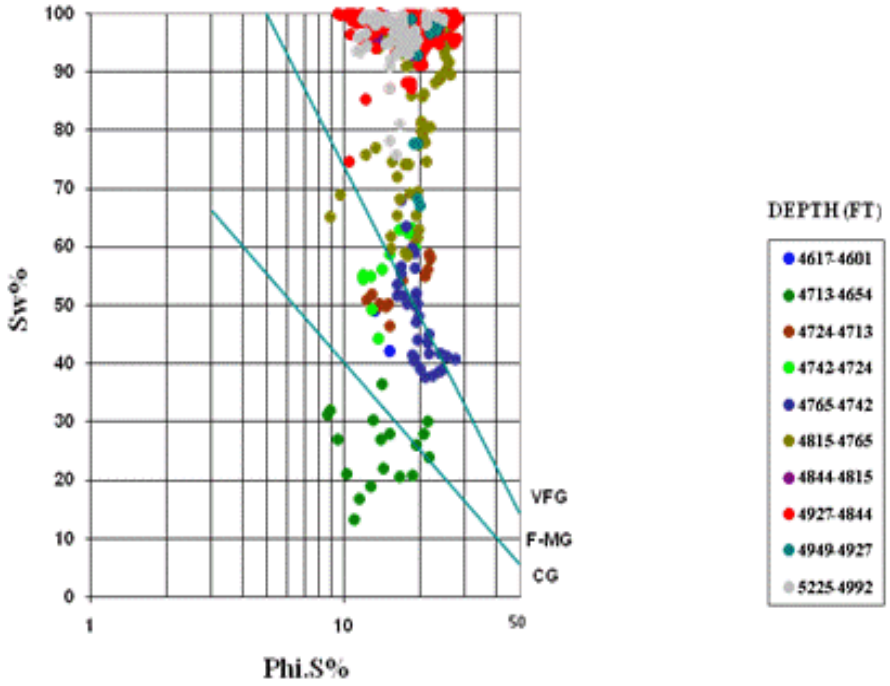

Fig. 14 Semilog representation between Sw (linear) and Φ (logarithmic) for Hawaz Formation at H2-NC186 showing grading from coarse grain sand (CG) at the upper levels to very fine grain (VFG) at lower levels representing coarsening upward sequence

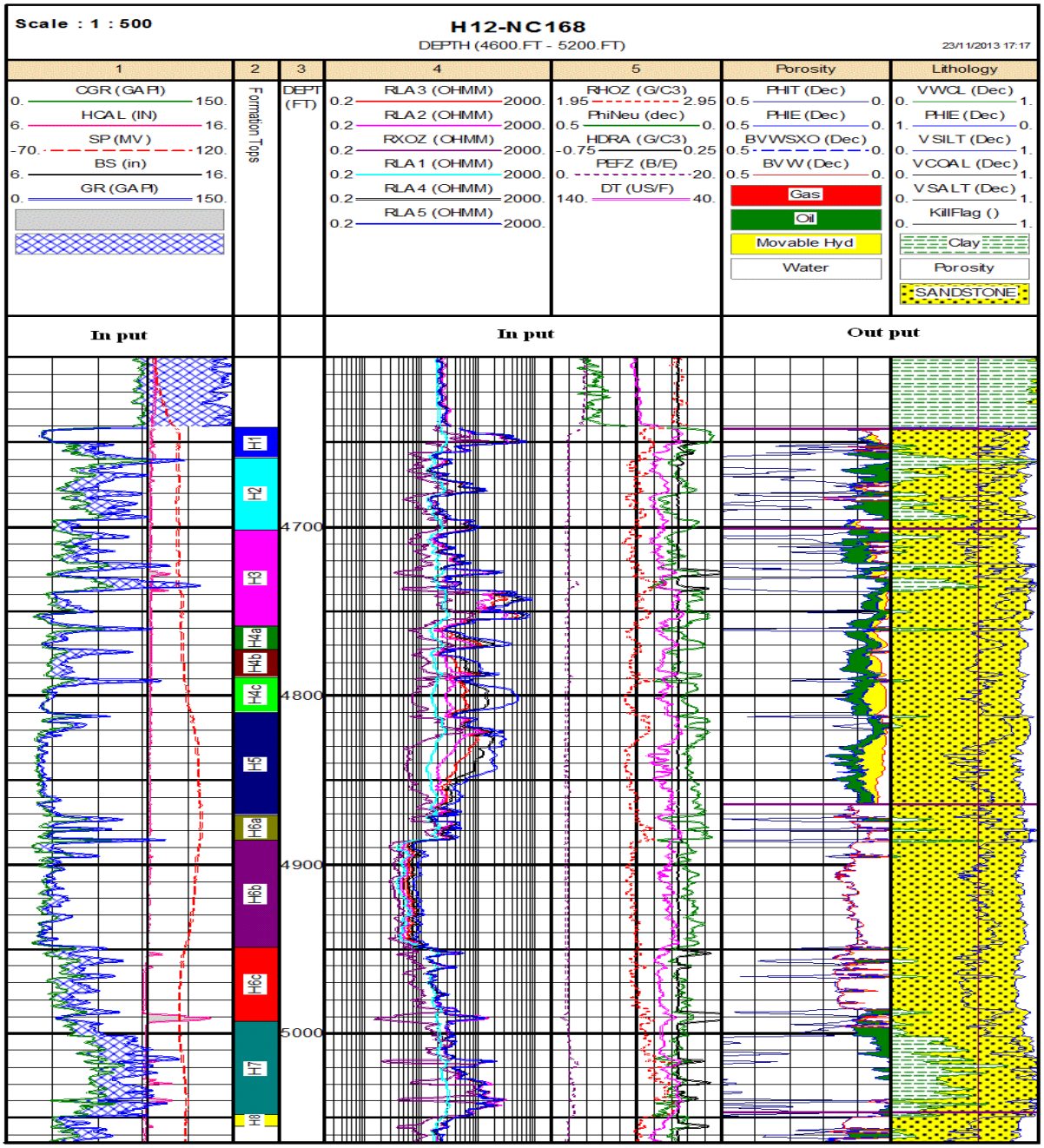

Fig. 15 litho saturation cross-plot for well H12-NC186

It is important here to notice that both BVW and BVWsxo coincide at high values confirming the wet nature at this depth. The most striking feature noticed here is the presence of residual oil in the base of H6c and top of zone H7 beneath the water sand seen from base H5 until the base of H6c. This residual oil encountered in zones of high gamma ray and high shale content with high resistivity which may reflect presence of source rock.

The lithosaturation cross-plot for well H4-NC186 (Fig.16) indicated the extremely low shale volume for Hawaz Formationn in this well. Vsh ranges from 0.1% to 1.2% with average 0.4 %. The average Φeff is 13.6%,. The average oil is 58.1%. The top of Hawaz formation is at 4584ft with a gross thickness of 642ft. and net pay thickness 133.5 ft. It is clear from figure 16 that base H3, H4,H5 and H6 contain the main oil reservoir. The movable oil is small. Again H7 zone may be represent source rock as the shale is the main constituent with very high resistivity and extremely high gamma ray (out of scale) . The top and bottom sand of zone H8 contain a percent of movable hydrocarbon.

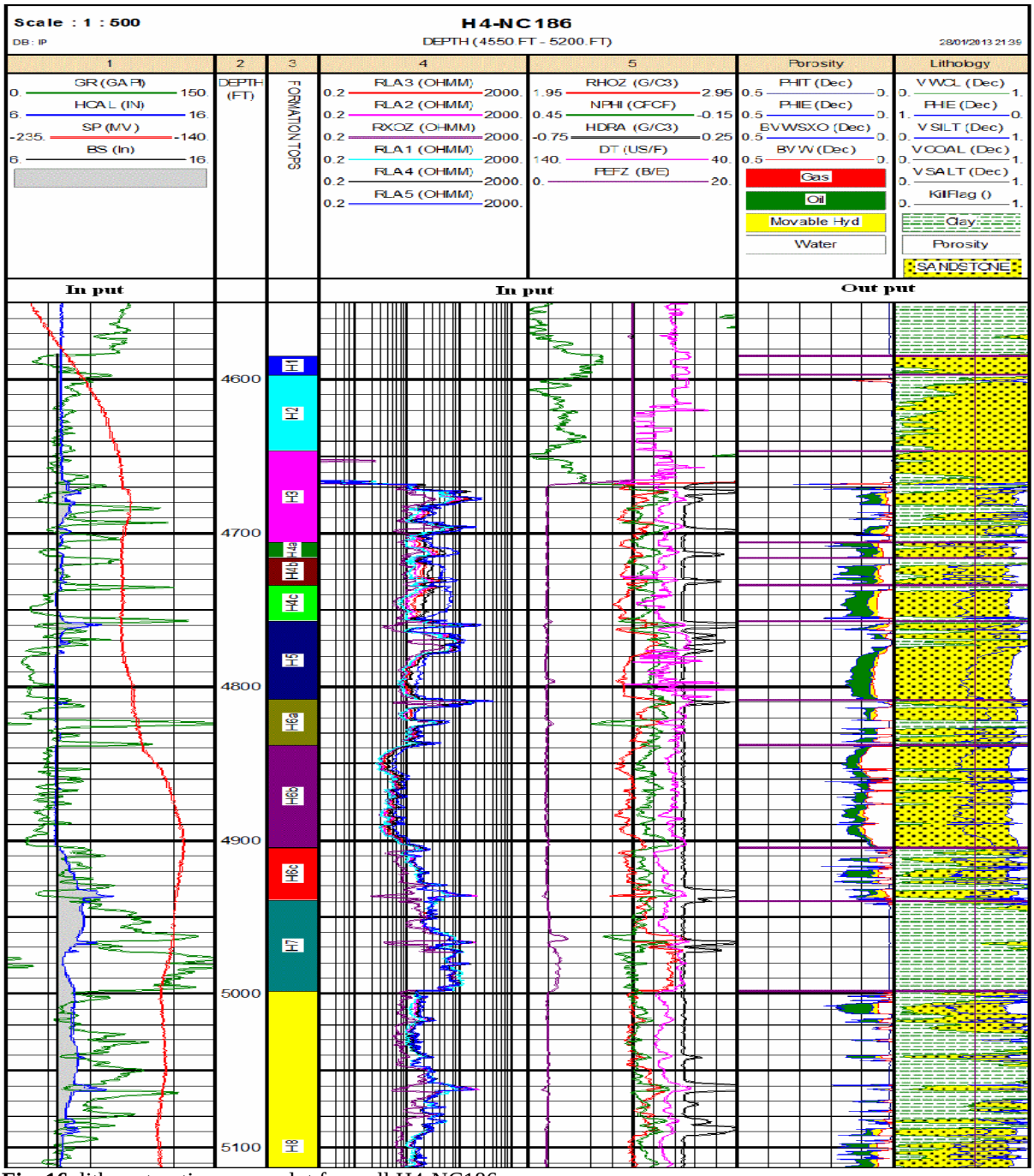

Fig. 16 litho saturation cross-plot for well H4-NC186

The iso parametric maps of Hawaz reservoir.

A number of isoparameteric maps showing the aerial distribution of the reservoir petrophysical parameters (net pay, Φeff. And Sw) were constructed and presented in Figures 17, 18 and 19. The net pay thickness map (Fig. 17) indicates a general increase at the northern part of the area with maximum thickness of 471 ft at well H1-NC186, while it decreases gradually from the center to the east. The effective porosity contour map of this reservoir (Fig. 18) shows a general increasing towards NW and SW of the area recording a maximum value of 16.4% at well H7-NC186. The water saturation contour map (Fig. 19) of the reservoir illustrates a considerable distribution pattern with a general increase towards NE ward, recording a maximum value of 75% at well H2-NC186. This value decreases gradually in the center of the study area recording a minimum value of 34% at well H8-NC186.

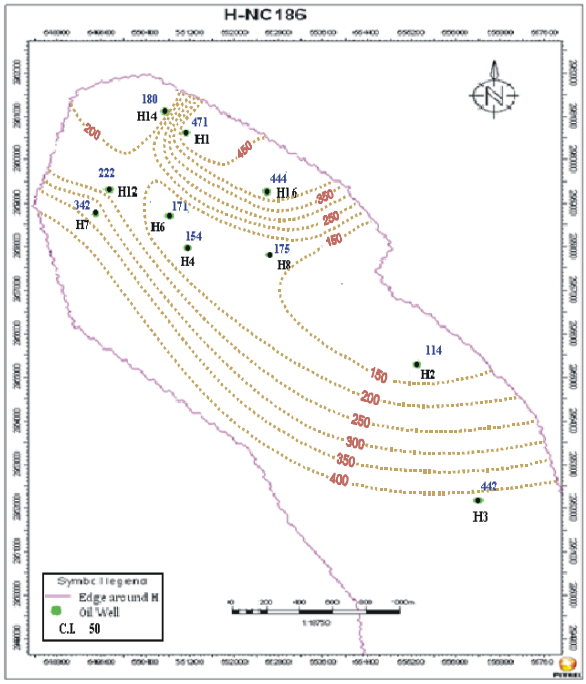

Fig. 17 Net pay thickness map for H oil field, Concession NC186, NW Murzuq basin, SW Libya

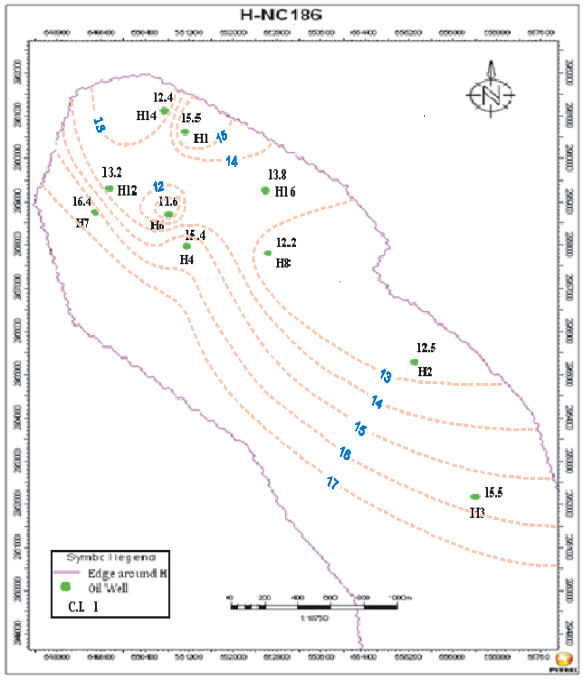

Fig. 18 Average effective porosity contour map H-NC186 for H oil field, Concession NC186, NW Murzuq basin, SW Libya.

Conclusions

This research paper is focused on studying the petrophysical parameters and hydrocarbon potentialities of Hawaz Formation in H oil field, concession NC186. The analytical and graphical formation evaluation reveals that the reservoir consists mainly of clean sandstone. This sandstone is characterized by coarsining upward sequence from horizon H8 at the bottom level until horizon H1 at the top. The results indicated that the Hawaz reservoir is mainly oil-bearing. The lithosaturation crossplots resulted through IP program indicated that horizons H4 and H5 contain the main oil reservoir. Also horizon H7 may be considered as possible source rock where the resistivity is exceptionally high for the shale encountered and also the exceptionally very high radioactivity levels. The isoparametric maps indicated that the northern part of the area of study contained the main productive wells.

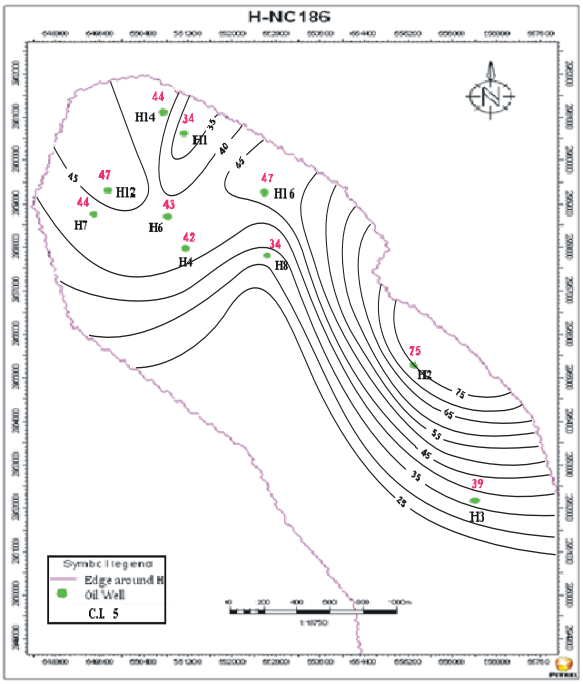

Fig. 19 Average water saturation contour map for H oil field, Concession NC186, NW Murzuq basin, SW Libya

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الملخص العربى

الخصائص البتروفيزيائية لمتكون حواز، حقل H، الامتياز NC186، شمال غرب حوض مرزق، جنوب غرب ليبيا

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[2] كلية الموارد الطبيعية ـ جامعة الزاوية ـ ليبيا

تم تقييم الخصائص البتروفيزيائية لمتكون حواز بحقلH بالامتيازNC186 داخل حوض مرزق ليبيا، وذلك من خلال تحليل تسجيلات الآبار لعدد 10 آبار استكشافية. هذه التسجيلات تم تحليلها من خلال رسم بعض العلاقات cross plots، ثم استخدام نتائج هذه العلاقات فى الحصول على بارامترات لإدخالها في برنامج interactive software وذلك لتحديد المتكونات الصخرية للمكمن حواز وتحديد قيم تشبع السوائل التي يحتويها هذا المتكون.
هذه النتائج تم رسمها في صورة Litho-saturation cross plots والتي أظهرت أن متكون حواز يحتوي أساسا على نفط مع تواجد كميات قليلة من المياه، وأن الوحدات الصخرية لمتكون حواز والمتمثلة في H4 and H5 هي النطاقات المنتجة. هذا التقييم أظهر أيضا أن السحنة الصخرية لهذا المكمن تتكون أساسا من حجر رملي والتي تتدرج إلى أعلى من ناحية زيادة حجم الحبيبات الصخرية. تم رسم مجموعة من الخرائط الكنتورية لإظهار التوزيع الجانبي لهذه الخصائص البتروفيزيائية، وأكدت على أن متكون حواز يعتبر صخر مكمن جيد.