Reservoir Quality Analysis of Hawaz Reservoir, (A) Oil field, Murzuq Basin, Libya

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Abstract

Murzuq basin represent one of the most important basins in libya. It has many oil fields; (A) field is one of the new discoveries in NC186 concession in Murzuq basin. The present paper deals with evaluation of petro-physical parameters of Hawaz Formation in (A) oil field, Murzuq basin through the analysis of well-log data available for two exploratory wells, distributed in (A) oil field. A comprehensive formation evaluation has been applied through numbers of cross-plots and using their output parameters as input data for interactive petro-physics software (IP) in

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order to evaluate the lithological constituents and fluid saturations. The litho-saturation cross-plot indicated that the Hawaz Formation consists of sandstones with few shale. These sandstones are generally fine to very fine grains but occasionally coarse to very coarse grained. Generally coursing upward sequence is indicated. The litho-saturation cross-plots also illustrated that horizon H4, H5 and H6 are the main reservoirs in Hawaz formation

Keywords: *Hawaz Formation, A field, well logging, petro-physical parameters*

1. Introduction:

The study area is located in Murzuq Basin and covers a huge area extending southward into Niger . This area is one of the Murzuq oil fields and it is called A field. It is located in concession NC186 that was encountered by several exploratory and development wells, distributed on the northwestern flank of Murzuq Basin, southwestern part of Libya (**Fig.1**). It has been affected by the structural and tectonic movements of Murzuq Basin and created paleo-high during the post-Hawaz erosional events. This feature of paleo-high is clearly represented in the 2-D seismic line shown in (**Fig.2**) by Akakus Oil Operations represented in the area of study. 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 displays also as the main source rock in the area of study. Two exploratory wells distributed in A oil fields in concession NC186 will be the focus of this study. These wells were drilled in Hawaz reservoir of Middle Ordovician. This formation is informally subdivided into 8 horizons, named H1 to H8. Some units have been subdivided into sub-units. Each horizon is characterized by its own petrophysical parameters.

This research paper is carried out as an extension to the previous studies (Selim et al., 2015) and (Adel K., Kashlaf 2016) to analyze the petrophysical characteristics of Hawaz formation in H oil field, but here it will be focusing mainly on the quick look analysis of log curves and plotting crossplots between the petrophysical parameters

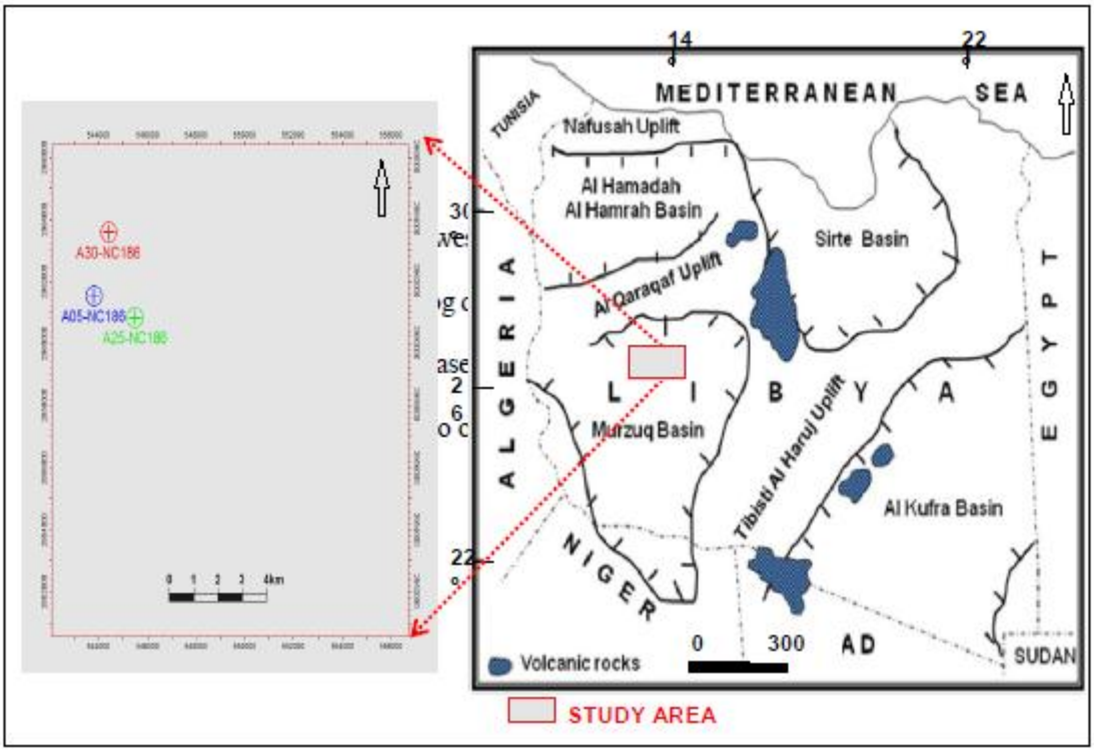


Fig. 1. Location map of the attitude wells distributed in A Field (Akakus Oil Operations , 2007).

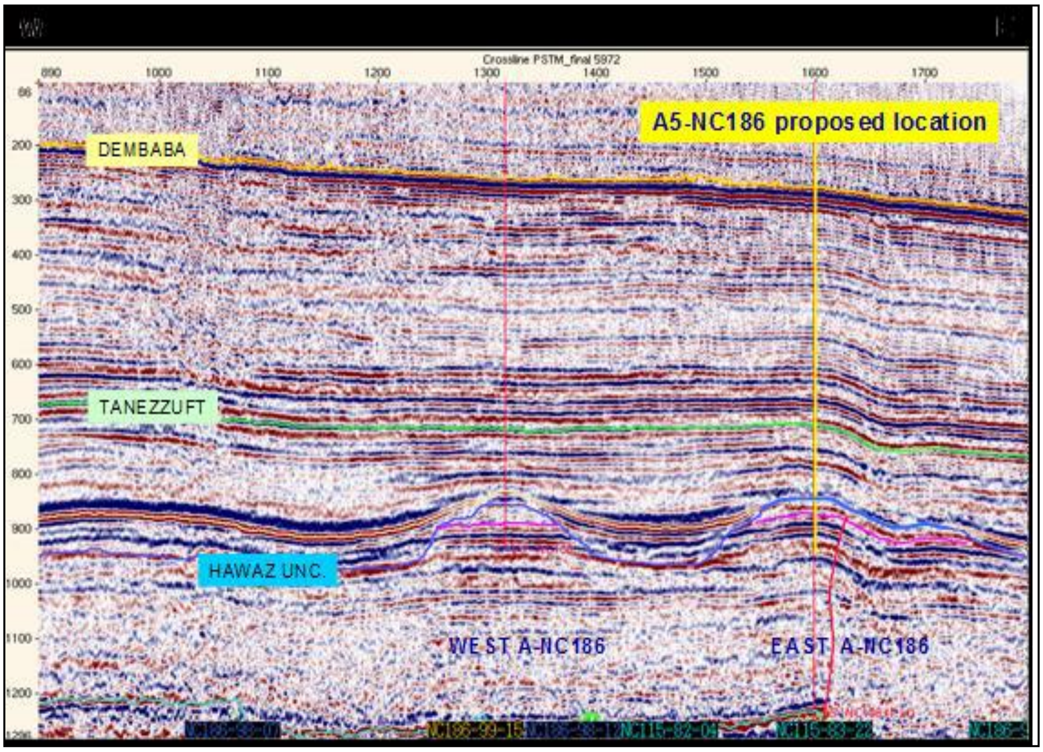


Fig. 2. Interpreted seismic line No. 5972 shows the Eastern and Western Hawaz paelo-highs of the A-NC186 field (Akakus Oil Operations , 2007)

This paper is devoted to study the hydrocarbon potentialities of Hawaz Formation in A oil field through analysis of the available well log data. A comprehensive analytical formation evaluation has been applied using interactive petro-physics (IP) software. it will be focusing mainly on the quick look analysis of log curves and plotting cross plots between the petrophysical parameters. The well log data comprise resistivity, sonic, neutron, density, nuclear magnetic resonance, spontaneous potential, caliper, gamma ray and natural gamma ray spectrometry logs.

2. Methodology 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.

The processing of the well logging data in this study has been carried out utilizing constructing Pickett cross-plot for deriving formation water resistivity (**Rw**), cementation factor (m).These parameters were used as input parameters for the interactive petrophysics software to evaluate Hawaz reservoir. The pay zone petrophysical sums and averages were computed using **Vshale** cut-off 40%, Porosity cut off 10% and **Sw** cut-off 50%. These cut-off percent's 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.

2.1. Analytical formation evaluation

The preliminary investigation of the well logging data response is of prime importance after doing environmental corrections (Mohamed et al., 2013). The quick Look technique of log records is well known and used, as an alternative to quantitative comprehensive formation evaluation of Hawaz reservoir (Mohamed, 2016), to describe many petrophysical characteristics such as the nature of the reservoir in the form of the prevailing lithology, shaliness, porosity, and the possible presence of movable hydrocarbons. Also connate water resistivity (Rw) can be quickly estimated when the reservoir is homogeneous clean with intergranular porosity fully saturated with water.

The pickettcross-plot (Pickett, 1972) is one of the simplest and most effective cross-plot methods in use. This technique is based on the observation that true resistivity (**Rt**) is a function of porosity (ø), water saturation (S_w), and cementation factor (**m**). On the plot, a zone with constant water saturation will have data points along a single straight line trend. The slope of the straight line representing **SW**=100% represent –m and its intersection with 100% Φ is **aRw. Figures** 3 and 4 represent the Pickett plots for Hawaz formation in wells A5-NC186 and A30-NC186. It was found from the cross-plots that the average value of **Rw** equals to 0.32 Ω m^2 m^{-1}, which is correlateable with that obtained by core sample data executed by Repsol oil operation. It was also found that m is equal 2.

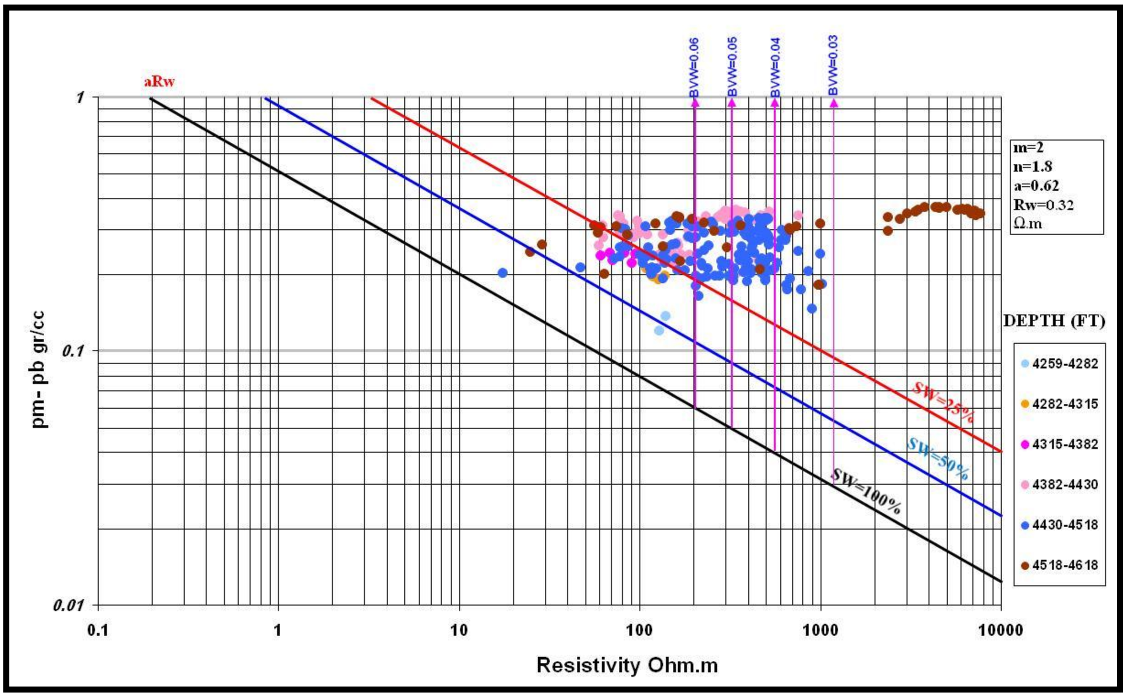


Fig. 3. Pickett Plot For A5-NC186 Well.

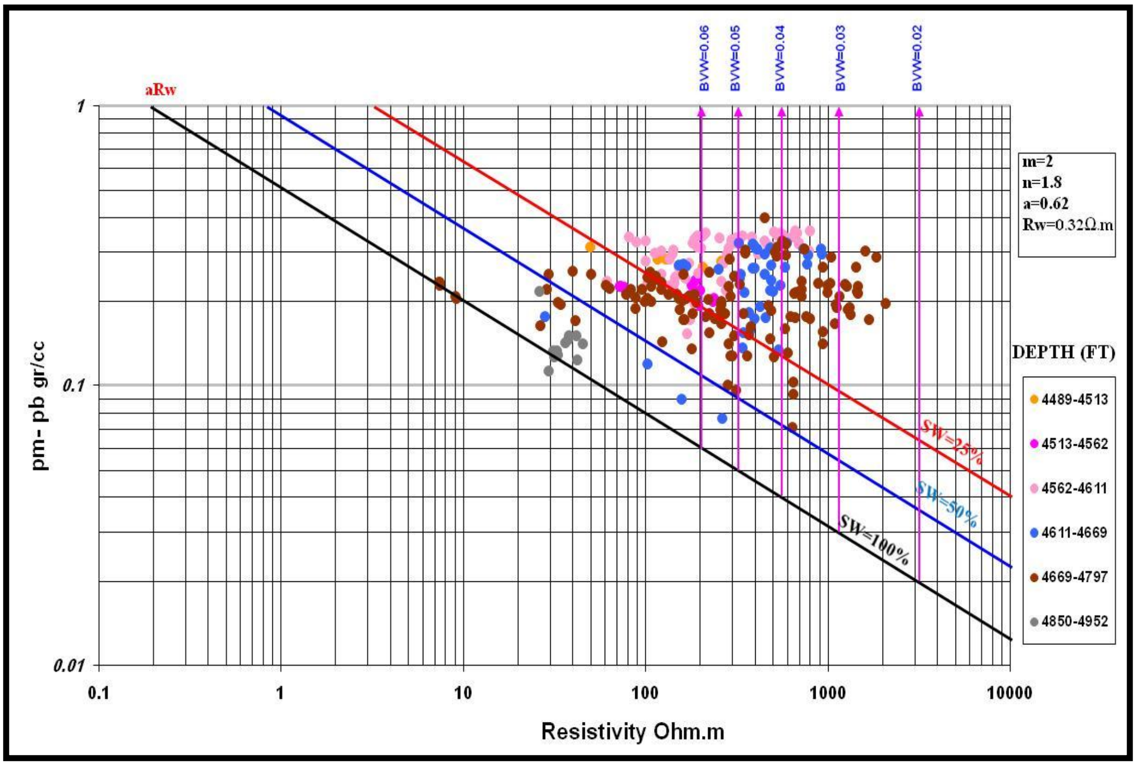


Fig. 4. Pickett Plot For A30-NC186 Well.

The water saturations for A5-NC186 well are represented on the Pickett plot (**Fig**.**3**). Points represent H4a, H5 and H6a plotted on and below 25% **Sw** line indicating high oil saturation. The majority of the plotted points are clustered in the area between 0.05 and 0.03 Bulk Volume of Water and below 25% **Sw** line reflecting the high potentiality of H4a , H5 and H6a horizons (magenta, blue and brown). There are some brown colored points arranged close each other situated on the north east corner of the plot and have exceptionally high porosity (>30%) and Resistivity (>2000). These values may be due to tool malfunction or hole conditions problem, and hence, must excluded from any reservoir parameters estimations.

The Pickett plot for A30-NC186 well, (**Fig.4**) indicate the good quality of H4a, H5 and upper H6a horizons (magenta, blue and majority of brown balls). The area confined below 25% **Sw** and between 0.05-0.06 Bulk Volume of Water lines, expected to produce some water. Points represent H8 horizon are plotted between 50% and 100% **Sw** lines. Points plotted on the right hand side of the 0.05 Bulk Volume of Water line, are aligned on a straight lines indicating free water production (i.e at irreducible state).

Porosity-Saturation (Buckle) plot (**Fig.5**) for H4a in A5-NC186 well indicate firmly that this horizon is indeed at irreducible state and will produce free water oil as the plotted points track exactly Bulk Volume of Water 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 Bulk Volume of Water direction). The lowest **Sw** value on this curve represents **Swirr** (0.11 in this case). Exactly as H4a at well A30-NC186 has Bulk Volume of Water also 0.02 and 0.11 **Swirr**. Accordingly, H4a, H5 and H6a will be considered for more quantitative interpretation. Horizon H8, which is well known water bearing throughout Hawaz Formation in A Field when plotted on Buckle (**Fig.6**) 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.

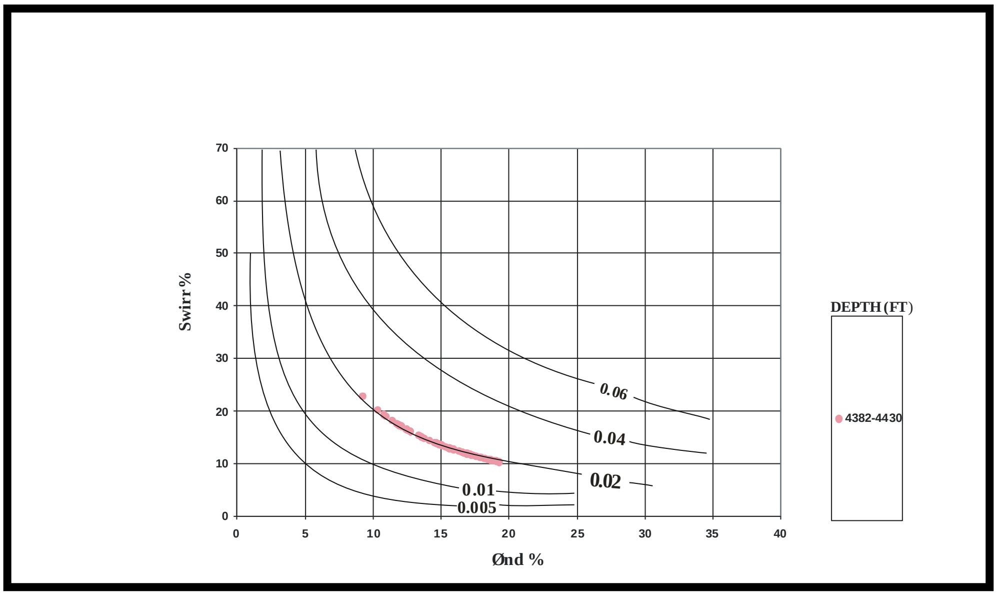


Fig. 5. Porosity Versus Water Saturation (Buckle) Cross-Plot for Hawaz Formation (Horizon H4a) In A5-NC186.

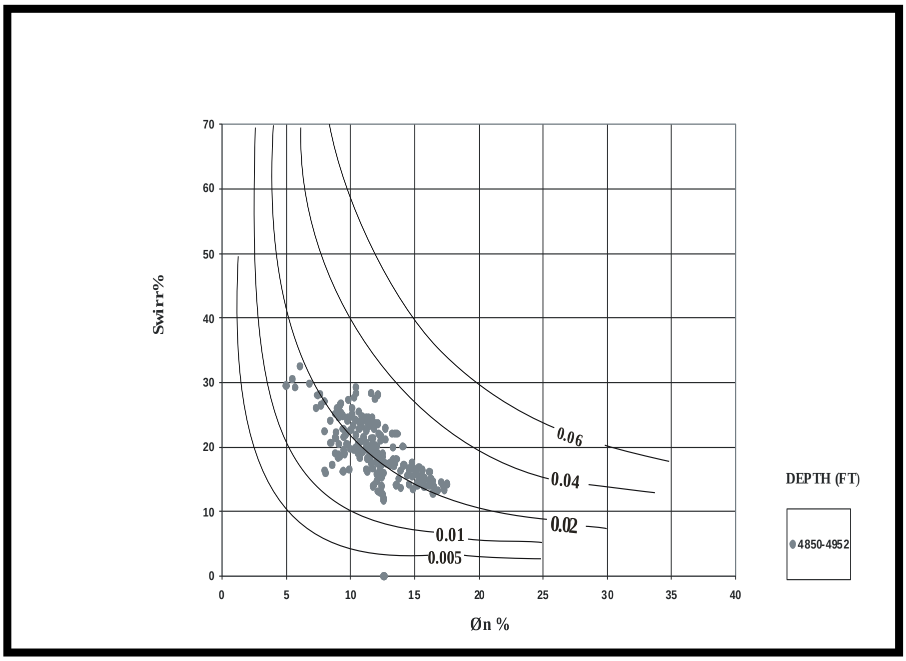
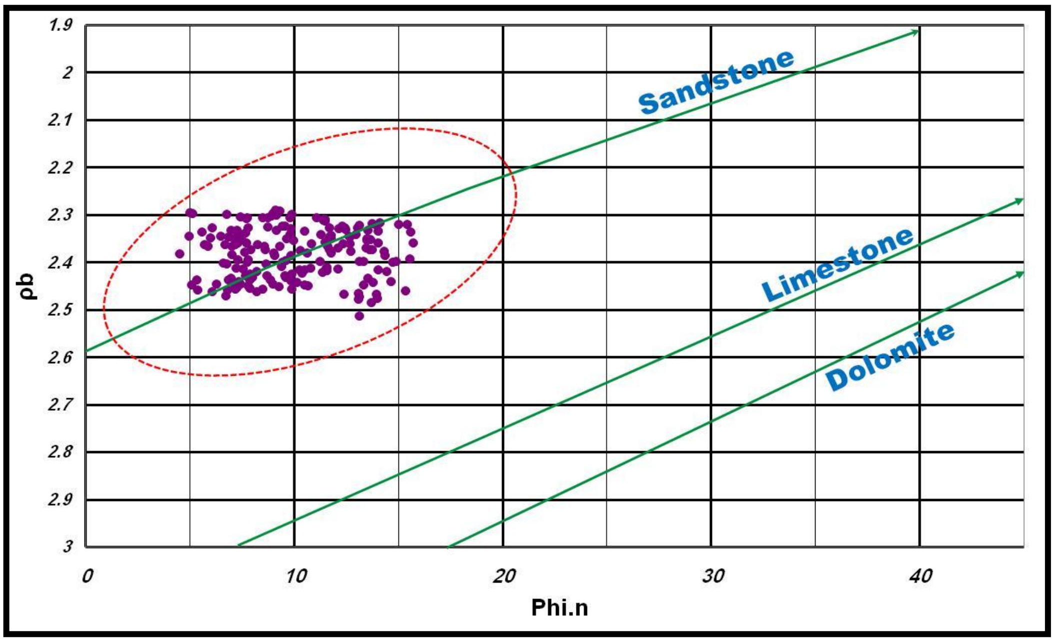


Fig. 6. Bulk Volume Water (Buckle) PLOT For Horizon H8 in A30-NC186 Well.

Digital Image Analysis (DIA) porosity cross plot between ρb versus ΦN is used for evaluating matrix lithology and porosity. The lithological facies for Hawaz formation in A5-NC186 well consists mainly of sandstone matrix (**Fig.7**).



Fig, 7. ρb & Øn cross-plot for Hawaz Formation at A5-NC186.

This sandstone is characterized by coarsening upward facies from horizon H8 at the bottom level to horizon H1 at the top (**Fig.8**).The calculated **Swirr** (=$\sqrt{\frac{F}{2000}}$) for each zone are cross-plotted versus Picket **Sw** to evaluate qualitatively **Krw** (**Fig.9**), **Kro** (**Fig.10**) and **WC** (**Fig.11**) depending on pattern recognition technique. The Points at depth (4850-4952 feet), which represent H8 horizon, and interpreted to be water wet, are clustered above 0.1 **Krw** line (**Fig.9**) and towards very low or zero **Kro** (**Fig.10**). Very high water cut (>60%) will be produced from this horizon (**Fig.11**).

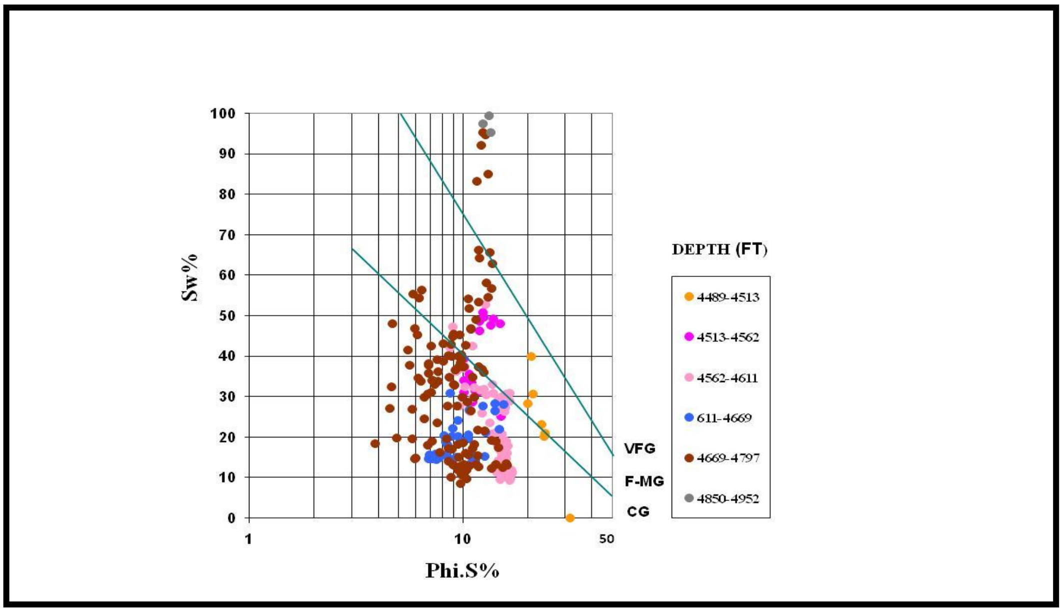


Fig. 8. Sandstone showing coursing upward sequence, Cross-plot for Hawaz Formation at A30-NC186.

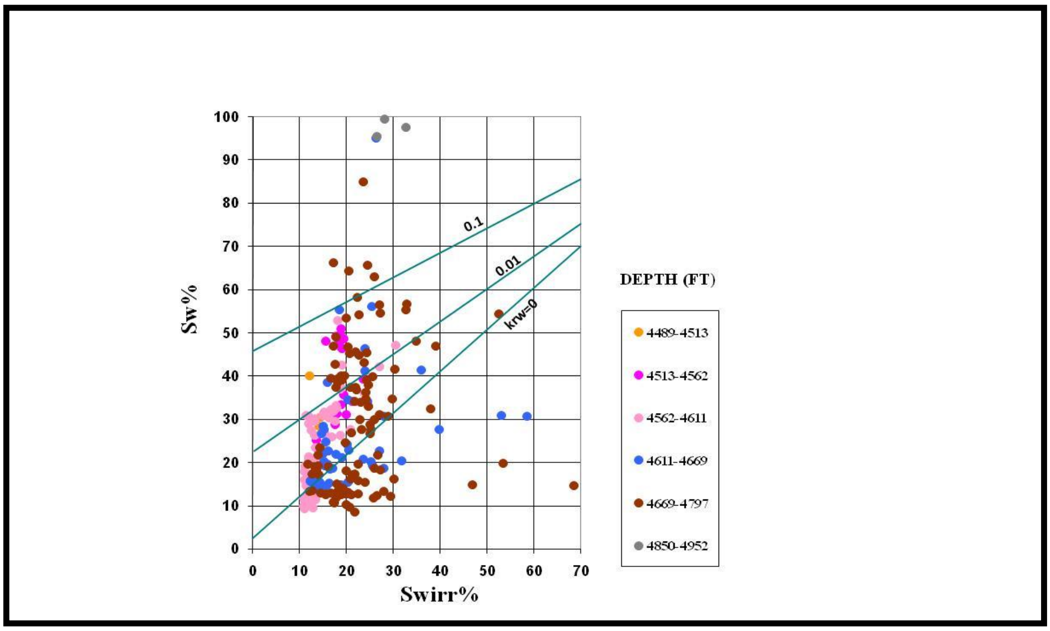


Fig. 9. Crossplot Between Sw versus Swirr for Hawaz Formation, A30-NC186 well, Showing Relative Permeability to Water (Krw).

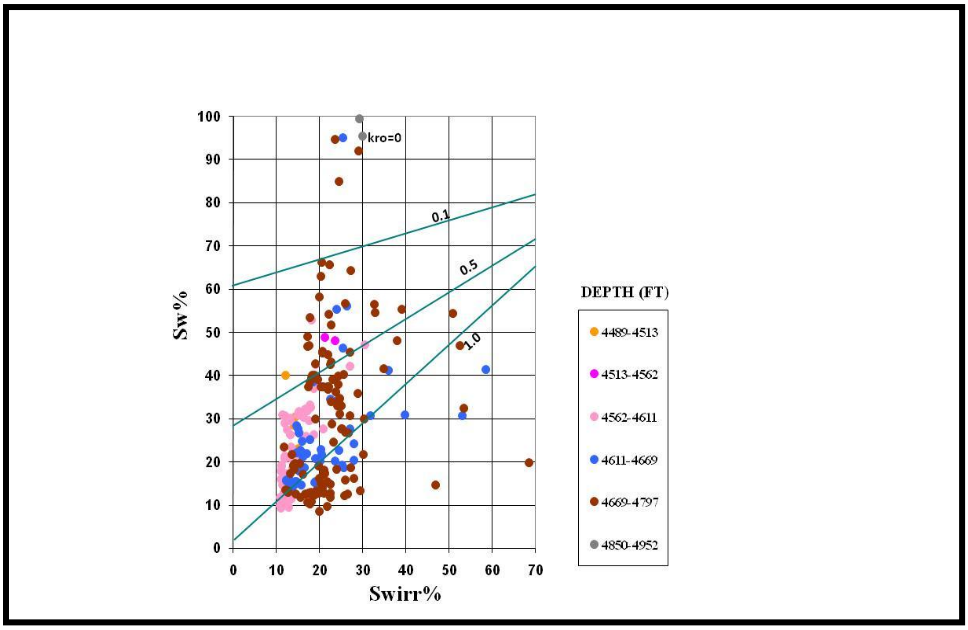


Fig. 10. Crossplot Between Sw versus Swir for Hawaz Formation, A30-NC186 well, Showing Relative Permeability to Oil (Kro).

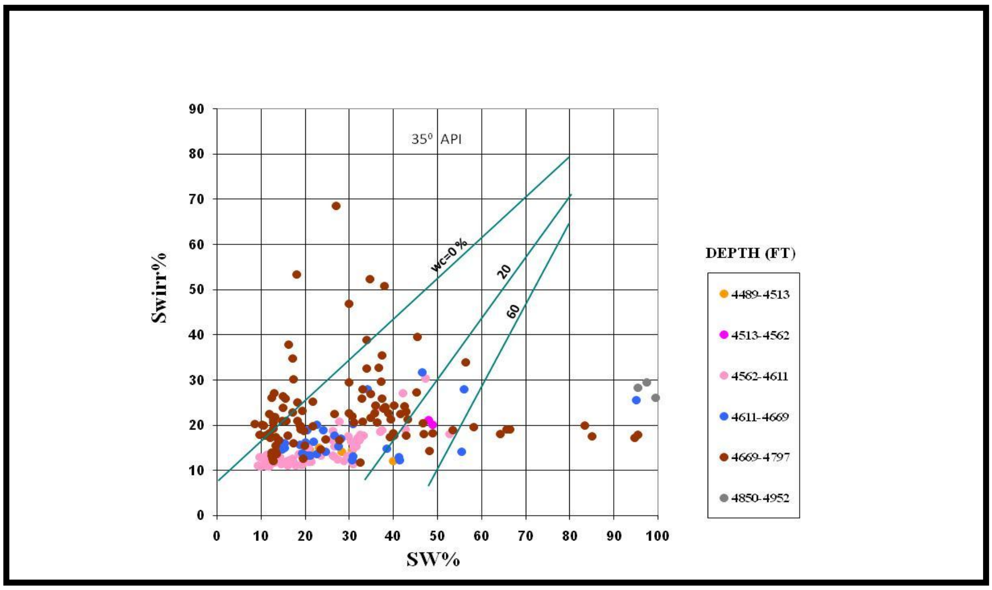


Fig. 11. Irreducible water saturation (S_{wirr}) verses water saturation (S_w) crossplot to determining percent water-cut for Hwawz Formation at A30-NC186.

Again, these criteria represent additional confirmations for the excellent reservoir characterizations for H4a ,H5 and H6a horizons in A30-NC186 well. Timur equation (1968) will be used here graphically (only qualitatively) using calculated Swirr ($\sqrt{F/2000}$) against **ΦN** for A30-NC186 well (**Fig.12**). On this plot, points of low Swirr and high porosity and permeability reflect high reservoir quality. Points with porosity and permeability lower than 9% and 1md will be excluded as they did not consider reservoir.

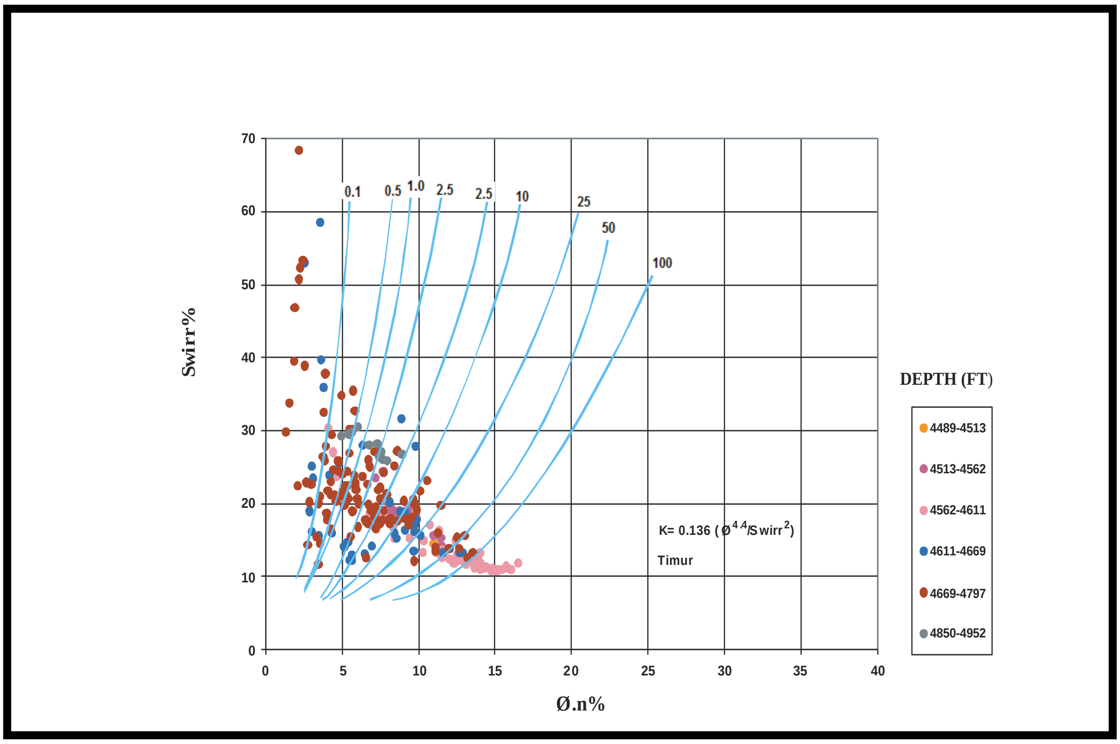


Fig. 12. Irreducible water saturation (S_{wirr}) verses porosity (Ø) crossplot to determining permeability for Hwawz Formation at A30-NC186.

2.2. IP output results.

The IP output results were presented in the form of lithosaturation cross plots for Hawaz Formation in the study area. This formation was subdivided into eight subzones. These subzones have its own petrophysical parameters (**Vsh, Sw, Sh** and **Φ**). These parameters are vary from well to well. These percentages have been discussed for some preferred wells only for illustration as discussed below.

The calculated effective porosity of the A30-NC186 well (**Fig.13**) ranges from 11.7 % to 14.6 % with an average of 12.7%. The water saturation ranges from 21 % to 49.4 % with an average of 33.5 %. The top of Hawaz Formation is at 4489 ft with a gross thickness of 463 ft and the net pay thickness is 228 ft.

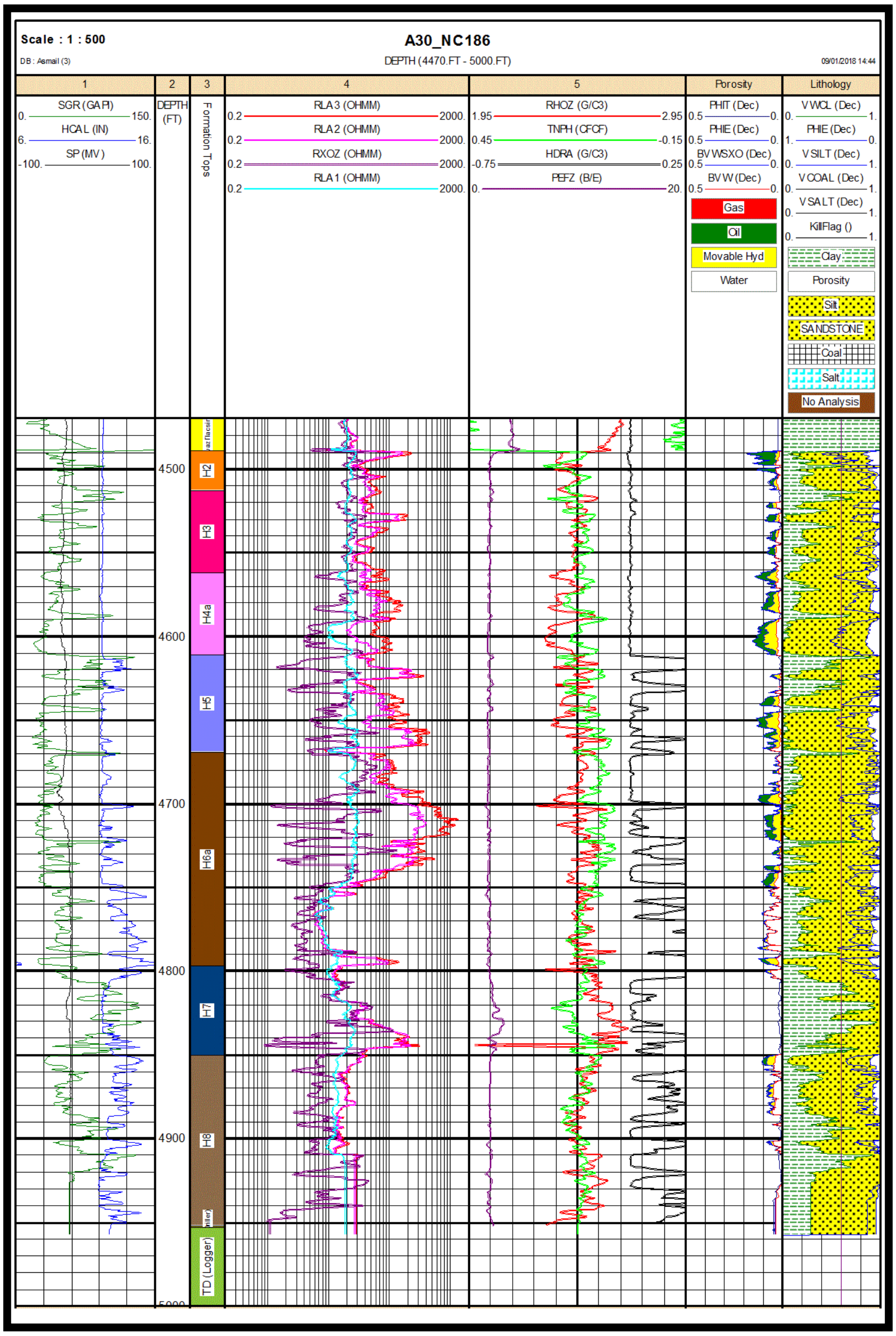


Fig. 13. Well Log Curves and IP Results for A30-NC186 Well.

Positive resistivity separations are clearly visible opposite H4a and H5 horizons with highest one exist at upper H6a one. Accordingly, these sites may contain oil and will be processed quickly to verify their potential. It is important here to notice that, upper H4a consider slightly shaly while the others clean. Table (1) summarizes the log readings and the calculated Bulk Volume of Water and the expected fluids when compared with Bulk Volume of Water BVWmin values of 0.05 and 0.07 for clean and slightly shaly zones respectively

Table (1): Calculated BVW and expected fluid type production for Hawaz Formation, A30-NC186 well Murzuq Basin, SW Libya ,compared with 0.05 BVWmin for clean intervals and 0.07 for slightly shaly one.

Horizon		Depth feet	RT $\Omega.m^2/m$	Φ %	SW %	BVW fraction	Expected fluid
H4a	shaly	4560-4570	90	18	32	0.057	Oil
	shaly	4575-4590	160	11	40	0.044	Oil
	clean	4590-4610	100	17	34	0.058	Oil +Water
H5		4650-4670	300	15	21	0.032	Oil
H6a		4690-4720	700	10	22	0.022	Oil

On the other hand, the lithosaturation cross-plot of well A5-NC186 (**Fig.14**) displays that the calculated effective porosity ranges from 13.2 % to 21.6 % with average 14.3 %. The water saturation ranges from 36.2 % to 55.4 % with average 40.1 %. The top of Hawaz formation is at 4259 ft with a gross thickness of 484 ft. and net pay thickness 282.5 ft. It is indicated also that subzones H4a, H5 and,H6a are potentially the most productive zones. Through these horizons, resistivity has high positive separation (corrected true resistivity RLA3 much higher than invaded zone resistivity RXOZ) indicating presence of high permeability and movable hydrocarbons (yellow color coded). Separation between Neutron porosity (NPHI) and Density porosity (RHOZ) curves together with gamma ray (GR) reading reflect the matrix and shaliness nature of the investigated interval (intervals 4400-4570). The very low gamma ray GR reading reflect the clean nature of the reservoir.

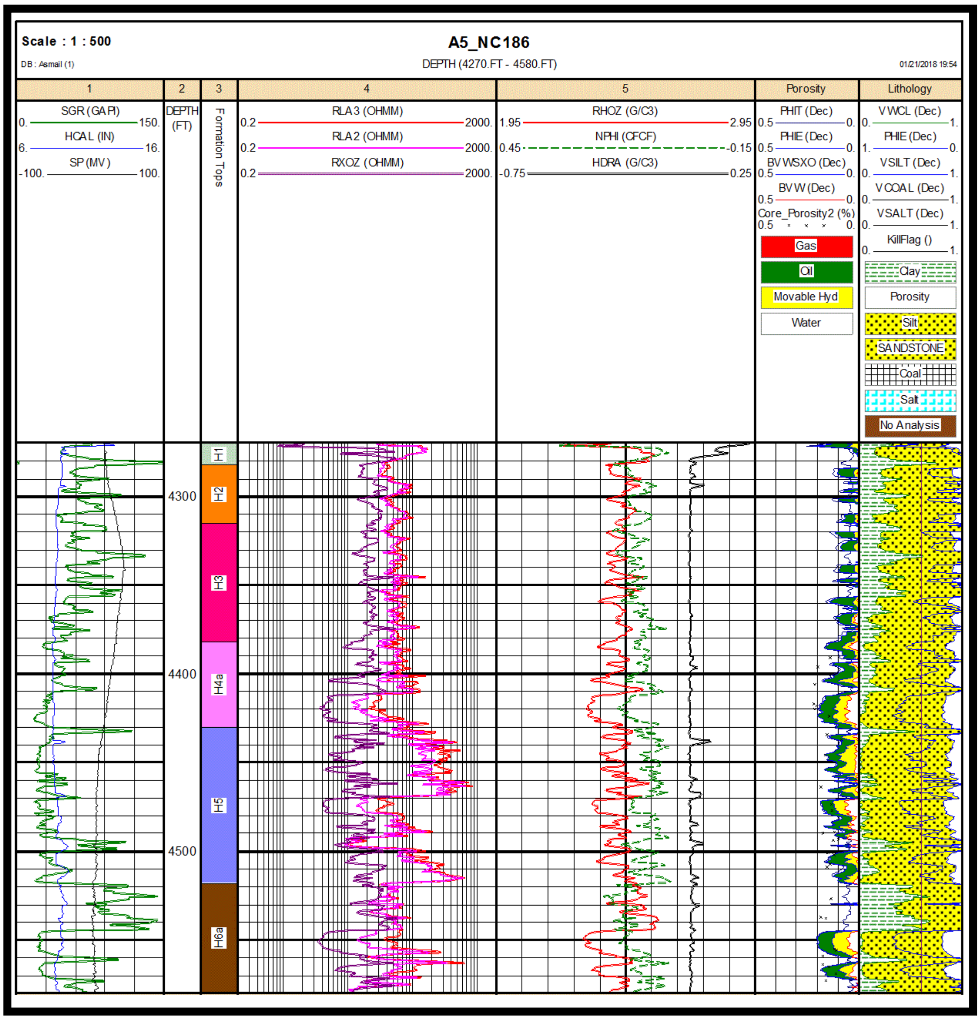


Fig. 14. Well Log Curves and IP Results for A5-NC186 Well.

As Hawaz reservoir in this well is almost clean sandstone as described above, the RTmin value for free water production is 148 Ωm2/m (400x 0.37). Accordingly, only zones with true resistivity Rt more than 140 $\Omega m^2/m$ and Bulk Volume of Water less than 0.05 will be expected to produce oil with zero Water Cut (WC).The calculated results for Hawaz Formation in this well are presented in Table 2 below.

Table (2): Calculated BVW and expected fluid type production for Hawaz Formation in A5-NC186well, Murzuq Basin, SW Libya compared with 0.05 BVWmin.

Horizon	Depth feet	RT $\Omega.m^2/m$	Φ %	SW %	BVW Fraction	Expected fluid
H4	4410-4430	400	18	15	0.027	Clean Oil
H5	4430-4460	300	14	26	0.03	Clean Oil
	4470-4475	400	18	15	0.027	Clean Oil
	4475-4480	200	18	21	0.038	Clean Oil
	4500-4510	150	15	30	0.045	Clean Oil
	4510-4520	500	12	21	0.025	Clean Oil
H6	4545-4560	1000	18	9	0.016	Clean Oil
	4565-4570	100	17	34	0.057	water

3. Conclusions:

As a general, the analytical formation evaluation in the studied field reveals that the lithological facies consists mainly of sandstone and little shale. This sandstone is coarsening upward. Also, most of the horizons are at irreducible state (no water) except for some zones in the field. The most important conclusions extracted from the presented work are listed below:

- Top Hawaz surface ranges between 4259 ft in the A5-NC186 Well and increases to more than 4489 ft in A30-NC186 Well in northwestern parts of the study area.
- The base of the Hawaz Formation starts with a transgressive surface culminating in a maximum flooding surface represented by H7, the upper members H6a to H4a stand on a sequence boundary above which stacked fluviotidal channels are deposited in response to a forced regression representing the best reservoir facies.
- The well logging data analysis illustrates that horizons from H4a, H5 and H6a are mainly oil bearing zones while horizons from H6c to H8 are mainly water bearing zones.

Acknowledgment:

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