# Reservoir Efficiency Of Hawaz Formation, H Oil Field, Concession NC186, NW Murzuq Basin, SW Libya

***Dr. Adel A.Kushlaf***
***Dept. Of Engineering geology, Faculty of Oil and Gas***
***Zawia University***

## Abstract:

*The current paper deals with evaluation of petrophysical parameters of Hawaz Formation at H oil field, Concession NC186 in Murzuq basin through the analysis of well-log data available for ten exploratory wells, distributed in H oil field. This field has been affected by the structural and tectonic movements of Murzuq Basin and created paleo-high during the post-Hawaz erosional events. A comprehensive formation evaluation has been applied through numbers of cross-plots and use their output parameters as input data for interactive petrophysics*

*software (IP) in order to evaluate the lithological constituents and fluid saturations. The litho-saturation cross-plot indicated that the Hawaz Formation consists of sandstones with interbedded 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 horizons H4, H5 and H6 are the main reservoirs in Hawaz Formation.*

***Keywords**: Hawaz Formation; H field; well logging; petrophysical parameters*

## Introduction:

Murzuq 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 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 ten exploratory and development wells, distributed in the field (H-NC186) on the northwestern flank of the Murzuq basin, southwest part of Libya (**Fig.1&2**). The investigated H oil field lies between the latitudes 26º 43'and 26º46'N & and longitudes12º 32' and 12º 36' E as shown below in (**Fig.2&3**).

This paper is devoted to study the hydrocarbon potentialities of Hawaz Formation in H oil field through analysis of the available well log data. A comprehensive analytical formation evaluation has been applied using interactive petrophysics (IP) software. The well log data comprise resistivity, sonic, neutron, density, nuclear magnetic resonance, spontaneous potential, caliper, gamma ray and natural gamma ray spectrometry logs.

## Geologic background of the study area:

The oil bearing zone in field H-NC186 is the Middle Ordovician Hawaz Formation productive in the eastern part of H-NC115 field and in (A) and (D) -NC186 surrounding fields. The structure is the classic Hawaz palaeo-high created during the post Hawaz erosional event and the hydrocarbon source and seal is the Silurian Tanezzuft Formation (kilitzsch 1969; Fello,etc., 2006). Time of expulsion and migration is estimated to be during the late Cretaceous to early Tertiary period.

Hawaz depositional environment is characterized by a gently dipping shelf covered by epicontinental seas developing an extensive coastal plain area dissected by fluvio-tidal channels (Pierobon 1991).

Later these sediments were deeply eroded forming a spectacular terrain of escarpment and incised valleys with topographic relief in excess of 1000 ft. This extensive topography was then partially in-field by subaqueous ice margin deposits of the upper Ordovician Melaz Shuqran Formation consisting of argillaceous sandstones and mudstones. The more proximal sediments of the extremely sand-rich Mamuniyat Formation completed this in-fill process, and in some areas of the basin completely submerging the Hawaz topography (Pierobon1991).

## Methodology:

The processing of the well logging data in this study has been carried out utilizing constructing two cross-plots(Pickett and Hingle) for deriving formation water resistivity ($R_w$), cementation factor ($m$) and matrix parameters ($\rho_{ma}$ , $\Delta t_{ma}$ ).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 and maps.

## 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 H1,H2,H3,H4"H4a-H4b-H4c",H5, H6"H6a-H6b-H6c",H7 and H8. These subzones have their own petrophysical parameters (Vsh,Sw,Sh and$\Phi$).

The lithosaturation cross-plot of well **H14-NC186** (**fig.4**) displays that the calculated effective porosity ranges from 10.4% to 16% with average 12.4%, the water saturation ranges from 21 % to 83.8 % with average 43.8 %. The top of Hawaz Formation is at 4433ft with a gross thickness of 542 ft. and net pay thickness 179.5 ft. It is indicated also that subzones H4b, H5 and, H6b are potentially the most productive zones (**fig.4**). The effective porosity of **H7-NC186** well (**Fig5**) ranges 13.4% to 18.8% with average16.1%. Water saturation ranges from 22.5% to 80.4% with average 49 %. The top of Hawaz Formation is 4562ft with a gross thickness of 495 ft. and net pay thickness is 342.5ft. It is well known that H4C is potentially the most productive subzone. On the other hand, the calculated effective porosity of **H8-NC186** well (**Fig6**) ranges from 10.2% to12.3% with average 11.2%, the water saturation ranges from 8.3 % to 58.6 % with average 33.7 %. The top of Hawaz Formation is at 4555 ft with a gross thickness of 516 ft. and net pay thickness is 175 ft. The H3 to H5 are potentially the most productive subzones.

## Results and Discussion :

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 7 and 8** represent the Pickett plot for Hawaz formation in wells **H6-NC186** and **H14-NC186**. The water saturations for H5 and H6b horizons in H14-NC186 well are represented on the Pickett plot (Fig.8) as deep blue and deep purple spheres , respectively , plotted below 25% Sw line indicating low to very low water saturations. Deep yellow spheres of H8 horizons are plotted between 50% and 100% Sw lines. This is exactly as deduced qualitatively in the previous paragraphs. It was found from the cross-plots that the average value of Rw equals to 0.32Ωm2/m, which is correletable with that obtained by core sample data executed by Repsol oil operation. It was also found that m is equal 2 and On the other hand, matrix parameters ($\rho_{ma}$ , $\Delta t_{ma}$) have been obtained from Hingle cross-plot (Hingle, A.T., 1959). In this study, the matrix values have been determined by the intersection of SW=100% line and the horizontal axis. **figures 9 and 10** represent Hingle cross plots for Hawaz Formation for **H14-NC186** and **H8-NC186** wells respectively. The results indicated that $\rho_{ma}$ value is 2.66gm/cc and $\Delta t_{ma}$ is 55 $\mu sec/feet$. Dia porosity cross plot between ρb versus ΦN is used for evaluating matrix lithology and porosity. The lithological facies for Hawaz Formation in **H14-NC186** well consists mainly of sandstone matrix (**Fig.11**). This sandstone is

characterized by coarsening upward facies from horizon H8 (Deep yellow spheres) at the bottom level to horizon H1 (blue spheres) at the top (**fig.12**).The calculated Swirr ($=\sqrt{\frac{F}{2000}}$) for each zone are cross-plotted versus Picket Sw to evaluate qualitatively Krw (**Fig.13**), Kro (**Fig.14**) and WC (**Fig.15**) depending on pattern recognition technique.

The deep yellow spheres (4784-4979 feet), which represent H8 horizon, and interpreted to be water wet, are clustered above 0.1Krw line (**Fig.13**) and towards very low or zero Kro (**Fig.14**). Very high water cut (>60%) will be produced from this horizon (**Fig.15**).

Porosity-Saturation (Buckle) plot (Buckles, R.S., 1965) (**Fig.16**) for H6b in H14-NC186 well indicates firmly that this horizon 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, indicates 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). Exactly as H6b has BVW also 0.02 and 0.11 Swirr.Accordingly,H6b and H5 will be considered for more quantitative interpretation. Horizon H8, which is well known water bearing throughout Hawaz Formation in H Field when plotted on Buckle (**Fig.17**) 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.

## The iso parametric maps of Hawaz reservoir:

The deduced petrophysical parameters are represented by 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 18, 19 and 20. The net pay thickness map **(Fig.18)** indicates a general increase at the northern part of the area with maximum thickness of 197 ft at well H16-NC186, while it decreases gradually from the center to the south east of the area where the very low (h) values are observed. The minimum thickness is located at H2-NC186 (57 feet) while it record zero at well (H3-NC186). The most important point observed is that, at H3 well, where Sw equals 44% while it has zero net pay thickness. This confirms the validation of the presented interpretation techniques.

The effective porosity contour map of this reservoir **(Fig.19)** 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.20)** of this reservoir illustrates a considerable distribution pattern with a general decrease along NW-SE trend. As a general view, the water saturations through the entire studied wells are less than that of critical (<50%).

## Summary and Conclusions:

This paper has been carried out to study and evaluate the petrophysical characteristics of Hawaz Formation in H oil field of concessions NC186. The conclusions which can be extracted are as follows:

- The analytical formation evaluation reveals that the hawaz reservoir is mainly clean sandstone . This sandstone represents coarsening upward facies.
- Hingle plot, although gave a good matrix density (2.65 gm/cc) compatible with the description of core samples, did not give reliable Sw and Rw values. Accordingly, Pickett technique is recommended in

case of Hawaz Formation in Concession NC186, NW Murzuq Basin, SW Libya.

- Quick look interpretation for Hawaz reservoir by applying Archie model to calculate both RTmp and RXomax.p reveals that , for Hawaz Formation in H Field the true resistivity must be greater than 20Ωm/m and flushed zone less than 5.8Ωm/m to consider the reservoir is free water oil producer.
- H4,H5 and H6 subzones are potentially the most productive in Hawaz Formation as indicated from the litho saturation cross-plots.

## ***References:***


- ***Buckles**, R.S., 1965, Correlating and averaging connate water saturation data; Journal of Canadian Petroleum Technology, v. 9, no. 1, pp. 42 to 52.*
- ***FELLO, N**. M. AND TURNER, B. R., 2006. 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 (3rd –5th September 2001).*
- ***Hingle**, A.T., 1959, The use of logs in exploration problems: paper presented at the SEG 29th International Annual Meeting, Los Angeles, November.*
- ***KLITZSCH, E** ., 1969.Stratigraphic section from the type areas of Silurian and Devonian strata at Western Murzuq Basin, Libya. In: J. J. Williams (Ed.). Geology Archaeology and Prehistory of the southwestern Fezzan, Libya. Petrol. Explore. Soc. Libya, 8thAnnu. Field Conf., P. 83-101.*

- *Repsol oil operation, 2005, field H development plan, Repsol exploration Murzuq S A* ***(Internal report )***
- ***PIEROBON, E. S. T., 1991****. Contribution to the stratigraphy of the Murzuq Basin, SW LIBYA. In: Salem, m. j. and Belaid, M. N (Eds.). The geology of Libya, Academic Press London, Vol.* ***V****, P. 1767-1784.*
- ***Picket****t. G.R. 1972, practical formation evaluation Golden Colorado.*

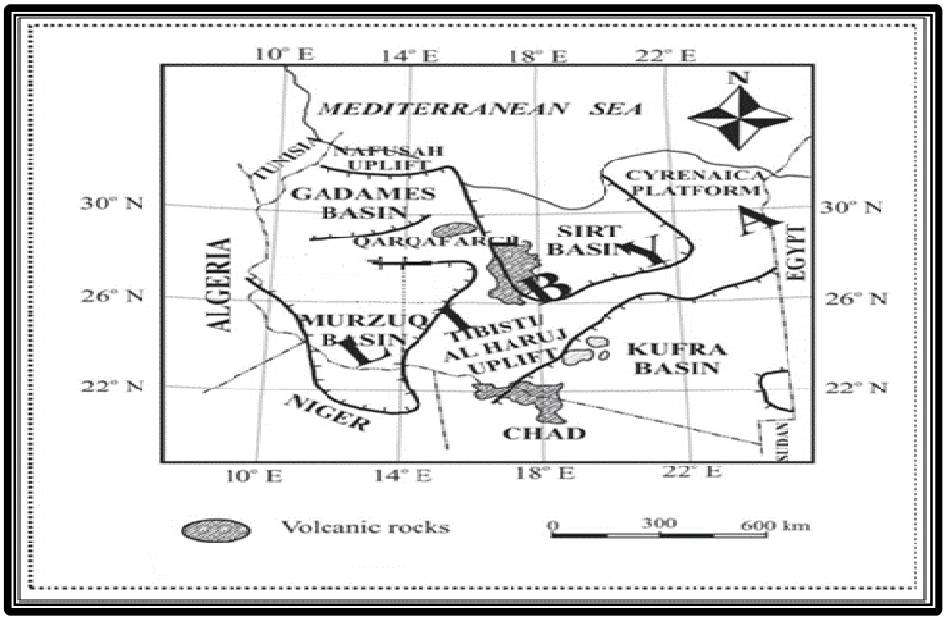


**Fig.1. Location Map of the Sedimentary Basins of Libya (After Fello, 2001)**

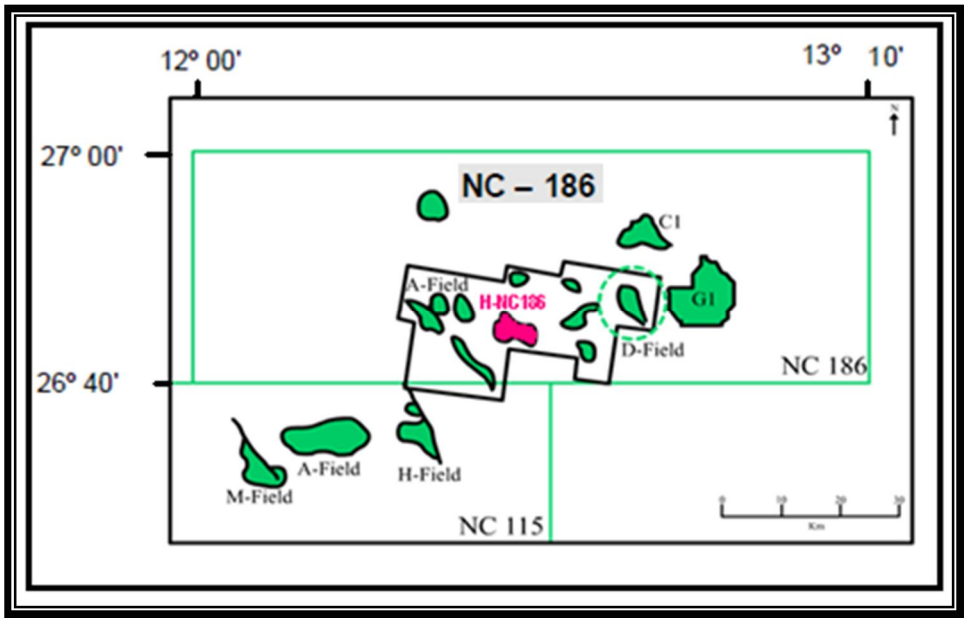


**Fig.2: Location map of H oil field, concession 186**

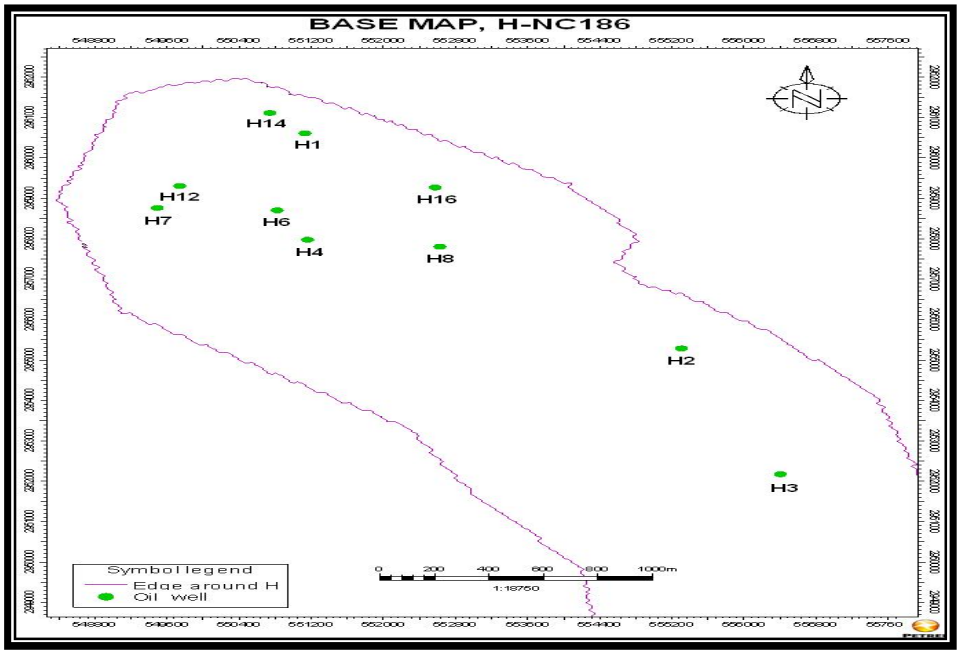


**Fig.3: location map of H oil field, concession 186, Murzuq basin**

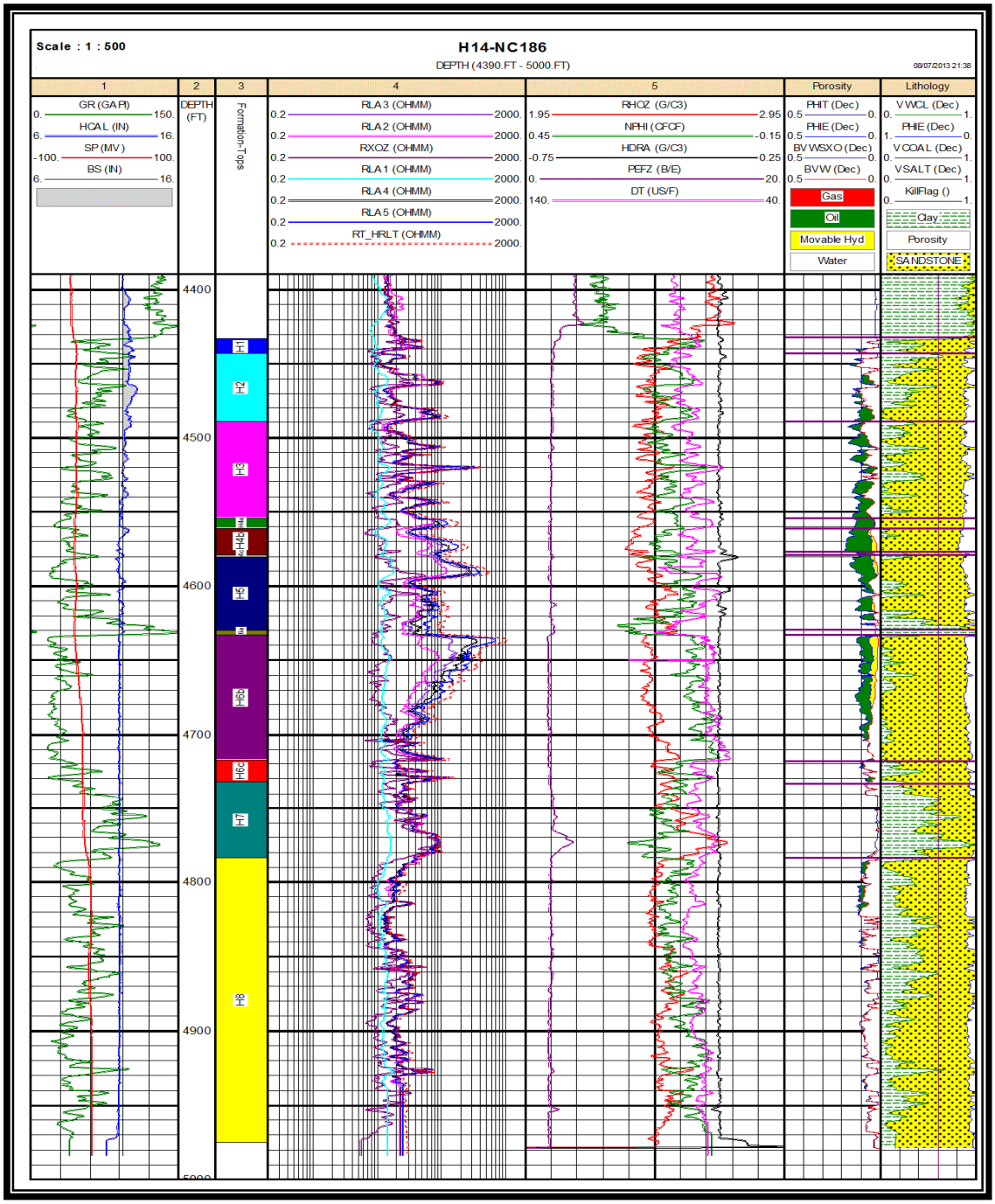


**Fig. 4: litho saturation cross-plot for well H14-NC186.**

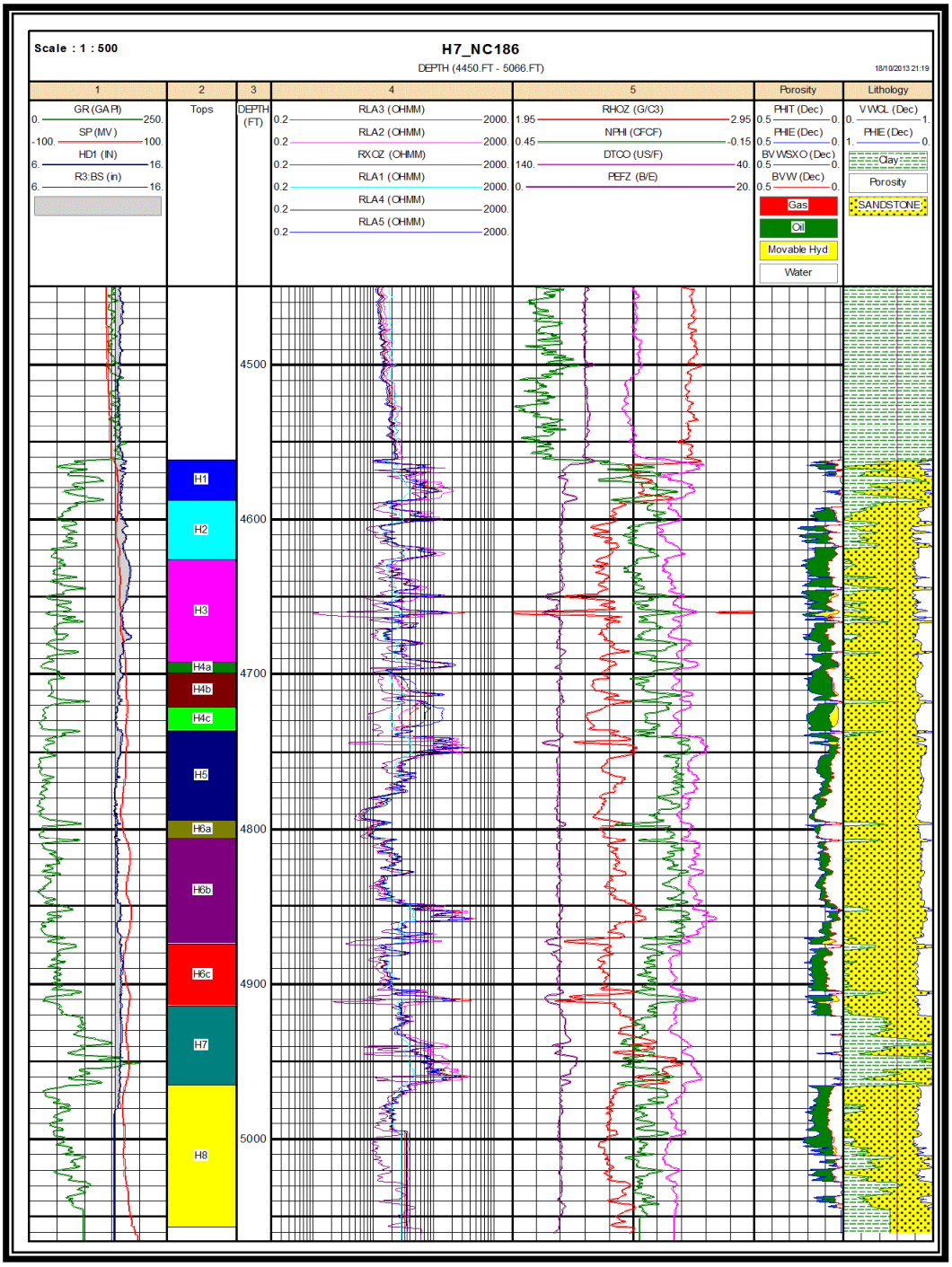


**Fig.5: litho saturation cross-plot for well H7-NC186.**

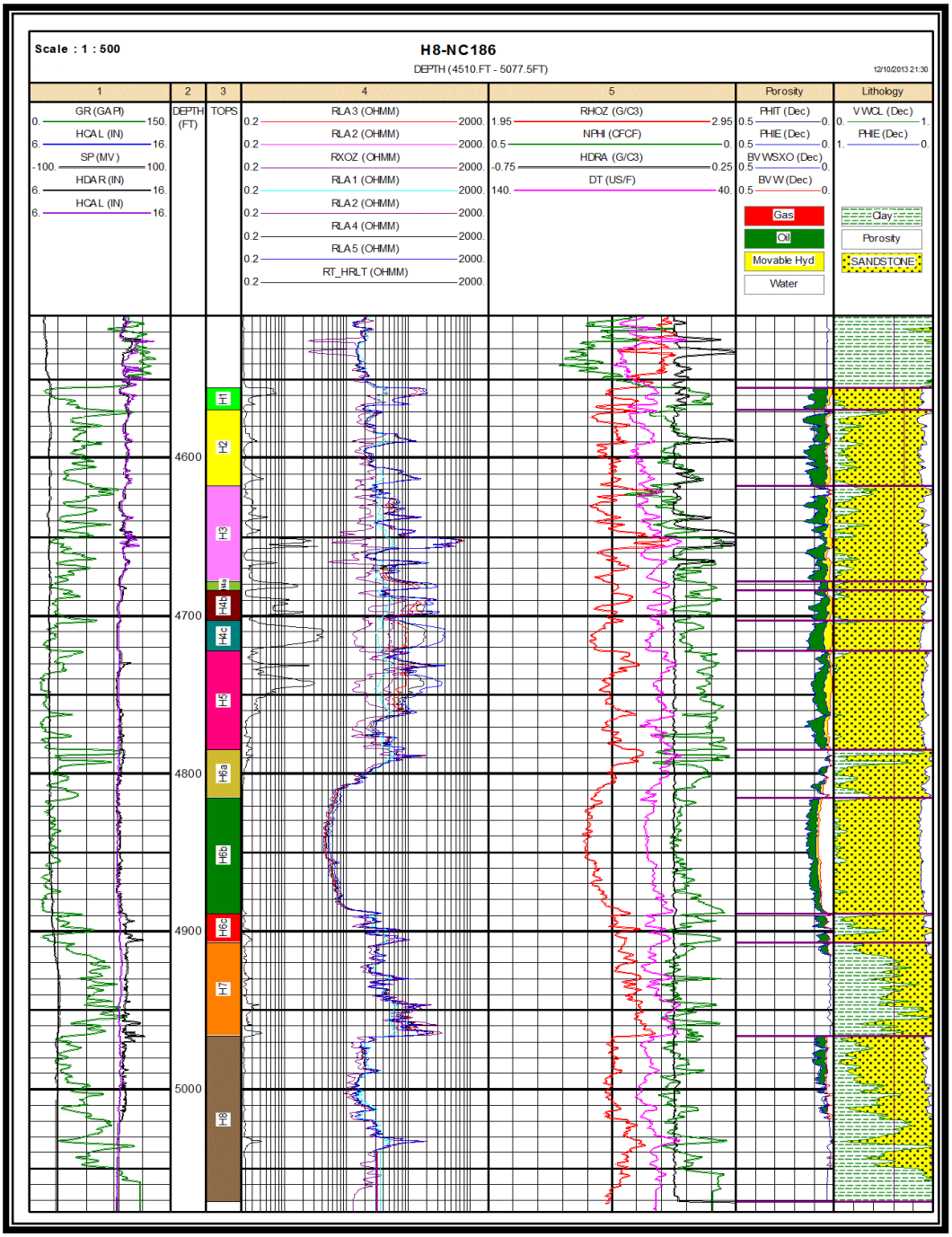


**Fig.6: litho saturation cross-plot for well H8-NC186**

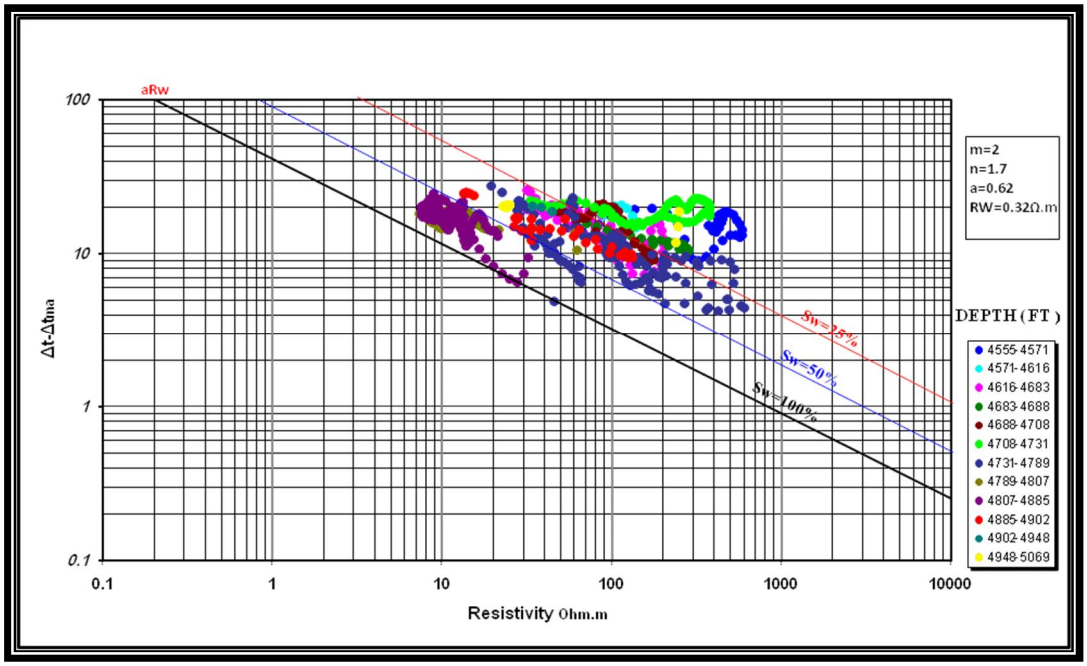


**Fig.7: Super Pickett plot for Hawaz Formation at H6-NC186**

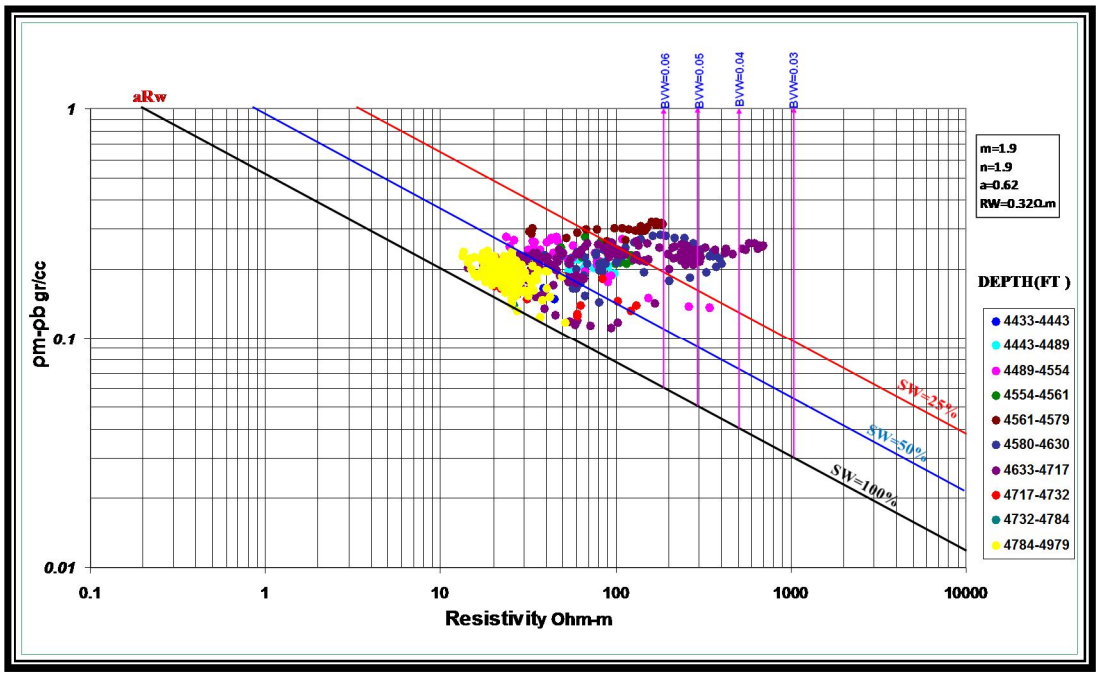


**Fig.8: Super Pickett plot for Hawaz Formation at H14-NC186.**

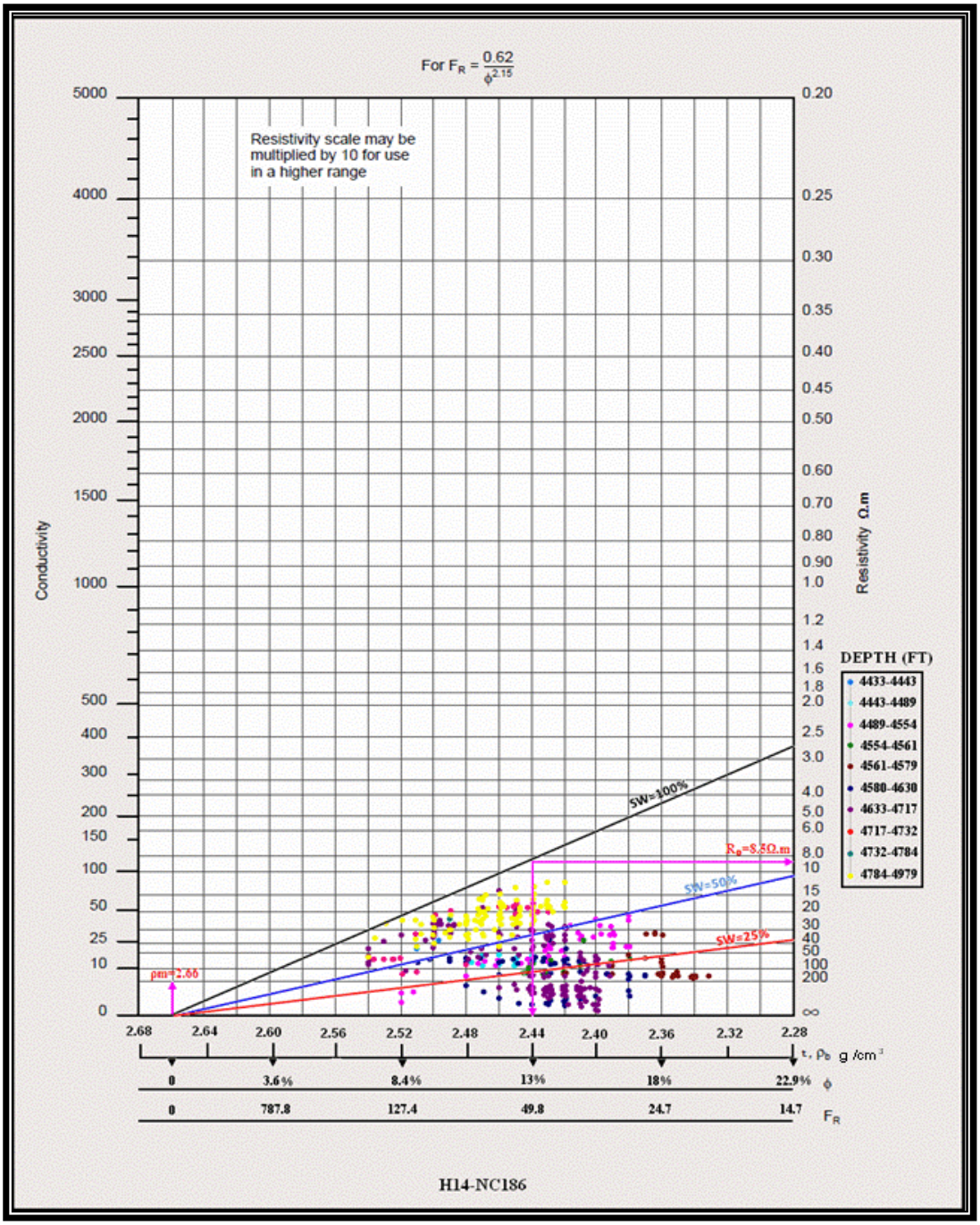


**Fig.9; Hingle cross-plot for Hawaz Formation at H14-NC186.**

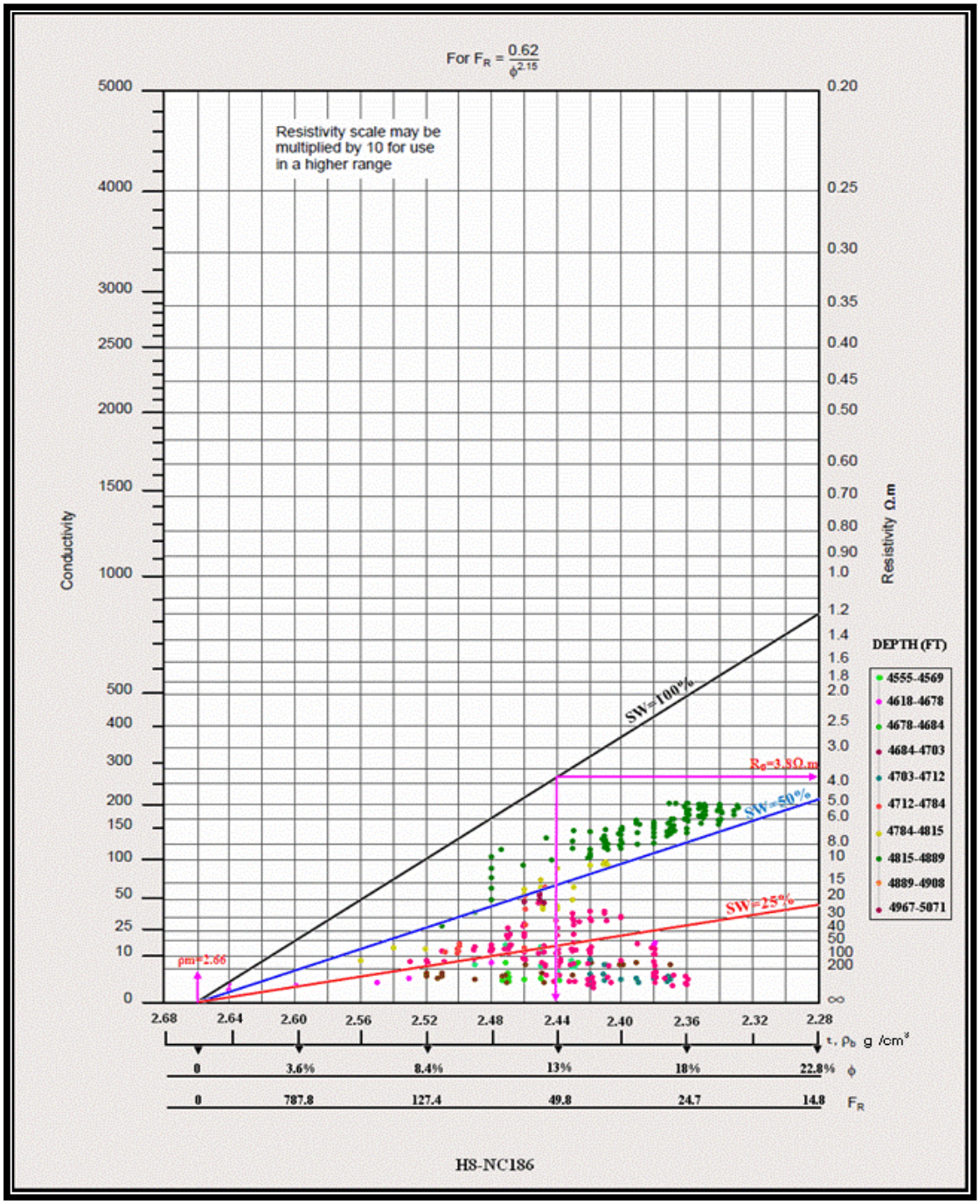


**Fig.10: Hingle cross-plot for Hawaz Formation at H8-NC186.**

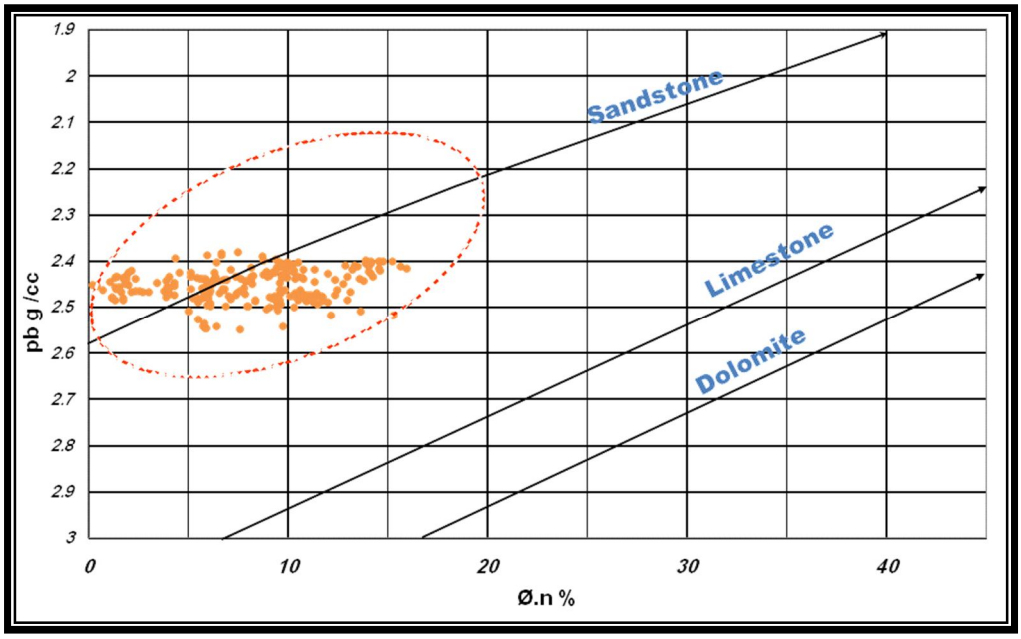


**Fig.11: porosity ρb & Øn cross-plot for Hawaz Formation at H14-NC186**

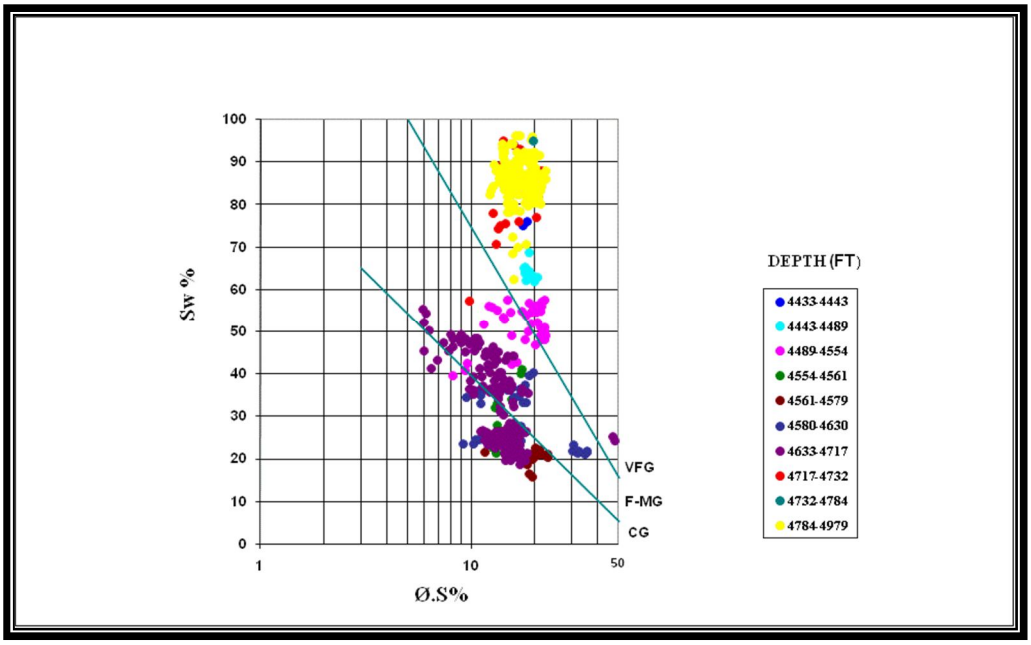


**Fig.12: Sandstone showing coursing upward sequence, Cross-plot for Hawaz Formation at H14-NC186**

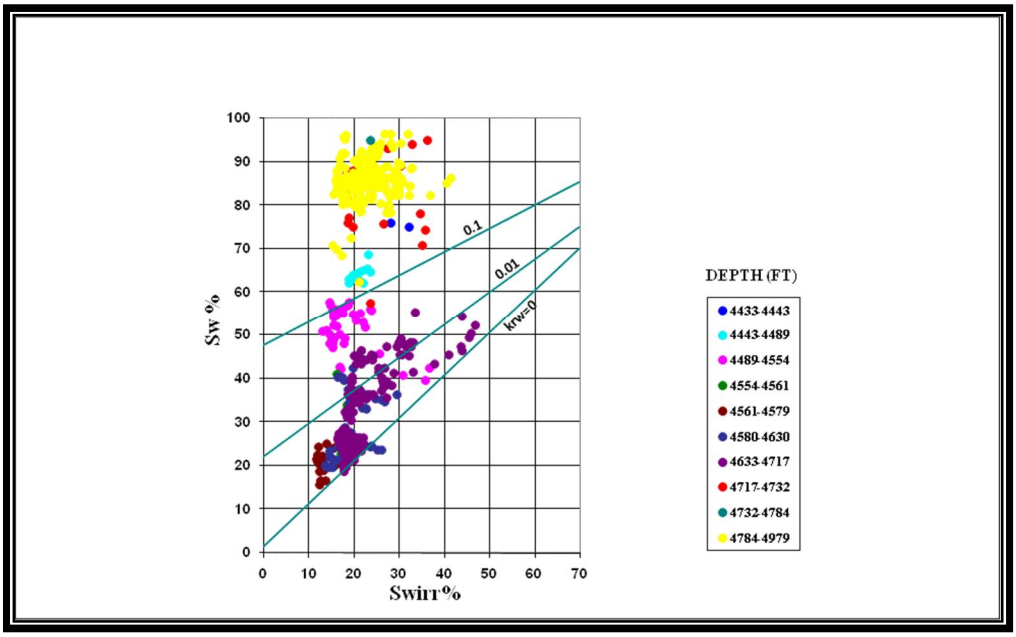


**Fig.13: Irreducible water saturation ($S_{wirr}$) verses water saturation (Sw) crossplot for determining relative permeability to water (Krw) for Hwawz Formation at H14-NC186.**

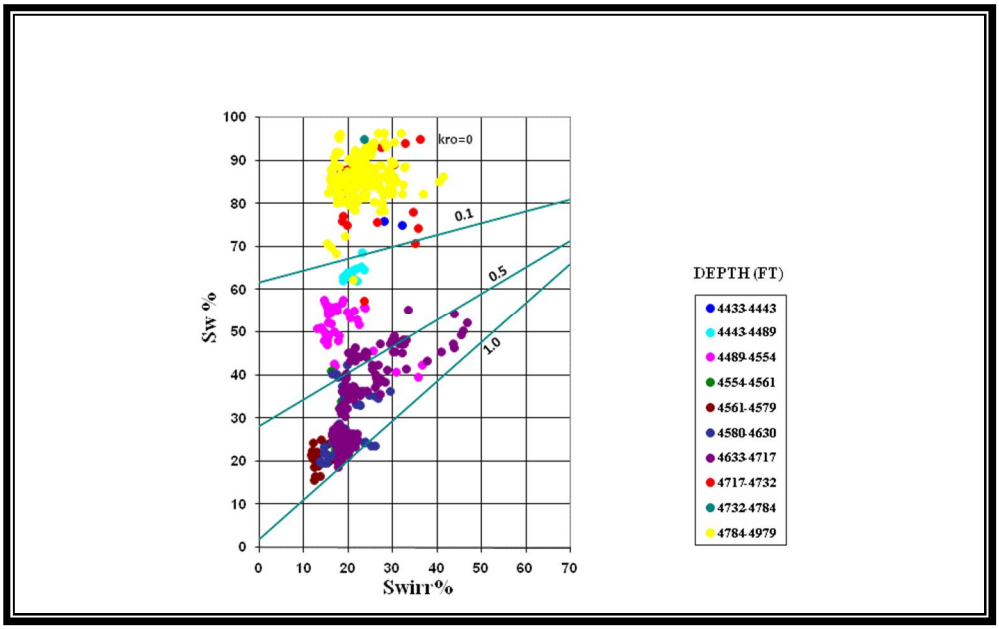


**Fig.14: Irreducible water saturation ($S_{wirr}$) verses water saturation (Sw) crossplot for determining relative permeability to oil (Kro) for Hwawz Formation at H14-NC186.**

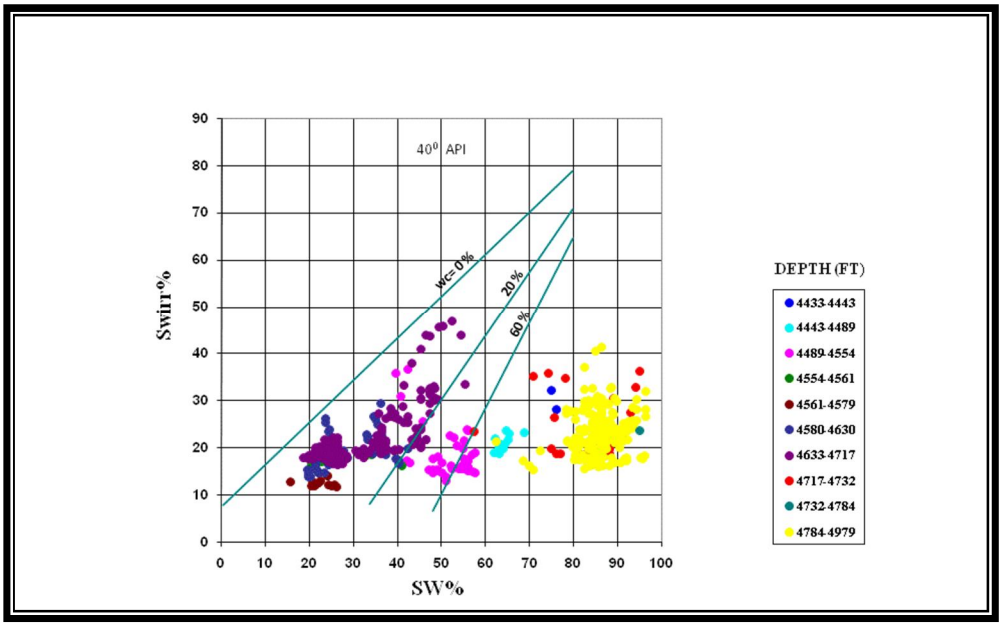


**Fig.15: Irreducible water saturation ($S_{wirr}$) verses water saturation ($S_w$) crossplot to determining percent water-cut for Hwawz Formation at H14-NC186.**

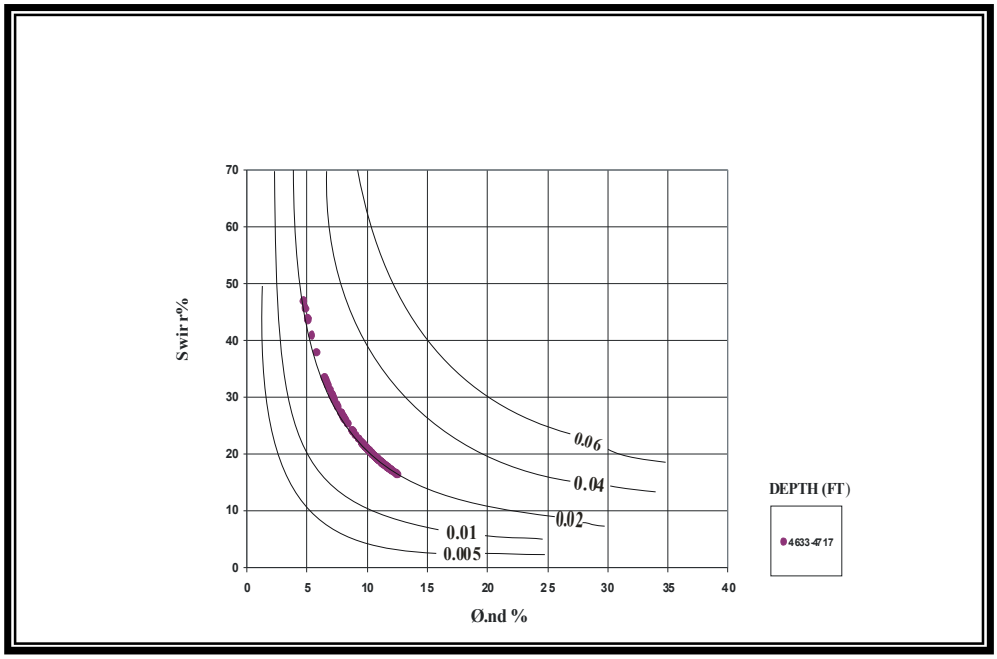


**Fig.16: Porosity verses water saturation crossplot to determining bulk volume water for Hwawz Formation (horizon H6b) at H14-NC186.**

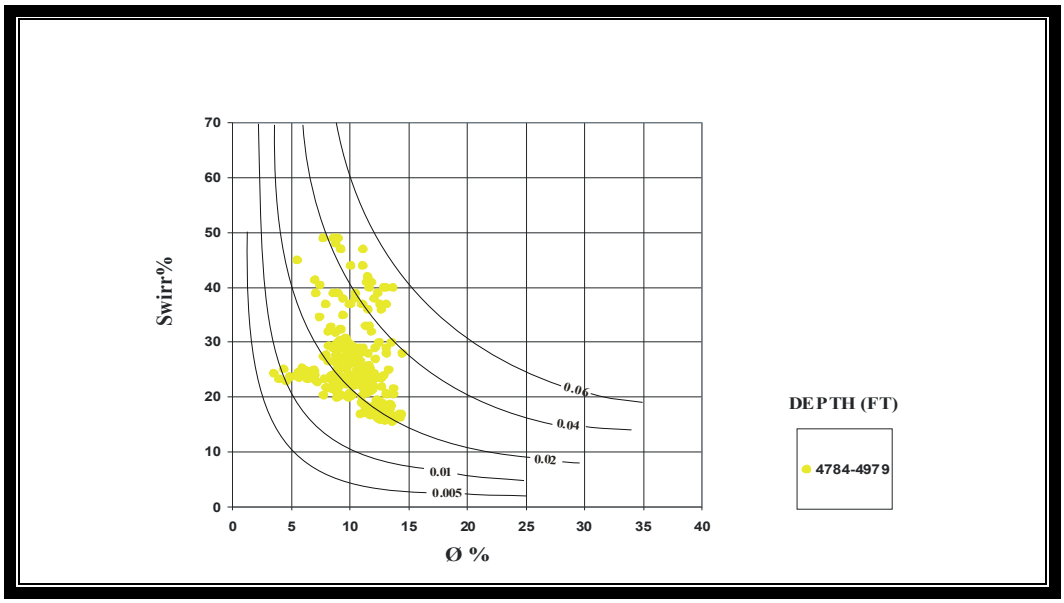


**Fig.17: Porosity verses water saturation crossplot to determining bulk volume water for Hwawz Formation (horizon H8) at H14-NC186.**

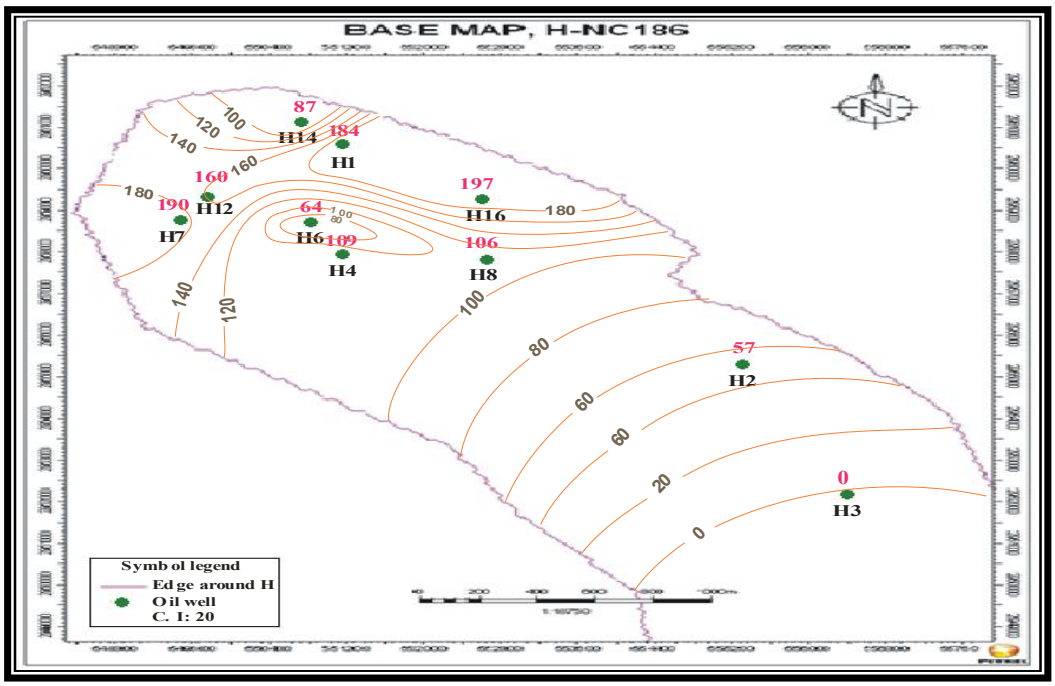


**Fig.18: Net Pay Thickness (h)Contour Map for Hawaz Reservoir in H oil field, Concession NC186, NW Murzuq basin, SW Libya.**

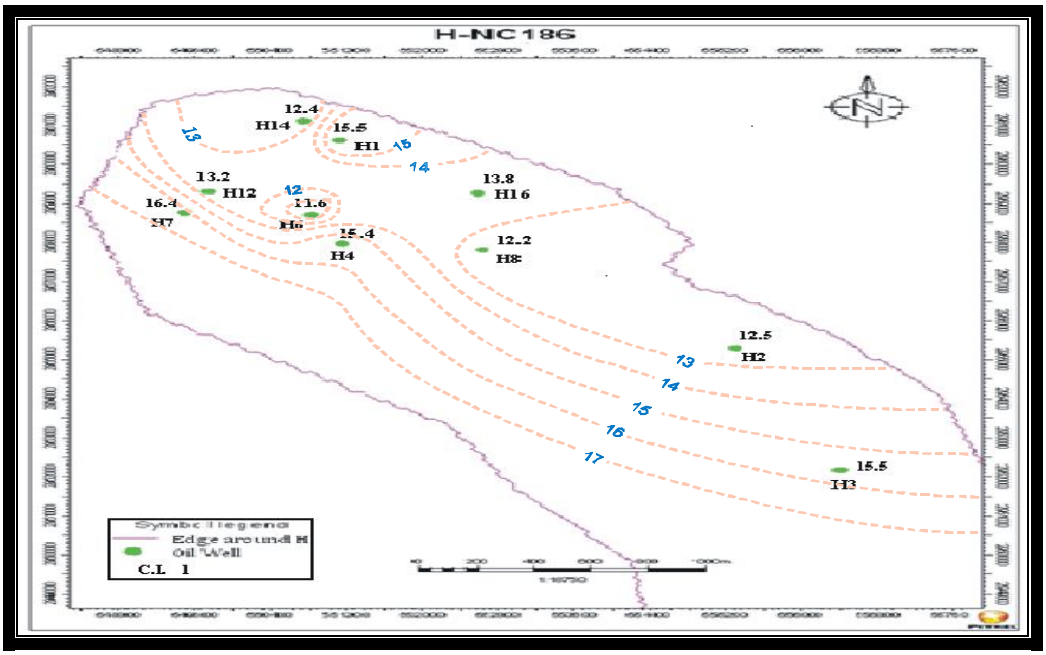


**Fig.19: Average Effective Porosity Contour Map for H oil field, Concession NC186, NW Murzuq basin, SW Libya.**

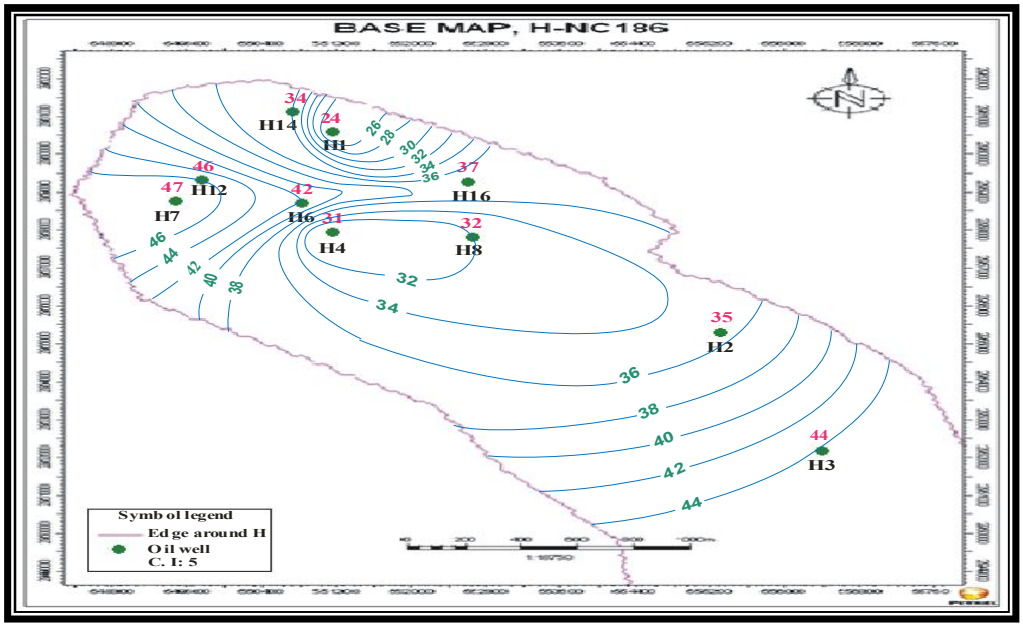


**fig.20: Average Water Saturation Contour Map for Hawaz Formation in H oil field, Concession NC186, NW Murzuq Basin, SW Libya.**