Estimation of Petro Physical Properties in Bentiu Formation, Rakuba Sub Basin, Sudan

Abbas M. Yagoub, Hafiza Babiker
College of Petroleum Engineering Technology, Sudan University of Science and Technology (SUST)

Received: 13/06/2015
Accepted: 19/10/2015

ABSTRACT - This paper focuses on estimating the petro physical characteristics as porosity, permeability and water saturation of Bantui formation. The formation is considered to be a reservoir rock in Rakuba depositional sub-basin. The properties have been estimated by analyzing and interpreting open hole logs of three wells. The raw log data were processed using Interactive Petro physics software version 3.5(IP v 3.5). Density-neutron cross plot logs was interpreted in order to estimate shale volume and porosity. The resistivity logs were corrected so that water saturation can be calculated with reasonable accuracy. Water saturation has been estimated using Archie's equation and the permeability has been calculated using Timur's equation. As a result of applying this methodology, Bentiu's formation porosity was found to be a good porosityas far as permeability are concerned, average porosity in Bentiu's formation 20%, permeability ranges from 0 to264 m.D, and water saturation value 100%.as final point Bentiu can be considered as a good reservoir but regrettably it is full of water.

Keywords: *Petrophysics, Lithology, porosity, Rakuba sub basin*.

المستخلص– تركز هذه الورقة العلمية في تحديد الخواص الفيزيائية لمتكون بانتيو مثل المسامية ،النفاذية, تشبع الماء. يمكن اعتبار المتكون صخور مكمن في ترسيب حوض راكوبة الرسوبي الفرعي. تم تقييم الخواص عن طريق تحليل وتفسير بيانات تسجيلات الآبار لثلاث آبار باستخدام برنامج3.5 Interactive Petro physics version في تحليل البيانات الخام. تم تفسير الرسم المتقاطع بين تسجيلي الكثافة والنيترون لتحديد وحساب كمية الطفل والمسامية.تم تصحيح قراءات تسجيل المقاومة لتمكن من حساب التشبع بالماء بدقة عالية.تم حساب التشبع باستخدام معادلة ارشي. كما تم حساب النفاذية من معادلة تمير. بتطبيق هذه الطرق،وجد ان متكون بانتيو يحتوي علي مسامية جيدة بنفس القدر النفاذية.قيمة المسامية المتوسطة لمتكون بانتيو 20% ونفاذية متكون بانتيو تتراوح بين صفر الي 264 ملي دارسي ، و قيمة التشبع بالماء 100%.في الأخير يمكن اعتبار متكون بانتيو مكمن جيد لكن لسوء الحظ مشبع تماما بالماء.

INTRODUCTION

Studying physical rock prosperities (petrophysics) plays main role in oil industry around the world, which distinct reservoir formation from other formations, then determine is the rock has storage capacity or hasn't, moreover, fluid types are defined and their percentages. In this stage initial oil in place is easily estimated. So then formation Producibility must be known.

Although well logging consider the first technique in determining petrophysics, according which well logging data are gathered, analyzed, and interpretated. As a result of the technique values of porosity, water saturation, and permeability are well estimated. Then reservoir can be described clearly. Many technical papers ware published, which are focusing into petrophysics study, as example: They had estimated reservoir properties in Oshioka field based on data from two wells using geophysical well logs, the results carried out with petrel and hydrocarbon data system [5]. The results correlated with mud log and geology information and found that porosity and permeability values form hydrocarbon bearing reservoir are good enough for commercial accumulation in the Niger delta.

They had evaluated the formations in the KG-5 which is a vertical well drilled to evaluate an exploration prospect in the onshore "Green Field" Niger Delta [15]. Used a conventional suite of wireline logs including gamma ray, calliper, sonic, density, neutron, dual laterolog and micro-SFL resistivity were acquired for formation evaluation purposes.

Data from six well which are (well logging and core data) to evaluate the petrophysical properties of shaly sand reservoir in Palouge-Fal oilfield ,Mult basin ,South Sudan [12]. Also they introduce the spectral gamma ray log as new method to identify the reservoir quality.

Determined petrophysical properties of Assam Arakan Basin, India [13]. They used open-hole logging tools such as gamma ray, neutron density, resistivity and caliper logging tools to determine the petrophysical properties of reservoirs. Petrophysical parameters such as effective porosity (Φ), water saturation (Sw), formation water resistivity (Rw), hydrocarbon saturation (So) and true resistivity (Rt) were being evaluated using the well log data. They conclude that Quantitative porosity and water saturation values obtained from Petro-physical well log analysis are good enough for hydrocarbon production.

The objectives of this study are to review available data, identify the different lithological units, complete a quantitative estimation of clay volume, porosity and saturation; determine the permeability and Provide average reservoir properties of porosity, saturation, and provide a summary report on the well results.

Overview of study area and pervious work:

Rakuba sub-basin is located in Block (C) and lies in the southwestern part of Sudan covering an area of approximately 65,750 square kilometers. It remains largely an under explored region in Sudan country adjacent to a proven prolific oil production trend of the northwest-southeast trending Muglad basinand eastern extension of Doba, Doseo, Salamat basins in Chad and Central Africa Republic. Figure 1 illustrates concision blocks.

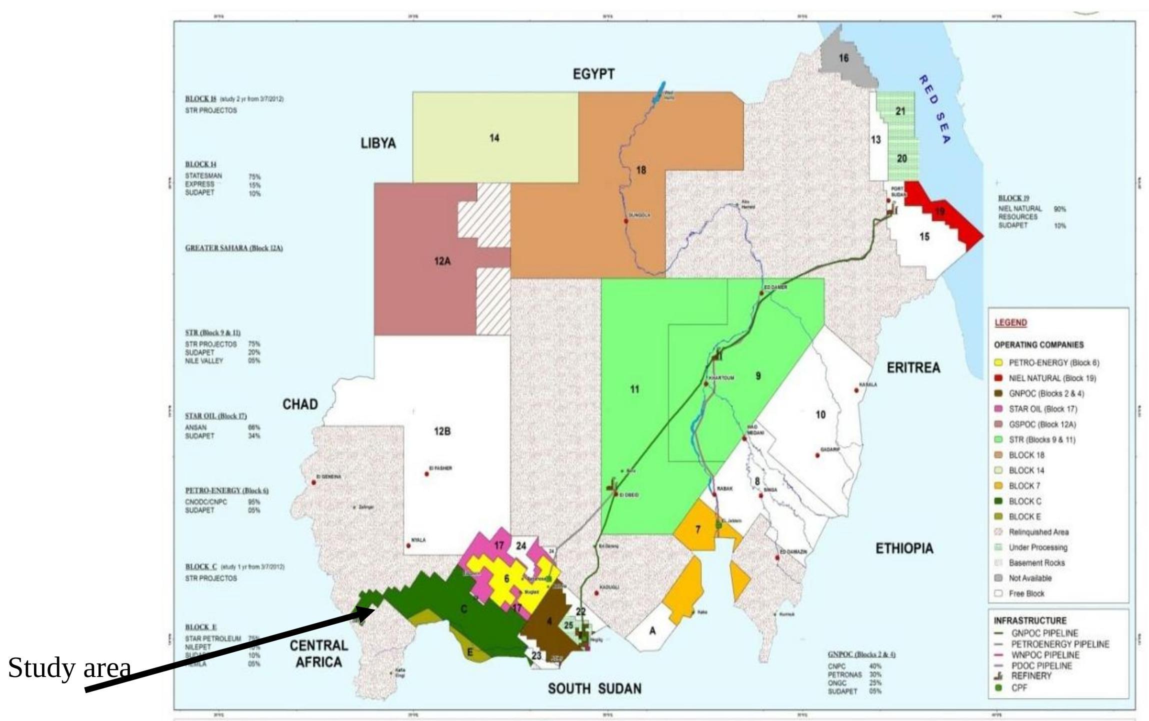


Figure 1: Study area (Block C)

The earlier suggestion supposed that the Sudanese interior basin does not contain commercial quantities of hydrocarbon reservoir fluids according to Agip company reports in 1959; in Seventeenth of the 20 century the space geological exploration (satellites) supposed that Sudanese basins may contain great quantities of hydrocarbon fluids.In 1979, chevron overseas company started exploration in south west of Sudan, resulting in the first oil discovery in the Sudan interior basins [14].

The Muglad Basin is a large rift basin in Northern Africa. The basin is situated within southern Sudan and South Sudan, and it covers an area of approximately 120,000 km2 across the two nations. It contains a number of hydrocarbon accumulations of various sizes.

Tectonics in Muglad Basin is highly complicated by faulting. Seismic data suggest large numbers of tensional faults have affected the overall basin and have defined several sub-basins, and structures. These sub-basins show significant variation in age of formation complexibility and size [1].

The sub-basins distributed around Muglad Basin are Rakuba sub-basin, Sufyan sub-basin, Ogr sub – basin, Nugara sub-basin, Hiba sub-basin, Sharaf-Abu Gabra ridge, El-fula sub-basin and Bamboo sub-basin.

The depocentre is extended to the south parallel to the Sharaf-Abu Gabra ridge and rises regionally up to the west and south west. The eastern area contains major faults at the basement which treding NW-SE, parallel to the axis of the main complex [10].

The Stratigraphy in Rakuba sub-basin is nearly similar to Muglad Basin, The Stratigraphy column includes interbedded sandstones, siltstones and shales ranged in age from lower cretaceous to recent, have been deposited under fluvio-lacustrine conditions Figure 2.

wells drilled in Rakuba sub-basin display a thick sequence of interbedded sandstones and shales, the principal reservoir horizons are limited to the Abu Gabra formation, Bentiu formation and possibly the sandstone within Darfur group.

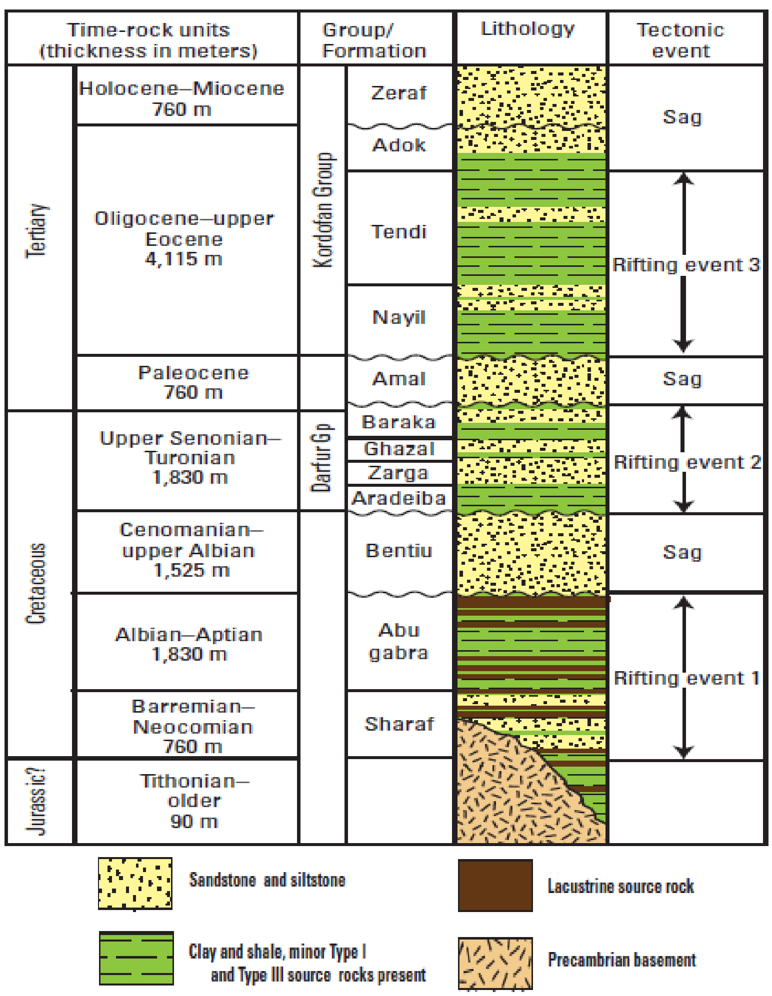


Figure 2: Typical formation consequences in Rakuba sub basin.

The stratigraphic sequence encountered in the two The Bentiu formation however shows porosities of between 13-24% averaging 21%, and sandstone thickness averaging 9’ [10].

MATERIAL AND METHODS

In this study, log data sets from three wells (Falah1, Najah1, and Rabah1) were utilized to characterize the petrophysical properties. Logs data (density log, neutron log, and resistivity log) were gathered from wells.

In order to get a clear estimation of parameters interactive petrophysics 3.5 (IP v3.5) software was used. The following paragraphs give good concept of internal process which applied in data.

Shale volume determination:

The outstanding method of computing shale volume is to use Neutron Density cross-plot technique, provided very important values: [18] a clean sand line is typically established using the common sandstone parameters for density (2.65g/ cm^3) and neutron (≅ 0.07) where as a clay line is established from dry solid point (density =2.3~2.85 g/cm^3 neutron≅ 0.1-0.4)to the 100%porosity fluid point. See Figure 3. So then shale volume for Bentiu formation is estimated by:

$$VclND = \frac{(Dencl2-Dencl1)*(Neu-Neucl1)-(Den-Dencl1)*(Neucl2-Neucl1)}{(Dencl2-Dencl1)*(Neuclay-Neucl1)-(Denclay-Dencl1)*(Neucl2-Neucl1)} \quad (1)$$

Where, Dencl1&Neucl1 and Dencl2&Neucl2 are the density and neutron values of the ends of the clean lines. Figure 4 illustrates the shale volume parameters for Bentiu formation in well Najah1, which have been determined statistically using cross plot and compared with the histograms for neutron, and density individual.

Porosity:

Porosity can be determined from density, neutron and sonic individually or from cross plot. The neutron –density cross plot is the best method for determine porosity. The effective porosity for the mineral mixtures was calculated from the Individual mineral porosities according to equation 2.

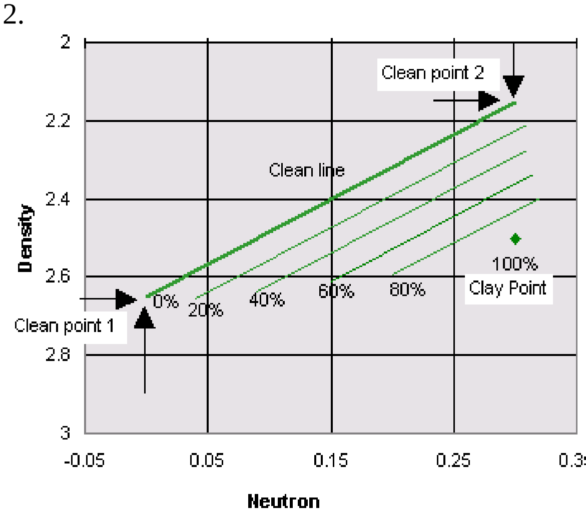


Figure 3: Typical frequency cross plot for neutron porosity vs. density [5].

$$\emptyset_e = \emptyset D_1 + \frac{(\emptyset N_1 - \emptyset D_1)}{1-(\emptyset N_1 - \emptyset N_2)/(\emptyset D_1 - \emptyset D_2)} \quad (2)$$

where; $\emptyset D_1$: Density porosity for matrix mineral 1m $\emptyset D_2$: Density porosity for matrix mineral 2, $\emptyset N_1$: Neutron porosity for matrix mineral 1, $\emptyset N_2$: Neutron porosity for matrix mineral 2.

Water saturation:

Archie’s equation is the basis for essentially all saturation determination methods, mentioned [2] an equation for determination of water saturation in clean sand as

$$S_w = \sqrt[n]{\frac{aR_w}{\emptyset^m R_t}} \quad (3)$$

R_w = resistivity of connate water ($\Omega.m$), R_t =Resistivity of uninvited formation ($\Omega.m$), m = cementation factor set to 2 in the simple case

n = saturation exponent, set to 2 in the simple case,

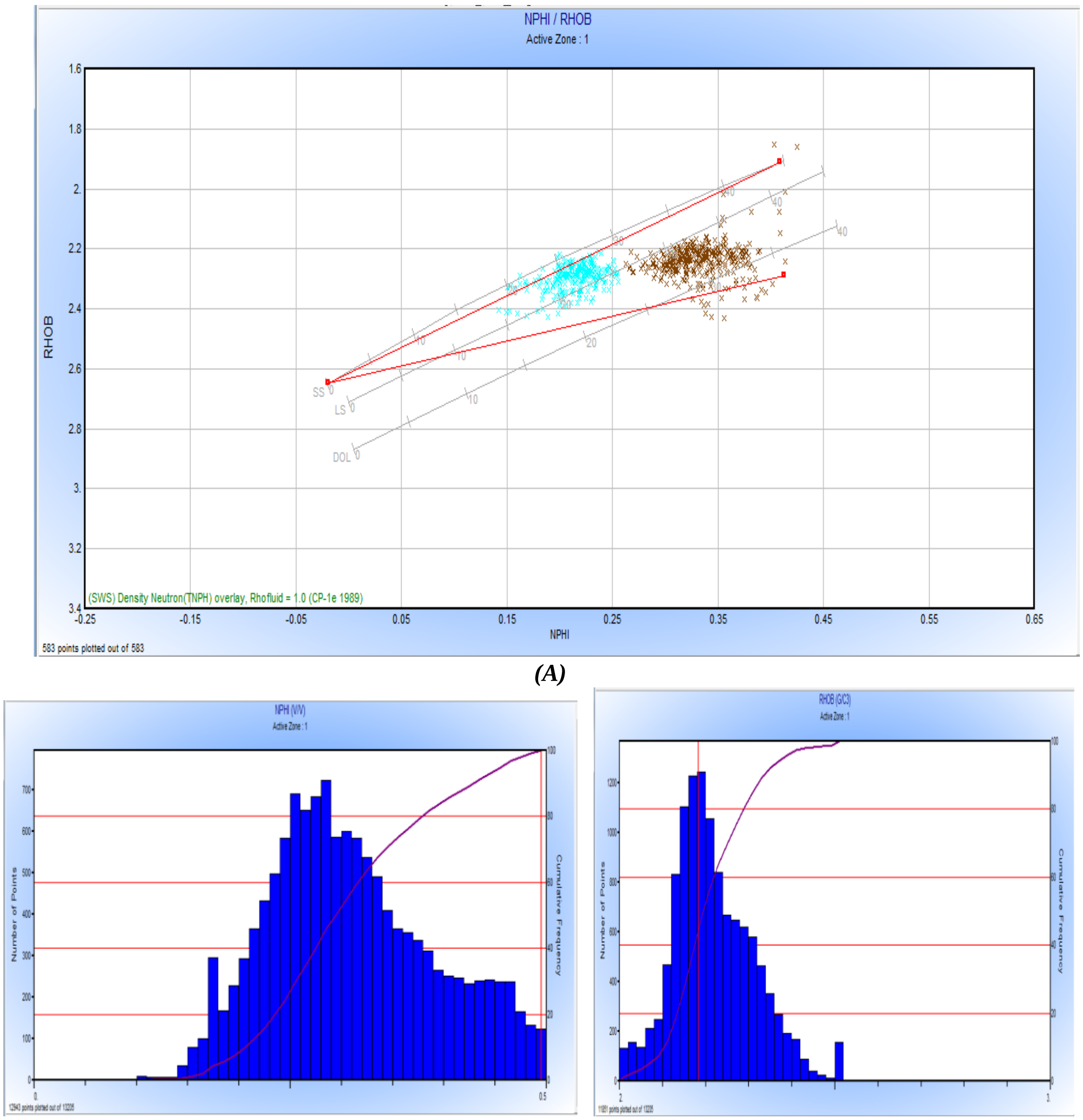
a = constant, set to 1 in the simple case.

Formation water resistivity:

Formation water resistivity can determined from equation 4:

$$R_w = \frac{R_t * R_{mf}}{R_{xo}} \quad (4)$$

where; vR_{mf} = Resistivity of mud filtrate, R_{xo} = Resistivity of flushed zone, The value of R_{mf} and R_w must be corrected by temperature from using



(A)

(B) **(C)**

Figure 4: (A) Neutron-Density cross-plot for Bentiu formation in well Najah1 compared to (B) Neutron histogram, and (C) Density histogram.

$$R_2 = R_1[(T_1 + 21.5)/(T_2 + 21.5)] \quad (5)$$

where; R_2 =water resistivity at formation, temperature ($\Omega.m$), R_1 =water resistivity at surface, temperature ($\Omega.m$), T_1 =surface temperature (°C°F)
T_2=formation temperature (°C°F)

$$T_f = G_g * D_f + T_s \quad (6)$$

where; T_f=formation temperature, D_f=formation depth

$$G_g = \frac{BHT - T_s}{T_D} \quad (7)$$

where; $G_{g=}$ Geothermal gradient, BHT =bottom hole, temperature from well logging, Ts =surface temperature, TD=total depth.

Permeability:

Permeability controls how fluid can migrate through the reservoir. Permeability plays an important role in subsurface fluid flow studies, being one of the most important quantities for the predictions of fluid flow patterns. Commonly, the permeability increases with increasing porosity, increasing grain size and improved sorting. The estimation of permeability fields is however critical and necessary for the prediction of the behavior of contaminant plumes in aquifers and the production of petroleum from oil fields.

It is not possible to measure the permeability directly from well logs, In this study the Timur's equation 8 Oil equation which are experimental relations have been used to calculate the permeability due to lack of valuable core permeability's [4], [7]

$$K = 8581 * \frac{\emptyset e^{4.4}}{Swi^{\wedge}2} \quad (8)$$

Where; K = permeability, $\emptyset_e$ = effective porosity, S_{wi}= irreducible water saturation.

RESULTS

According to methods described in above sections. Data have been processed. Figures 5 - 7, and tables 2 through 4 represent the petrophysical properties which have been obtained from processing. Table 1 illustrates formation interval.

TABLE.1BENTIU FORMATION THICKNESS THROUGH WELLS

Well name	Top	Bottom	thickness
Najah-1	1430	2061	631
Falah-1	1746	2310	546
Rabah-1	1807	2693	886

DISCUSSION

Bentiu formation shows the maximum thickness inRabah-1(886m) and minimum thicknessFalah-1(546m). The upper section of Bentiu formation is sandstone and shale interbedded, and the lower section is considerably sandstone with interbedded shale. Shale has resistivity ranges from (4-12ohm.m) and density range from (2.19-2.3g/cm3), and sandstone has density vary from (2.2-2.4g/cm3), resistivity range from (6-13ohm.m) and low GR.

All wells were penetrated Bentiu formation; Table 1 shows its interval. Results in Tables 2, 3 and 4 show balanced trend parameters, thus Bentiu formation can be describe as a homogeneous formation has shale volume of 30%, average porosity of 20%, which agreed with [10]. Permeability varies from 0 to264 md. So it is a good reservoir

Saturation results which appear in Tables 2 to 4 show that formations are full saturated with water. This indicates another output; either wells drilled in wrong locations so they penetrate water zones in spied of oil zones, or the fields are already empty from oil. Porosity results in Rabah-1 which located in Tables 4 show that effective porosity and total porosity are equal in both formations. This reflects to a secondary porosity operations.

CONCLUSIONS

The qualitative well log interpretation was studied through a correlation to display the homogeneity and similarity of the log responses in the different rock units. The physical properties of Bentiu formation were studied; the logs responses of this formation indicate the response of changing lithologies represented by sandstone and shale.

The density neutron techniques have been the ideal two curves shale indicator method to calculate the shale volume. Porosity can be estimated in sand and shale formations using different methods (sonic, neutron and density and the combination method (neutron density cross plot). The porosity obtained from each method including shale effect is called effective porosity.

The saturation can be determined from various methods, but the simple method used to calculate the water saturation is Archie's equation.

Permeability estimated from well log using Timur's equation, which is a function in effective porosity and water saturation.

REFERENCES

[1] Abdelhakam E. Mohamed and Ali Sayed Mohammed (2008), Stratigraphy And Tectonic Evolution Of The Oil Producing Horizons Of Muglad Basin, Sudan, Journal of science and technology9(1):1-8.

[2] Archie, G.E, (1942), The Electrical Resistivity Log as an Aid in Determining some Reservoir characteristics :54-62.

[3] Asquith, G. 1982, Basic Well Log Analysis for Geologists the American Association of Petroleum Geologists, Tulsa, Oklahoma, USA. pp 216.

[4] Baker Hughes INTEQ. (1992), Advanced Wire line & MWD Procedures Manual. Technical Publications Group. Houston, USA.

[5] Aigbedion S.E. Iyayi (2007), Formation Evaluation of Oshioka Field Using Geophysical Well Logs. Middle-East Journal of Scientific Research2 (3-4):107-110.

[6] Ishwar N.B. and Bhardwaj (2013), Petrophysical Well Log Analysis for Hydrocarbon exploration in parts of Assam Arakan Basin, In: 10th Biennial International Conference & Exposition, India..

[7] Monireh Ataei (2012),Log Facies Evaluation and Property Modelling of a Turbidite Reservoir, the Gulf of Mexico. Norwegian University of Science and Technology. Norwegian.

[8] Motaz Eltahir Bakri Ahmed (2013), Comprehensive petrophysical evaluation of reservoir formation utilizing well logs and reservoir engineering data – a case study in palouge-fal field, Melut basin, south east of Sudan. SudanUniversity of science and technology, sudan

[9] Rashid A.M.Hussein and Motaz Eltahir Bakri Ahmed (2012), Petrophysical evaluation of shaly sand reservoirs in palouge-fal oil field, Melut basin, south east of sudan. Journal of science and technology 13:1-20.

[10] Robertson Research International PLC (1988), The Geology and petroleum potential of Southern, enteral and eastern Sudan, 3.

[11] Schlumberger Educational Services, 1989, Log Interpretation Principles/Applications

[12] Schlumberger. (1999) edit, Oilfield Review Winter Petrophysics and fundamentals of well logs interpretation.

[13] Schlumberger. (2008), Interactive Petrophysics user manual version 3.5. Ternan House. Banchory, Scotland.

[14] Schull, T.J, (1988), Rift basins of interior Sudan: petroleum exploration and discovery. AAPG Bulletin72:1128-1142.

[15] O. A. Anyiamand A. W. Mode and A. C. Ekwe (2010), Formation evaluation of an onshore appraisal well 'KG-5', "green field", Niger Delta, Nigeria. American journal of scientific *and industrial research* **1(2)**: 262-270.

TABLE 2: ILLUSTRATE PETROPHYSICAL PARAMETERS FOR BENTIU FORMATION IN NAJAH1. (STATISTICAL)

	Vsh%	PHIT%	PHIE%	S_w%	K,md
Min	10	13	11	100	112
Max	60	31	27	100	264
average	31	24	19	100	7.22

TABLE 3: ILLUSTRATE PETROPHYSICAL PARAMETERS FOR BENTIU FORMATION IN FALAH1. (STATISTICAL)

	Vsh%	PHIT%	PHIE%	S_w%	K,md
Min	6	10	5	100	0
Max	57	25	22	100	122
average	30	18	15	100	87.9

TABLE 4: ILLUSTRATE PETROPHYSICAL PARAMETERS FOR BENTIU FORMATION IN RABAH1. (STATISTICAL)

	Vsh%	PHIT%	PHIE%	S_w%	K,md
Min	5	12	12	100	8.7
Max	57	26	26	100	223
average	31	19	19	100	90.6

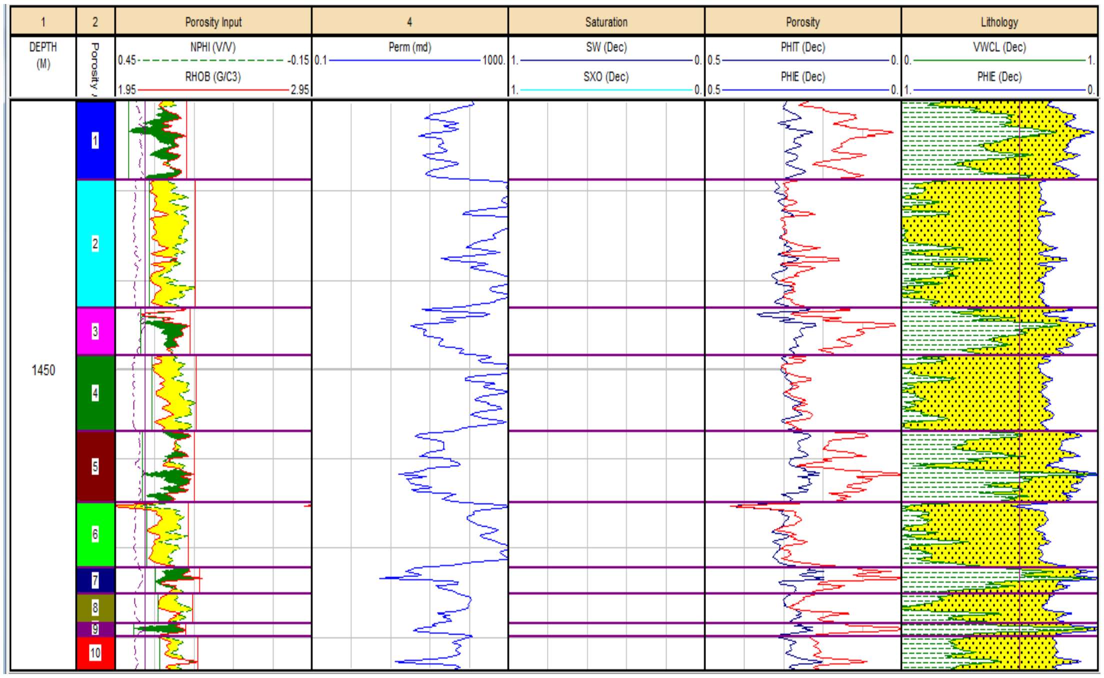


Figure 5: Petrophysical parameters for Bentiu formation (Najah-1)

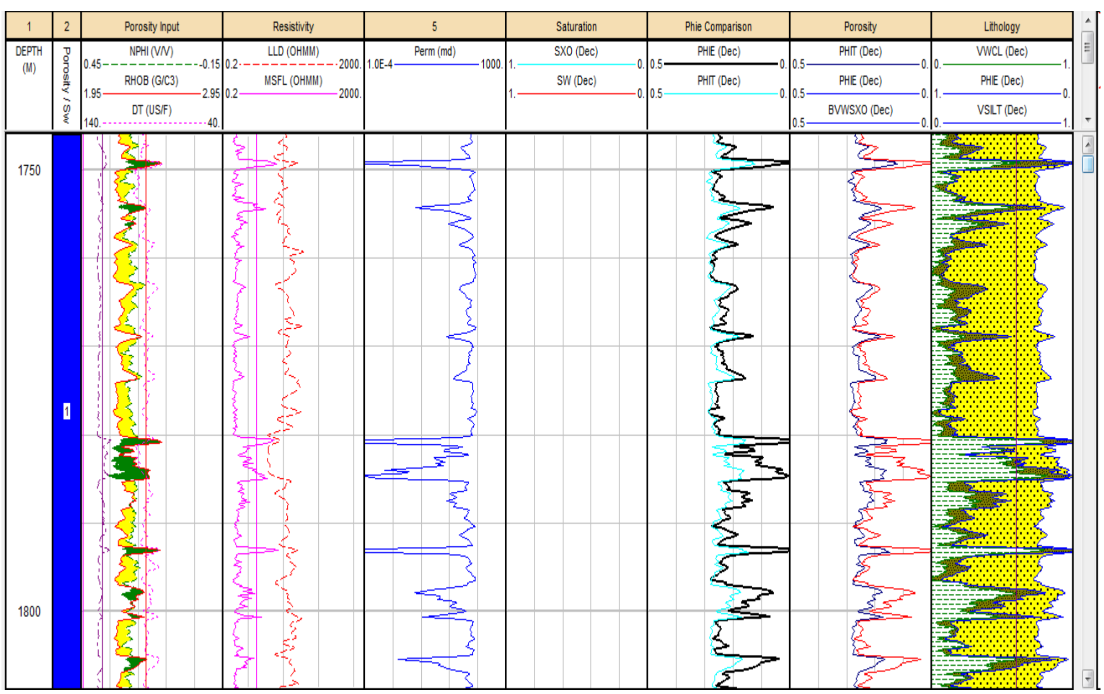


Figure 6: Petrophysical parameters for Bentiu formation (Falah-1)

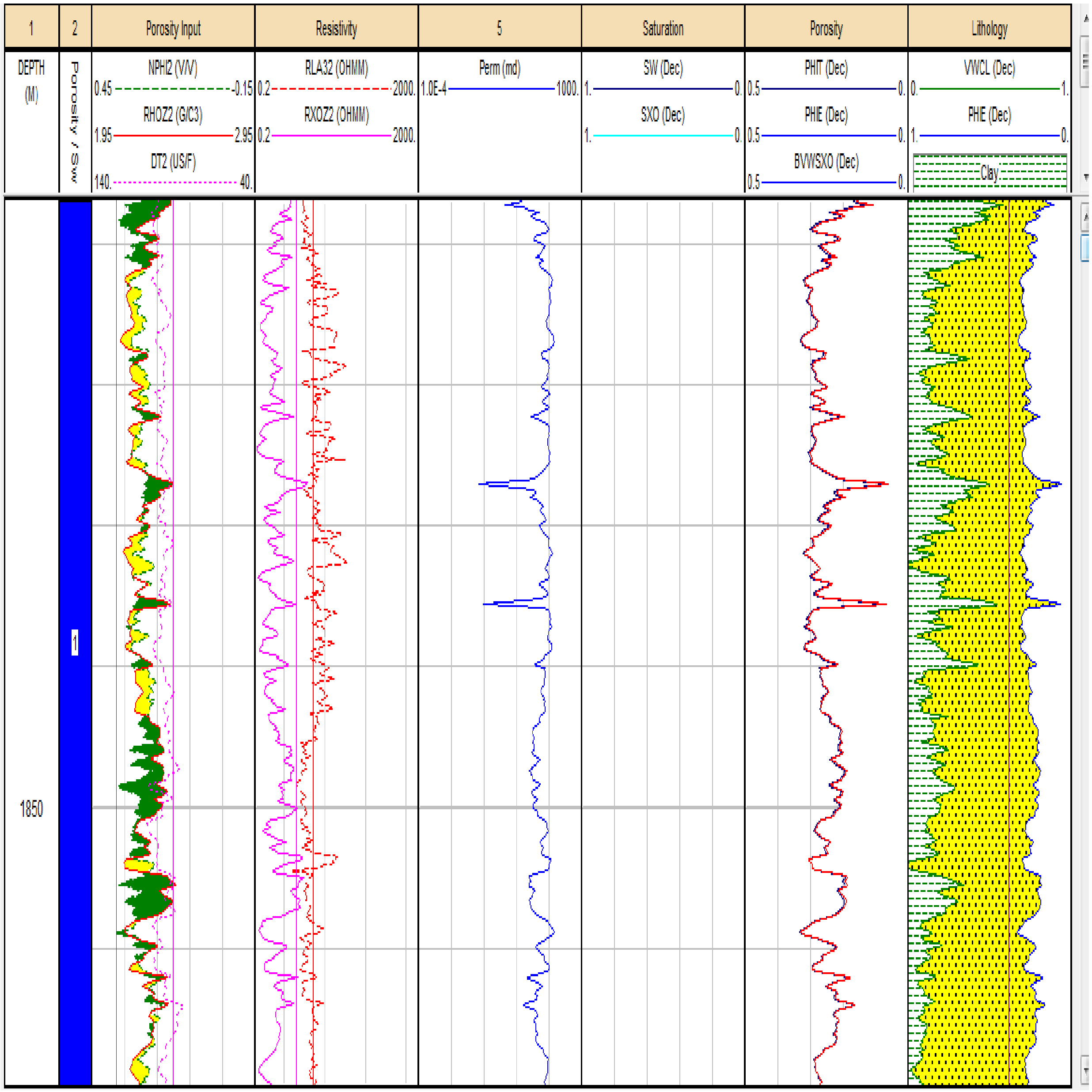


Figure 7: Petrophysical parameters for Bentiu formation (Rabah-1)