

REVIEW ARTICLE

## WELL LOGS ANALYSIS TO ESTIMATE THE PARAMETERS OF SAWAN-2 AND SAWAN-3 GAS FIELD

Raja Asim Zeb<sup>a</sup>, Muhammad Haziq Khan<sup>b</sup>, Intikhab Alam<sup>c</sup>, Ahtisham Khalid<sup>a</sup>, Muhammad Faisal Younas<sup>c</sup>

<sup>a</sup> Institute of Earth Sciences, University of Poonch Rawalakot AJK

<sup>b</sup> Faculty of Geosciences and Environmental Engineering, Southwest Jiaotong University, Chengdu China

<sup>c</sup> The Institute of Geology, University of Azad Jammu and Kashmir AJK

\*Corresponding Author Email: [haziqkhan912@gmail.com](mailto:haziqkhan912@gmail.com)

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ABSTRACT

The lower Indus basin is leading hydrocarbon carriage sedimentary basin in Pakistan. Evaluation of two sorts out wells namely Sawan-2 and Sawan-3 has been assumed in this work for estimation and dispensation of petro physical framework using well log data. The systematic formation assessment by using petro physical studies and neutron density cross plots reveal that lithofacies mainly composed of sandstone. The hydrocarbon capability of the formation zone have been mark through several isometric maps such as water saturation, picket plots, cross plots, log analysis Phie vs depth and composite log analysis. The estimated petro physical properties shows that reservoir have volume of shale 6.1% and 14.0%, total porosity is observed between 14.6% and 18.2%, effective porosity ranges 12.5-16.5%, water saturation exhibits between 14.05% and 31.58%, hydrocarbon saturation ranges 68.42% -86.9%. The lithology of lower goru formation is dominated by very fine to fine and silty sandstone. The study method can be use within the vicinity of central Indus basin and similar basin elsewhere in the globe to quantify petro physical properties of oil and gas wells and comprehend the reservoir potential.

KEYWORDS

Petrophysical Evaluation, Central Indus basin, Lower Goru formation, Reservoir Potential

1. INTRODUCTION

The petro physical constant appraisal from well logs is a key part of the hydrocarbon exploration and production which comprehend the subsurface reservoir properties like porosity, permeability, water and hydrocarbon saturation etc. In 1927, Schlumberger brothers initially instigate wire line logging in Alsace, France. It can be executed by visual examination of samples acquired to the surface from subsurface (e.g., cuttings logs, core logging or petro physical logging) or by lowering the equipment's into the borehole (Ofwona, 2010). Basically, there are three types of logging that included open hole logging, cased hole logging and production logging. Frequently used logs include Gamma ray (GR), density (RHOB), sonic (DT), neutron (NPHI), resistivity, caliper log and cement bond log (Rider, 1996). The present research work is supervised by make use of conventional logs run in the Cretaceous Lower Goru Formation perforate in Sawan-2 and Sawan-3 wells of the Sawan Gas Field, Central Indus Basin, Pakistan. Sawan Gas Field is located at latitude (27°02'22.7"N) and longitude (68°58'19.5"E) in Central Indus Basin, Khairpur, Pakistan. The Central Indus Basin comprised of Sulaiman Fold Belt, Sulaiman Fore deep and Punjab Platform shown in (Figure 1). It is adjoining by Sargodha High and Pezu uplift; Indian Shield; Indian Plate marginal zone and Sukkur Rift in the North, East, West and South respectively (Kadri, 1995). Accordant with lithology, the Goru Formation is subdivided into Lower Goru and Upper Goru (Kadri, 1995). The Lower Goru Formation on the whole is made up of basal, middle and upper sands unstrung by lower and upper shales. Main hydrocarbon producing zones belongs to the upper sands. This zone consists of sub zones i.e. A, B, C and

D sands divided by Turk, Badin and Jhol shale respectively (Quadri and Shuaib, 1986).

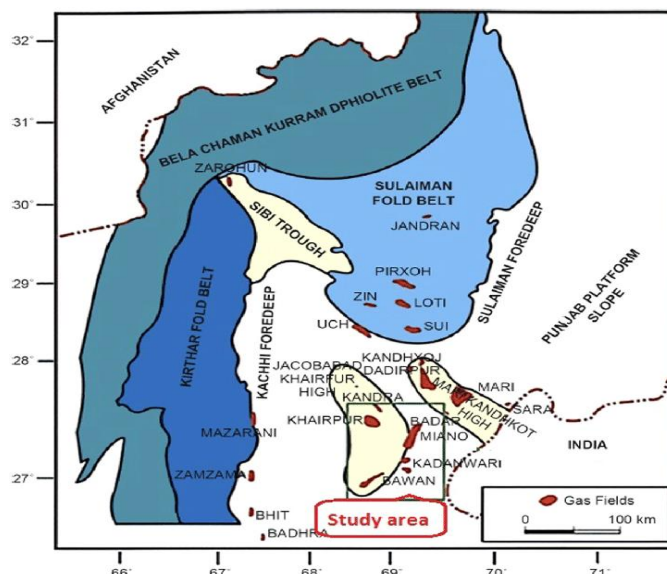


Figure 1: Regional tectonic map showing the location of Sawan Gas Field (Krois et al., 1998).

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In the subsurface of the Southern Sindh Monocline (Lower Indus Basin, Pakistan), a studied environments of deposition of Upper sands (B-sand) of Early Cretaceous Lower Goru Formation (Solangi et al., 2016). They concluded that the Lower Goru Formation (Bsand) is a reservoir facies and deposited as barrier bar and transgressive facies in deltaic to shallow marine conditions. In Sanghar Block of the Lower Indus Basin, some researchers evaluated the petrophysical properties of the Lower Goru Formation penetrated in Fateh-01 and Panairi-01 wells (Nisar et al., 2016). According to them, the Lower Goru Formation is water-saturated in the drilled wells. A group researchers conducted the petrophysical characterization of the Lower Goru Formation in Sawan-03 and Sawan-07 wells and determined that the subject formation has good effective porosity but low water saturation (Abbas et al., 2015). A group researchers worked out the sedimentological investigation of the Lower Goru Formation (upper sands) using ditch cuttings and geophysical logs penetrated in the Sindh Monocline, Southern Indus Basin, Pakistan (Sahito et al., 2013). According to them, the sands are moderate to well sorted, sub-angular to well-rounded with mean sand grain size varying from fine to medium grained.

**1.1 Geology and tectonic setting**

A geologically depressed area with thick sediment in the center and thinner towards edges called a sedimentary basin. This formation is precisely fit for Baluchistan and Indus basin where stratigraphic record is not much influenced by tectonic activities (Shah, 2009). Due to intense phase of quartz overgrowth the initial porosity was lost. In addition, 5 to 10% porosity was found due to secondary alteration and finally it was concluded that lower goru is tight sand reservoir and will produce in future with proper fracturing job (Mohsin, et al 2010). A comparison of core and well log permeability of sawan tight sand of lower goru has done core-log and well test permeability are not usually the same because core-log gives absolute while well test data provide effective permeability profile of reservoir rock. The noticeable difference has been detected in core-log permeability and well test permeability was also compared with other industry reported case (Ahmed et al., 2010). The use of spectroscopy log provides accurate petrophysical evaluation by characterizing the rock matrix in terms of lithology and matrix properties which in turn is very important for accurate calculations of porosity and permeability (Aziz et al., 2011). Pakistan is unique because it's located at the junction of these two diverse domains the southern part of it belong to gondwanian domain and it is sustained by indo-pak crustal plate. Second is tethyan domain which is consisting of complex geology of northern and western part of Pakistan (Kazmi and jan, 1997). The subduction of northern edge finally closed the Neo-Tethys Ocean and Indian Ocean and collision structured the Himalayan and other mountain ranges. This gives rise to thrust belts dipping in north-south direction (Shami and Baig, 2002). Out crops of sedimentary rocks in Punjab platform are not exposed on surface and are covered with thick alluvium deposit of clay silt and sand layers. Tectonically it is broad monoclinic dipping gently toward the sulmain depression (Raza et al., 1989). Seismic evidences of this area are buried anticlines that might form at the expense of flow of Eocene shale (Kadri, 1995).

**1.2 Stratigraphic correlation**

The stratigraphy of study area is comprised from the rock ranging from sember formation to alluvium (Wandery et al., 2004). Effective sealing mechanism provided by transgression shale of the upper and lower goru for the entrapment of hydrocarbon in the lower goru sand reservoir (Nisa, 1986). The maturation of the source rock started in cretaceous time and reached its peak during Eocene-Miocene time (Kadri, 1995). The lower goru formation proposing great to brilliant source potential have favorable porosity and permeability to store and transmit fluid at the same time.

**2. MATERIALS AND METHODS**

Log based petro physical analysis were conducted on the data from two wells located in the central Indus basin namely Sawan-2 and Sawan-3. The well log data comprises of conventional logs such as neutron, density, sonic, gamma ray and resistivity (shallow and deep). These data sets were provided by DGPC Pakistan. Kingdom SMT 8.2 was used for developing the burial history model while the interactive petrophysics was used to conduct qualitative and quantitative reservoir evaluation. Lithological composition was identified based on Schlumberger charts such as (NPHI vs. RHOB) neutron vs. density. Moreover, neutron density initial model was used to derive the total and effective porosities. A 10% porosity cut-off was applied to identify more porous and promising zones within the

reservoir (EL-Din et al., 2013). The density porosity was calculated by using Wyllie's equation while the neutron porosity was estimated based on response given by neutron tool (Wyllie's 1963).

$$\phi D = (\rho_{ma} - \rho_b) / (\rho_{ma} - \rho_f)$$

Where  $\phi D$  density porosity,  $\rho_{ma}$  is the matrix density,  $\rho_b$  is bulk density and  $\rho_f$  is the mud filtrate density. Moreover, it is essential to determine the type of shale distribution within the reservoir. Relation between SP and Gamma ray logs was used to determine the shale habit in the reservoir. In the present study Sawan-2 and Sawan-3 were subjected to dual water saturation model (Clavier et al., 1984). In addition, 50% cut-off was applied to differentiate between sandy and shaly zones its mean that rocks displaying more than 50% of shale content were considered as non-reservoir rocks while the rocks with equal or less than 50% of shale were considered as promising reservoir.

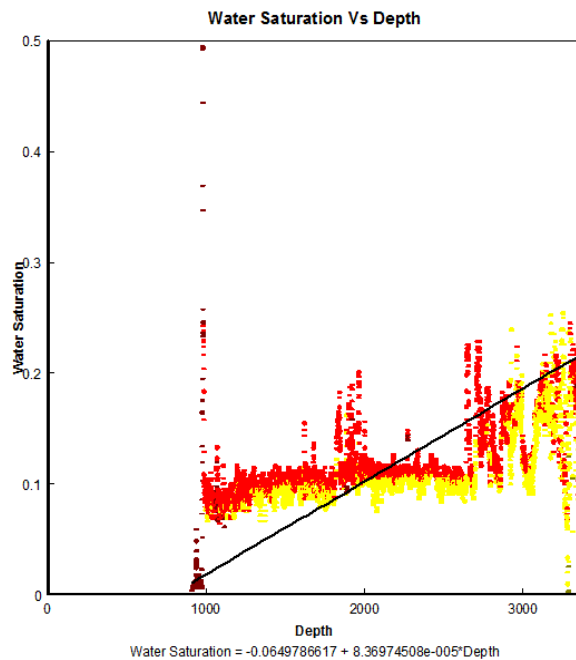


Figure 2: Shows relationship b/w water saturation and depth.

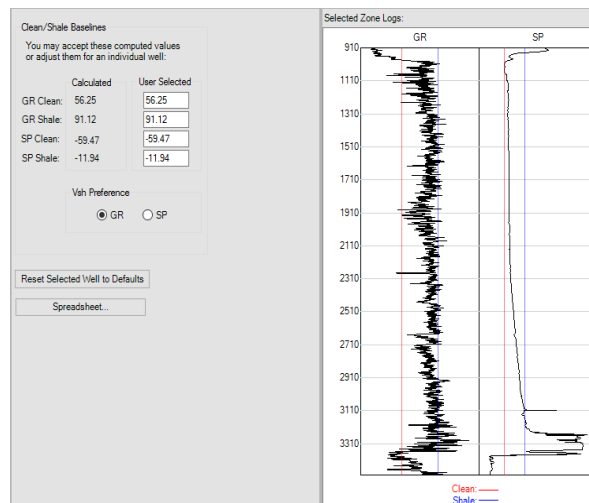


Figure 3: Shows relationship b/w Gamma ray log and SP log indicating the volume of shale

The water saturation of uninvaded zone ( $S_w$ ) in the lower goru formation was estimated by using dual equation while the hydrocarbon saturation ( $S_h$ ) was estimated by the equation given below (Rider 1996).

$$S_h = 1 - S_w$$

In addition, residual hand moveable hydrocarbon saturation was also calculated by following equations (Asquith and Krygowski, 2004).

$$S_{hr} = 1 - S_{xo}$$

$$Sh_m = S_{xo} - S_w$$

Moreover bulk volume of water in uninvaded and flushed zone was calculated by multiplying  $S_w$  and  $S_{xo}$  with the effective porosity  $\phi_e$  using the equations below (Asquith and Krygowski, 2004).

$$BVW = S_w \times \phi_c$$

$$BVSXO = S_{xo} \times \phi_c$$

After 50% water saturation cut-off was applied to distinguish between water wet and hydrocarbon bearing zones.

### 3. RESULT AND DISCUSSION

#### 3.1 Neutron (NPHI) versus Density (RHOB) cross-plot

The neutron (NPHI) versus density cross-plot shows that the Lower Goru Formation within the selected wells appears to be dominantly composed of sandstone with carbonates (Limestone and Dolomite) as shown in figure 4 the NPHI vs. RHOB cross-plot also indicates the presence of subordinate shale's. This cross-plot also helps in estimating a relationship between different lithology and porosity types (Hakimi et al., 2017; Al-Qayim and Rashid, 2012). Since the cross plot indicate the presence of both sandstone and carbonates which also indicate the presence of both inter granular and secondary porosities with an equal proportion.

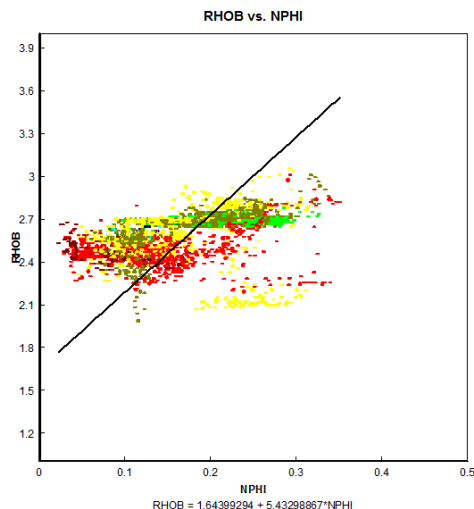


Figure 5: Cross plots shows the lithology / matrix index

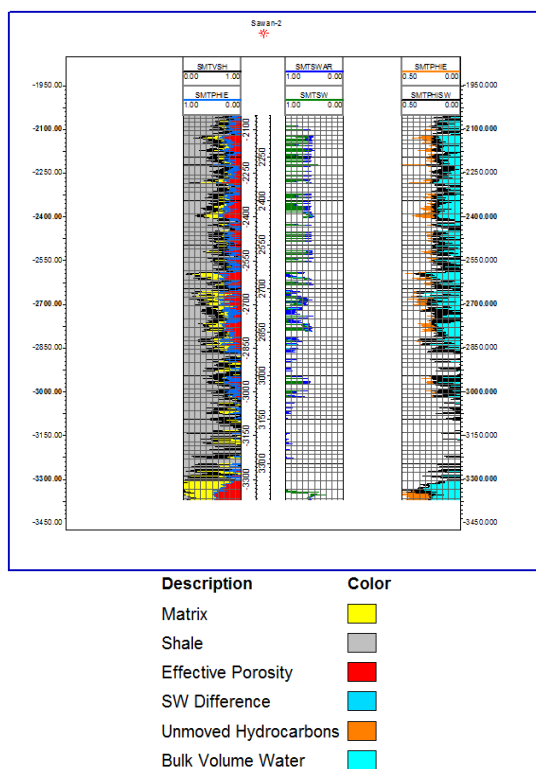


Figure 6: Shows Petrophysical results of the derived well logs (Sawan-2)

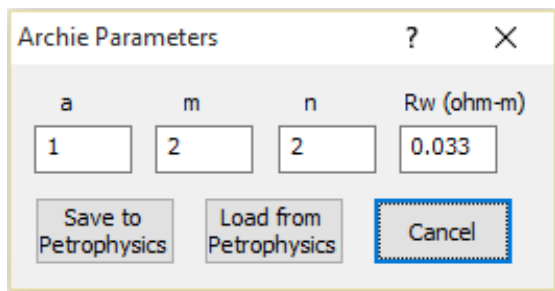
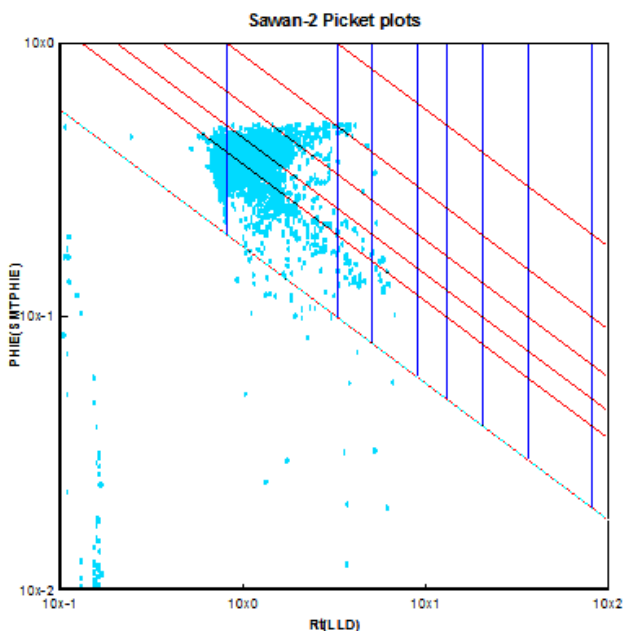


Figure 4: Picket plots shows resistivity of water/ water saturation

#### 3.2 Gross and net pay thickness

Net pay is important parameters when it comes to evaluate the reservoir potential as it identifies the zones having enough hydrocarbon volume and acting as producing intervals (Worthington, 2010). Net pay is a sub interval within the gross thickness and is quantified by applying petro physical cut-offs to well log data  $\Phi_i < 10\%$ ,  $V_{sh} < 30\%$ ,  $S_w > 50\%$ . In the present study a total twenty-three net pay sun intervals have been identified in Sawan-2 (8 pay zones), Sawan-3, and the highest number of pay zones identified in Sawan-2. The results indicate the total net pay zones for studied well range between 36.76 and 140.06 m.

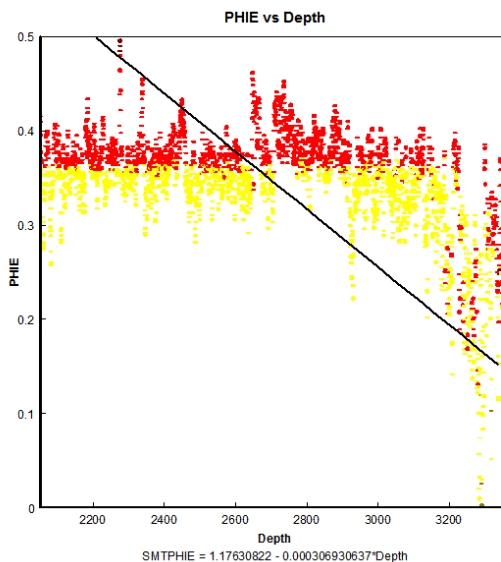


Figure 7: Shows relationship b/w PHIE and Depth.

### 3.3 Volume of Shale's

In figure 8, curve is giving response with respect to shale volume. Density of the shales is higher than that of limestone or sandstone. From depth 3365 to 3410m in Figure 8, curve is in the right side of the red line which mean density of shale is higher because of lower volume of shale, representing sand lithology. The again from 3350 to 3600 m, curve is moving to right side of the red line giving higher values of density of shale representing high volume of shales.

Table 1: Result shows petrophysical parameters of Sawan-2 and Sawan-3 wells				
Parameters Average	Range	Average	Range	
Sawan-2		Sawan-3		
RHOB	2.1-3	0.6	2.1-3.3	3.75
NPHI	0-0.3	0.15	0-0.4	0.2
BVW	30-75	67.5	40-70	75
GR Clean	3110-3350	80-85	1300-3600	50-55
Sw	25-40	32.5	25-40	45
Hc	60-75	97.5	60-75	25-40
Total porosity	15-25	27.5	18-26	31
Effective porosity	30-35	47.5	30-40	50
Depth	910-3100	-	0-3600	-
Phie	0.2-0.5	0.45	0-0.3	0.15
Rt LLD	25-50	50	15-30	30

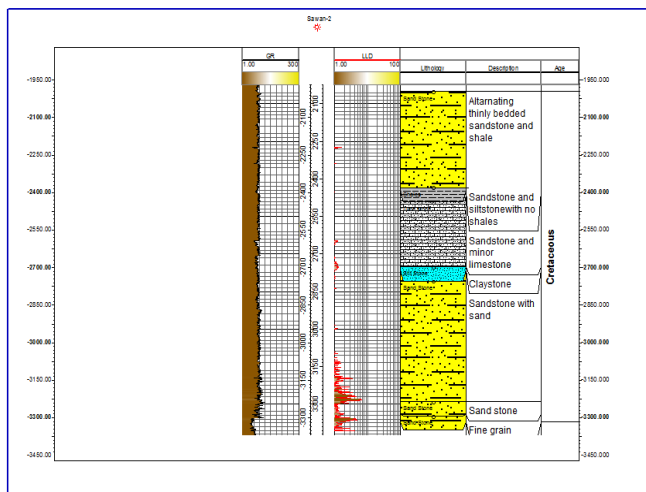


Figure 8: Composite log shows the stratigraphic columns.

### Sawan-3 Figures

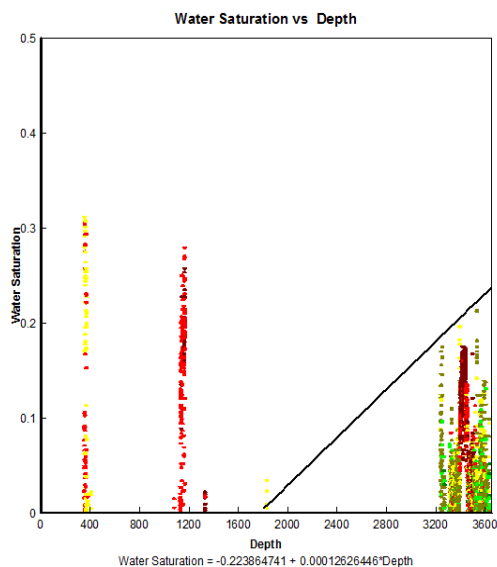


Figure 9: Shows relationship b/w water saturation and depth.

### 3.4 Log derived porosity estimation (Total and Effective)

The total and effective porosities range from 14.6 to 19.03 respectively. The type of porosity within the reservoir formation has been estimated by Neutron density log and depth vs. PHIE log (Figure 2).

### 3.5 Fluid saturation Estimation

Low goru formation act as a reservoir because of 55% sandstone with 9% effective porosity. Percentage of water saturation in this unit is 25 to 35% which mean hydrocarbon are present (Figure 10). While percentage of water saturation in the pores is 1%.

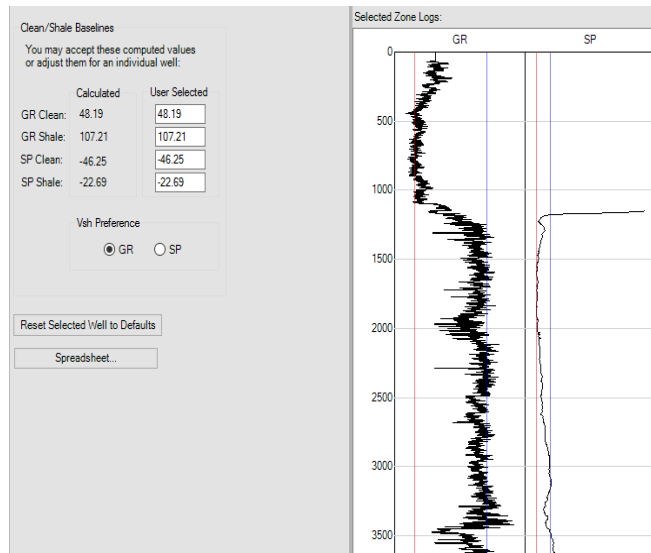


Figure 10: Shows relationship b/w Gamma ray log and SP log indicating the volume of shale

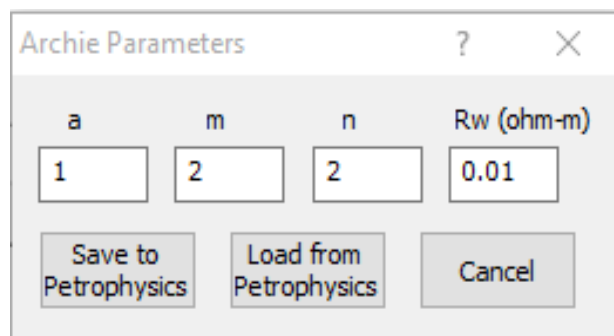
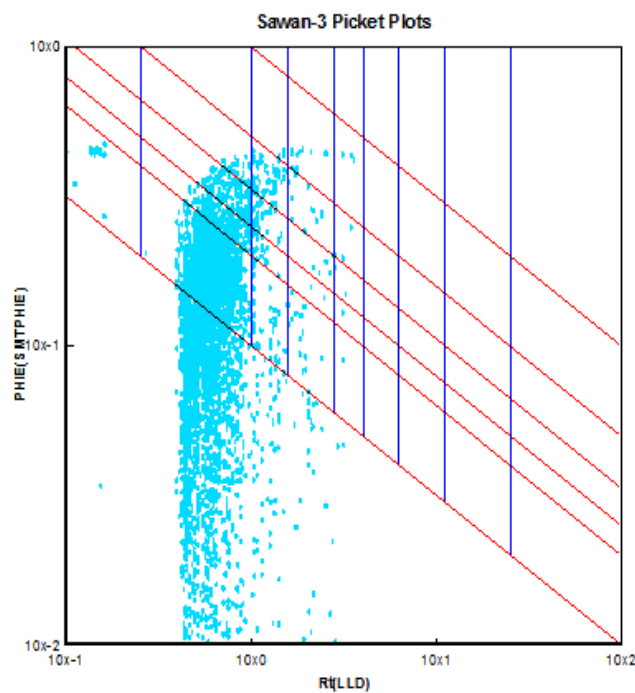


Figure 11: Picket plots shows the resistivity of water

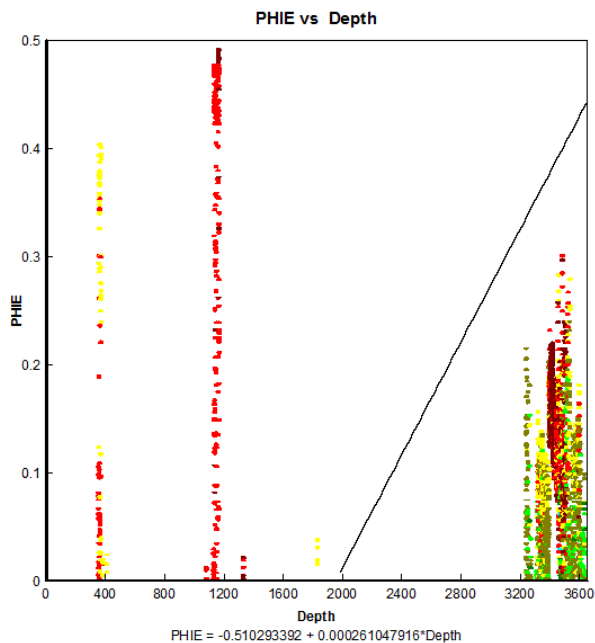


Figure 12: Shows relationship b/w PHIE and Depth.

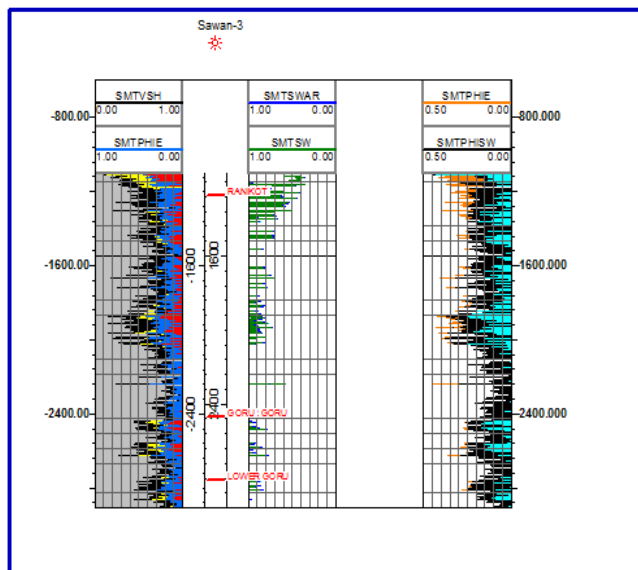


Figure 13: Shows Petrophysical results of the derived well logs (Sawan-3)

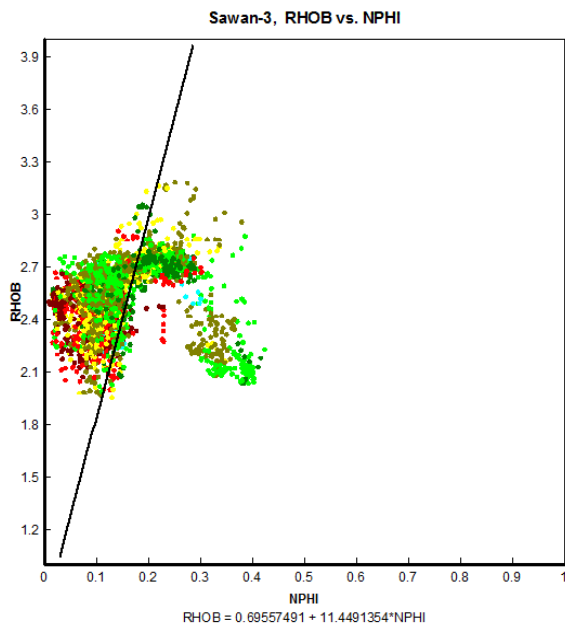


Figure 14: Cross plots shows the lithology / matrix index

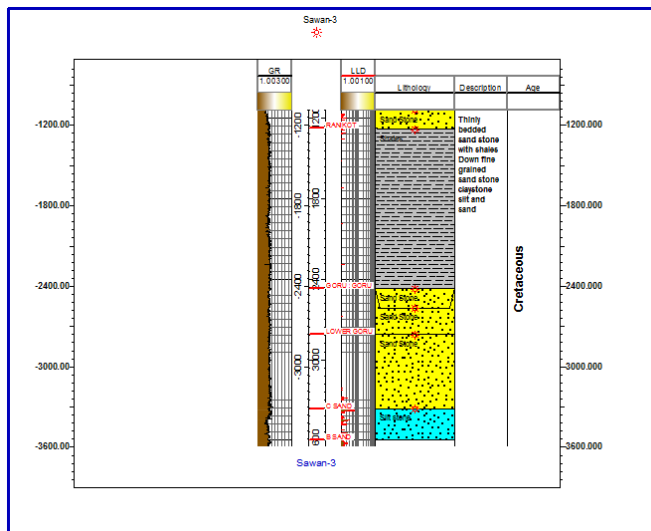


Figure 15: Composite log shows the stratigraphic columns (Sawan-3).

#### 4. CONCLUSION

Present study reveals the reservoir characteristics of Sawan-2 and Sawan-3 wells of central Indus basin of Pakistan. A total twenty-three net pay sum intervals have been identified in Sawan-2 (8 pay zones), Sawan-3,(15) pay zone and the highest number of pay zones identified in Sawan-2. The results indicate that the total net pay zones for studied wells range between 36.76 and 140.06 likewise cross plots reveal that the formation of interest is mainly composed of sandstone, shale and carbonates. The volume of shale has been estimated between 6.1% and 14.0% from the studied wells. Similarly, the total porosity is observed between 14.6% and 18.2% while the effective porosity ranges 12.5-16.5%. The water saturation exhibits between 14.05% and 31.58%. Moreover, the hydrocarbon saturation ranges 68.42% -86.9% in the studied wells. 23 pay zones with variable thickness and significant hydrocarbon presence have been identified within the studied wells, thus proving the Lower Goru Formation as a promising reservoir. Lower goru formation act as a reservoir because of 55% sandstone with 9% effective porosity. Percentage of water saturation in this unit is 25 to 35% and hydrocarbon saturation is 70-75% which means that hydrocarbon is present while only 1% pores are saturated with water. Results reveal that wells are favorable for hydrocarbon extraction.

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