IDENTIFICATION OF UNCONVENTIONAL SHALE-GAS PLAYS AND RESERVOIR CHARACTERIZATION THROUGH ΔLOGR METHOD AND WELL LOG INTERPRETATION : A CASE STUDY FROM LOWER INDUS BASIN, PAKISTAN

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ABSTRACT

Unconventional reservoirs mostly consist of fine-grained wealthy with organic shales trapped gas are considered as source, seal, and the reservoir rock. Integration of well logs played an important contribution in evaluation of unconventional reservoirs in order to identify the shale deposited basinward on the basis of their position in Basin, Total Organic Contents (T.O.C), mineralogical composition and reservoir parameters like porosity, saturation, fracture, brittleness, etc. required for optimizing recovery and production of hydrocarbons by integrating of seismic and petrophysical attributes. Seismic data is also used to map the shale gas away from well and identify its distribution with in the basin. In this regard, Passey's method has been used for the identification of T.O.C contents in shale, commonly known as ΔlogR Method used for assessment of shale gas and depends upon cross plot Gamma Ray (GR), Density (DT) and LLD logs. Using cross plots of GR, DT and LLD Zone with high organic matter (OM) has been identified and integrated with results of petrophysical interpretation of Log to identify Shale Gas of producing fields of Sinjoro Blok, Lower Indus Basin of Pakistan.

1. INTRODUCTION

This research work is based on identification of unconventional shale-gas plays and reservoir characterization using petrophysical investigation of logs from Sinjhoro block, Lower Indus Basin, Pakistan. Unconventional reservoirs mostly consist of fine-grained wealthy with organic shales trapped gas are considered as source, seal, and the reservoir rock. Integration of well logs played an important contribution in evaluation of unconventional reservoirs in order to identify the shale deposited basinward on the basis of their position in Basin. Source shales have also been proved to be good reservoir rock though they have tight-porosity, low-permeability and certain quantity of silt. Analysis of source rock parameters is mainly based on organic carbon, maturation of organic matter, geochemical and geophysical parameters in order to find closure for reservoir. The organic carbon of source rock has specific velocity, density and resistivity characteristics which affect log and seismic responses. Thus, source-shale's and shale-gas reservoirs can be analyzed through logs. In this paper, application of integrated well log interpretation techniques has been applied on shale-gas plays of producing fields of Sinjhoro Block, Lower Indus basin of Pakistan [1-2].

2. GEOLOGICAL SETTING OF THE AREA

The study area is the part of Sinjhoro Block located in Lower Indus Basin of Pakistan.. Several Oil and Gas fields were discovered in Lower Indus Basin. Lower Indus is characterized by extensional tectonics [3-6]. Tilted faults have been resulted due to the extensional tectonic in the Cretaceous with in and surroundings of the study area. The deposition of the reservoir Lower Goru sandstones and interbedded source rocks took place in a passive margin region formed during the rifting of the Indian plate from the eastern margin of Africa during the break up of Gondwanaland. Figure 1 is showing Generalized Stratigraphic Cross section of Lower Indus Basin [7-9]

Many of the discoveries from Lower Goru have been successful (Ahmed et al., 2004). Sembar Formation and Interbedded Shale of Lower Goru are proved source rock [10-12] discussed the Shale Gas potential in Central and Lower Indus Basin. Lower Goru sands are considered as Proved Reservoir Rock of Indus Basin. Various Nomenclatures are used for Lower Goru Formation. [6] [9-10] discussed various nomenclature used for description Lower Goru Formation. In this paper "C Sand", the OMV classification of Lower Goru is taken into account which is equivalent to Albian Age. A depth structure map on top of Lower Goru Formation showing drilled wells shown in Figure 2.

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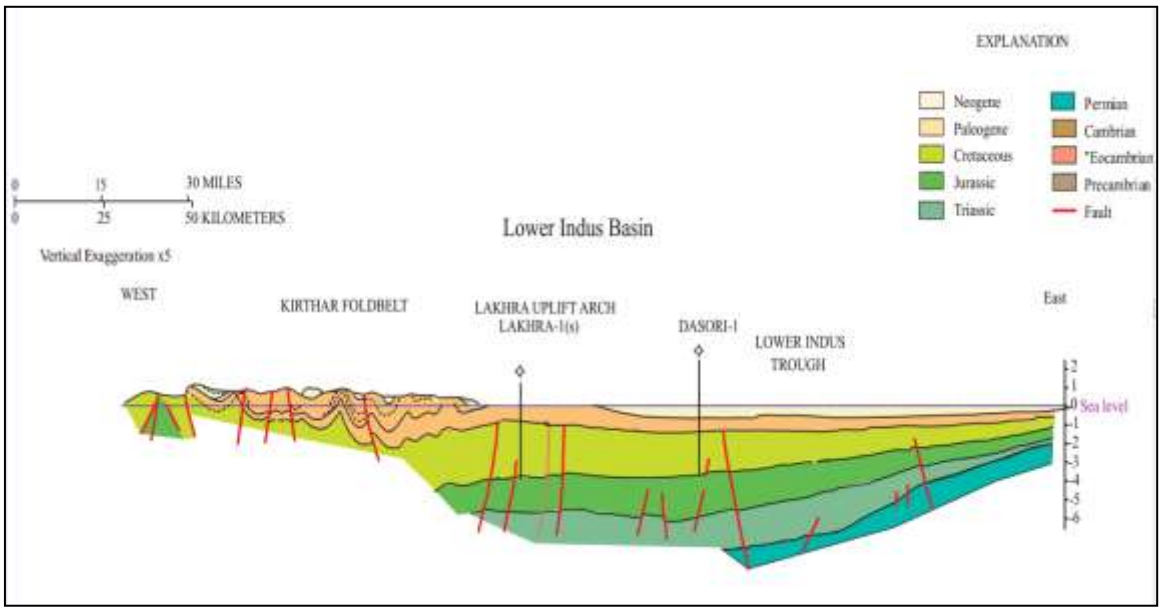

Figure-1: Generalized Cross section of Lower Indus Basin (Kadri, 1995)

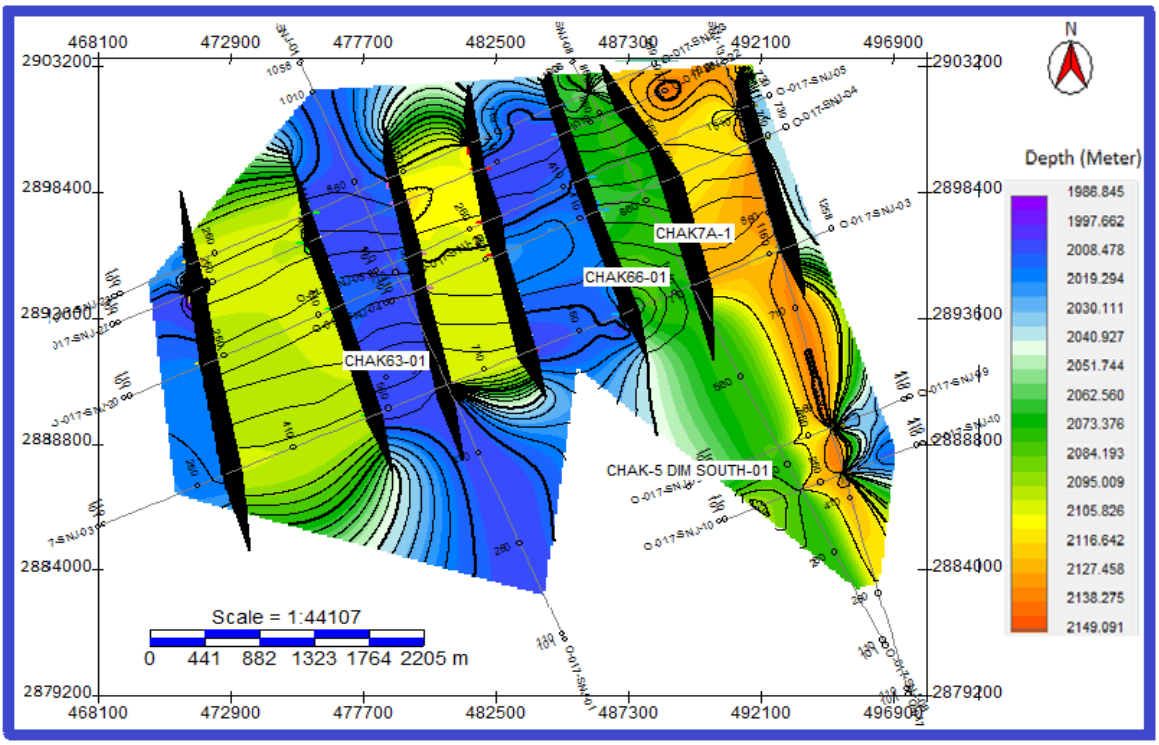

Figure 2: Depth contour map of Lower Goru Formation

3. PETROPHYSICAL INVESTIGATION

All kind of studies carry out to study subsurface data of well using wireline log motifs is called as Petrophysical studies. Such study involves conventional study of formation and specialized study and Advance Studies using specific tools and techniques. Conventional logs (GR , Resisitivity , Sonic , Neutron Porosity and Density log to determine lithology , Porosity, Shale Volume , Water Saturation and contents of moveable and immoveable Hydrocarbons. Calculation of TOC content using Porosity Logs (Sonic, Density) and Resistivity logs is called as specialized study. TOC study involves calibration of values with lab data for precise data. While Elemental Composition Spectrometry (ECS), FMI Imaging are advance tools to study composition of

minerals and subsurface bedding plane character respectively.

3.1 CONVENTIONAL PETROPHYSICAL STUDY

Different logs have been used in order to identify the shale sequences One of the most common cross plot is the RHOB, LLD and GR log cross plot. This cross plot is used in petrophysical analysis for lithology determination and its sequence. Porosity is relatively invariant in different lithology like quartz with shale or calcite. The cross plots are prepared for the reservoir zone of Lower Goru Formation for different wells of Sinjhoro area. The three polygons indicate the lithology variation of Lower Goru and result shows that the formation mainly consists of sand shale sequence with mostly Sandy Shale lithology. CHAK 66-01 cross plot ranges from depth 2000m to 3050m and indicates that the formation mainly consist of shaly sand with bottom part of formation have shale. Only clean sand part is between 2850m to 2900m (Figure 3). CHAK-5 DIM SOUTH-01 cross plot ranges from depth 2050m to 2900m and indicates that the whole formation have shaly sand with a small lense of sand at depth 2870m to 2885m (Figure 4).

After plotting the log curves of wells (Figure 5, 9) Petrophysical results of CHAK 66-01 shows that also there are clean sand in Zone-A because of low shale value and high matrix value indicated but water saturation increases in this zone and hydrocarbon is less in this zone (Figure 6), while Zone-B is mainly based on Sandy Shale and it have good effective porosity with few amount of hydrocarbons are also present which may be recovered (Figure 7) and Zone-C has more Shale sequence than Sand but lower part in this zone has sand packages which also have fair amount of hydrocarbon (Figure 8).

Petrophysical result of CHAK-5 DIM SOUTH-01 shows that Zone-A has good amount of hydrocarbon present at different depths (Figure 10). Mainly 2020m to 2035m where saturation of hydrocarbon is almost 45% and have high sand lithology with almost 90% while its effective porosity is 10% other productive zone in Zone-A is starting from 2180m to 2200m where saturation of hydrocarbon is 45% and have high sand lithology with almost 90% while its effective porosity is 15%. Lower part of this zone starting from 2240m to 2300m also can be very productive as saturation of hydrocarbon is almost 45% and have high sand lithology with almost 90% while its effective porosity is 15%. Zone-B of starting from 2300m to 2600m which have higher amount of hydrocarbon throughout this zone. Lower part of this zone have high amount of shale (Figure 11) and have high amount of hydrocarbon and high porosity as well which means that either this indicates hydrocarbon in shale which needs to study further as shale gas or its data issues. Caliper log shows high deflection in this zone which means that the zone of invasion is high which may act as error for log recording. But if it's tight gas then this whole zone may act as productive zone and Zone-C has higher amount of shale but at few depths sand packages found (Figure 12). So by and large this zone cannot said to be as productive zone but at the lower part of this zone at depth 2790m to 2850m a large sand package is identified which indicates good amount of hydrocarbon with good porosity.

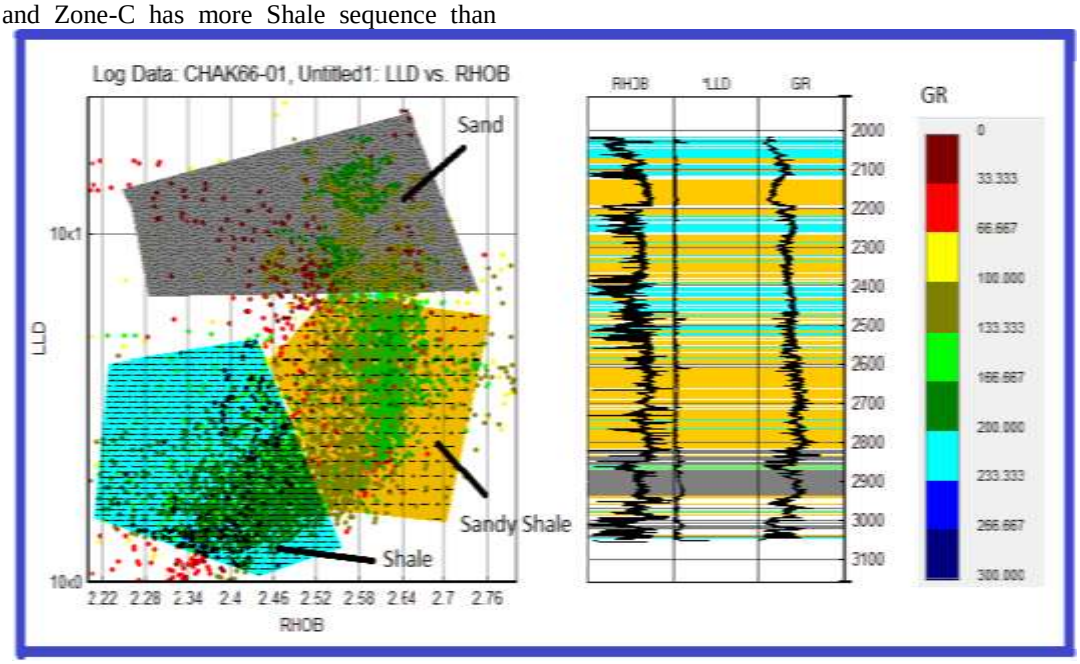

Figure-3: Facies analysis of CHAK 66-01

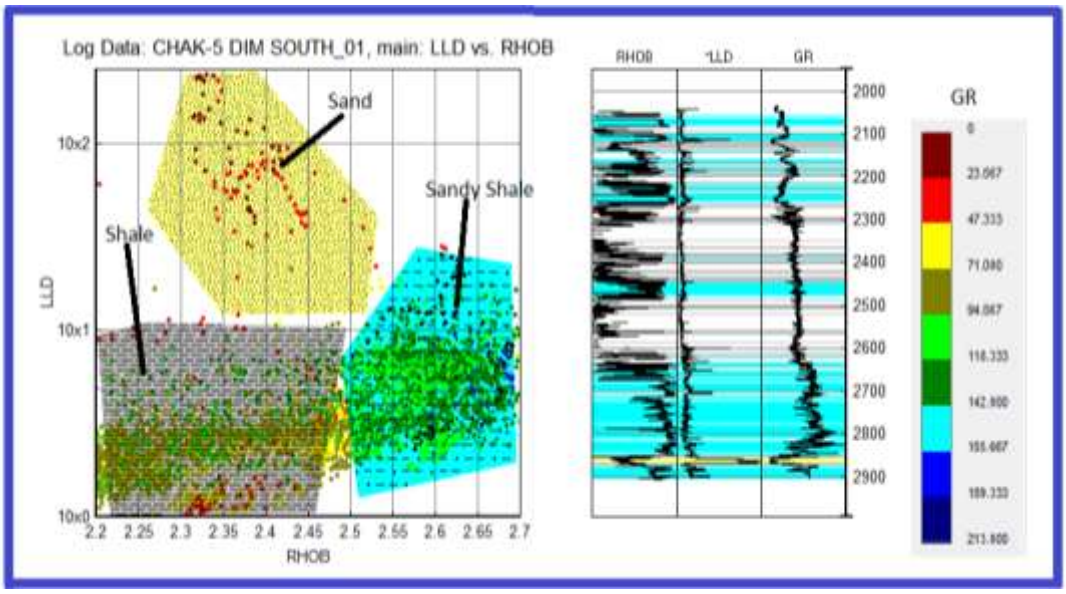

Figure-4: Facies analysis of CHAK-5 DIM SOUTH-01

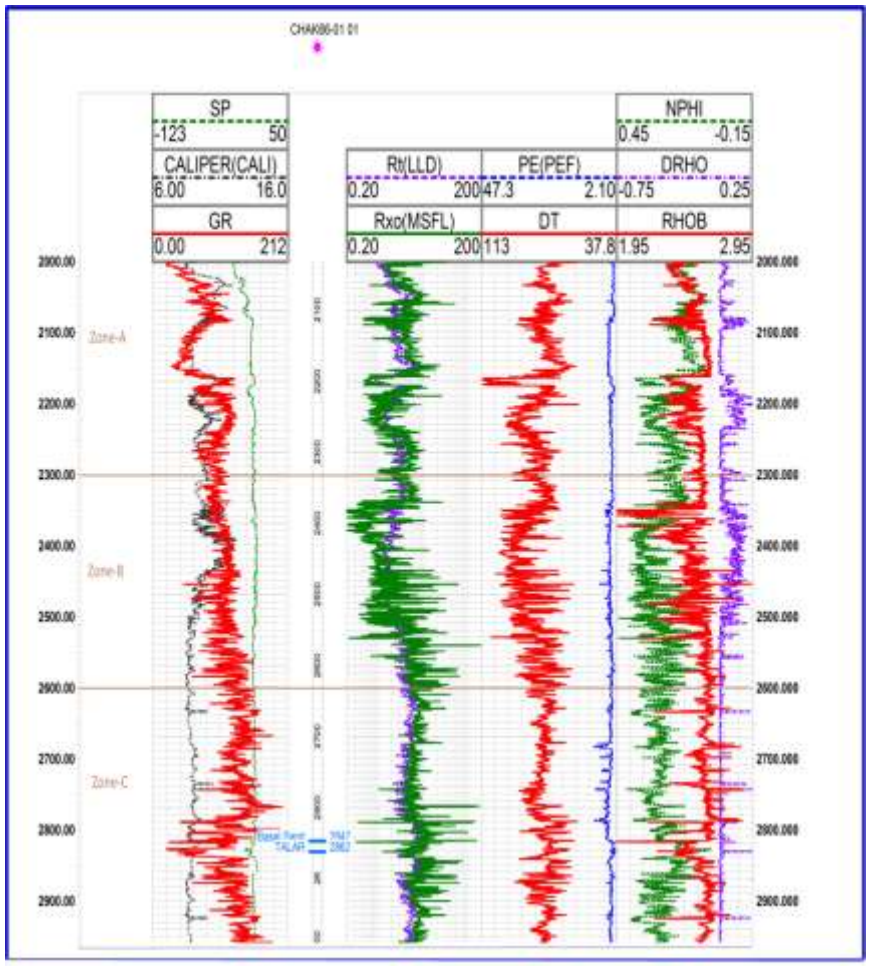

Figure-5: Well log data of CHAK 66-01

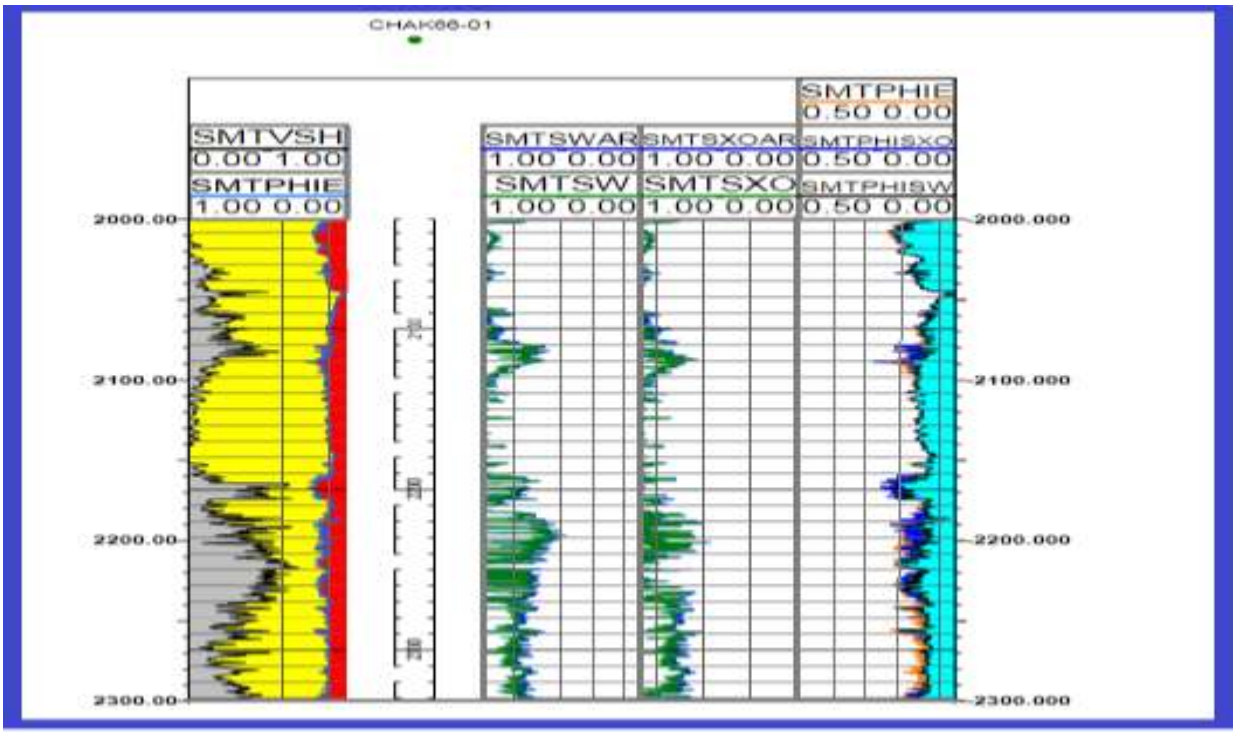

Figure-6: Petrophysical Results of Zone-A of well CHAK 66-01

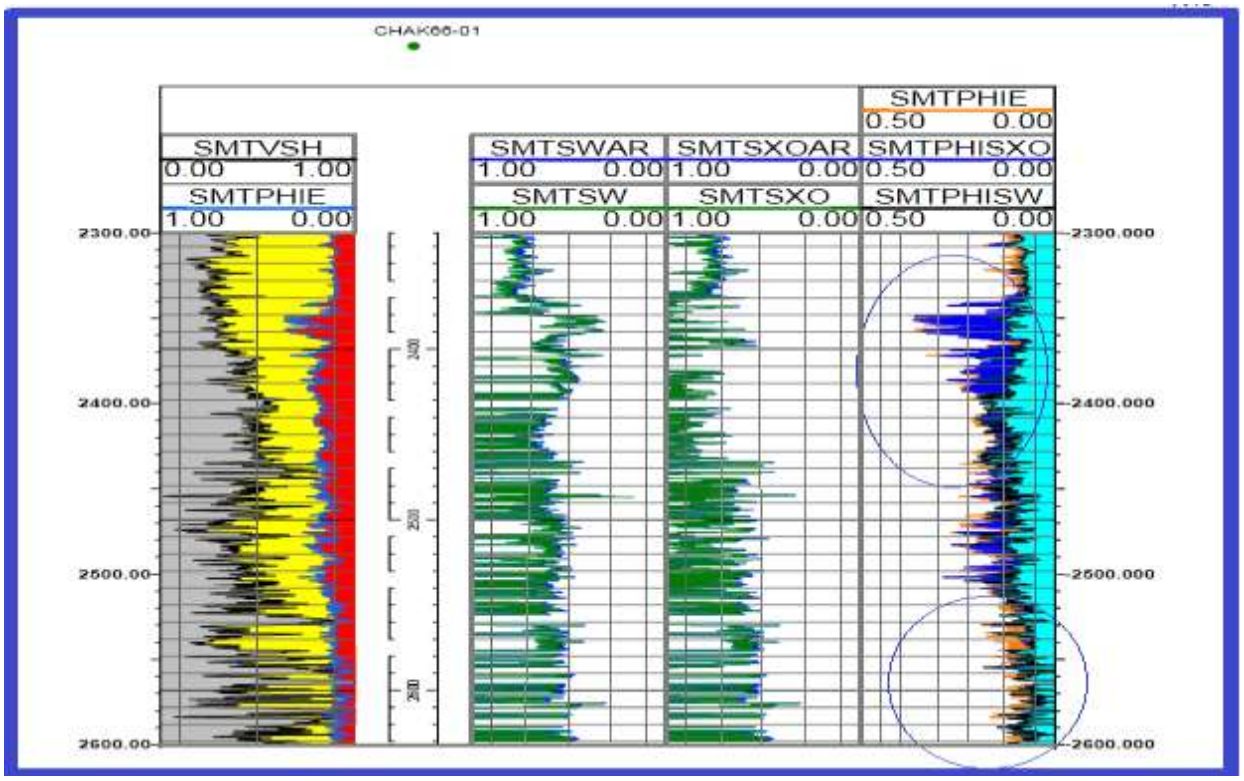

Figure-7: Petrophysical Results of Zone-B of well CHAK 66-01

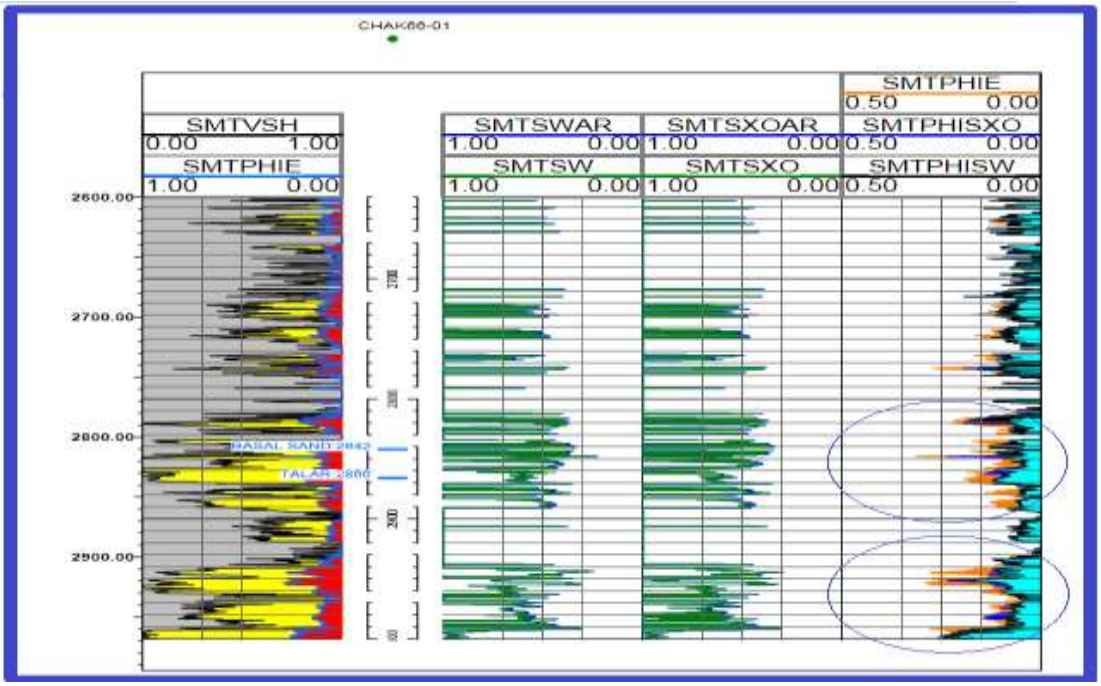

Figure 8: Petrophysical Results of Zone-C of well CHAK 66-01

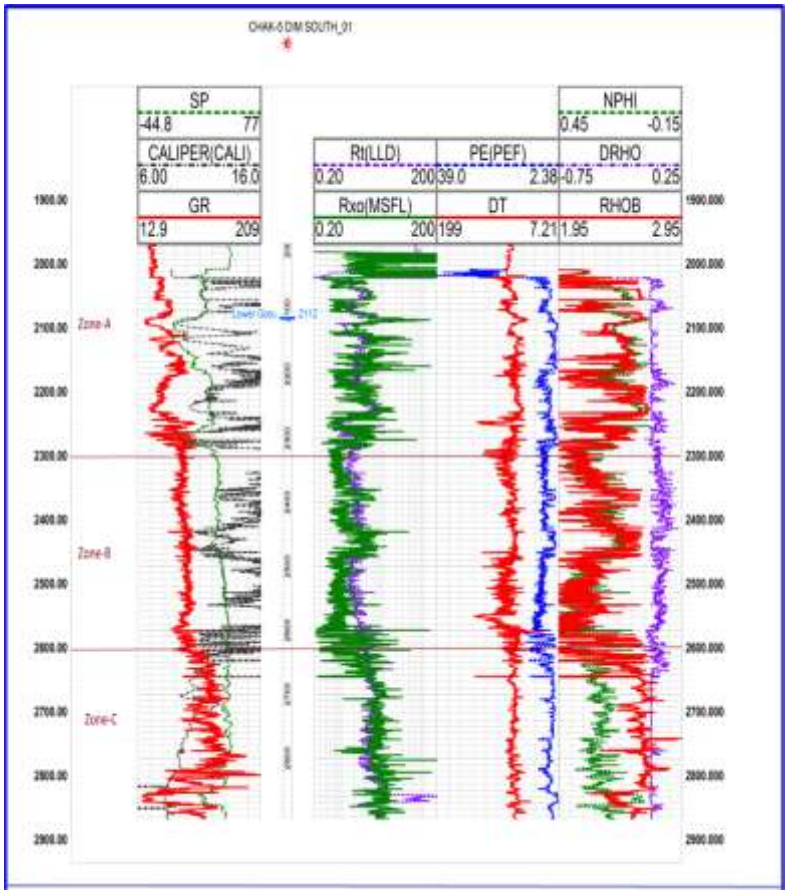

Figure 9: Well log data of CHAK-5 DIM SOUTH-01

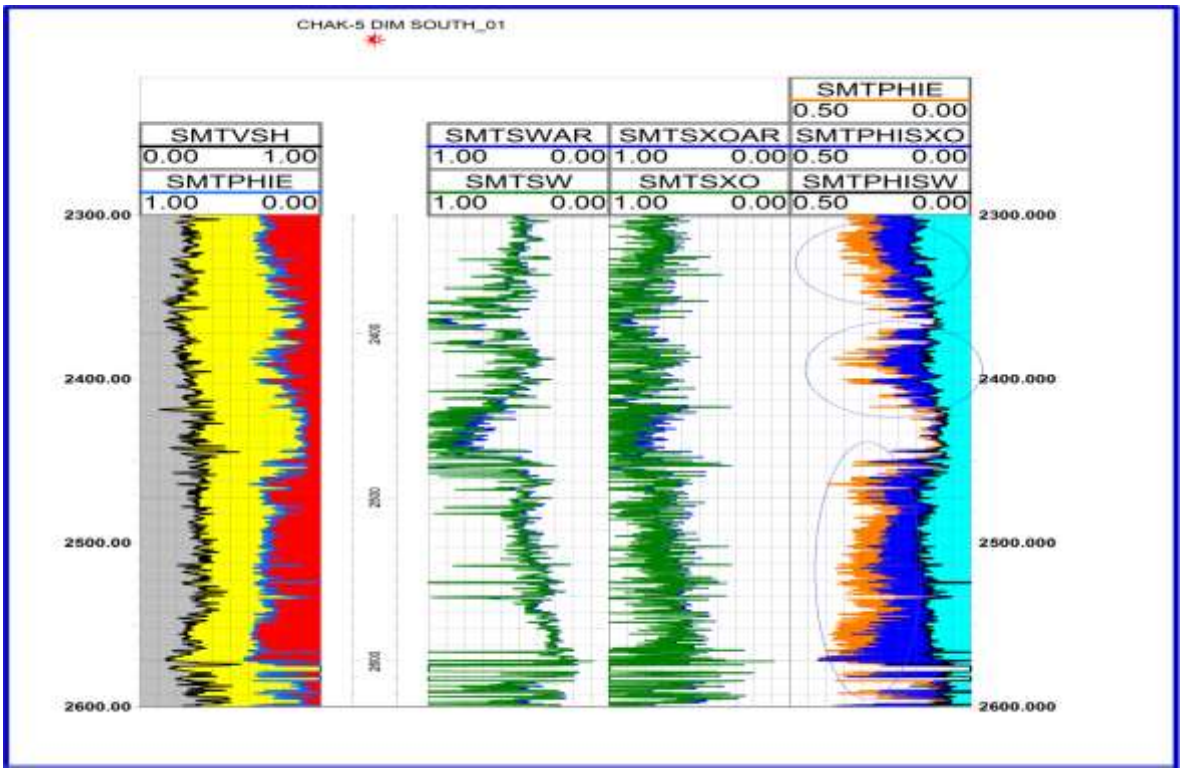

Figure-10: Petrophysical results of Zone-A of CHAK 5 DIM SOUTH-01

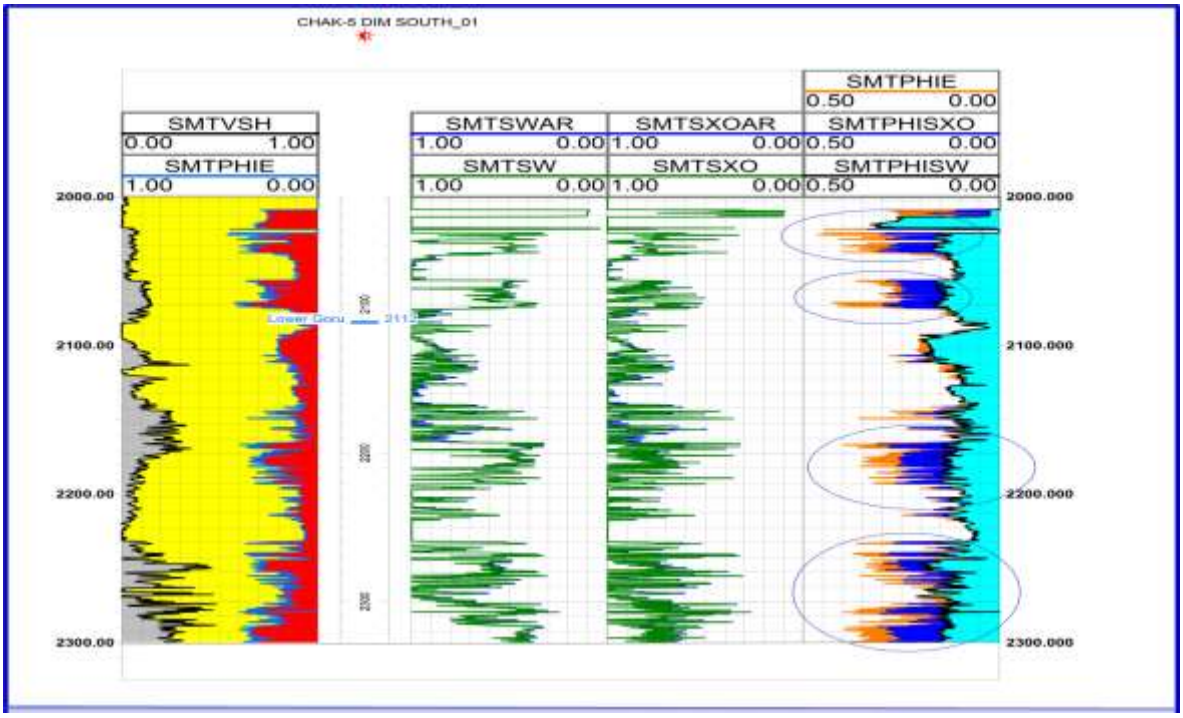

Figure-11: Petrophysical results of Zone-B of CHAK 5 DIM SOUTH-01

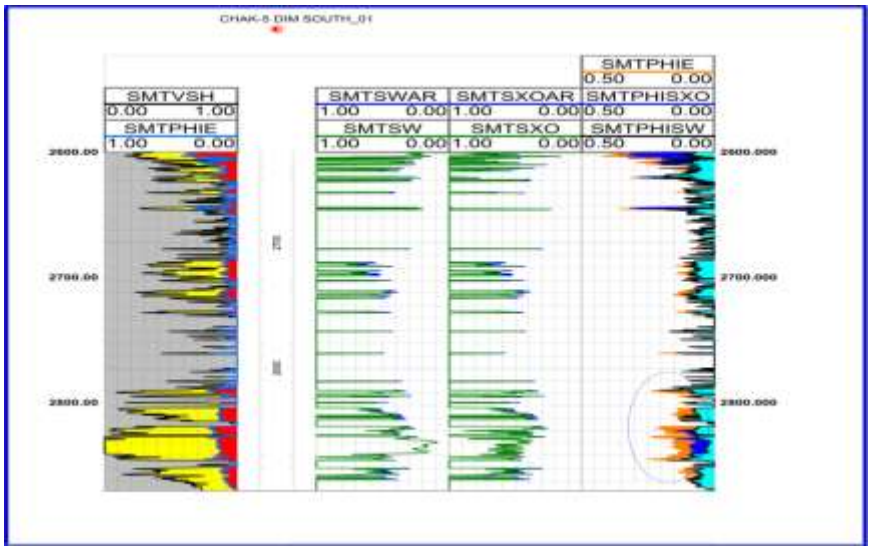

Figure-12: Petrophysical results of Zone-C of CHAK 5 DIM SOUTH-01

3.2 Cross Plots of Deep Resistivity and Sonic

Basic theme behind the ΔlogR Interpretation is developed by [13-14] and based on assumption that shale's and lime-mudstones contains significant amount of OM (organic Matter) and Non source rocks (sandstone, Limestone) also contains OM but not in significant amount. ΔlogR is separation between resistivity and porosity logs (Sonic, Neutron and Density) and bears primary relationship between TOC and ΔlogR; ΔlogR separation increases , value of TOC also increases. However Resistivity Deep Log (LLD) and Sonic (DT) is considered as best combination to calculate ΔlogR. . The best description of the method is also posted on the online magazine Search and Discovery, in "Direct Method for Determining Organic Shale Potential from Porosity and Resistivity Logs to Identify Possible Resource Plays [15-16]. Crossplots should be constructed keeping GR values in mind because it will prove the shale presence. Hence at those depths where DT, LLD and GR log show high values may confirm the rich organic shale content. Crossplots should be constructed keeping GR values in mind because it will prove the shale presence. Hence at those depths where DT, LLD and GR log show high values may confirm the rich organic shale content. Therefore cross plot of DT vs LLD has been carried for Chak-63-01 and Chak 5 Dim South-01 (Fig-13 and Fig 14). Such cross plot also shows that there are zones where DT value and LLD shows high values in petrophysical identified hydrocarbon bearing zones. This shows that organic enrichment (Figure 13) is present in shaly sand (depths 2300m to 2500m) of CHAK 66-. Similarly Chak 5-Dim South-01 also shows presence of organic shale plays at depths of 2600m to2900m (Figure 14). Hence it is also proved that Shale and also these zones may be explored as 'Shale Gas.

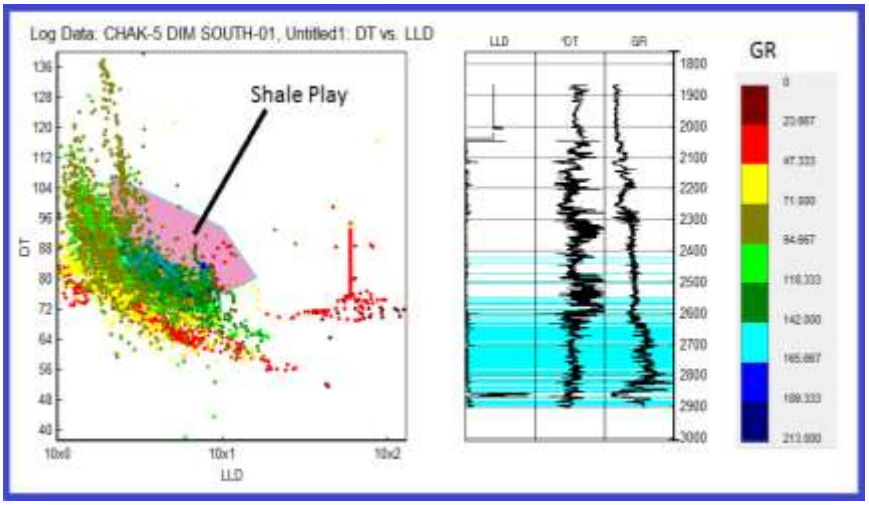

Figure-13: Crossplot of DT vs LLD and Shale play of CHAK 63-01

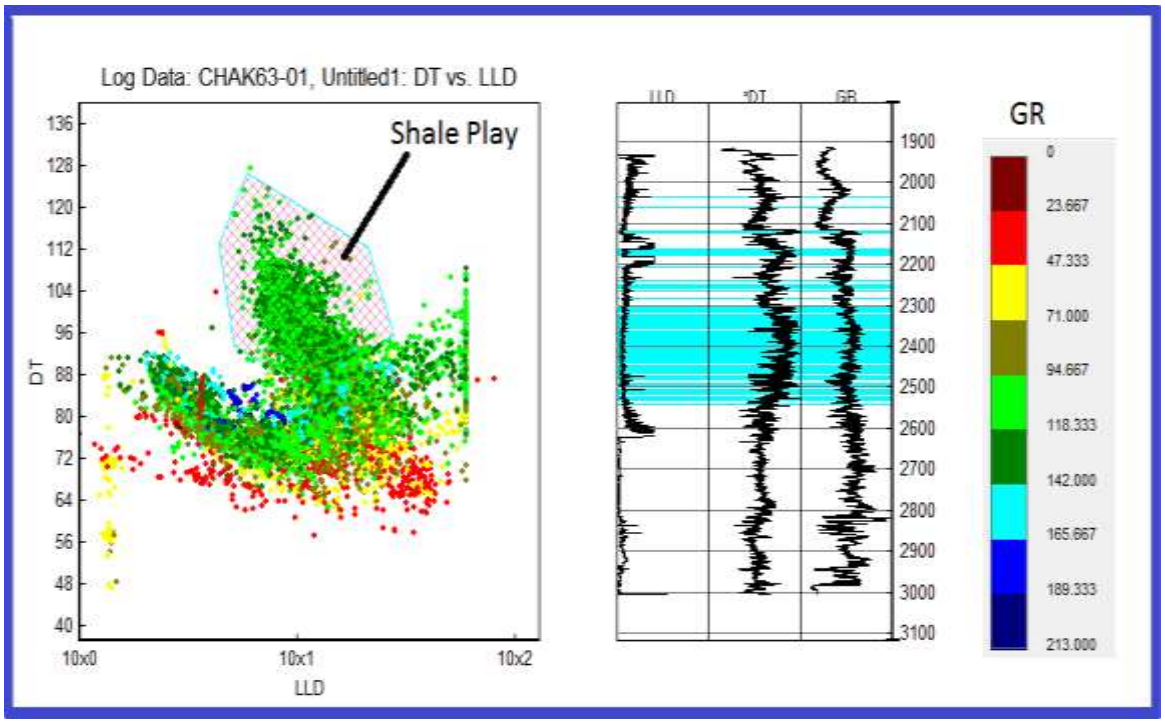

Figure 14: Crossplot of DT vs LLD and Shale play of CHAK 5 DIM SOUTH-01

4. CONCLUSIONS

Petrophysical results of CHAK-5 DIM SOUTH-01 shows that Zone-A has good amount of hydrocarbon present at different depths. Mainly 2020m to 2035m where saturation of hydrocarbon is almost 45% and have high sand lithology with almost 90% while its effective porosity is 10% other productive zone in Zone-A is starting from 2180m to 2200m where saturation of hydrocarbon is 45% and have high sand lithology with almost 90% while its effective porosity is 15%. Lower part of this zone starting from 2240m to 2300m also can be very productive as saturation of hydrocarbon is almost 45% and have high sand lithology with almost 90% while its effective porosity is 15%. Zone-B of starting from 2300m to 2600m which have higher amount of hydrocarbon throughout this zone. Lower part of this zone have high amount of shale and have high amount of hydrocarbon and high porosity as well which means that either this indicates hydrocarbon in shale which needs to study further as shale gas or its data issues. Caliper log shows high deflection in this zone which means that the zone of invasion is high which may act as error for log recording. But if it's tight gas then this whole zone may act as productive zone and Zone-C has higher amount of shale but at few depths sand packages found. So by and large this zone cannot said to be as productive zone but at the lower part of this zone at depth 2790m to 2850m a large sand package is identified which indicates good amount of hydrocarbon with good porosity. Similarly Chak 5-Dim South-01 also shows presence of organic shale plays at depths of 2600m to2900m (Figure 14). Hence it is also proved that Shale and also these zones may be explored as 'Shale Gas

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