GEO India 2018

PaperID **AU433**

Author **ASHUTOSH SINGH , ONGC , India**

Co-Authors **BISWAJIT PAIT, PRASHANT SINGH**

Methodology for Sweet Spot Identification of low Resistivity hybrid shale plays using well log data in South Cambay basin

1. Introduction:

Well log data provides a lot of in-site petrophysical properties of the formation encountered along the borehole. These petrophysical properties along with geochemical inputs are extensively used in describing the sweet spots of organic shales. Shale reservoirs are a kind of self-generated and self-stored reservoirs. Relative to non-hydrocarbon source rocks, proven shale gas reservoirs have a definite difference in well logging response due to the unique physical properties of organic matter, showing the characteristics of high TOC, high acoustic transit time, high resistivity, high gamma ray and low density. However, the log characteristics of the organic shale plays observed in the present study area (South Cambay Basin) are very different. The organic shales in this area bear moderately high gamma and low resistivity characteristics. The present study describes the methodology used to identify the sweet spots of this low Resistivity hybrid Shale plays using well log data.

Broach depression of Cambay Basin is pioneer in shale oil exploration. Cambay Shale is the main source rock in this basin, where organic rich and organic lean intervals are juxtaposed, thus the term hybrid shale resource system is applied. Well logging interpretation method was used to get the key evaluation parameters of shale reservoir and determine the distribution of sweet spots in vertical direction. The key log parameters are Gamma, Resistivity, Sonic, Neutron vs Density (N-D) separation, Fluid Saturation, Porosity and Permeability etc. Recording of some advance logs are also helpful in the identification of interesting intervals in shale reservoirs. The engineering sweet spot identification of shale refers to the evaluation of the shale on the basis of rock mechanical parameters. The Geomechanical properties (Young's modulus, Poisson's ratio) of Cambay shale is derived from acoustic logs and from these properties brittleness index (BI) is estimated. BI is one of the most important geomechanical sweet spot indicator.

The data used in the present study belongs to two objects of a shale exploratory well drilled in South Cambay basin. The well is named as A. The Cambay Shale formation was encountered at a depth of XX37-XX92m and terminated at XX05m within Olpad formation. In this well, conventional logs viz. Gamma, Resistivity, Neutron, Density and Sonic as well as advanced logs were recorded.

2. Methodology:

2.1 TOC computation: An organic rich shale section can be identified by overlaying a properly scaled porosity log (DT) on a resistivity curve (RT). This technique, commonly known as ΔlogR technique, was proposed by Passey et al, 1990 and has been largely used in the industry for the evaluation of organic shales and total organic carbon content (TOC). In organic lean rocks, the two curves overlay each other, while in an organic-rich rock, separation between the curves exists.

The algebraic expression that was used by Passey for the calculation of ΔlogR from the sonic/resistivity is:

$$\Delta logR = \log R/Rbaseline+0.0061(\Delta t-\Delta tbaseline)$$

Where ΔlogR is the curve separation between porosity log and resistivity log. Passey used the following empirical equation to calculate TOC in source rocks from ΔlogR:

$$TOC = \Delta logR \, x10(2.297-0.168LOM) + \Delta TOC$$

Where LOM is the amount of level organic metamorphism and ΔTOC is regional background level.

2.2 Sonic log: A sonic log delivers a formation interval time, which depends on lithology, rock type and texture. The OM has low velocity while high transit time 180μs/ft (Mendelson and Toksoz, 1985). Thus, the log response to OM depend upon distribution of OM in matrix. P-wave and S-wave velocities from this log along with bulk density log values were used to calculate the elastic properties (Vp/Vs ratio, Young's modulus and Poisson's ratio) of rock (Potter, 1997).

2.3 Resistivity log:

The increase in maturity and hydrocarbon generation replace the conductive pore water with non-conductive hydrocarbons that drastically increase resistivity (Meissner, 1978). The resistivity increases in mature source rocks due to generation of no conducting hydrocarbons (Nixon, 1973, Meissner, 1978, Schmoker and Hester, 1989). This response makes it possible tool for maturity indicator in organic rich source rock.

2.4 Density log:

The difference in densities between rock matrix and OM can be used as a tool in identification and quantification of organic richness in source rock. Depending on lithology the common matrix densities varies from 2.6-2.9 gm/cc. While OM has specific gravity in the range of 0.95-1.05 gm/cc. This low specific gravity of OM is in line with specific gravity of fresh water. The organic matter is part of the matrix in source rock and reduction in bulk density can be expected with OM (Autric, 2002).

2.5 Neutron log:

The neuron log porosity is relatively high in source rocks than non-source rocks because neutron tool measure hydrogen concentration which is present in water and hydrocarbons in rocks. The neutron porosity unit in shale is higher than silty or sandy units, thus having higher N-D separation. The neutron response to OM is average 67 porosity units (Mendelson and Toksoz, 1985) while matrix response are relatively close to zero.

2.6 Gamma ray Log:

It has been common to identify and quantify organic richness using well logs. Schmoker (1981) proposed the relationship between total gamma ray intensity and organic shales. The Organic rich source rocks can have high radioactivity and attributed to high gamma ray reading. This natural radioactivity is attributed to uranium, thorium and potassium contents. It can be concluded that high concentration of uranium in source rocks is indicative of marine deposition (Vernon E. Swanson, 1961).

3. Findings and Results:

The correlation were established between TOC from logs and TOC from samples which clearly indicate accuracy of each method. On the basis of petrophysical log outputs, geochemical & geomechanical analysis of cores/cuttings and analysis of geological information during drilling, the following prospective zones were identified in well A.

Zone-X (XX55-XX05m) - It mainly consists of the Younger Cambay Shale section which belongs to Eocene age and dominated by shales and claystones. The GR and resistivity values of the shales in this zone vary from 90-130 API and 1.5-15 ohm-m respectively. High uranium concentration observed in intervals (XX55-XX78m, XX95-XX05m) which is indicative of marine deposition (with expected organic content) but the ΔlogR separation, kerogen volume and the drop down of resistivity value in the uranium rich intervals negates organic richness. Slight increase in the N-D separation against these intervals is also observed in the log. High density peaks observed throughout the log is due to the presence of siderite peaks which has also been confirmed from lab study. Presence of siderite enhances the hydraulic fracability of the formation. The conventional PR vs VP/VS ratio (Track 7, Figure-1) also tend to show a minute cross-over indicative of presence of lighter hydrocarbon. Brittleness index (BI) calculated form elastic properties against this interval show its brittle nature (> 0.7). Cross-plots of the YM & PR (Figure-2) and fracture toughness & BI (Figure-3) indicates that the above interval bears good fracability. The Cambay Shale is rich in clay content (>50%) and is characterized by very low permeability. However, this zone is characterized by relatively low clay content (around 40%). Gas shows of 0.11-0.46% has been observed during drilling at XX95m. Based on the above petrophysical and geomechanical observations, interval XX74-XX92m was recommended for HF from shale oil point of view and the zone surfaced oil in flow back fluid.

Figure-1: Log motif of interesting Zone-X in well-A.

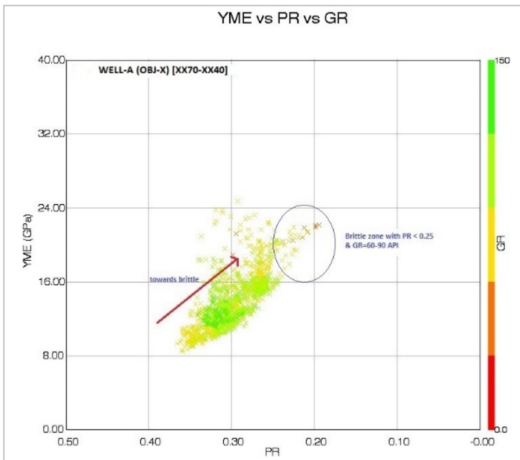

Figure-2: cross-plot of YME, PR and GR in Zone-X

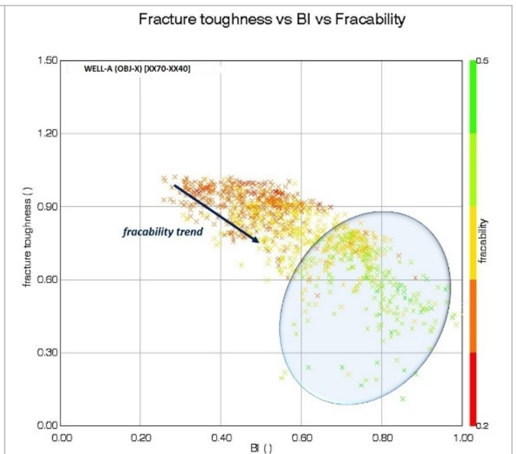

Figure-3: Cross-plots of the fracture toughness and BI in Zone-X

Zone-Y (XX95-XX55m) – This zone belongs to OCS section of lower Eocene. The GR, resistivity and CMR porosity values in this section vary from 90-105 API, 2-10 Ωm and 12-15% respectively. The average resistivity is 3-5 ohm-m, TOC content is 2-3 %, average kerogen volume of 10%, Sw ranging from 60-80 %

and average brittleness value > 0.6. The conventional PR vs VP/VS ratio (Track 7, Figure-4) also tend to show a minute cross-over indicative of presence of lighter hydrocarbon. The brittleness index in this zone indicates the formation to be comparatively more brittle. YM and PR cross plot (Figure-5) shows the brittleness trend with the highlighted zone having PR value < 0.25. X-plot of fracture toughness and BI (Figure-6) also suggest the zone is bearing good fracability. Maximum Gas shows of 0.49-4.5% has been observed during drilling at XX25m.

Figure-4: Log motif of interesting Zone-Y in well-A.

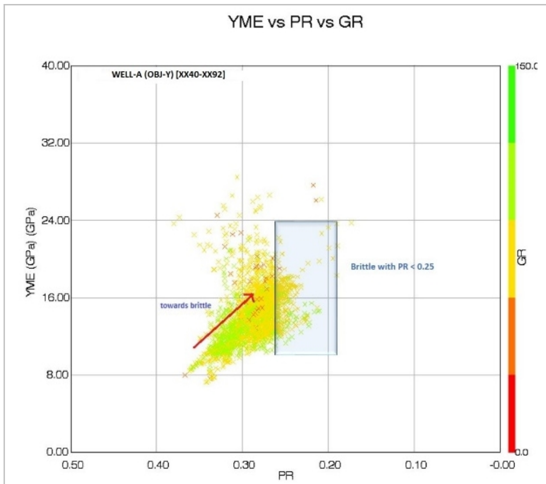

Figure-5: cross-plot of YME, PR and GR in Zone-Y

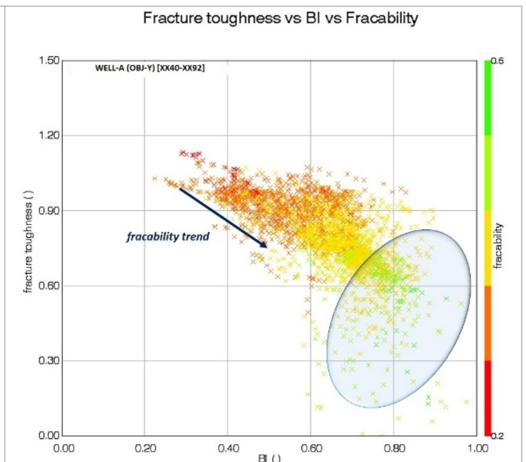

Figure-6: Cross-plots of the fracture toughness and BI in Zone-Y

Based on the above petrophysical and geomechanical observations, interval XX95-XX55m was recommended for HF from shale oil point of view and the zone surfaced oil in flow back fluid.

4. Conclusions:

It is evident from the present study that the integrated result obtained from the composite logs found to be very useful in identifying the good prospective zones for shale oil exploration and the same has been validated mainly with the available geochemical data and gas shows during drilling. The findings have been corroborated with the available testing results. The silt developed in Cambay Shale sequence appears to be hydrocarbon bearing on logs and on testing, the unit surfaced hydrocarbon.

5. Acknowledgements:

The authors are thankful to ONGC management for granting permission to publish the study. They also acknowledge the help and co-operation extended by the colleagues at COD Shale Exploration. The views expressed in this paper are solely of the authors and do not necessarily reflect the view of ONGC.

6. References:

Passey Q. R., Creaney S., Kulla J. B., Moretti F. J. and Stroud J. D., 1990, A Practical Model for Organic Richness from Porosity and Resistivity Logs by, AAPG Bulletin, V. 74, P 1777-1794.

Unpublished Petrophysical Report of Well-A (COD-Shale Exploration, ONGC, Vadodara).

Swanson V. E., 1961, Geology and Geochemistry of Uranium in Marine Black Shales, geological survey professional paper 356-C

Sun S. Z., Sun Y., Sun C., Liu Z., and Dong N., 2014, Methods of Calculating Total Organic Carbon from Well Logs and its Application on Rock's Properties Analysis.

Ahmad M. et al, 2017, Quantification of Organic richness through wireline logs.

Dautriata J., Dewhursta D. N, Clennella M. B., Ravenb M. D., Josha M. and Estebana L., 2017, Rock Physics and Petrophysics in a Hybrid Gas Shale System

Hakimi M. H., Shalaby M. R., and Abdullah W. H., 2012, Application of Well Log Analysis to Assess the Petrophysical Parameters of the Lower Cretaceous Biyad Formation, East Shabowah Oilfields, Masila Basin, Yemen.

Schmoker, J.W. and Hester, T.C., 1989, Oil generation inferred from formation resistivity-Bakken Formation, North Dakota: the log analyst, v.30, no.2, p.100

Meissner.F.F. 1978, Petroleum geology of the Bakken Formation Williston basin, North Dakota and Montana, in the economic geology of the Williston basin: Montana geological Society. 19

Mendelson.J.D, 1985, and M.N. Toksoz. 1985 Source rock characterization using multivariate analysis of log data. Transactions of the Twenty-sixth SPWLA Annual Logging Symposium, paper UU.

Nixon, R.P., 1973, Oil source beds in cretaceous mowry Shale of north-western interior United States: AAPG Bulletin. V. 57.p.136-161.

Potter C. C. & Foltinek D. S., 1997 Formation elastic parameters by deriving S-wave velocity logs: p.10-2