SPWLA INDIA CHAPTER

Quarterly Bulletin
Volume 2 Issue 2
July-September 2021

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Distance to Bed Boundary Image while Drilling Helps in Landing and Placement of Horizontal Drain-hole in a Challenging Matured Field

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Background: Landing and placement of horizontal wells is a challenging task, especially, in dipping reservoirs and in the presence of sub-seismic faults. Geosteering with conventional LWD tools can not detect an approaching shale boundary and accordingly, a part of the drain-hole is lost in the non-reservoir section. The distance-to-bed-boundary tool can detect approaching reservoir boundaries while drilling, thus offering a good control in well placement. The tool works on the resistivity contrast between the hydrocarbon bearing reservoir section and undesirable the non-reservoir section or water bearing reservoir. The technology was successfully deployed in a matured field in Western Offshore, India for placement of horizontal drain-hole with better productivity. The original well ABC#L was drilled in 2002 and was completed in two perforated intervals in Bassein Formation of Eocene age. With subsequent movement of OWC, water cut was on the rise. In 2020, it was decided to side-track the well.

Objective to deploy AziTrak DBBI tool: During the sidetracking of a well, it is very challenging to land the well in an optimal way to maximize the reservoir exposure where only a limited oil column is available for exploitation in a reservoir. There is a narrow window for the well placement between Bassein top and the OWC. So it was planned to deploy the 6 ¾” AziTrak Deep Azimuthal resistivity tool in the 8 ½” landing section so that the the well can be landed +/- 0.5 m TVD inside Bassein reservoir. After landing, the plan was to deploy the 4 ¾” AziTrak deep resistivity tool in the 6” drain hole to keep the drain-hole +/- 2m TVD below top Bassein, in the best porosity facies.

Value Addition through AziTrak: The pre-well model was created using the data of four offset wells ABC-3, ABC-4, ABC-6 and ABC-12. The LDBBI tool was deployed so that the approaching bed boundary upto a distance of 1 m to 1.5 m in TVD can be detected. Mukta formation was encountered at XX82 m TVDSS followed by RST unconformity at XY07 m TVDSS. The inclination of 85 deg was first maintained at XZ41 m MD and then 86 deg at XZ57 m MD to accelerate the reservoir entry. Finally, Bassein formation was penetrated at XA10 m MD / XY22.9 m TVDSS and the section TD was then declared at XA22.42 m MD / XY24.4 m TVDSS, just below the top of Bassein. Total of 235 m MD was steered inside the Bassein reservoir target window, maintaining 1-2 m from the top of Bassein along drilled well path with optimum porosity of 15 to 18 pu, thus achieving 100% Net to Gross reservoir exposure.

Results: After completion, the well produced QL @ 890 blpd and QO @ 196 bopd with 78% water cut, which is very good in comparison to the present performance of the near-by wells.

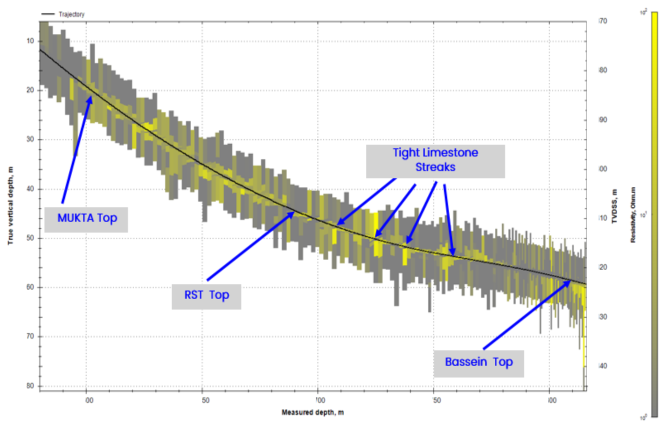

Fig:1 Layout of ABC#L Lateral Section Post well Interpretation

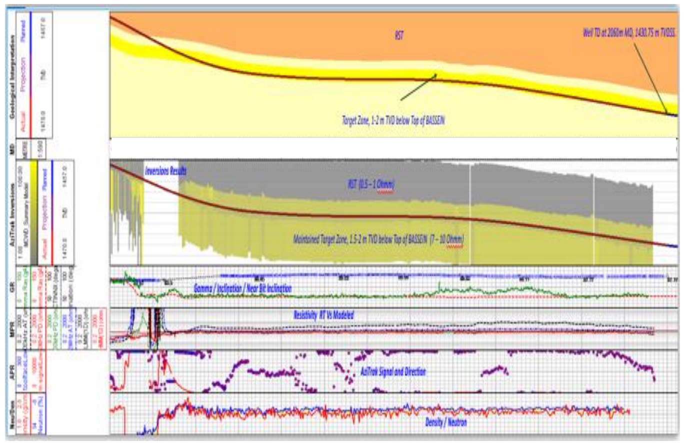

Fig: 2 Layout of ABC#L Lateral Section Post well Interpretation

NMR characterization of very low permeability formation on core samples from Shale Exploration wells

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Background: Shale reservoirs characteristics like pore size, organic matter, clay content, wettability, adsorption, and mineralogy limits the applicability of the conventionally used interpretation methods for their characterization. Shale contains micro-pores in the organic matter and nano-pores in the clay minerals and natural fractures. The presence of these different pore size scales in one rock complicates the interpretation process. Also on NMR data, it will be more challenging to decide if the peaks in NMR relaxation time distributions (T1 & T2) are resulting from different pore sizes or from different fluids in these pores.

Samples under laboratory study: The samples under study belongs to the well GNDR-XX in Cambay Basin. The wells were drilled exclusively for exploration of shale gas/oil prospectivity of Cambay Shale formation which is considered as a potential source rock.

Brief lithology, composition & characteristics: The megascopic study of conventional cores shows lithology is comprised of shale. TOC contents for the seven samples ranged from 4.41 to 0.76% by weight and averaged 2.90% by weight. TOC has also been computed on 32 cutting samples in this formation. Range of TOC computed from cutting samples is 1-5.5% (11 samples had TOC >3%). Shale Rock Property Data records showed average ~15% porosity and 1.2 x 10-5 md of Pressure Decay Permeability.

Study Approach and Methodology: A laboratory based workflow for fluid characterization in Oil Shale reservoir via 2D NMR has been defined. Subsequent to Shale Analysis and Pressure Decay Permeability study, data acquisition for NMR T1-T2 correlation map in 'As Received/Native' state is a key step. NMR T1-T2 response is again recorded in 'Dry' state core samples followed by 2D signal subtraction. Analysis of 2D NMR data and findings were validated by individual soxhlation of different plugs.

Analysis of results: The results (via NMR 2D mapping) even shows potential to differentiate Bitumen and OM (organic matter) vs. IP (inorganic or inter-particle) pore fluids. Laboratory measurements on the samples under Feasibility Study indicate that the variations in the T1/T2 ratio could be attributed to different fluid types including Bitumen, Inter-Particle (IP) water, Clay-Bound Water and Oil in Organic Matter (OM) Pores (Jiang et al.,2013; Rylander et al., 2013; Singer et al., 2013; Nicot et al.,2016 etc.). In comparison of 'as received' state and 'dry state' NMR T1-T2 experiment, the difference in signal or missing signal (mainly the movable oil in organic pores) got duly validated with the individual soxhlation extracts (i.e. oil). It was also observed that lower the T1/T2 ratio better is the mobility (or lesser is the viscosity) which corroborates with higher degree of hydrocarbon extraction on individual soxhlation.

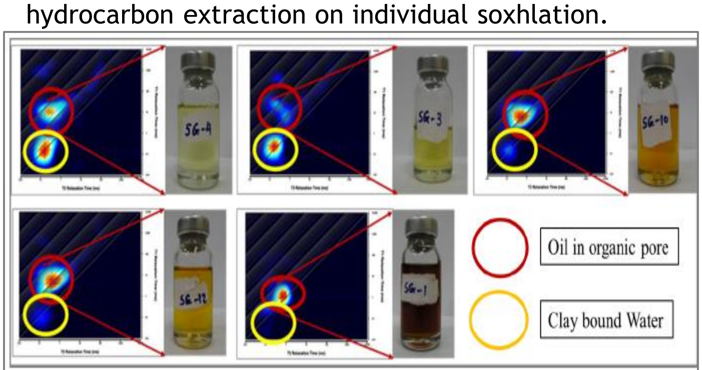

Fig. T1-T2 map: Fluid signatures vis-à-vis soxhlation extracts (example plugs)

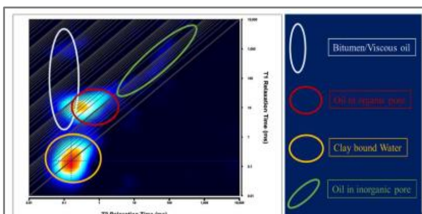

Fig: Fluid signatures on T1-T2 map (eg. Plug No: SG-4; As received sample)

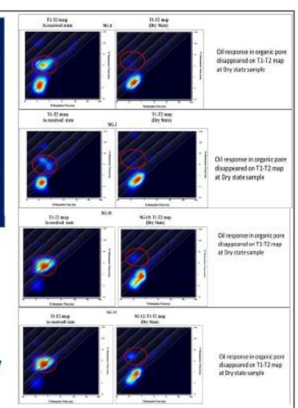

Fig. Signal Comparison: As Received vis-à-vis Dry state sample

Conclusions: The results shows potential to differentiate Bitumen and oil in OM (porosity in organic matter) vs. IP (in-organic or inter-particle porosity) pore fluids. T1/T2 ratio for oil in organic pores has been observed of the order 1-10 with 0.5<T2<5ms. Response having T2> 5ms with higher ratio indicates residual oil in inorganic pores. Comparative sample study reveals that for organic pore systems, lower the T1/T2 ratio better is the mobility (or lesser is the viscosity) and hence has resulted into higher degree of hydrocarbon extraction. Most of the samples showed presence of mobile oil within organic pore system (from the T1/T2 ratio and individual soxhlation). Since field NMR log indicates negligible free fluid porosity, this study corroborates the production testing which has resulted in surfacing oil.

Prediction of Porosity Logs (Density & Neutron) from Gamma Ray, Resistivity and Sonic using Machine Learning - Random Forest Technique

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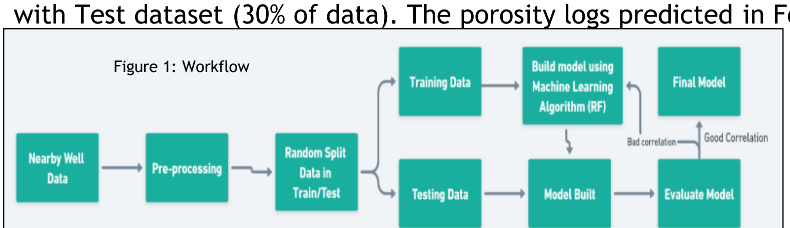
Problem Statement: In a development well-A, Only Resistivity, GR logs were recorded by LWD. Density and Neutron logs were not recorded as the well was having persistent losses and the chances of stuck up were quite high. Hence, it was decided to lower production casing after which cased hole neutron and acoustic logs were recorded. So, it was decided to predict porosity logs (Density & Neutron) logs with available Resistivity, GR, cased hole neutron and sonic logs using Machine Learning/AI techniques. Logs were available in nearby wells(Well B exploratory well and Well C development well) in this field.

Methodology: Machine Learning approach was followed using Random Forest algorithm. To validate whether by use of Random Forest Technique we can predict the porosity logs, a model was built by taking inputs from nearby well C and predicted in well A in Formation P where porosity logs were recorded, workflow followed is shown in Figure 1. From figure 2, It can be observed that Predicted Density has good correlation and is an approximate match with the recorded density log; Same applies to predicted neutron log. Further now, data from Formation Q of Well B was used to build a model (Inputs taken were GR, Resistivity and Sonic), tested with Test dataset (30% of data). The porosity logs predicted in Formation Q of well A is shown in figure 3.



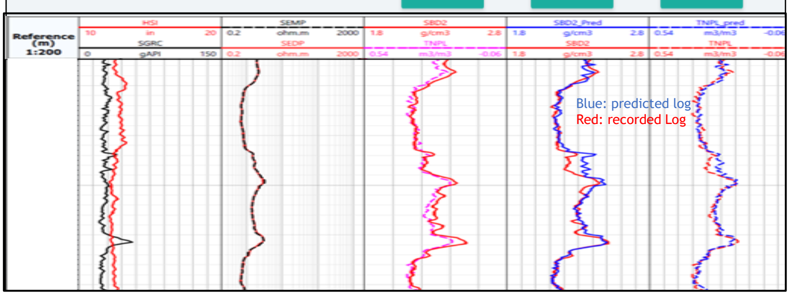


Fig 2: Predicted logs in Well A in Formation P(4th track shows density, 5th track shows neutron)

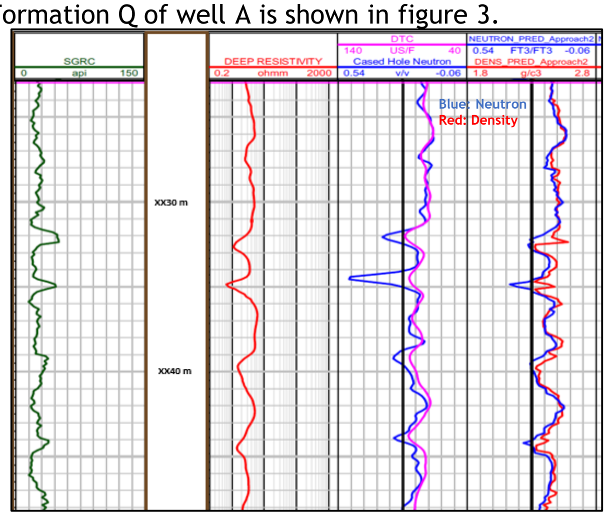
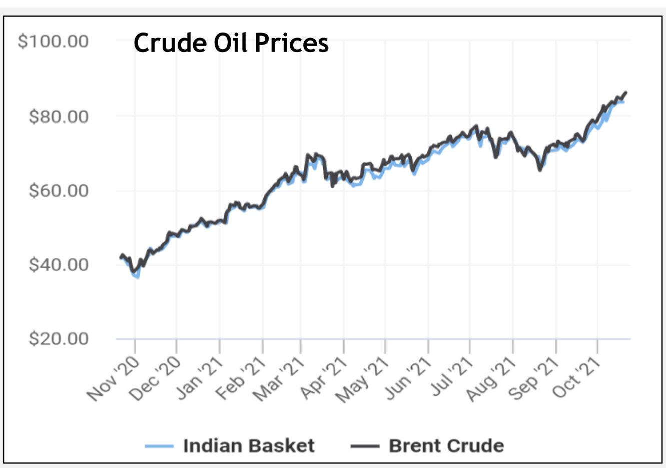
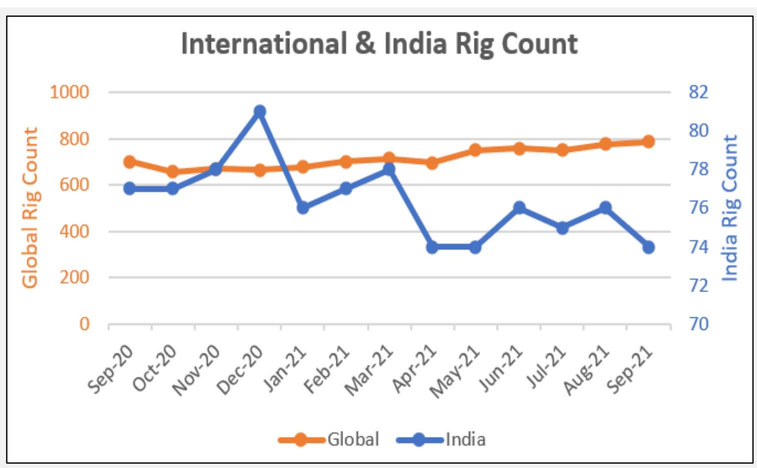


Fig 3: Predicted logs in Well A in Formation Q

Analysis on Output: In figure 2, first track shows GR, second track shows Resistivity (medium and deep), third track shows Neutron and DT, fourth track shows predicted logs. Here it can be seen that Density and Neutron curves predicted are smoother with inclusion of DT and depict realistic log features in sync with other curves.

Conclusion: A novel Machine Learning approach was applied to predict Porosity logs, initially validation of technique was done by prediction in Formation P which shows approximate match with original logs. Prediction in Formation Q depict realistic log features in sync with Resistivity, GR, Sonic and Cased Hole Neutron logs. A robust model can be made for each field and logs recorded can be used for building model, so that the logs can be predicted when they are not recorded due to well condition. *However, ML based techniques cannot be a substitute for actual data acquisition and should be used only in cases where data could not be acquired.*





Maiden use of Compact Drop-Off (CDO) Technology to acquire log data in challenging borehole conditions in the Well of Rokhia field of Tripura Asset

Author: Dinesh Mukati, ONGC Agartala

Tripura area constitutes the southern part of Frontal Fold Belt of Assam-Arakan Basin. The structural trend of the Tripura fold belt exhibit North-South trending series of elongated, sub-parallel, tightly folded anticlines bounded by longitudinal fault, arranged in en-echelon pattern and separated by intervening wide synclines. Axial traces of the folds show gentle convexity to the west. Most of these linear anticlines have multiple culminations.

Log data acquisition in such a complex geological area is very challenging. Well “Rokhia-X” was drilled as Development L-Profile well in Rokhia-Konaban area with maximum angle as 24 deg and azimuth of ~10 deg. Multiple layers were targeted in this well, like development of XP-‘A’ paysand, delineation of XP-‘B’ paysand and appraisal for XP-‘C’ and deeper pay sands of Konaban Field. Based on the well behaviour (frequent tight pulls & held-ups) during drilling in 12.25” phase, the option to attempt log data acquisition on wire-line has been ruled out. Log data acquisition on PCL was attempted and data could only be recorded from ~140m above from phase TD due to held-up of tool string before phase TD. One new sand XP-BB couldn’t be logged completely that led in uncertainty of its hydrocarbon prospectivity as well as estimation of its thickness.

Fig: CDO Tool on Cat Walk, Rig Site

Fig: CDO Tool

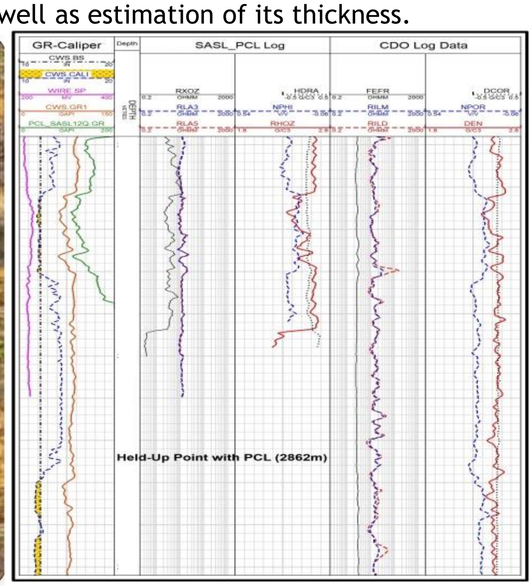


Fig: Depicting CDO Log, SASL PCL Log

The only alternative method for logging the remaining depth interval was to deploy logging-while-drilling (LWD) tools in sliding mode but that too ruled out due to its non-availability at the location. Also, it is more costly and prone to lost-in-hole risks. In the situation of non-availability of LWD tools and failure of PCL to Log up to phase TD, it was decided to use **Compact Drop-off (CDO)** conveyance method for Logging of remaining ~140m interval of 12.25” section. It enables to log a well with extremely hostile borehole conditions like washouts, clay swelling, differential sticking etc. using wireline tools. The tool can be retrieved using the wire-line, enabling early availability of data in the event of a stuck drill string. Multiple runs with different tool strings may be attempted without pulling out the drill string as compared to PCL.CDO is a through drill-pipe conveyance method used to deploy a Compact Memory Logging (CML) tool string. The tool string is run on wireline through the drill string and dropped –off in a no-go arrangement in the Bottom Hole Assembly (BHA). The wireline is then recovered and drill string is pulled back to the surface while recording data to the memory. A drop-off float valve is included in BHA to allow tools to pass through it for drop-off or pick-up and practically maintain well control during operation.

Using CDO (first ever in ONGC), Resistivity and Porosity data was recorded successfully in the interval XX50-XX90m in the 12.25” section of well “Rokhia-X”. The tool string is powered by a battery sub and data is stored in non-volatile memory chips housed in memory sub. Logs were recorded in time base and converted to depth logs when string was recovered at the surface. ***The recorded Log data on CDO has helped in evaluation of XP-BB pay sand and estimation of same, outside REC limit.***