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INSIDE THIS ISSUE

The Triaxial Journey at ONGC: Unravelling Uncertainties Step by Step

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The domain of Geomechanics took a giant leap in the E&P Industry during the last two decades. Starting with focus on addressing borehole stability issues it has graduated into the domain of Reservoir Geomechanics and touches each and every stage of E&P workflow. For tight & unconventional reservoirs Geomechanics is integral to the reservoir characterisation workflow and in deciding exploration & exploitation strategies. ONGC is closely following these developments and evolving its workflows accordingly. As the scope of work for Geomechanical Workflows expanded, so did the need to address various uncertainties. To address some of these uncertainties a Triaxial Rock Testing Facility was established at CEWELL, Vadodara in 2019. Concerted efforts were made to take conventional cores in key wells in tight reservoirs in Western Region (Nawagam, Gamij, Ahmedabad Fields) & Southern Region (Mandapeta & Malleswaram Field).

As a first step localised dynamic vs static correlations were generated for Mechanical properties (UCS, Young's Modulus & Poisson's Ratio) which helped to finetune the 1D MEMs. However the real value is coming from the statistical analysis of the database generated over the two years. A small but relevant case is presented to highlight this. Generally, borehole is relatively more rugose against shales compared to sands. However, in Mandapeta Field, KG Basin an opposite trend is seen against Mandapeta formation. Shales are seen to be more stable than sands. The borehole failure trends also could not be modelled perfectly even while using Triaxial Lab derived correlations for UCS, Young's Modulus & Poisson's ratio & Dick Plumb correlation (DPC) for Friction Angle, FA (Well MDP#A, Fig: 1a).

The Triaxial data generated across 4 wells in the area were therefore analysed for observing trends in all geomechanical parameters including Friction Angle (FA). The data revealed trends just opposite of Dick Plumb correlation. The FA vs (1-PHIT) trend seem to provide a better correlation for Friction Angle. The 1D MEM with this core based correlation (Fig 1b) was able to model all the borehole failures in a much better way in the present well and other 4 wells in the area.As more and more Triaxial experiment data is being added to database, the possibilities to understand field specific and generalised sensitivity in different Indian Basins is being explored. These reports are being percolated down as standard parameters to be used in different study areas.

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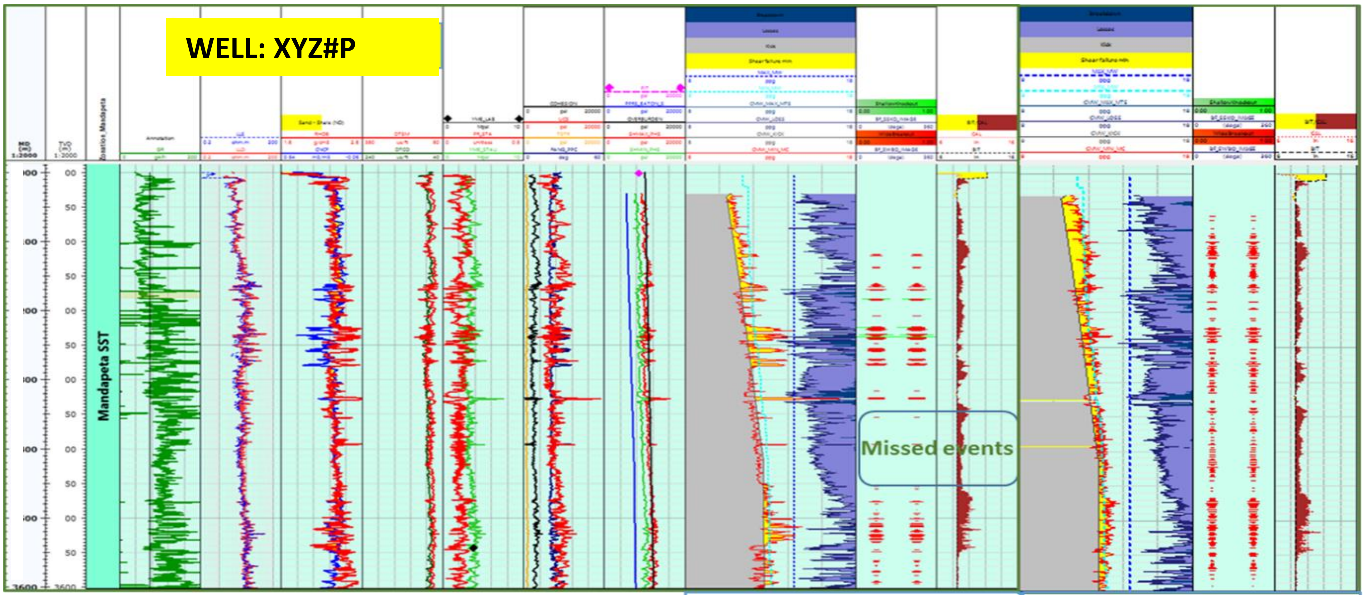

1a. Results using Dick Plumb Correlation for FA

1b. Results using Lab Derived Correlation for FA

Petrophysical Uncertainty Analysis in Deterministic Method- Discussion on various Workflows and Approaches

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Introduction: In any petrophysical interpretation there is always uncertainty on the results due to the parameters used in the equations or even the equation itself. It is often the case where the parameters or the equations used by the interpreter are, based on his experience and knowledge of the reservoir available during the interpretation. This will finally lead to an interpretation with a single value for hydrocarbon in place. However, during the project economic viability study, we need to consider the possible upside and downside of the interpretation. To do this Monte Carlo technique are used to quantify the uncertainties and its impact on the result.

Principally, the Uncertainty in petrophysical interpretation is due to the following factors such as, Random Uncertainty (Measurement noise and formation heterogeneity), Systematic Uncertainty (Log calibration errors) and Model-Based Uncertainty (Different interpretation models). Therefore, it is important to quantify the uncertainty and to know the best workflow/approaches pursued while analysing the uncertainty. A discussion and benefits about the different workflow/approaches of uncertainty analysis for deterministic petrophysical evaluation is given below.

Discussion about Deterministic Uncertainty- Workflow/ Approaches

Monte Carlo processing involves running a calculation, or a series of calculations, many times, while randomly varying each measurement and parameter within a given statistical distribution, to reflect the analyst's uncertainty in those variables. From this process many results are obtained, showing the range and distribution of possible answers given the uncertainty described.

First, we will discuss about the different Monte Carlo workflow generally used in deterministic uncertainty analysis. In deterministic method, Petrophysicist calculate the formation properties like shale volume, porosity, and saturation in a series of steps. It is possible to run each step in the process many times using different parameters. The output from each step will be either a mathematical distribution which closely matches the results or a set of three curves showing most likely, high, and low values for each result. These outputs are then used as an input for subsequent steps in the process. For example, Vsh could be run through a Monte Carlo process, then three versions of the Vsh curve could be used as input for the porosity calculations. This kind of Monte Carlo analysis step is known as "modular workflow".

Apart from modular workflow, it is also possible to run complete deterministic analysis in one step starting from shale volume to saturation in single step and this step can repeated with varying parameters in the range defined and can generate a distribution of output curves. This workflow is known as "single workflow".

Modular workflow analysis can increase the uncertainty when results from different modules which are dependent on each other are used in subsequent modules. For example, if porosity and saturation are both calculated with possible error bars, then the porosity uncertainty would be present in both the porosity and saturation error distributions. And these are used further to determine the bulk volume of hydrocarbons in place. This leads to a situation where combination of porosity and saturation uncertainty will be part of Monte Carlo results but which cannot co-exist.

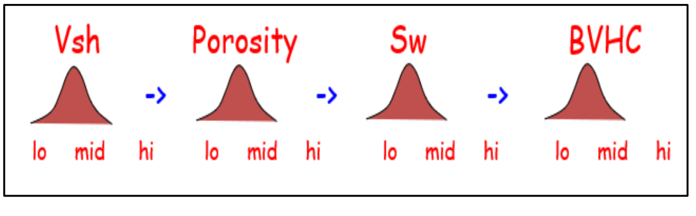


Fig 1: Image showing "Modular" Monte Carlo workflow

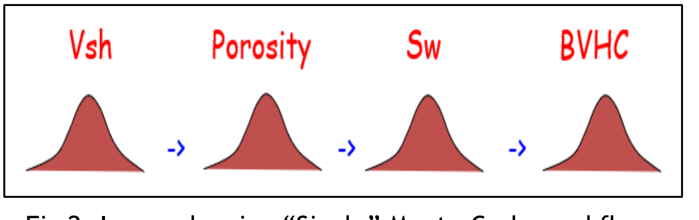
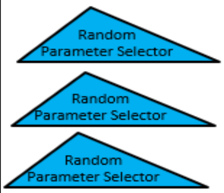


Fig 2: Image showing "Single" Monte Carlo workflow

In single workflow, each individual iteration gives a set of results which represent a valid interpretation. These results can be sorted based on the final computation, usually oil in place and actual P90, P50 and P10 results are produced. Another benefit of single workflow technique is that a sensitivity analysis can be run which gives the relative contribution of each log and parameter to the overall uncertainty, based on how much each one influences the results.

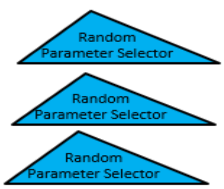
Second important aspect is the different method to run the Monte Carlo processing in deterministic analysis which is named “horizontal” and “vertical” processing. In horizontal processing, the parameter and log value offsets are randomly defined, and the full set of calculations are performed for a single depth increment. This process runs multiple times, with all the results are stored, before moving on to the next sample depth. Then for the next sample depth, a new set of parameters and log offsets are randomly defined. This will be continued for analysing the complete reservoir interval.



Depth	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
5000	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc
5000.5	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc
5001	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc			

Fig 3: Image showing Horizontal Processing Method

In vertical processing, the parameters and log value offsets are randomly defined and then used for the entire processing interval. Once the calculations are run for the entire interval, results are stored. Then the parameter and log value offsets are redefined before running the subsequent iteration for entire interval.

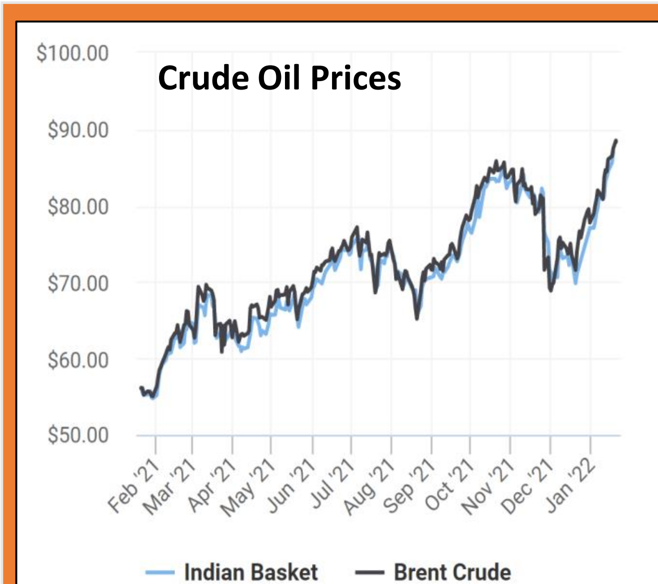


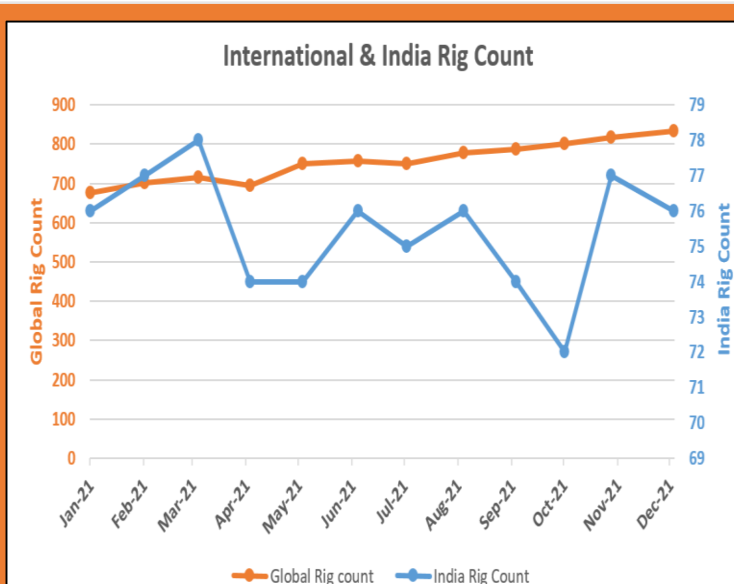
Depth	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
5000	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc		
5000.5	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc		
5001	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc	Vsh Ø Sw bvhc		

Fig 4: Image showing Vertical Processing Method

Horizontal processing allows an effective modelling of random uncertainty, but it does not incorporate the systematic uncertainties and is unable to generate percentile-based results such as P90, P50 and P10. On the other hand, vertical processing allows an effective modelling of both systematic and random uncertainty.

Conclusion: Uncertainty analysis play a crucial role in reserve estimation for visualizing the project economic scenarios. Therefore, it is important to understand the uncertainty associated in petrophysical interpretation which forms the basis for reserve estimation. Based on above discussed workflow/ approaches for understanding and addressing the uncertainties, Single workflow with vertically processing in Monte Carlo is found to better, as it provides better estimation of uncertainty on petrophysical results while using deterministic method.





Deployment of Advanced Ultrasonic Sound Speed Sensor for Accurate and Faster Real Time Down hole Fluid Identification in Complex Multiphase flow

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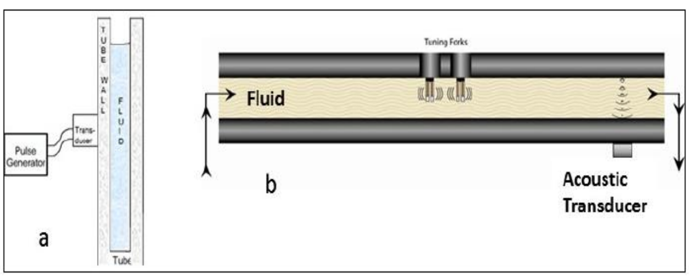
In a recently drilled crucial exploratory well in Mumbai Offshore, fluid analyser containing ultrasonic sound speed sensor was deployed for Formation testing and sampling in SOBM environment. The sensor measures the speed of the sound through the fluid utilizing a piezoelectric transducer mounted on the outer wall of the flow line. The sound signal travels through the fluid flowing in the flow line and travel back to the receiver. Based on the round-trip distance and travel time, fluid's sound speed is calculated. Changes in sound speed (or slowness) with time during pump out can be used to identify the fluids and to monitor the cleanup process.

The well presented various challenges including high overbalance (~3100 psi), low mobility and multiphase flow conditions. In addition to that stationary time needed to be minimized due to wireline deployment under high overbalance to manage the risk of differential sticking while sufficient pump out volume needed for accurate fluid identification and acquisition of clean samples. To address these challenges, RCX-S-eXcel with large area packer (33 sq Inches) along with Absorbance spectroscopy and Ultrasonic Sound speed sensor was deployed in this well.

The varying property of sound slowness in sobm, formation oil and water allowed to observe their cleanup trend simultaneously, thus helping in quick fluid identification (average pumpout time being 90 mins). Pump out was carried out at seven depths (FID) and five samples collected, out of which 2 were under multiphase flow conditions (Formation Oil+ Formation water+sobm). All desired objective of the operation were successfully met while avoiding stuck tool scenarios.



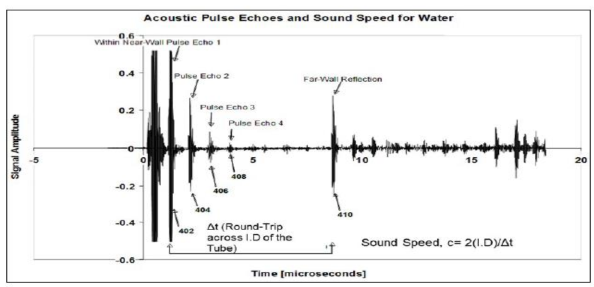
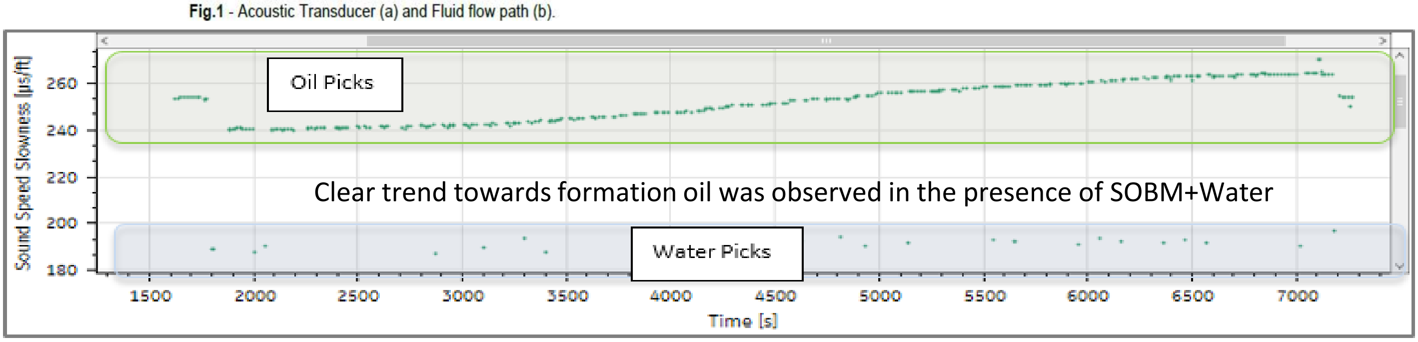
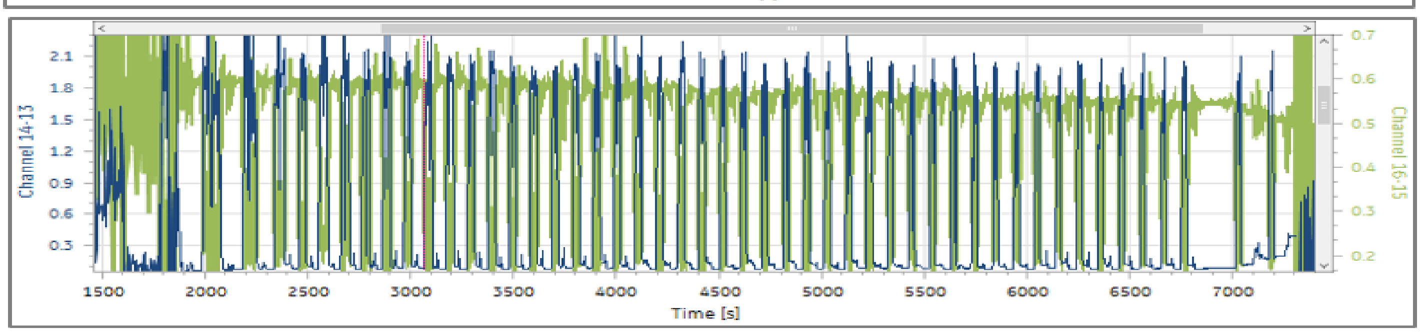


Fig.2 - Raw signal of sound speed sensor.

Fig.1 - Acoustic Transducer (a) and Fluid flow path (b).





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