Feasibility study for discriminating Litho-fluid type using elastic logs estimated through rock physics modeling to reduce uncertainty in seismic inversion study – A case study

Bisht, B.S., Jhaldiyal Beena, Singh RBN, Sanjay Singh ,GEOPIC (ONGC Dehradun), India*
***Email:** jhaldiyal_b@ongc.co.in, birsingh.bisht@gmail.com*

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Feasibility, Petrophysics, rock-physics, petro-elastic modeling, seismic reservoir characterization

Abstract
Quantification of the relation between geological process and geoscientifice data is the most important aspect of any geophysical study. Most of the time, intensive cost and extensive time consuming geophysical studies carried out without prior feasibility study conclude with ineffective results. Since all the geophysical studies are observation based and data intensive therefore a detail analysis of all types of data linked with the study is required. The ultimate objective of any geophysical study is to delineate a reservoir body which is interesting from hydrocarbon point of view. The problem becomes much easier if the area is having sufficient number of well log data and other geological information. Since the log data is recorded at very high resolution therefore its ability to identify different geological process is much more than any of the recorded data. But at the same time, during drilling process log data gets affected by borehole rugosity, invasion, mud cake formation, salinity, temperature & pressure etc. Sometimes the logs could be entirely missing or not usable due to bad hole conditions. The analysis made on such unreliable data may lead to wrong identification & estimation of litho fluid type. To overcome these situations various type of empirical relations, methods and model have been formulated. These techniques will help to re-estimate the various responses of subsurface for geological interpretation.
Once the data has been conditioned for interpretation it is further subjected to feasibility study to assess the achievability of the project objective, whether various lithologies with different type of fluids can be discriminated at the log scale or not. For this , various type of cross plots i.e between P-imp Vs Density and Vp/Vs with litho fluid color on Z-Axis are generally generated.

This paper highlights the important and deciding role of feasibility study to carryout seismic inversion study in the area where no litho-fluid discrimination is possible through crossplots generated by conventional log sets, thereby resulting in inconclusive results in post-stack seismic inversion study. This study further highlights that even a single well with proper DSI data can guide us through feasibility study, whether or not to proceed for rockphysics modeling to be use in Pre-stack seismic inversion.

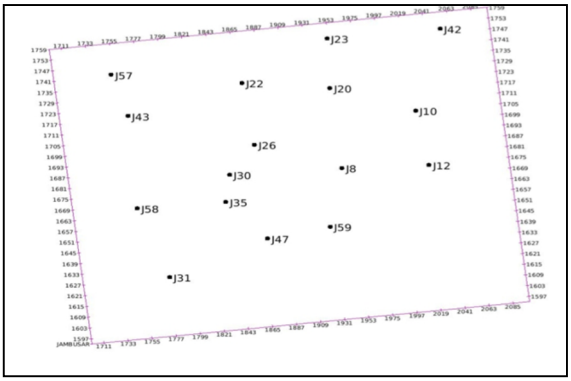
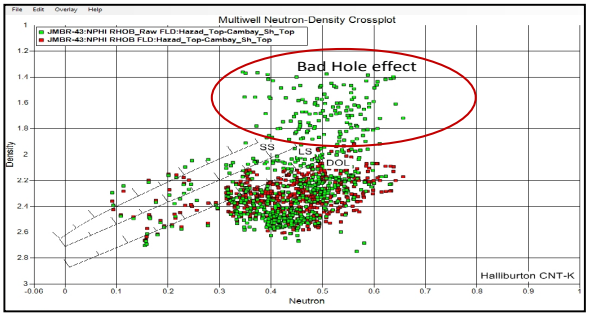


Fig: 1- Location Map of study area

This paper illustrates role of feasibility study on the scenario modeling of rock properties as applied in the study of Oil & gas field Jambusar in the Cambay basin of Western onland field of ONGC, India. Fig-1
Seismic inversion study requires set of elastic logs (Vp,Vs and Density) as input which are obtained through rock physics modeling, which uses petrophysical evaluated results as input. Thus to achieve best results appropriate constituent volumes, porosity and saturation are needed which is possible only through use of well conditioned log data.

Workflow
The following sequential workflow has been adopted for this process:

Log data conditioning
In general log data is effected due to bad hole condition, Invasion effect, Salinity of the formation water and some times with tool calibrations also as shown in Fig-2 below.



In certain cases quality of the log data is reasonable but in some intervals important logs are missing. Synthetic logs need to be generated by multiple linear regression techniques based on the other logs to fill the missing data gap. Once the data gap is filled necessary environmental corrections are applied along with the appropriate filter for spike and noise removal. This conditioned data is now suitable for further analysis. Thus log conditioning plays a very crucial role in the data analysis and to get the meaningful output Fig-3: A & B

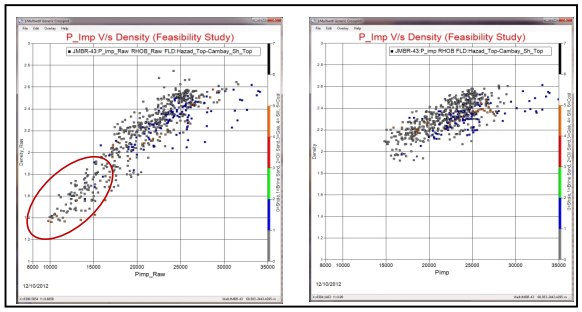


Fig: 3A- Showing raw data
Fig: 3B- Showing conditioning effect on data

Petrophysical Analysis

The objective of the petrophysical interpretation is to transform well log measurements into reservoir properties i.e. porosity, saturation, permeability, mineral component volumes etc. These parameters are responsible for oil/gas estimation and production. For determination of rock petrophysical properties an adequate logging suit is necessary which can measure the desired property accurately. Once the Petrophysical model has been fixed, it will be applied for estimation of the reservoir parameters i.e. Effective Porosity (Φ), Water saturation (Sw) and Volume of Clay (VCL) using multi-mineral inverse optimization technique. This technique takes into account the effect of conductive or nonconductive, heavy minerals, radioactive minerals and different clay contents reported in core studies.Fig-4 shows the petrophysical output of the two wells taken into study.

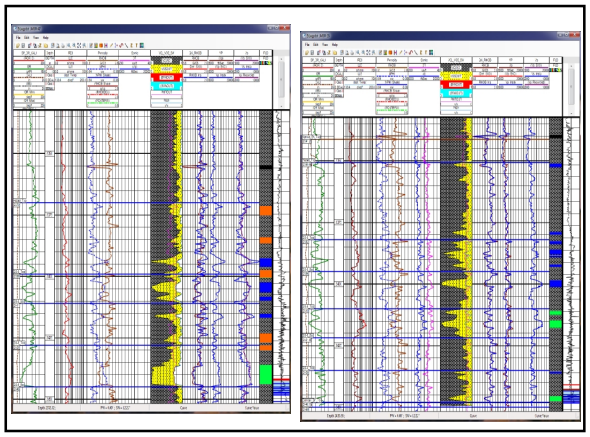


Fig: 4- Petrophysical output of well A& B

Feasibility Study

The feasibility studies are to assess the adequacy of the data to meet the objective of the project. The following steps were applied for this study:

1. The reservoir with fluid and non- reservoir were identified on the basis of petrophysical analysis of log data.
2. The reservoir with desired fluid and non- reservoir were differentiated with the help of elastic properties of formation. These elastic properties were obtained from elastic logs viz Rhob, Vp and Vs, which are responsible for seismic response.
3. Finding a relationship between petrophysical properties and elastic parameters of the formation by generating various kinds of cross plots.

Cross plots were taken between P_imp & Density for many wells of the study area. Unfortunately none of the well data gave any clue for the demarcation of the litho fluid in P_Impedance range as shown in Fig-5. All lithologies were falling in the same acoustic range, therefore based upon this analysis, Post Stack Seismic inversion study will lead to inconclusive results. Now, to assess whether Prestack inversion is suitable to carry out in this area, DSI data was required and hence it was decided to record DSI in a well which may lead to carryout rockphysics modeling in other wells where shear sonic is not available, for prestack seismic Inversion.

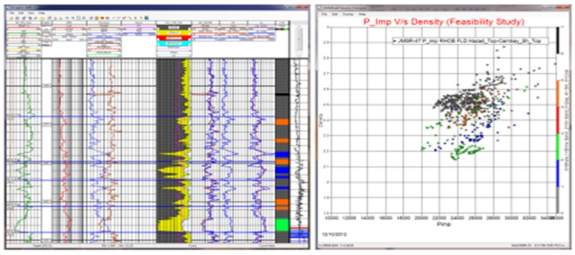


Fig: 5- Cross plot of P-Imp & Density with Lito-fluids

Based upon the recorded shear sonic a cross plot of P-Imp & Vp/Vs was taken which clearly showed the litho-Fluid

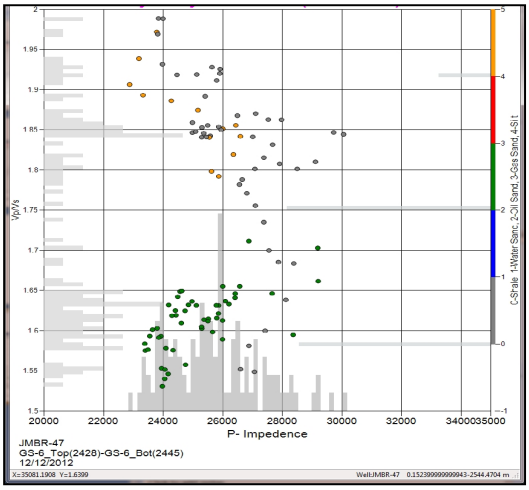


Fig: 6- Cross plot of P-Imp & Vp/Vs with Lito facies

demarcation in the Vp/Vs domain in the range of 1.55~1.65 as shown in Fig-6

Once the above relationship has been established with some kind of discriminator in acoustic impedance domain, then this can lead to forward modeling and synthetic log generation through rock physics modeling.

Rockphysics:

Rock-physics transform petrophysical results into elastic properties that can be used for seismic interpretation. This complementary nature of Petrophysics and Rock physics requires a tight integration for seismic reservoir characterization. Well log data plays a crucial role in this process of integration. In general, most of the times petrophysical evaluation, petro -elastic modeling and synthetic to seismic tie are done separately prior to integration. This introduces uncertainty and inconsistency across the geoscientific data. Ideally, Petrophysics and Rock physics modeling should be an integrated process that can produce a greater consistency between all the data and lead to reduced uncertainty.

The Rock Physics uses a phase drive mixing method or combination of methods to combine elastic properties of the minerals and fluids that predict the measured elastic logs i.e. density, P-velocity and S-velocity. The derivation of a modeling is complex task with iteration loop involving rock physics, log conditioning and petrophysical analysis. The minerals and pores space are mixed and then the fluids are filled, finally the other fluids are also introduced into the porous mineral via Xu-White modeling.

The Petrophysical model out put i.e. Volume of minerals , Volume of clay, total porosity fluid saturation has been taken into the rockphysics model to estimate the elastic logs i.e. Vp, Vs and Density through velocity Mix function using Xu-White approximation. Fig- 7 shows the integrated output of petrophysics and rockphysics.

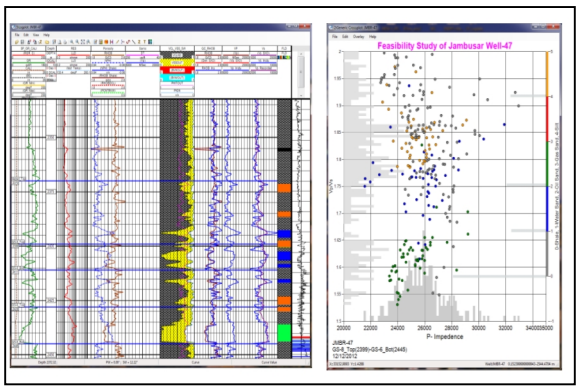


Fig-7: Shows the output of Petrophysics and Rockphysics

Application in Seismic Inversion

Rock physics modeled (RPM) logs were used for well to seismic tie & Wavelet extraction and interpretation of the

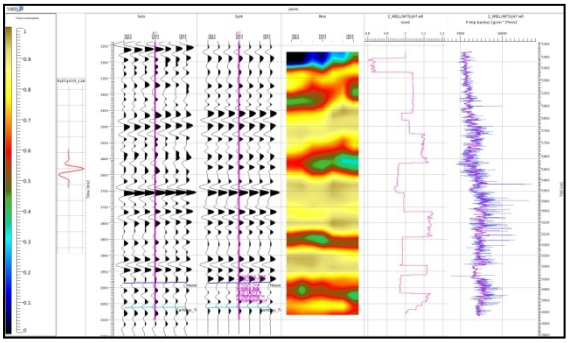


Fig. 8: Well to seismic tie and Wavelet extraction

lithology with fluids Fig.8 & 9. The wavelets of all the wells under study were similar in characteristics and stable for all angle stacks. Synthetic to seismic correlation was also good for all the angle stacks.

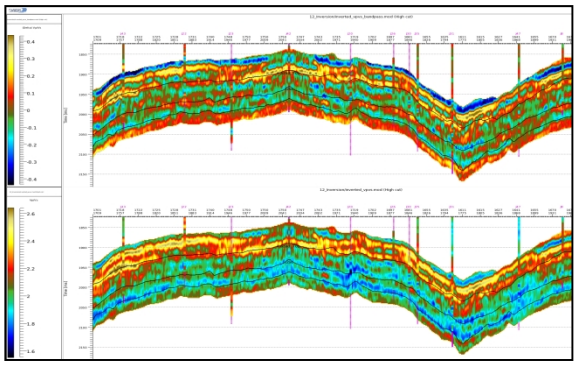


Fig. 9: inverted P-impedance, S-impedance and Vp/Vs

Discussion of results:

1.Feasibility Study:

- Feasibility study at log level is essential before carrying out inversion study.
- DSI log data helps to assess the feasibility for rockphysics modeling and prestack seismic inversion.
- Feasibility study opens a way to carryout Pre-Stack seismic inversion study where Post stack is not able to give conclusive results.

2. Rockphysics Modeling

- The rock physics modelled logs are free from invasion and borehole effects.

- Cross plots of Pimp versus Vp/Vs shows clear demarcation of gas.
- Rock physics modeling and Pretsack Seismic inversion has been carried out in this field.
- The modeled logs have been used for seismic reservoir characterisation

2. Inversion Study:

- Gas sand polygon selected from cross plot of extracted P-impedance and Vp/Vs of the wells and is used to delineate most probable oil / gas sand.
- Inversion results at unknown well shows good match with well log P- impedance and Vp/Vs.

Conclusion:

The elastic logs generated by Rock-Physics model have been used for well to seismic tie and low frequency model building. The petrophysical interpretation has thus been transferred into elastic domain to understand the corresponding seismic response in the entire area. The distribution of the reservoir sand at and away from the well location could be delineated from this simultaneous inversion. This approach has given an effective lead to the seismic reservoir characterization guided by rockphysics model.

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