9th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2012"

P-125

Role of a consistent model of Petrophysics & rock-physics for seismic reservoir characterization – A case study

***Bisht, B.S., Singh, R.B.N., Singh, S.K.,** *ONGC*

Summary

Petrophysics transforms well log measurements into reservoir properties i.e. porosity, saturation, permeability, mineral component volumes etc. 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. During drilling process log data are affected by borehole rugosity, invasion, mud cake formation, salinity, temperature & pressure etc. and even some times logs could be entirely missing or not usable due to bad hole conditions. In general, most of the times petrophysical evaluation, petro - elastic modeling and synthetic to seismic tie are done separately prior to integration. This approach increases 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. This paper highlights various issues pertaining to log conditioning, synthetic curve generation, petrophysical evaluation results for rock physics modeling and the various scenarios of fluid effects on rock properties as applied in the study of a gas field in Cauvery basin of ONGC, India.

The area under study falls in Tranquebar sub basin. A series of NE-SW to ENE-WSW trending faults having dissected the area form several fault blocks. The area experiences a thick pile of sedimentation from early cretaceous to recent time. The Precambrian basement, mainly granite is overlain by continental sediments of braided channel deposit followed by marine incursion during Albian time. The Cenomanian transgression brought the whole area under marine influence and this was overlain by high stand marine deposit consisting of coarsening upward sandstone cycle of Cenomanian to turonian age. This is followed by a shelfslope system which was established due to a new cycle of transgression and regression during coniacian – santonian to campanion – maastrichtian and marked the end of cretaceous sequence.

***Keywords**: Petrophysics, rock-physics, petro-elastic modeling, seismic reservoir characterization*

Introduction

Well log data is considered to be the most reliable in the industry and is used for petrophysical evaluation, petro-elastic modeling, scenario modeling, wavelet estimation, low frequency model building, calibration of seismic velocities, and hard data for geo-statistical modeling, time to depth calibration, reservoir model building & reservoir simulation studies. Therefore, a high quality, consistent and complete suite of data is required which can represent in-situ condition at different scale over reservoir and non reservoir intervals.

Well logs are sometimes viewed by geophysicists as hard data and not subjected to same level of scrutiny as the seismic data which may lead to mistakes as well logs are susceptible to errors from a number of sources.

The common problems which are faced by the interpreters are the data set of different service companies with different tool vintage. Sometimes the wells are drilled with different drilling fluid in a long span of time. It is also possible not to have recorded log in important zone due to bad hole condition. To overcome this situation the data from the different sources is to be rescaled, normalized, synthesized and corrected for drilling disturbances before incorporating in any kind of interpretation. This process is known as log conditioning.

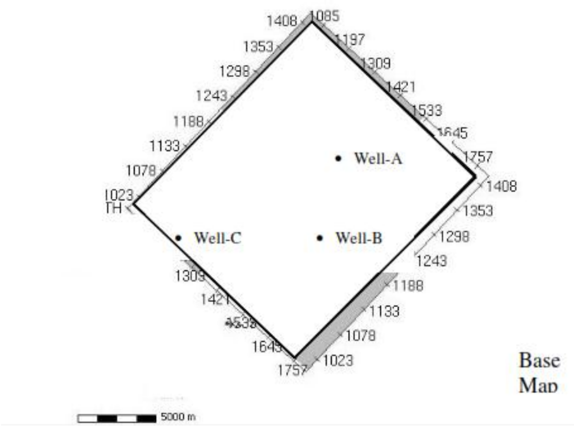
Room No.402, INTEG, GEOPIC, ONGC, Dehradun
Emails: bisht_bs@ongc.co.in

Well log analysis for geophysics differs in several important ways from standard log analysis. In most cases well logs are obtained for the purpose of estimating recoverable hydrocarbon volumes. Therefore the zone of interest is mainly the producing intervals. For geophysics, well logs form the basis for relating seismic properties to the reservoir. While we are still concerned about producing intervals, we also need good information about all of the rock through which the seismic waves have passed. Therefore the zone of interest for reservoir seismic is much larger and encompasses basically everything from the surface to total drilled depth.

The objective of the rock-physics modeling is to generate elastic logs ρb, Vp & Vs which is free from borehole effects, invasion of borehole fluid into the reservoir and to compensate for scale and frequency difference between sonic & seismic measurements. The petrophysics and rock physics modeling has been carried out in the same platform to find a model which is consistent with all the data from the wells. This consistent model of petrophysics & rock-physics is found to be useful for carrying out meaningful seismic reservoir characterization in the area of study.

Case Study

This case study pertains to a gas bearing clastic reservoir in east cost of India, wherein the sediments are of Cretaceous age. The reservoir is moderately clean having 10-15 % of high density shales. The porosity varies from 5-25 %. Gas saturation is up to 90 % in some of the gas bearing sands. Three key wells A, B & C as shown in Base Map having Clastic (X), Shale (Y) & Clastic (Z) formations have been considered for analysis which represents the gross lithology of the field.



The quality of the log data is reasonable but in some intervals important logs are missing. Synthetic logs have been generated by multiple linear regression techniques based on the other logs to fill the missing data gap (Fig-1). Once the data gap is filled necessary environmental correction is applied along with the appropriate filter for spike and noise removal. Manual editing is done to remove the spurious spikes. This conditioned data is used for the purpose of further analysis. Log conditioning plays a very crucial role in the data analysis and to get the meaningful output.

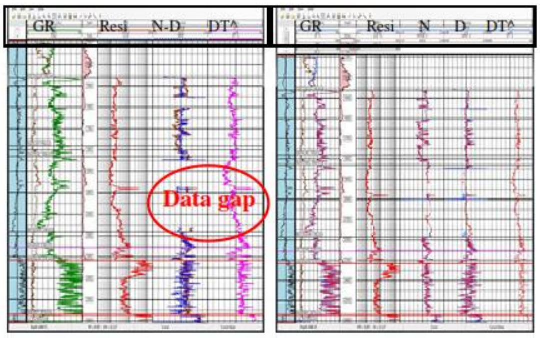


Fig-1 Log Conditioning & Synthetic curve generation

Before taking up the data for Petrophysical analysis a consistency check is required by taking histograms of GR, Sonic & Density logs of Wells- A, B & C together. This check is required to be done formation wise Fig-2 shows the improvement of pattern in histogram of conditioned data as compared to raw ones for different formations.

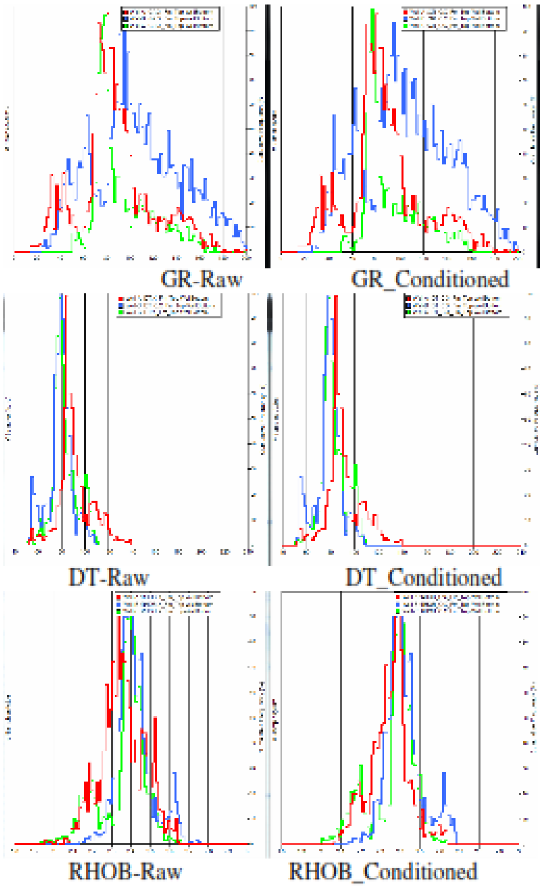


Fig-2 Histograms of Raw and Conditioned data of formations.

After conditioning, the data has been subjected to feasibility study to determine the objective of the project whether various lithologies with desired type of fluids can be discriminated at the log scale. Therefore, a cross plot has been taken between P-imp & Gama Ray and P- Imp & Density with the lithology & fluid type in Z axis Fig 3 & 4.

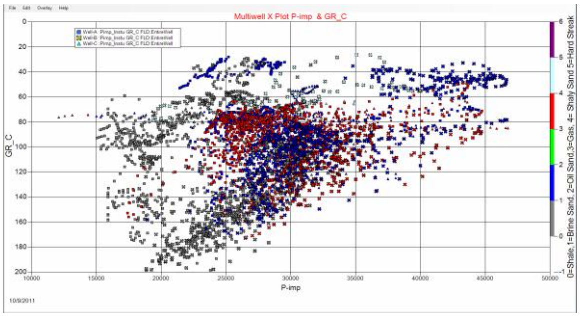


Fig-3 Crossplot between P-imp & GR

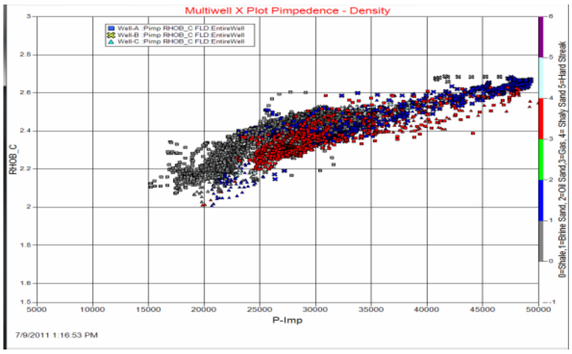


Fig-4 Crossplot between P-imp & Density

These cross plots do not indicates a clear demarcation of various types of lithologies with fluid since all the points are falling in the same cluster and therefore the criteria to distinguish various sand with fluid cannot be established. Since with these available log data we are not in a position to discriminate various lithologies with fluid type, we looked for some other parameters which can provide us the relevant information. S-Impedance is also a very important physical property, which may be used for this purpose, but unfortunately the recorded shear logs are not available in any of the wells in this field. To overcome this problem rock physics modeling may be done to generate elastic logs which can be used for this analysis. This requires the mineral volumes and rock properties to build a rock physics model for generating modeled elastic logs.

To generate the required input for rock physics modeling, log processing has been done by taking all the relevant parameters required for log processing. A shale-sand-silt model has been taken for this case and Simandoux water saturation equation has been used. Fig-5 shows the volumetric analysis of well–A. Similarly the processing of other two wells B and C have also been done for rock physics modeling.

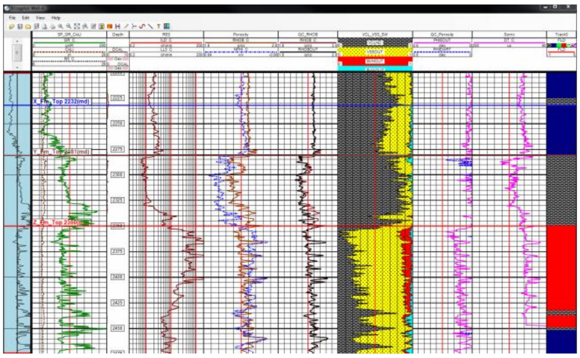


Fig-5 Processed Log output for Rock Physics model

Once the reservoir properties i.e. effective porosity (φeff), total porosity (φtotal), Volume of clay (Vclay), water saturation (Sw), volumes of mineral Sand(Vsand) & Silt (Vsilt) have been estimated, a rock physics model has to be established which will provide a link between Petrophysics and elastic properties to generate modeled elastic logs.

An attempt has been made by conceptualizing a rockphysics model from the available resources which has produced the elastic logs viz. ρb, Vp & Vs as modeled logs which are free from the borehole environmental effects during the drilling process.

A self-consistent model has been taken for this case with Xu-White approximation, all the relevant parameters required to generate elastic logs have been taken from published literature. The minerals and fluid volumes have been taken from petrophysical processed log output. This process has been carried out in an integrated software PowerLog-RPM from Fugro-Jason. This is iterative processes which require fine tuning of mineral volumes to achieve the near perfect match between the recorded logs and the modeled logs in invasion, insitu & fluid substitution situations. The output of petrophysics and rock physics has been shown in Fig. 6 & 7.

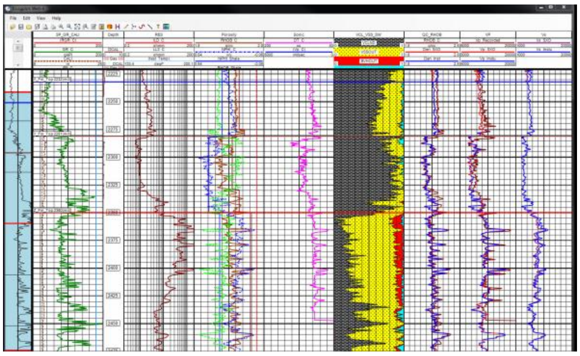


Fig-6 Modeled insitu logs ρb, Vp & Vs

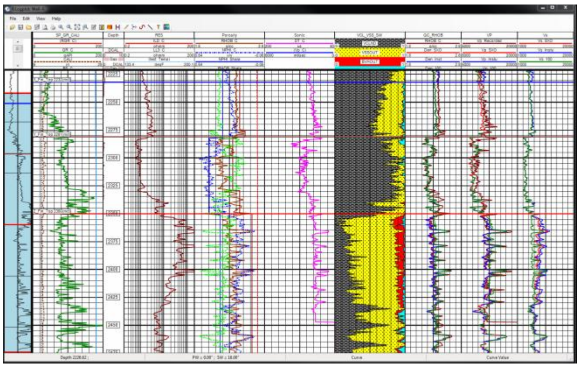


Fig-7 Modeled ρb, Vp & Vs logs with fluid substitution Sw=100 %

Once the shear log has been generated cross plot between Gamma Ray and Vp/Vs, P-imp and S-imp, P-imp and Vp/Vs, S-imp and Vp/Vs have made. These crossplots are shown in Fig8 to Fig.11

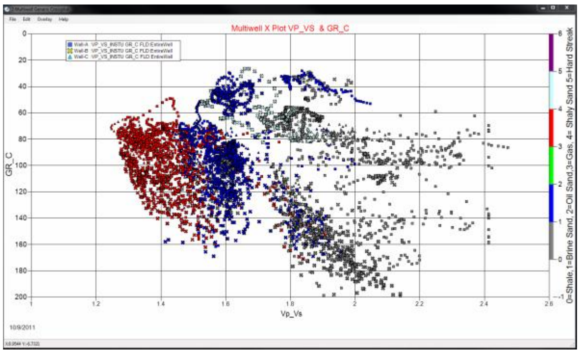


Fig-8 Crossplot between GR and Vp/Vs after RPM

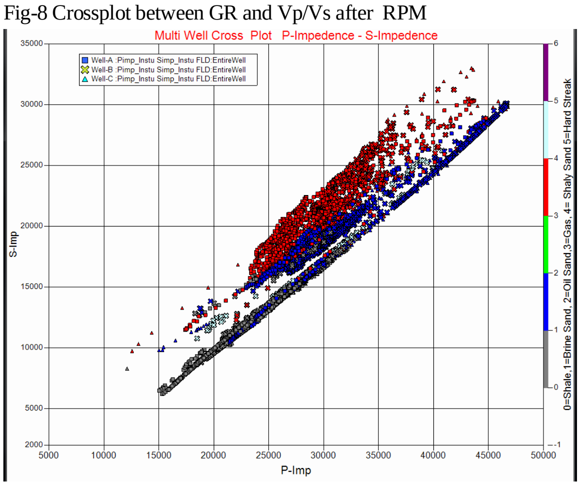


Fig-9 Crossplot between P-imp and S-imp after RPM

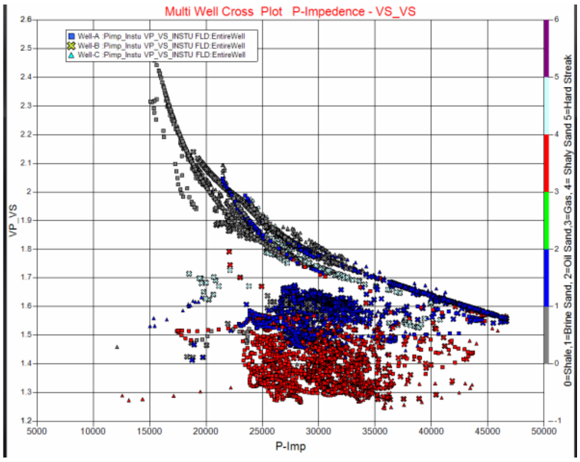


Fig-10 Crossplot between Pimp and Vp/Vs after RPM

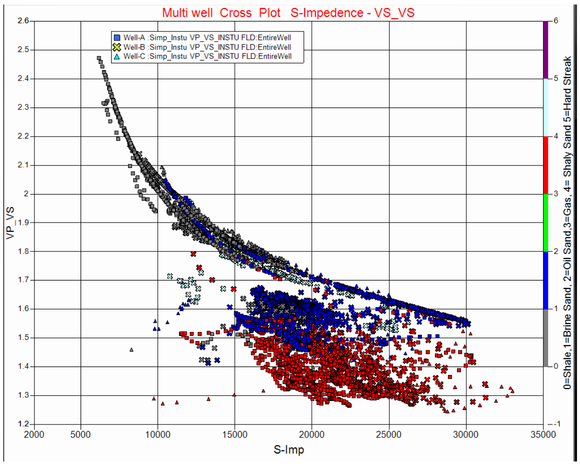


Fig-11 Crossplot between S-imp and Vp/Vs after RPM

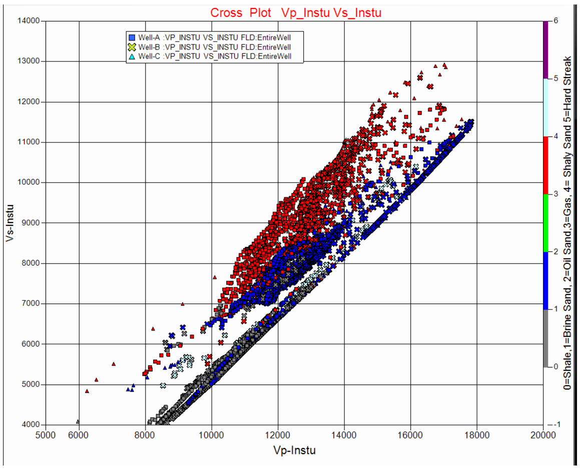


Fig-12 Crossplot between Vp_insitu and Vs_insitu after RPM

All these cross plots show a clear demarcation of lithology with fluid which prove the feasibility for a reservoir characterization study using seismic pre-stack inversion. From these cross plots a relationship can be established to interpret the properties in the entire 3-D area of the study. To examine the effect of the fluid substitution in the model the gas has been replaced by brine by using Sw as 100% in the Gassman fluid substitution method. The effect of the fluid has been seen in the cross plot in Fig.13. The results of this process are useful to integrate seismic inversion results in situ conditions and which consequently helps geoscientists to increase the level of confidence for successful drillable locations.

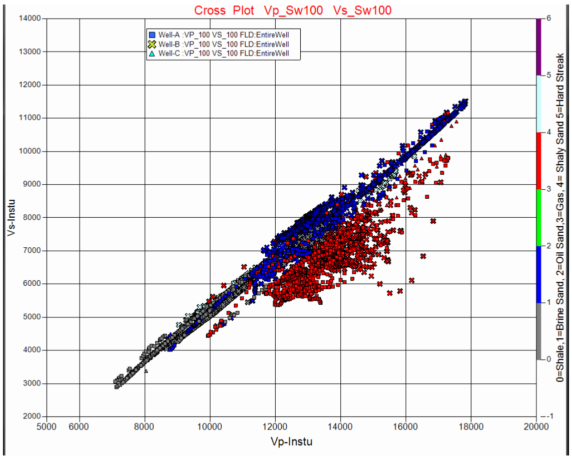


Fig-13 Crossplot between Vp_Sw100 and Vs_Sw100 after RPM

Conclusions

Many, if not most, original well logs require editing and correction before they are used for petrophysical and rockphysics modeling. The main reasons for this, a combination of theoretical, empirical, and heuristic models can be applied to repair the bad or missing data.

Rock physics modeling can help us to understand the properties of the reservoir and non-reservoir zones and correct for some of the problems encountered in well log data.

It is the process of finding a rock physics model that is consistent with the available well and core data. The consistent model generated for this field has brought out clear discrimination of various lithologies with different fluids which may lead to meaningful seismic reservoir characterization.

Acknowledgements

The authors are indebted to Shri S.K. Das, ED-HOI-GEOPIC, Dehradun, India for providing the technical input and guidance for writing this paper.

Thanks to Shri AK Tandon Head-INTEG, GEOPIC, Dehradun, India for providing all kind of support.

We wish to express our thanks to Shri Rajesh Kumar, Business Manager, Fugro-Jason, India for providing technical help in Petrophysics and rock-physics modeling.

The authors are grateful to the concern geoscientist of this domain for providing necessary input during the project work and writing this paper.

We thank ONGC management for allowing us for submission of this paper in SPG international conference - 2012

The views expressed in this paper are exclusively of the author and may not match with the official view of ONGC.

References

Shihong, C., Torres-Verdin, C., Wu, J., and Alpak, O.F., 2004, Assessment of Mud-Filtrate Invasion Effects on Elastic Parameters: SPE paper 90159.

Vasquez, G.F., Dillon, L.D., Varela, C.L., Neto, G.S., Velloso, R.Q., and Nunes, C.F., 2004, Elastic Log Editing and Alternative Invasion Correction Methods: The Leading Edge 23, 20-25.

Walls, J.D. and Carr, M.B., 2001, The Use of Fluid Substitution Modeling for Correction of Mud Filtrate Invasion in Sandstone Reservoirs: SEG Expanded Abstracts, 385-387.

Xu, S., and White, R.E., 1995, A new velocity model for clay-sand mixtures: Geophysical Prospecting 43, 91-118.

Sams, M. S., and D. Saussus, 2007, Estimating uncertainty in reserves from deterministic inversion: Annual International Conference and Exhibition, EAGE, Extended Abstracts, P17.

Jarvis, K., Folkers, A., Mesdag, P. [2004] Reservoir characterization of the Flag Sandstone, Barrow Sub-Basin, using an integrated, multiparameter seismic AVO inversion technique. The Leading Edge, 23(8), 798-800.

Mavko, G., Mukerji ,T. and Dvorkin, J. [2009] The rock physics handbook: tools for seismic analysis in porous media. Cambridge University Press.

Sams, M. [2001] Geostatistical lithology modeling. ASEG 15th Geophysical Conference and Exhibition, Extended Abstracts