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Rock Physics Modeling in Oil and Gas Field Development: A Methodology for Reservoir Characterization in Low Salinity Pay

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SUMMARY

In this paper, we described some of the key challenges faced and their solutions during the reservoir characterization study. Shear log prediction can be done quickly by methods, such as multi linear regression and also by building a robust petro-elastic model, if pore geometry and rock moduli are known. Both methods provide comparitive results and helps to rectify inaccurate data or fill missing gap. Rock physics modelling also helps to gain confidence on the quality of petrophysical curve by comparing the difference between original (measured) vs. predicted (modelled) curves. Reservoir and non reservoir rocks can be distinguished on elastic properties cross plots. Some thoughts are shared on the methods to calculate petrophysical input, such as shale volume, porosity, water saturation with field wide approach. Once consistent set of logs are available, further analyses, such as well to seimsic tie, AVO and time lapse study can be accomplished.

Introduction

Reservoir characterization projects require geoscientists to predict rock properties by integrating petrophysical & seismic data, which lie on two extreme ends of resolution scale. Rock physics plays a crucial role to bridge this gap. The success of such project depends on the quality of acquired data; however that does not impose a restriction to carry out such studies. A robust dataset may help to expedite a project without losing time in the initial phase. Its quality can further be enhanced by applying suitable techniques such as post processing conditioning on seismic data and well log data.

In our recent experience,while working on an Australian basin dataset, we had come across with some of these challenges. Measured shear wave were missing in most of the wells. Shear wave serves as an essential component to compute elastic properties such as VP/VS ratio, Poisson’s Ratio and Elastic Impedance. This helps to further discriminate fluid. Once shear wave was predicted, the secondary challenge was the poor contrast of elastic properties observed for different lithofacies which caused difficulties in distinguishing reservoir from non-reservoir rocks. Other key challenge was to understand elastic properties behavior due to pressure and temperature variability. This required a robust petro-elastic model, which link reservoir properties to seismic based elastic attributes.

Shear wave prediction

The methods for shear wave prediction can be broadly categorised into two main categories i.e. empirical regression methods or effective medium theory. One of the commonly used empirical relations is (e.g., Greenberg & Castagna, 1992), whereas models (e.g., Kuster & Toksoz, 1974) fall under effective medium theory. No single technique is universal in its application & local data calibration is required. A comparative analysis which includes log plots and finding correlation between measured and modelled logs is required to arrive at final shear wave using various methods. In this vast array of solutions, some quick look methods are also available. These do not require making assumptions about pore geometry and rock moduli. On the other hand, they have wide acceptance. The advantage of these methods is that they are quick, simple to apply and produce similar results to those of the effective medium models. Multi linear regression technique and neural network methods top the list. Shear wave is predicted by taking into consideration of good quality logs like GR, resistivity, neutron, density and depth as shown in (Figure 1). With these input logs, multi regression model is built and is applied to the well or a section of well, where the shear wave is incorrect or missing. One of the downside of this technique is that the predicted curve tends to bias towards the curve which has maximum correlation with the targeted shear wave curve. Multi linear regression model can be applied on the same or other regional wells in the study area with similar depositional settings.

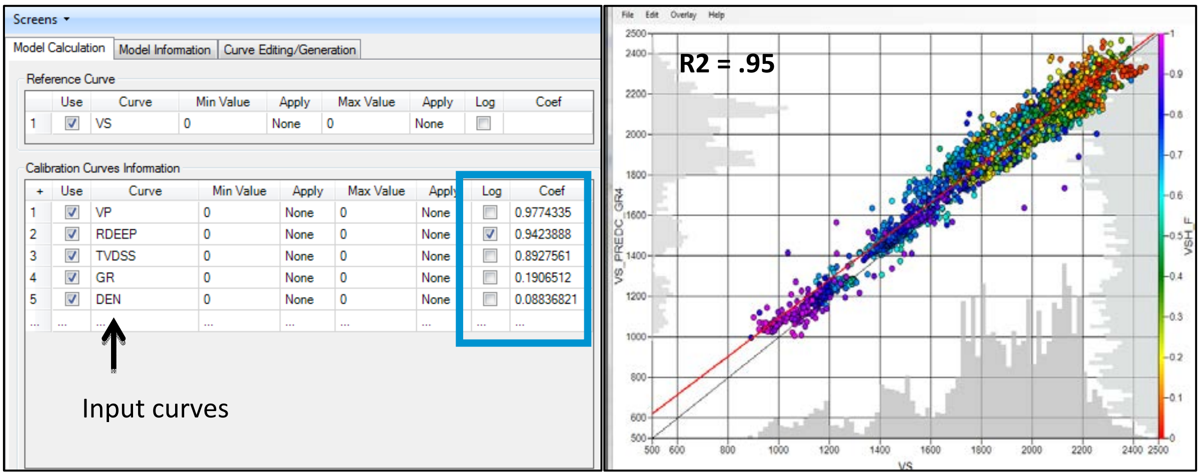

Figure 1 *Shear wave prediction using multi linear regression & its comparison with measured log.*

Elastic property contrast

One of the main objectives of a quantitative interpretation study is to model elastic response for various lithofacies at various temperature and pressure conditions. The idea is to delineate reservoir from non-reservoir rocks. One of the commonly used techniques is to build cross plots using different log attributes. It helps to investigate the data spread and identify elastic properties for individual facies. In our example, most of the well log data shows poor contrast in elastic properties of hydrocarbon and brine sand at insitu conditions as shown in AI_VPVS & LMR crossplot (Figure 2). Synthetic scenarios can be analysed by artificially varying reservoir properties such as shale volume, porosity, saturation, pressure & temperature.

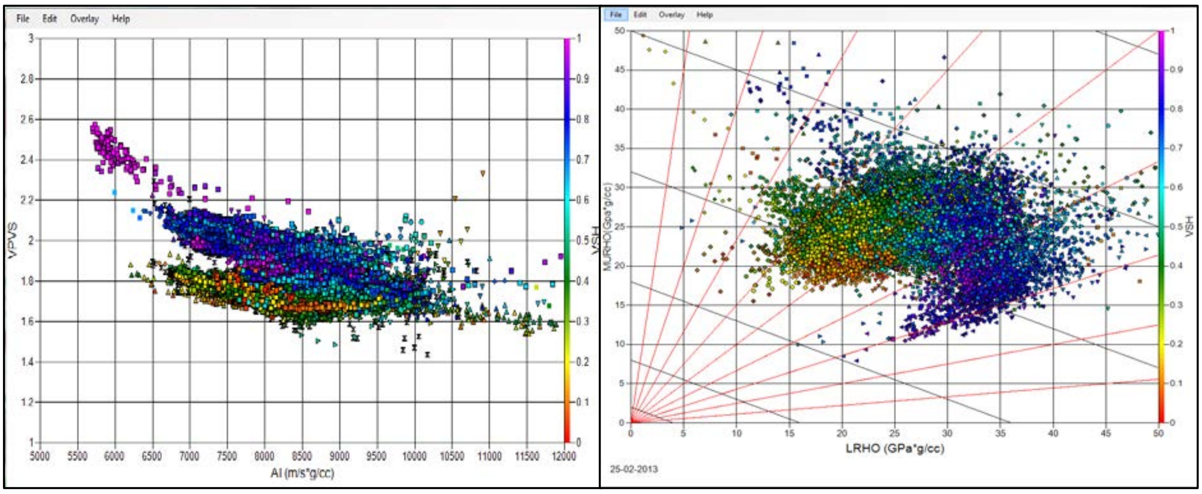

Figure 2 *AI_VPVS & MuRho_LambdaRho crossplots showing overlapping brine sand & hydrocarbon sand.*

Petrophysical input

Petrophysical inputs such as shale volume, NTG, porosity & fluid saturations are required to build a petro-elastic model. These parameters need to be computed by adopting consistent approach across the study area. The real challenge is to find suitable parameters in order to compute these curves. One should prepare a detailed data inventory capturing crucial information about drilling history, type of drilling fluid, any formation losses or gains in the well. These can be captured from sources, such as well completion report, mud log drill cutting, sidewall core, formation pressure data & PVT analysis report. One can adopt deterministic or stochastic approach depending on the objective. Gamma ray and neutron-density are mostly used for computing shale volume. Other curves, such as Resistivity and SP logs can also be incorporated. Total Porosity is computed by using density log in shale, brine sand and both density-neutron (Gaymard average) in hydrocarbon filled sand. In our case, water saturation was initially estimated by Archie equation but was later revised and replaced by Indonesian equation due to the presence of relatively fresh formation brine (salinity~1700 ppm) causing low contrast between brine and hydrocarbon sand (Figure 3). Log derived saturation can then be calibrated with core derived saturation by building saturation height modelling function.

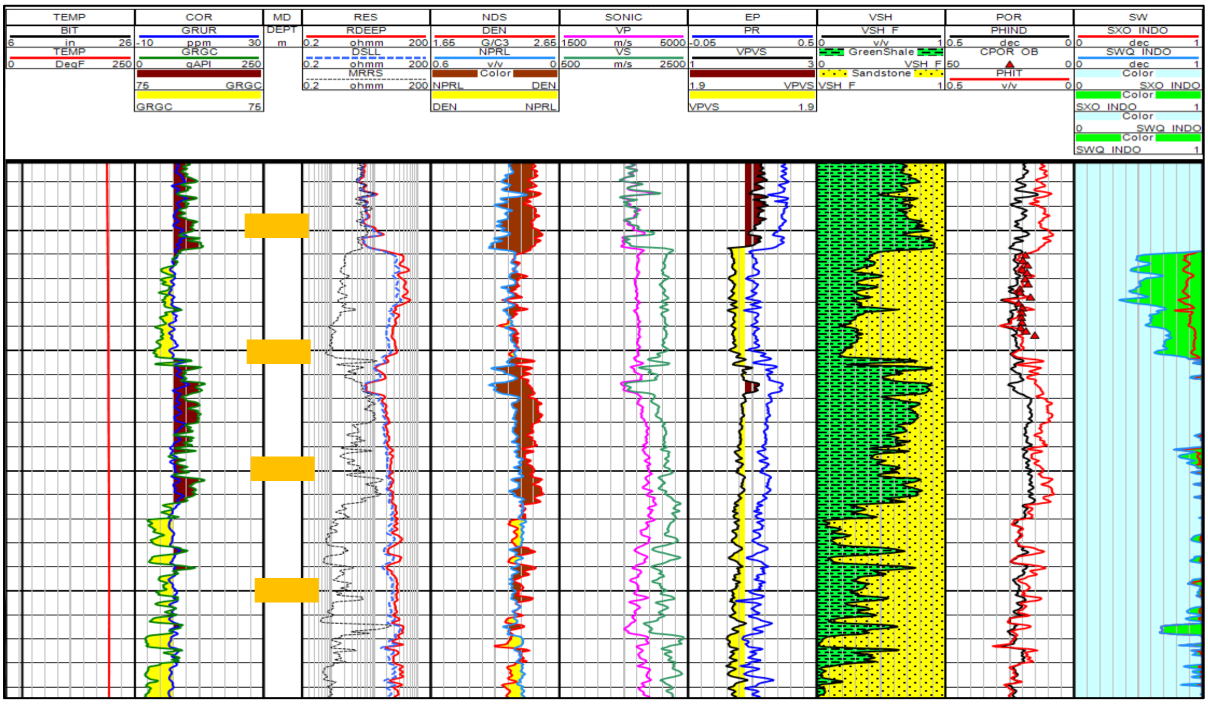

Figure 3 *Petrophysical curves (Vsh, Por & Sw) computation QC plots.*

Building PEM

Once all input curves were available, a petro-elastic model was built using "ROCK SI" which is the CGG proprietary rock physics modelling software. POR_AI cross plot (Figure 4) shows a distinct V-shaped with increasing clay content, where VP reaches to the maximum and porosity to the minimum, when clay equals to the sand porosity. This phenomenon occurs at the transition of grain-supported sediments to clay supported sediment. The other cross plot which helps to pick the suitable rock physics model is POR_Bulk Modulus. Elastic logs are back predicted (Figure 5) using Petro-elastic model which is built using constant cement sand model. This model is picked over unconsolidated sand model after a few iterations and after compiling core data information.

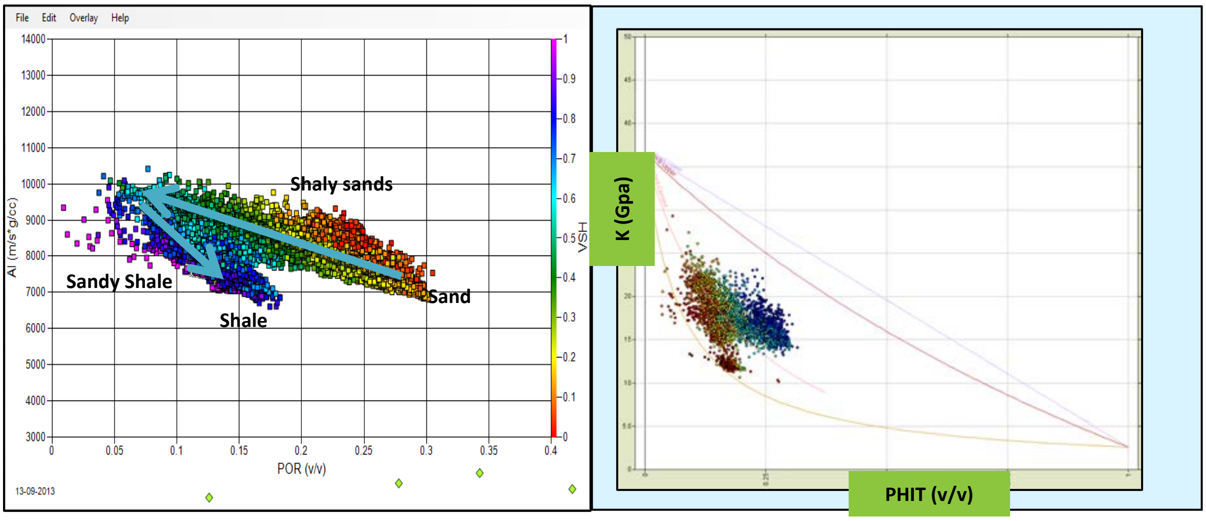

Figure 4 *POR_AI showing typical V shape & POR_K with default cement sand model overlay.*

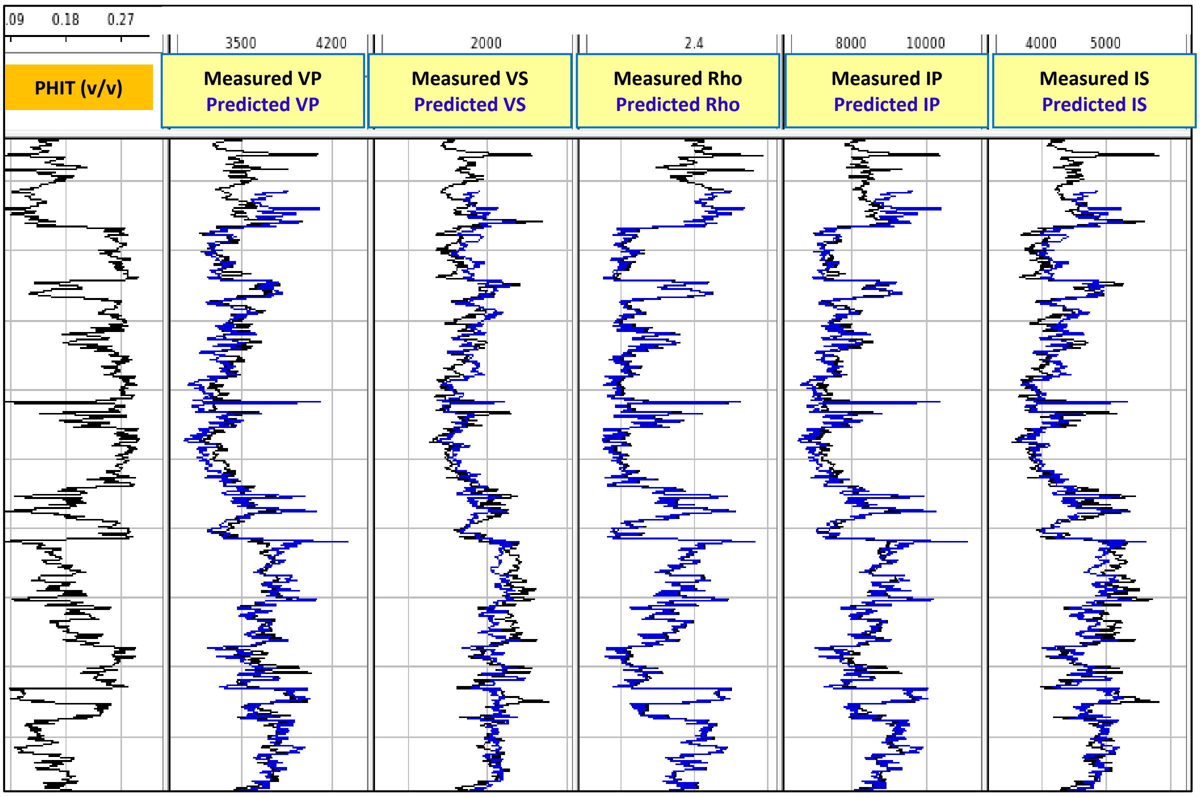

Figure 5 *Elastic log prediction using constant cement sand model.*

Conclusions

In this paper, we described some of the key challenges faced & their solutions during the reservoir characterization study. Shear log prediction can be done quickly by methods, such as multi linear regression and also by building a robust petro-elastic model, if pore geometry and rock moduli are known. Both methods provide comparitive results & helps to rectify inaccurate data or fill missing gap. Rock physics modelling also helps to gain confidence on the quality of petrophysical curve by comparing the difference between original (measured) vs. predicted (modelled) curves. Reservoir & non reservoir rocks can be distinguished on elastic properties cross plots. Some thoughts are shared on the methods to calculate petrophysical input, such as shale volume, porosity, water saturation with field wide approach. Once consistent set of logs are available, further analyses, such as well to seimsic tie, AVO and time lapse study can be accomplished.

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