CMP16_684

Interactive Rock Physics: A modeling approach solution in multi-well studies in the Gulf of Mexico

Paola Vera de Newton, William Marin, Fady Hanna. RSI
paola.newton@rocksolidimages.com, william.marin@rocksolidimages.com,
fady.hanna@rocksolidimages.com

Abstract

Quantitative interpretation of geophysical data requires rock physics as the link between rock properties observed at core/well scale to observations away from the wellbore. This process may include empirical, theoretical, or other modeling techniques, and it assumes that well log data has been corrected. By perturbing the rocks using a rock physics model, explorationists can interpret changes that relate to a geophysical response in elastic and electrical domains. An interactive rock physics approach is presented to encapsulate the modeling phase without generating unrealistic cases not supported by the rock physics diagnostics (RPD). This approach was applied to the Great White well in the Gulf of Mexico. The workflow consists of (a) geophysical well log conditioning, and RPD (b) fluid, porosity, mineralogy, seismic and/or electromagnetic modeling (c) interactive modeling using a real time visualization tool. Using rock physics models embedded in the workflow, interactive rock physics modeling results of fluid sensitivity show, for example, AVO anomaly changes from class III to II as a function of changing sand facies. Simultaneous changes included API gravity, dissolved gas and water salinity. Modeling was also utilized to build a rock physics template so that numerous rock property scenarios are modeled when interpreting geophysical data.

Introduction

Rock physics diagnostics is widely used to describe the relation between elastic rock properties and petrophysical properties. This process involves the calibration of a rock physics model which is used to understand the impact of reservoir property variations on geophysical signature. The process requires an in-depth petrophysical model and appropriate well log data conditioning in the reservoir zone and encasing sediments. Additionally, as more wells become available, they can be incorporated into this rock property modeling as a way to validate the model and its effectiveness for accurately representing possible litho-facies changes. In some cases, where no log information is available, the modeling of reservoir quality zones can also be achieved via pseudo-well modeling exercises.

Identifying a rock model accurate enough to represent rock type and its microstructure can be an exhausting task when performed in multiple reservoirs and wellbores. One common challenge is that teams will require constant input from rock physicists to first calibrate such a model, and most importantly, to generate numerous iterations that cover those possible scenarios that may explain the geophysical signature in question. For this reason, this case study shows the advantages of an interactive rock physics modeling approach where the models are available to other geoscientists, without generating unrealistic cases that are not supported by the rock physics diagnostics. It also allows interpreters to see the results in real time and understand reservoir heterogeneity and possible facies scenarios due to changes in the elastic and electrical domains.

This concept can be applied to any size project, but it proves to be extremely convenient when dealing with multi-well studies or large areas including multiple well control points. Exploration efforts in areas such as the GOM for example, have been ongoing for over 100 years, and more areas have regained interest within and outside US waters. Protraction areas such as Walker Ridge, Mississippi Canyon, Green Canyon, Alaminos Canyon, and Keathley Canyon have continued to be highly prospective over time with field discoveries such as Trident, Silver Tip, Great White, and, more recently, Shenandoah and Leon. An area covering more than 540 wells can be seen in figure 1, and it highlights the Alaminos field as one example where the interactive rock physics approach was applied using the visualization tool rockAVO.

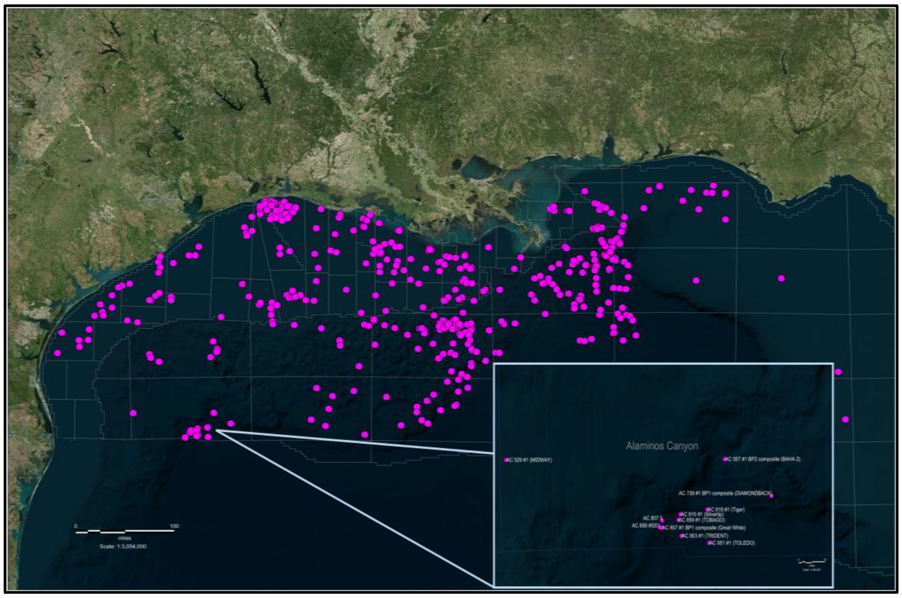

Figure 1. Map of the Gulf Mexico highlighting the Alaminos Canyon protraction area where the interactive rock physics modeling approach was applied.

Methodology

The modeling results for this example have been provided using the real-time modeling visualization tool called rockAVO™. Given the nature of these rocks, the base type of modeling is fluid substitution followed by the calculation of the resulting synthetic seismic signatures. Fluid substitution can provide a good understanding of AVO changes as a function of fluid phase change for a given rock. In addition, matrix changes are performed so that the effect of changes due to porosity and mineralogy can also be observed instantaneously. In summary, the workflow comprises the following steps:

- Step 1: All well data must be processed through a rigorous well log conditioning step called Geophysical Well Log Analysis (GWLA), and it includes the Rock Physics Diagnostics (RPD) phase so that all logs are corrected (if needed) in a consistent manner. In this step, a rock model or combination of models are identified for reservoir quality rocks. This model will be used as a proxy for perturbational modeling purposes.

- Step 2: Based on the selected rock model, the reservoir is perturbed for variations in fluid, porosity, and dominant mineral content as the main changing variables. Since the aim of the integrated result is understanding theoretical responses of reservoir changes, synthetic seismic and/or electromagnetic modeling is also incorporated into the workflow so that geoscientists can visualize the effect of changing these properties on pre-stack seismic response and, ultimately, CSEM data.
- Step 3: Finally, all results are merged into the rockAVO visualization tool which is used as the delivery mechanism, and which allows users to see the modeled changes in real-time.

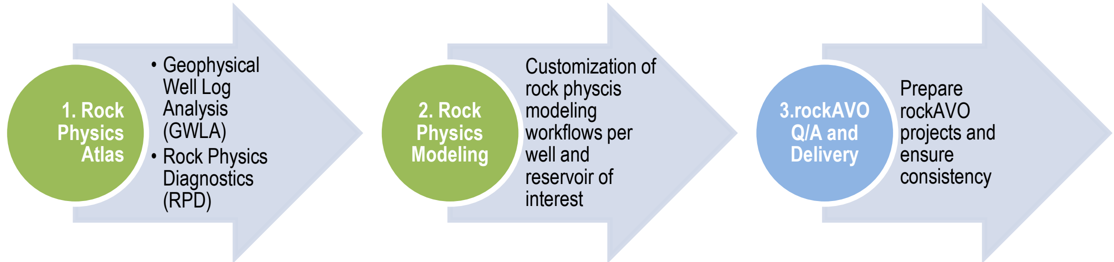

Figure 2. Generalized workflow of the interactive rock physics modeling in rockAVO.

Rock Physics Modeling

The granular model combination of soft and stiff sand models (Dvorkin and Nur, 1995) and Greenberg Castagna's relationship was identified in the rock physics diagnostics phase. Litho-classes in the area ranged from blocky oil sands to silty and shaly sands with residual oil saturations. These reservoir zones are selected for more detailed modeling of cases not present at in situ conditions. An example of the fluid sensitivity results for the main oil sand in the Great White well (AC857-1) is shown in Figure 3. Gassmann's theory is used in the elastic domain and data is then upscaled using the Backus averaging process for the dominant seismic frequency. Acoustic impedance and Poisson's ratio represent the most discriminative spaces for the reservoir sands in this wellbore. Two main sand domains are observed when cross plotting these attributes. High impedance sands tend to show the least sensitivity to fluid than low impedance ones due to a porosity change between them. Hydrocarbon responses show, in general, lower Poisson's ratio than wet sediments and they are more distinctive than wet in the low impedance sands. This modeling is only valid though for this unique combination of rock and fluid properties.

The use of interactive rock physics modeling incorporating rock model constraints provided in the workflow panel enables geoscientists to, for example, understand how theoretical AVO signatures in the field vary. Simultaneous changes to this particular example include the modeling of API gravity, dissolved gas, and water salinity, which can also affect how the fluid facies separate from the background data trend. Quick quality control in AVO anomalies changes from class III to II can also be determined as a function of sand facies change.

Alternatively, rock modeling can also be utilized to build a rock physics template for efficient lithology and pore-fluid interpretation of well log data (Avseth et al., 2005) so that numerous rock property scenarios can be modeled as an aid to interpreting geophysical data. This common technique allows us to understand reservoir property signatures with the principal objective of minimizing uncertainty and risk.

For the multi-well studies, as in the GOM case, it can be built upon the existing modeling conducted as part of the regional rock physics atlas for a specific location.

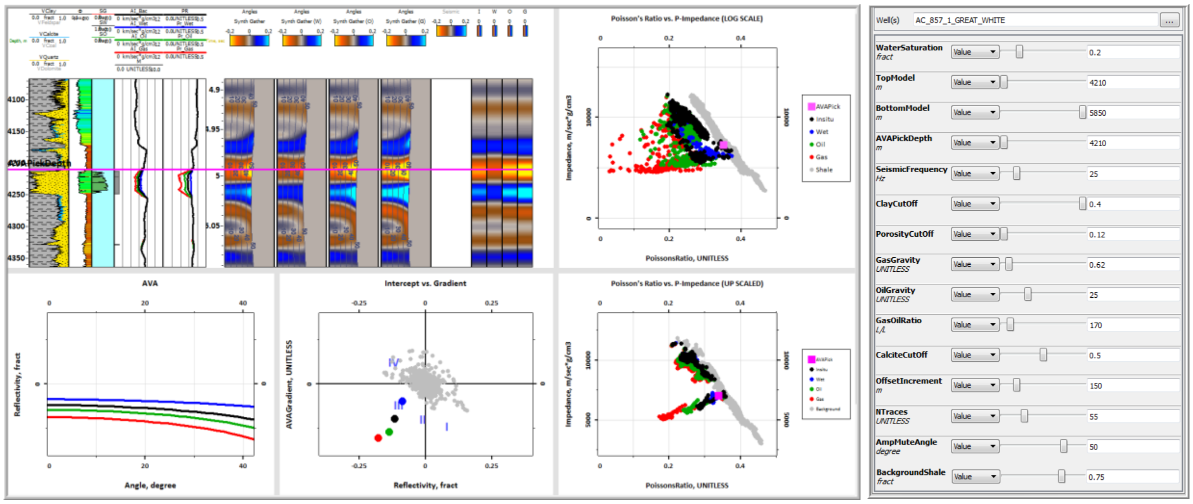

Figure 3. Dynamic deliverable in rockAVO for the Great White (AC857-1) well in Alaminos Canyon. Upscaled elastic attributes (P-Impedance and Poisson's ratio) are displayed after fluid substitution modeling (80% gas in red, 80% oil in green, and 100% brine in blue). From left to right, ray traced synthetic gathers and stacks are shown for in situ, brine, oil and gas cases. Bottom left plots show the reflectivity response at the depth indicated by the magenta line. P-Impedance and Poisson's ratio plots show the log scale (upper right) and upscaled (lower right) response within the zone of interest and sand response (magenta square). The panel with slider bar controls shows the properties the user can interactively change while using rockAVO.

Conclusions

Combined rock physics workflows in this case simplifies one of the many modeling combinations that can be presented in an interactive way to other geoscientists while keeping the rock model foundations untouched. It provides an intuitive accessible solution to common rock physics practices that are often unavailable within multi-disciplinary teams. The application of integrated workflows also ensures higher confidence in the modeling criteria when dealing with a larger number of well log datasets, and a common, consistent source of rock physics modeling results.

Acknowledgements

RSI would like to thank their QI petrophysics team for the rock physics modeling compilation generated in the Alaminos Canyon area.

References

Avseth, P., T. Mukerji, and G. Mavko, 2005, Quantitative seismic interpretation: Applying rock physics tools to reduce interpretation risk: Cambridge Univ. Press.

Dvorkin, J., and Nur, A., 1995, Elasticity of high-porosity sandstones: Theory for two North Sea datasets: submitted to Geophysics.

Gassmann, F., 1951, Uber di elastizitat poroser medien: Vier. der Natur Gesellschaft, 96, 1-23.

Greenberg, M. L., and Castagna, J. P., 1992, Shear-wave velocity estimation in porous rocks: Theoretical formulation, preliminary verification and applications: Geophysical Prospecting, 40, 195-209.