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3D Seismic Petrophysical Evaluation of Complex Clastic-Carbonate Sequences in the Neuquen Basin, Argentina. A Case Study

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Abstract

The four reservoirs found at the Pata Mora area are characterised by high lateral complexity due to rapid variation of facies and main petrophysical properties, such as porosity and fluid saturation. With more than 40 wells drilled, spread in an area of 180 Km2, and extensive well log and core data acquisition, it is still a big challenge to establish a meaningful reservoir distribution. The complexity of the carbonate-clastic sequences is further increased by the presence of anhydrite and halite in the sections nearby the reservoirs. The work shown here represents an attempt to integrate seismic based properties, well logs and geological information into the reservoir model of this field, through quantitative seismic interpretations. The main objectives were to update the Reservoir Model and to generate maps to help the drilling campaigns using the existing post-stack seismic data.

The first 22 wells of Pata Mora field were drilled from 1970 to 1989 but none stayed in production. In 1990, a second stage began, in which 6 new wells were drilled with objectives in La Tosca or Chorreado reservoirs, however, by 1998 all of them were closed by low productivity. The turning point of this tendency was in 2002, when an exploration well produced 100m3/d of oil from the Chorreado limestones. From 2003 to 2007, 27 new wells and 9 worked over in the area allowed to increase the field production to a peak of 189m3/d. In this last stage 4 reservoirs were defined, and gave an important potential for the development of the Pata Mora field and it was decided to test it with 8 appraisal wells drilled at the end of 2008.

The producing formations in the Pata Mora area, have in general medium reservoir quality and low fluid pressure (all of them are under-pressured), which results on a high declining production, therefore increasing the necessity to accurately predict reservoir quality distribution that allow us to design the optimum developing strategy.

We present the results of the Reservoir Seismic Characterisation performed at all the reservoir levels, each one with different lithological characteristics, through the integration of Advanced Petrophysical Techniques, Rock Physics analysis/modelling, Seismic Stratigraphy, Seismic Facies Analysis and Seismic Inversion. The integration of multiple disciplines is the most essential part of our Reservoir Characterisation workflow. It allows us to incorporate important information that is commonly ignored or neglected in quantitative seismic interpretations, such as mineralogy changes (identified in core/log data), the porosity system, diagenesis, electrofacies, seismic facies, stratigraphy, etc., which give geological sense to our mathematical estimations and interpretations. All this knowledge, once integrated into the reservoir model, reduces the uncertainty of the results and provides a better understanding of the reservoir characteristics that ultimately results in better decision making for the field development.

The first step in our analysis is to perform a detailed multi-mineral petrophysical evaluation that allows us to understand in detail the properties that control the reservoir changes. Then, our detailed Rock Physics analysis brings understanding on how those reservoir properties are related the seismic signal and define mathematical correlations, allowing us then to estimate those petrophysical properties in 3D from the seismic. Within this stage, we also try to determine if the observed seismic trace shape changes are related to geological facies changes and how accurately we could condition the sedimentological model using the seismic data. In this case, the layer total thickness and porosity were identified as the main parameters controlling the seismic amplitude/trace shape changes. A detailed seismic interpretation is also crucial in our analysis, as it is important to identify all the changes observed in the

seismic, not only those related to tectonic events, but also those related to depositional changes. Here, an unsupervised pattern recognition technique, based on a neuronal network algorithm, is used to interpret the internal architectural distributions in the reservoirs (down-laps, top-laps and off-laps). Then all the interpreted surfaces together with the well data are used to generate the Low Frequency Model (LFM) for the Seismic Inversion process. We improve the generation of this LFM by running a series of sequential self-conditioned inversions, and at each iteration we evaluate how much information is extracted from the seismic and we try to reduce the influence of the well data and horizons, as well as validating our results by analyzing how closely the inversion matches the blind test well data.

Total Porosity maps were generated for each of the 4 reservoirs independently, which were incorporated into the reservoir model together with the petrophysics and geological results. During this stage, we compare the seismic estimations against those driven only by wells and geology. Both estimations show consistent distributions (i.e. the results do not contradict each other), but the seismic based properties show more geological features coming out of the seismic. One of the most important findings of the geological modelling was the observation that the difference between the seismic conditioned effective porosity (PHIE), and the original seismic derived total porosity (PHIT), perfectly correlates to the areas of high clay content (validated with the well data). This result makes perfect geological sense as the difference between total porosity and effective porosity is precisely the clay bound water.

The 32 wells available in the 180 Km2 covered by the seismic with sonic or density logs plus several other wells with either sonic or density available at the reservoir levels, as well as the complex combination of clastic and carbonate sequences in the area, make this a unique dataset to demonstrate the accuracy of quantitative interpretation techniques; and furthermore, to evaluate the real value or advantages of incorporating quantitative seismic maps into the reservoir model. From all these wells, 15 are used for the Rock Physics and the Low Frequency Model building that constrained the Seismic inversion, and the rest of the wells are used as blind tests to validate the results. Our computed seismic properties (i.e. P-impedance and total porosity) match the well log measurements with more than 85% of accuracy, including the 17 blind tests.

In parallel to the execution of this project 3 new wells were drilled in the area, far away from the rest of the wells, which provided us with invaluable information to demonstrate the consistency of our predictions. We performed a post-mortem analysis to see how closely our properties matched the recently acquired well log measurements.
Our seismic based properties matched the new blind tests with more than 80% accuracy, validating the overall results of the Reservoir Seismic Characterisation.

This work provided important information that contributes significantly to the understanding of the reservoir distribution, making available a predictive model for the reservoirs. The results of the study are powerful tools that allow us to have better STOOIP estimations, more accurate development strategies and new ranked opportunities.