THE USE OF SEISMIC ATTRIBUTES AND SPECTRAL DECOMPOSITION TO SUPPORT THE DRILLING PLAN OF THE URACOA-BOMBAL FIELDS

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Summary

Interpretation of 3D seismic attributes including AVO, spectral decomposition, spectral inversion and multi-attribute inversion data, proved to be the key driver to set the drilling program for heavy oil, Miocene reservoirs in the *Uracoa* and *Bombal* Fields.

230 km^2 of 3D seismic and close to 200 wells were used for calibration. Petrophysical evaluation and fluid substitution analyses were conducted to ensure robust calibration of seismic attributes. The integrated interpretation led to identify anomalies associated to structural and stratigraphic traps filled with hydrocarbons that were confirmed by drilling.

AVO and velocity analysis on gathers allowed deriving moderate-to-good S/N ratio seismic information. Despite low acoustic contrast among net-sand, net-pay and encasing shales, the combination of different attributes led to identifying areas to set new drilling locations.

Spectral decomposition and pseudo density from multi-attributes inversion, proved to be a lithological / hydrocarbon predicting tool when properly calibrated with well logs. Pseudo impedance and reflectivity computed using spectral inversion techniques were used for sand/shale delineation that provided a large improvement of the structural and stratigraphic frameworks.

Fine-tuned velocity analysis and geostatistical techniques, tied to geological tops and seismic horizons, were used as driving elements to run a time-to-depth conversion of the seismic volumes. The seismic information represented in depth, honored the key geological tops of the reservoir, and has been used -successfully- to forecast the entry point and total depth of wells in the latest drilling campaign. Bounding features -unseen in previous studies- were identified on depth converted seismic cubes, generating a more robust model of the reservoirs.

Introduction

The Oficina Formation within the Uracoa and Bombal fields is located in the *Monagas Sur* area, Eastern Venezuela (Figure 1). The study was run by *Petrodelta*, a *PDVSA*-Harvest Vinccler joint venture in Venezuela. Two main objectives were defined for this study: 1) the characterization of mature oil and gas sandstone fields and, 2) to provide geophysical support to the drilling of new locations.

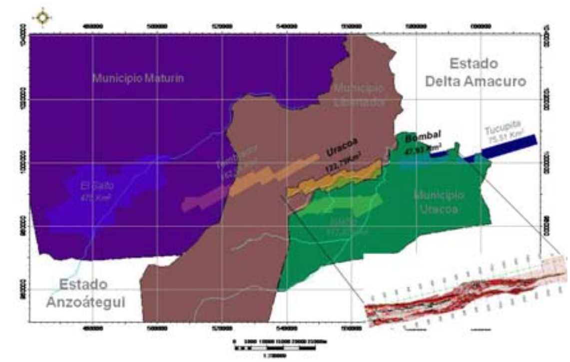

Figure 1: Location of the uracoa-Bombal fields. The seismic survey coverage extends along these two fields with a total area of 230 Km^2.

The Uracoa field has extensively been drilled however; there are still zones with potential for further development within the area. 3D seismic coverage was provided originally, with the idea of refining the structural and stratigraphic frameworks. Just recently, the idea of using the seismic information for reservoir characterization was implemented. The methodology consisted of a calibrated analysis of well information with different seismic attributes derived through multiple techniques such as spectral decomposition, spectral inversion, AVO, and multi attribute and neural network inversion.

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Methology

Detail petrophysical analysis was done at key wells for calibration. This analysis included edition of existing logs, generation of pseudo logs (where missing) using multilineal inversion techniques, invasion/dispersion corrections to represent sonic and density measurements within a frequency range equivalent to surface seismic scale. And finally, fluid substitution was done to simulate responses to different saturation scenarios (in situ, brine, oil and gas) (figure 2).

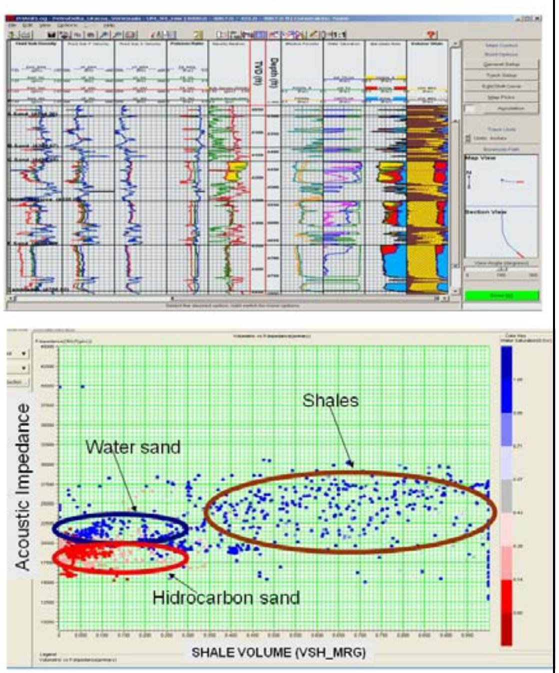

Figure 2: Upper: Full petrophysical analysis was done at key wells throughout the field. Fluids substitution helped to understand seismic response of the reservoir to different saturation conditions. Lower: lithology discrimination based on log response, was establish as a function of impedance.

The fluid substitution results were used to calculate synthetic gathers/traces for different saturation conditions. The results helped to understand the AVO response, as well as the spectral response within the area due to fluid content in the rock (figure 3).

It was observed that gas produces an effect of bright amplitudes which is typical of porous sandstones. Response due to oil saturation can be differentiated from brine saturation however the differences in amplitude are subtle. The modeling of spectral response through high resolution spectral decomposition techniques lead to derive similar conclusion as for AVO modeling.

Once the modeling work was completed, a detail review of seismic gather information was done. It was observed that the velocity field used for migration required refining in order to flatten seismic horizons within the reservoir. Detail velocity analysis was performed and subsequently an automated residual velocity analysis using a tomographic technique was implemented in order to provide the detail that was required.

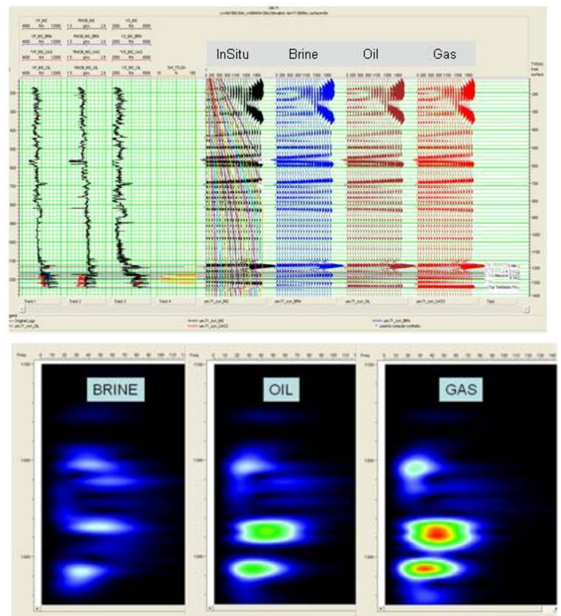

Figure 3: Upper: synthetic seismic gathers computed from log response at different saturation conditions. Lower: Synthetic spectral response computed from zero offset synthtic traces at different saturation conditions.

It was also observed that anomalous reflections associated to the contact between cretaceous rocks and crystalline rocks from the basement, could be removed by limiting the stack to a maximum angle of 30 degrees (figure 4)

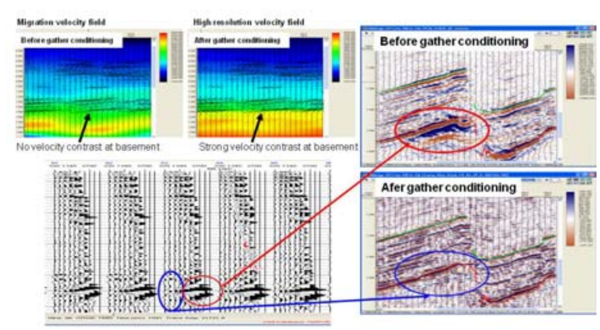

Figure 4: Velocity field before and after high resolution velocity analysis. Upper right and left. Stacks before and after angle limiting of traces from gathes to 30 degrees.

Spectral Decomposition and spectral inversion

Given the lateral and vertical heterogeneity in sandstone distribution, it was required the use of a high resolution spectral decomposition technique, as well as a spectral inversion technique that could help to boost a higher frequency content from the original seismic data. Upper half of images in Figure 5, shows examples of different representations of seismic data in the spectral domain. The analysis of amplitude response at different frequencies turned out being adequate to characterizing heterogeneity, fluid content, and structural framework of the reservoir.
On the other hand, the use of spectral inversion provided reflectivity data with enough vertical resolution that helped to resolve stratigraphic features such as pinchouts and limits of sand bodies. Representing reflectivity as pseudo impedance provided the interpreters with an enhanced attribute that helped them to identify and map low impedance sandstones.

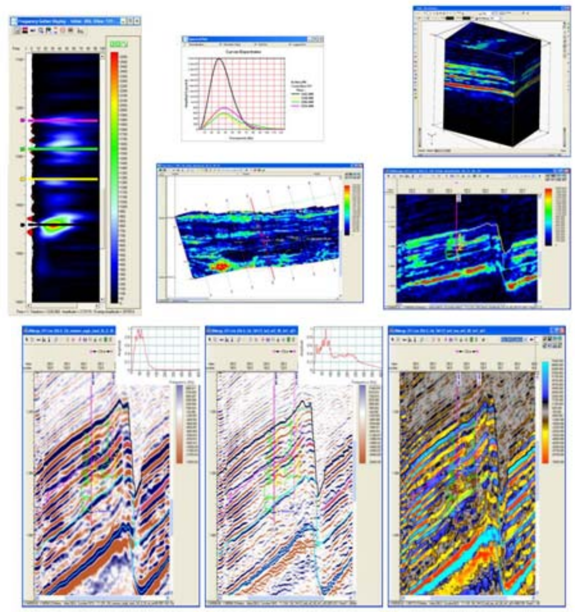

Figure 5: Upper: figures correspond to several types of displays of spectral decomposition information.Lower left is a section of seismic amplitudes, upper middle and right are the corresponding reflectivity and impedance from spectral inversion.

Multi attribute inversion

Other techniques that were incorporated in the workflow were multi attribute and neural network inversions. A large number of wells exist in the area and an adequate number of these wells contained proper information to implement the inversion techniques. However, multi attribute inversion was the technique that provided more consistent results that were adequately validated.

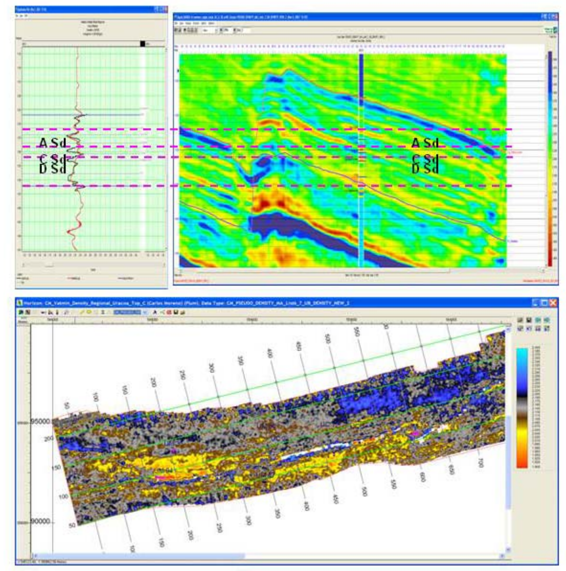

Figure 6: Upper: Pseudo density from multiattribute inversion at a calibration well. Lower: Map of sand distribution for a particular sand body.

Depth conversion of seismic data

All the different attributes were generated from seismic data in time however, it was required to be able to handle all the information in depth in order to provide calibrated information with the existing wells and the wells being drilled. All the seismic volumes were converted to depth using a procedure that incorporated geologic/acoustic tops from more than 200 wells, seismic key horizons interpreted from the time volumes and a high resolution velocity field.

Examples

The first example (figure 7) shows a combination of panels with vertical sections of pseudo impedance running in the north-south direction. Below the sections a pseudo impedance map is shown in which both oil/water and oil/gas contacts are drawn.

Identification and detailed mapping of sand bodies was possible due to the enhanced response of the sandstones in the spectral, pseudo density and pseudo impedance attributes.

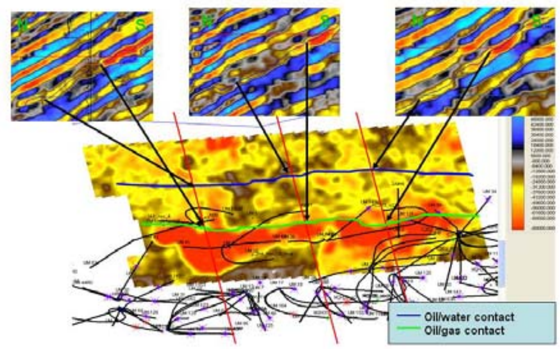

Figure 7: Oil/water and oil/gas contacts are infered from impedance response and known contacts from well information. Upper sections correspond to lines running south to north.

The second example corresponds to results of mapping a sand body while drilling the location. Upper image from figure 8 shows the actual path followed during drilling of the well. The impedance results tied accurately with the shale interval penetrated by the well (blue zone when the well changes path to horizontal) before entering the producing sand. Lower image from figure 8 shows the path of the well in map view and the extension of the sand body that was targeted.

Conclusion

Detailed analysis of seismic data and the conditioning and calibration of these data, allowed generating useful seismic attributes for reservoir characterization. The conversion to depth of all the attribute volumes helped to better correlated seismic information to well data and to reduce uncertainty in placing new wells.
The results of the reservoir characterization provided a better understanding of the complexity in sand distribution and their fluid content throughout the field.
Criteria for seismic attribute analysis were documented which helped to provide geophysical support to new locations as was as actively providing support during the drilling process.
Observations and criteria made within this field can be extended to adjacent fields with equivalent structural and stratigraphic frameworks

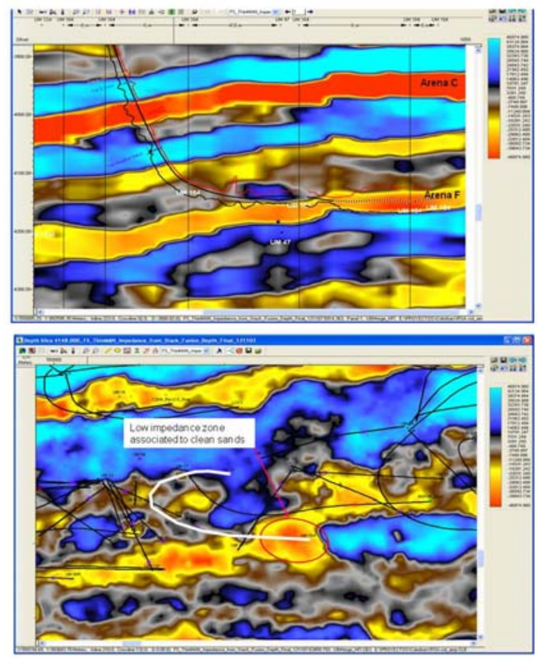

Figure 8. Upper: Pseudo impedance vertical section along well path that shows the target sand as low impedance. Lower: constant depth slice showing the aerial extension of the target sand.

Acknowledments

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EDITED REFERENCES

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REFERENCES

Proyecto Uracoa - Bombal - Soporte Geofísico Integrado para perforación de pozos, 2007–2008, Internal Report.