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Petrophysical properties estimation by integrating AVO, seismic inversion and multiattribute analysis in a 3-D volume of Playuela, Veracruz.

ABSTRACT

We carry out a static reservoir characterization in Veracruz Basin, Mexico, using 3-D distributions of petrophysical properties by applying an integrated methodology, which considers amplitude variation with offset (AVO), seismic inversion and multiattribute analysis. Calibrating the results with well logging, we identify some prospects by interpreting Lamè's constant and rigidity attributes as well as neutron porosity and resistivity maps that indicate gas. Using a 3-D gamma ray prediction, we are capable of providing detailed information about reservoir continuity associated to sand channels. Thus, integration of these seismic tools proves to be a robust methodology for discerning fluids and lithology since it provides geological information, which helps to propose new well locations.

INTRODUCTION

Interest in reservoir characterization focuses on the need to quantify and reduce uncertainty associated to the geological model of different prospects in exploration and production areas. In this way, our main objective is to achieve a complete static characterization of Playuela Field, located in Veracruz Basin, Mexico, by integrating AVO, post-stack seismic inversion and multiattribute analysis. Using the lithology and fluid discriminator methodology proposed by Goodway *et al*. (1997), we estimate elastic parameters like Lamè's constant (l) and rigidity (m) starting with an AVO analysis whose results are inverted into P- and S-wave impedance. After that, we transform impedance values to get elastic attributes. Additionally, with multiattribute analysis we predict petrophysical properties over a 3-D seismic volume based on intrinsic relationships between seismic attributes and well logs. Such relationships were determined using multiple linear regressions and neural network methods. Then, we approximate neutron porosity, gamma ray and induction deep volumes. In this way, we discriminate sand bodies by interpreting the gamma ray predicted map and we discern gas zones identify with elastic parameters maps and as well as resistivity and porosity distributions.

AVO INVERSION AND ELASTIC PARAMETER ESTIMATION

Performing an AVO analysis using Fatti´s simplification of Zoeppritz equations (Fatti *et al*., 1994) we derive P- and S-wave reflectivities. Then, we transform such reflectivities into P- and S-wave impedances values with a post-stack recursive inversion algorithm. Therefore, considering general velocity equations, which depend on Lamè's constant (l), rigidity (m) and density parameters (r), it is possible to get simple expressions that combine P- and S-wave impedances to approximate properties associated to the fluids incompressibility and rigidity of rocks from Lamè's constant, rigidity and density products, l r and m r, respectively (Goodway *et al*., 1997).

In addition, we apply multiattribute analysis to predict 3-D distributions of geophysical properties from well logs. This process consists of two steps: 1) prediction operator design, from seismic and well log data, and 2) the application of this operator over a 3-D seismic volume. Thus, first step includes two processes: training, which consists on comparing real seismic data and well logs that interest to predict, and validation of the prediction, which allows evaluate the real prediction power, Hampson *et al.* (2001).

Validation proves if designed operators are capable of reproducing the real well log used in training for each well in the study. Finally, we apply those operators to each of our input volumes (AVO attributes, impedances and seismic attributes) to generate 3-D maps of geophysical properties like resistivity and porosity measured in well logs.

Particularly, the goal of this technique is to find some linear or non-linear relationship that can convert a group of different attributes into the desired property. To find the transformation rule we can use a multiple linear regression method or neural network methodology. Therefore, we optimize the error between predicted logs and real well logs to estimate porosity, resistivity and lithology volumes.

DISCUSSION OF RESULTS

We calibrate elastic parameters through crossplots, using well log information from a gas well in the area, Playuela-301. By interpreting l r *vs* m r crossplot we discriminate the fluid effect from background since minimum values in λρ domain suggest the presence of gas, which is a compressible fluid (Figure 1). Besides, l r-m r *vs* l r/m r crossplot, shown in Figure2, helps to discern lithological units as well as to attenuate the inherent effect introduced by density in measurements of elastic properties (Batzle *et al*., 2001).

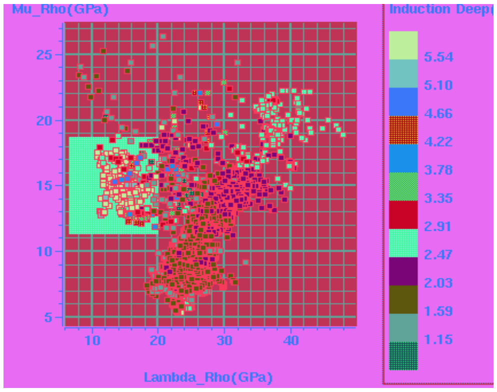

Figure 1. l r *vs* m r *crossplot*. Yellow zone depicts maximum values of induction deep log associated to minimum incompressibility measures in l r attribute, which verifies gas in a known producing interval of Playuela-301.

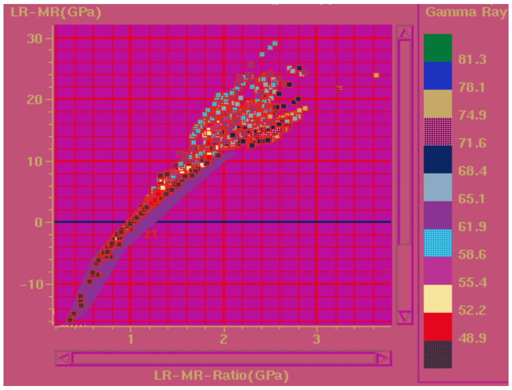

Figure 2. l r/m r *vs* l r-m r *crossplot*. Sand bodies that produce gas in the field represent the minimum values of gamma ray log, which show a linear behavior associated to red zone.

Subsequently, we create 3-D distributions of lr and mr elastic attributes as well as lr-mr and lr/mr combinations. Considering results of crossplots, we locate zones in a shallower producing level associated to gas from lr and λρ–μρ maps, due to anomalies of minimum magnitude (yellow) are similar at measurements observed from those pay zones at Playuela-301 (Figure 3).

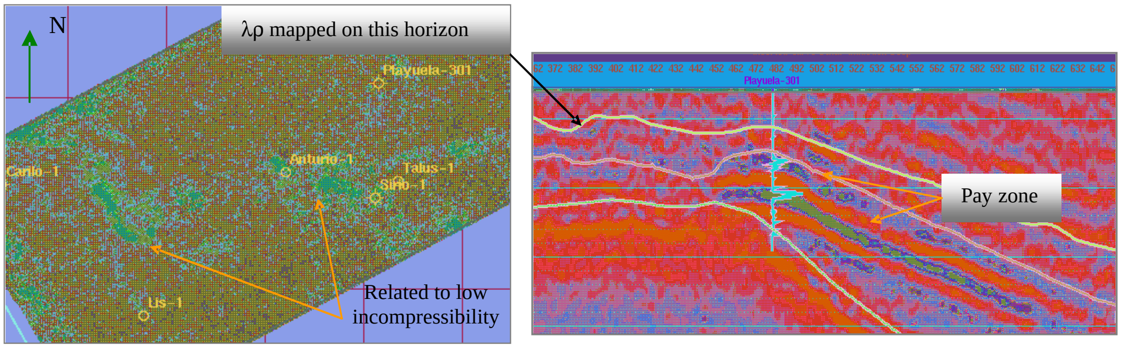

Figure 3. (Left) 3-D distribution of lr attribute is mapped on shallower level from the producing horizon for Playuela-301. (Right) Seismic section of λρ attribute at Playuela-301 well location. Yellow anomalies verify gas at the well location and suggest some prospects at shallower depth related to a possible channel indicated by the orange arrows.

Then, we predict a lithology volume using gamma ray logs to separate sand from shale. We use a multiple linear regression method to find the prediction operator. Figure 4 shows the predicted lithology map computed on the shallower producing horizon, which offers a good estimation of the channel distribution observed before.

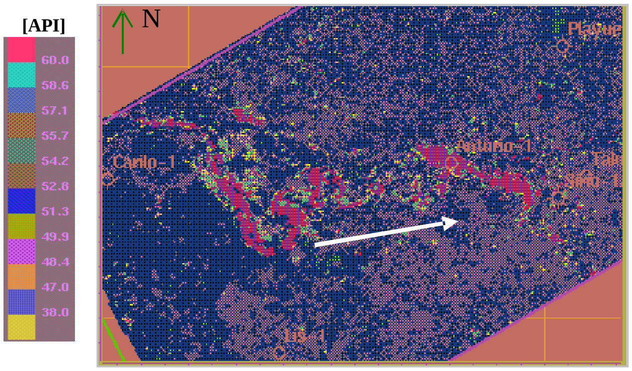

Figure 4. Gamma ray map allows distinguishing lithological units. We discern the complete sand channel length towards the East of Playuela Prospect interpreting sand from minimum values of gamma ray. Notice the meandrous shape of channel derived from multiattribute analysis.

Similarly, we obtain a 3-D distribution for porosity using a probabilistic neural network trained with neutron porosity logs (Figure 5). Since neutron porosity measurements respond to hydrogen content, gas anomalies produce drops in this log. As well, we achieve a model prediction for resistivity using induction deep logs via a multiple linear regression (Figure 6). Maximum values of induction deep log, related to high resistivity zones, confirm gas saturated rocks. Therefore, both of two volumes let us to distinguish hydrocarbon saturated zones inside of the sand channel interpreted in lithology volume.

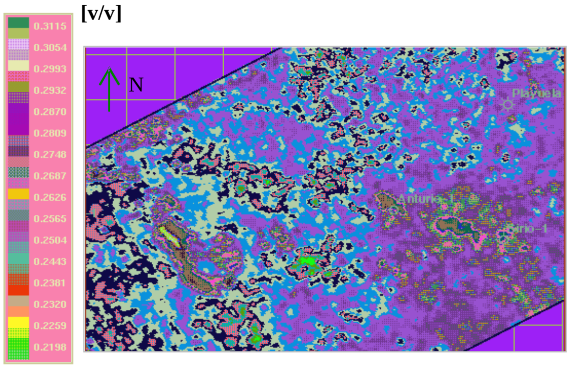

Figure 5. Neutron porosity map validates the presence of gas characterized by minimum values as potential hydrocarbon zones.

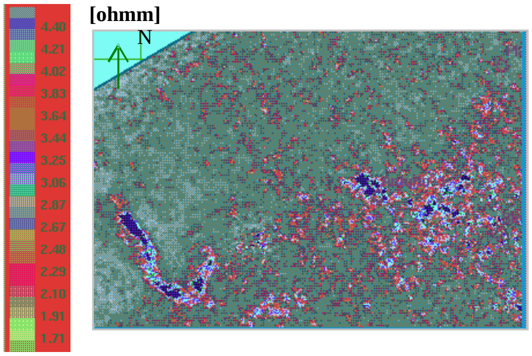

Figure 6. Resistivity distribution allows distinguishing gas saturated zones (green) inside of the sand channel in a more accurately approach than porosity prediction.

CONCLUSIONS

We perform a static reservoir characterization identifying lithology and fluids using AVO, seismic inversion and multiattribute analysis integration. In lr domain, we find notorious contrasts between gas sand and shale, or other lithological units, and they improve on lr-mr domain, which give us useful criteria to identify gas sands in a quantitative way. From predicted gamma ray volume, we identify and define the dimension of sand channel. Moreover, we identify gas zones inside of the sand bodies interpreting porosity and resistivity distributions.

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