UR01

Seismic Inversion for Unconventional Resources

O. Fabela Rodriguez (Pemex), L.R. Caraveo Miranda (Pemex), V. Mercado Herrera *(Independiente), H. Avalos Torres (Pemex)

Summary

Deterministic elastic seismic inversion is a powerful tool to mix logs information with seismic data and propagate them in places that haven't been drilled.
This technic estimates the extension of a reservoir, applied to exploration in unconventional resources allow us to estimate helpful petrophysical properties as TOC, porosity, water saturation or brittleness.
The methodology involves from data conditioning until wavelet estimation in seismic well tie. Each one with effective quality control.

Introduction

Until recently, the use of seismic data for detection and characterization of source rocks was of very limited interest. However, after the advances in horizontal drilling and hydraulic fracturing, the source rocks now have greater attention, due to their ability to generate hydrocarbons and their role as unconventional reservoirs. Seismic data has been successful in the exploration of rich organic shales, as well as in the identification of the kerogen content and in its maturity, by indirect methods. The information on the organic phase of unconventional rock deposits includes the total organic carbon content (TOC) and the maturity index, where vitrinite reflectance is used as a source of petrographic data to determine the degree of maturity of the organic matter.
The concentration of TOC and the level of maturity of the kerogen are key parameters in any characterization of unconventional deposits. The seismic properties of the kerogen are still poorly understood, so that the prediction of the seismic response of a rock-kerogen system and the kerogen maturity are a great opportunity for seismic exploration.
The information coming from core data and calibrated core records such as TOC and fracture pressure gradient are critical for the development of any unconventional shale deposits. Therefore, petrophysical models are essential for estimating TOC and other key petrophysical properties, as well as the zones of greater fragility for better hydraulic fracturing.
To understand the geophysical properties of unconventional deposits it is important to know the many factors that control the physical properties of rocks, as well as the depositional environments and diagenetic processes that do not have a universal relationship between TOC and the mineral composition expected for this type of rocks. Although it is not practical to know all the relationships of TOC with other minerals to understand the variations of the seismic velocities and their impedances it is plausible to consider two scenarios: 1) silica-rich rocks (Fig.1), where quartz is relatively abundant and TOC is positively correlated with quartz content, but has a negative correlation with clay content, and 2) rocks rich in clay (Fig.2), where clay is relatively abundant in rocks and weak TOC, there is no good correlation with the contents of clay and quartz, but there is with calcite (Fig.3).

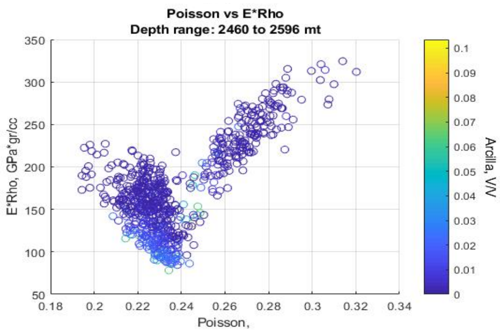

Figure 1 *Young*rho vs rel. Poisson and Color Qz.*

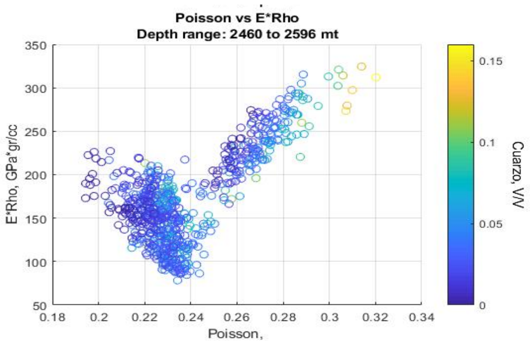

Figure 2 *Young*rho vs rel. Poisson and Color Clay.*

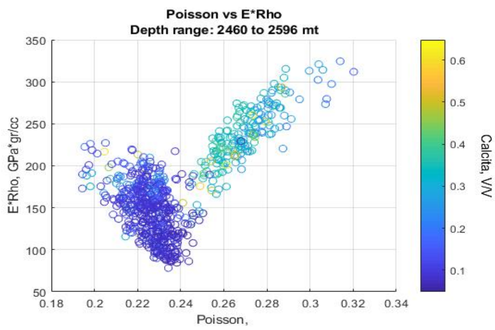

Figure 3 *Young*rho vs rel. Poisson and Color Calcite.*

Workflow

A feasibility study will be done to inspect if the target in the study area can be defined in terms of seismic resolution. It examines seismic sampling, frequency bandwidth, Pimpedance, Simpedance as well as some petrophysical properties on cross plots.
Seismic inversion is very sensitive to signal/noise ratio, so it is necessary to conditioning seismic data to suppress noise. There are several methods to perform that depending on data quality. Usually, stacking with near traces in lines and cross lines is done. Radon filtering will also be used. To lead with ground roll a high pass filter will be selected. After performing a fullstack, wells will be tied and seismic horizon interpretations will be performed in a vertical window around 300 ms of the target.
At this point, the quality of the process is checked out by a synthetic gather at wells and comparing the AVO response with real data. Data then will be ready to execute the simultaneous seismic inversion process with partial stacks.
One of the most thorough process is the seismic-well tie. Placing each well in its exact time position is essential in seismic inversion. The stability of both the inverse filter and the low frequency model, depend on this.
Several fitting tests are needed to get the best parameters: extraction wavelet window, wavelet length, and well position for each well and partial stack. Each partial stack will have a representative wavelet for every considered well with better features of tie and stability.
The low frequency model contributes with the regional geological information of the area and must be conformable with the structural pattern, faults, pinch outs, unconformities, salt or volcanic intrusions.
The low frequency bandwidth has to be chosen according to the seismic spectrum of the original data. Low frequency model provides the low frequencies that seismic data does not possess. This is an extra benefit of using seismic inversion results.
The quality control in this process will be the visual correlation between seismic inversion (figure 4) and well logs. Statistical methods can also be used.
Variations in magnitudes can be treated with wavelet scaling. A common practice, is getting elastic properties in the first inversion run with default parameters and then varying each one of them, increasing adjustment.

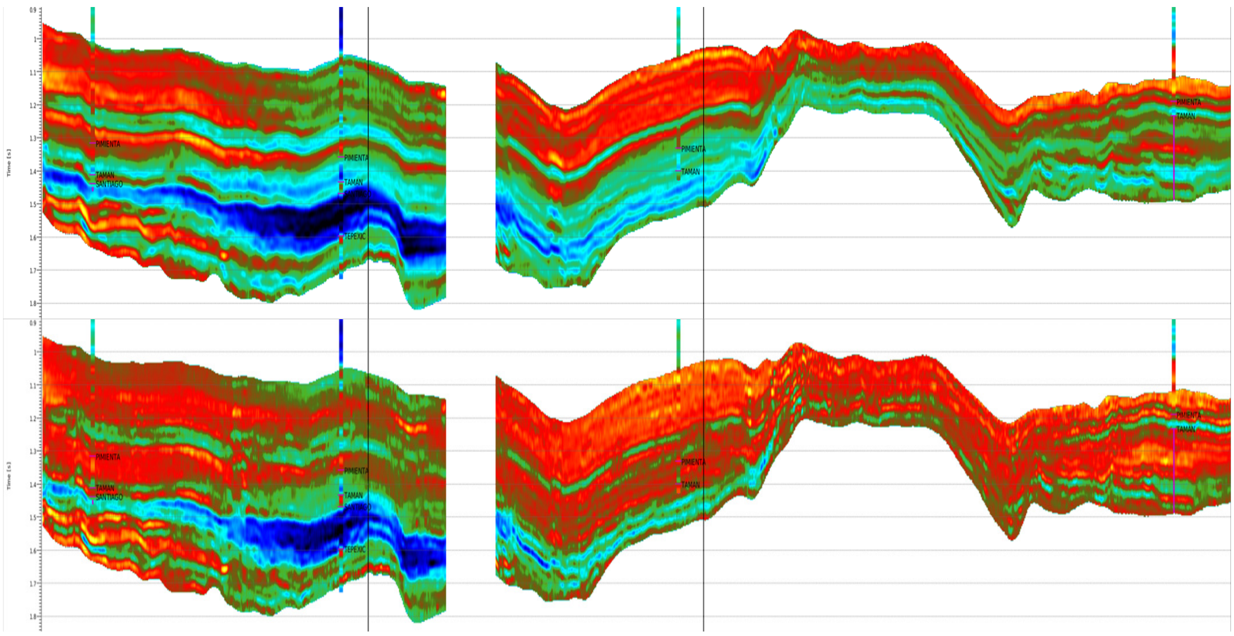

Figure 4 *Seismic sections displaying P-impedance (above) S-impedance (below).*

Finally, once the inversion process has already finished, the last step into the workflow will be the estimation of petrophysical properties from elastic properties.

During this process, it is recommended to use a variety of cross plots employing elastic properties as Mu-rho, Lambda-rho, P impedance, S impedance, density, Vp/Vs ratio or Poisson module to evaluate useful trends. Density is required for the calculation of the Young's modulus of the seismic data. The calculation of density in fact requires large offset seismic data, which were not available for the study area. E-rho attribute would exhibit a high value and serve as a brittleness indicator, (Fig. 5). High brittleness and higher TOC indicates better quality of organic shale rock, better porosity and higher potential for production (Fig. 6).

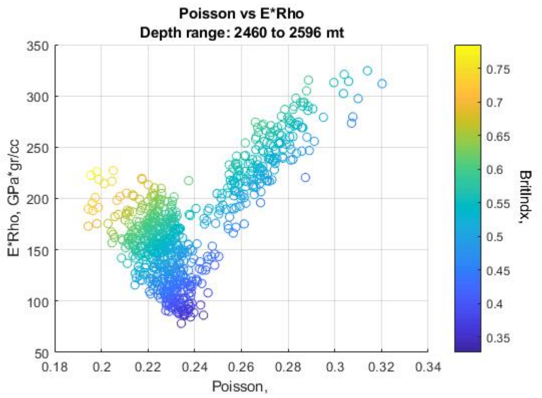

Figure 5 *Young*rho vs rel. Poisson and Color Brittle.*

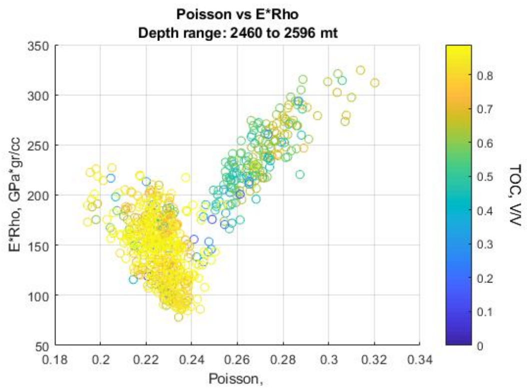

Figure 6 *Young*rho vs rel. Poisson and Color TOC.*

Conclusions

A seismic inversion process is strongly recommended to evaluate unconventional resources. Simultaneous AI-SI inversion of prestack seismic data provides accurate elastic properties to estimate reservoir properties of unconventional shales. The shales with high TOC are characterized by lower fracture gradient and hence better brittleness.

References

David Eberly 1998 Least Squares Fitting of Data.

Alvarez, P., F. Bolivar, W. Marin, M. Di Luca, y T. Salinas, 2015, Multiattribute rotation scheme: A tool for reservoir property prediction from seismic inversion attributes. SEG Technical Program Expanded Abstracts 2015: pp. 2723-2727.

Ritesh Kumar Sharma and Satinder Chopra, May 2015, Determination of lithology and brittleness of rocks with a new attribute, TLE, SEG