Acoustic impedance and Porosity cubes from genetic algorithms, well logs and seismic amplitude.

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Abstract

Nowadays, it is possible to obtain some rock attributes from seismic volumes based on geophysical data, but often this approach contains a high approximation error. The proposed methodology is a non linear process that is able to derive an acoustic impedance volume or a porosity volume based on sonic, density and neutron logs with high control of the error. The used data consist in a 3D seismic volume with 170 km² of area, and 19 wells. The main objective is to elaborate a seismic impedance and a porosity cubes based on genetic inversion, in this sense the seismic inversion is a combine result of multi layer neural networks and genetic algorithms.

The volume properties calibration is the most important thing we have to do, because we are predicting rock properties in areas where wells don't exist. In this order of ideas, a neural network has trained using well logs and the rock characteristic was predicted using genetic algorithms.

A lot of tests were performed in order to better define the well resample required to control the neural network prediction, the main difference between a traditional neural network and genetic algorithms is that this last one uses the wavelet form and its relationship with each property identified on well logs as a biological DNA characterization.

As result was obtained the property cube (Acoustic Impedance and porosity), as well as a pseudo log related with the predicted property, using the log result compared with the original dataset, the error was defined between 10% and 30% in the whole log, and it is less than 15% inside reservoir levels. This result is very helpful to define reservoir levels, 3D facies distribution, and fluid prediction, among others; if we consider that it is possible to get a good porosity and seismic impedance cubes in few hours and in the initial phase of the exploratory project using this method.

Resumen

Actualmente, utilizando datos geofísicos es posible obtener algunas propiedades de roca a partir de cubos sísmicos; sin embargo, frecuentemente esta aproximación presenta errores altos de aproximación. La metodología propuesta consisten en un proceso no lineal que es capaz de derivar un cubo de impedancia acústica o porosidad a partir de los registros de pozo sónico, densidad y neutrón con alto control del error. La base de datos consiste en un cubo de sísmica 3D que tiene 170 km² de área, y 19 pozos. El objetivo principal es construir cubos de impedancia acústica y porosidad basados en inversión genética, en este sentido la inversión sísmica es un resultado combinado de red neural multicapa y algoritmos genéticos.

Lo más importante a ser realizado en el proceso de inversión es la calibración de las propiedades generadas, debido a que están siendo calculadas propiedades en áreas en las cuales no existen pozos. En este orden de ideas, la red neural fue entrenada utilizando registros de pozo y las característica de la roca fue calculada utilizando algoritmos genéticos.

Un conjunto grande de pruebas fue realizado para definir el mejor valor de re-muestreo del registro de pozo requerido para controlar la predicción realizada por la red neural, la principal diferencia entre una red neural tradicional y una de algoritmos genéticos es que la ultima utiliza la forma de la ondicula y su relación con cada propiedad identificada sobre el registro de pozo, de la forma como es realizada una caracterización de DNA en el área de biología.

Como resultado se obtuvo el cubo de propiedades (impedancia acústica y densidad), así como un pseudo-registro que presenta la propiedad de roca calculada, utilizando el resultado del registro y comparado con el dato original el error fue definido en un rango entre 10% y 30% para todo el registro y menos de 15% en el nivel de los reservorios. Este resultado es de gran utilidad para definir niveles reservorios, distribución tridimensional de facies y predicción de fluidos entre otros; si se considera que es posible obtener un buen cubo con distribución de porosidad e impedancia acústica en pocas horas y en fases iniciales de un proyecto exploratorio utilizando este método.

Introduction

Through the last years geophysics have been improving methodologies in order to achieve better geological models, and less exploratory risk using geophysical datasets.

In this sense, seismic attributes based on horizon interpretation are helpful to understand reservoir variations in that stratigraphic level, but it is difficult to control the variance of facies and fluid presence in a actual 3D geological model; as consequence, it is necessary to control this variation in both direction vertical and lateral.

Until now, to obtain an impedance acoustic volume was necessary to interpret some seismic horizons, control the impedance variation using well logs for Stochastic inversion or to knowledge the source wavelet to do Sparce Spike Inversion, often a difficult task. When used only neural networks the approximation error is very high, most of 60% because there are levels outside the reservoir where the networks train doesn't work very well.

Log prediction using neural networks and geoestatistical functions has been developed since 1998 or earlier, but rock attributes prediction using neural networks and genetic inversion is a very new application that could help us to define geological facies and fluid content in the beginning of exploratory projects.

The general objective is to build a seismic impedance and a porosity cubes based on genetic inversion, in order to define vertical and lateral facies variation as well as fluid content inside the seismic cube, the project uses a 3D seismic volume with 170 km² of area, and 19 wells from the North Sea. The dataset shows mainly a shallow and deeper marine sedimentation in a passive margin, deformed by salt movement on recent stages, this configures the hydrocarbon traps associate to rollovers and extensional tectonic system.

As general knowledge, we are defining as genetic inversion the algorithm that combined together the multi layer neural network and genetic algorithms in order to provide a robust forward seismic inversion. The required inputs to perform this task are limited to seismic amplitude and Acoustic Impedance (AI) well logs, in cases when AI well logs are not available it is possible to do the cross correlation between the density and sonic logs.

As advantage, this method constrain the convergence of the inversion in a way of achieving a global minimum error.

Method

To obtain the genetic inversion over the dataset, Petrel Genetic Inversion Algorithm was applied. The first step is to create the crop volume that is going to be training by well logs (Figure 1)

The impedance logs must to be created from density (RHOB) and sonic (DT) logs, if the result is an AI cube, if the result is an porosity cube neutron logs are used. The original log have to be re-sample to reproduce the seismic resolution in this case the logs were resample each 6 feet's, the original log and the resample log look like the figure 2 (the original in the left and the resample in the right side)

The genetic relationship was created using the crop volume, and the AI logs inside the volume as input, in order to teach the neural network, a total of 10500 learning iterations were performed. As result was obtained a pseudo log generated by the genetic inversion (Figure 3) and the AI (Figure 4) and/or porosity (Figure 5). training cube When the result shows a good correlation percentage the process is applied in the whole seismic volume.

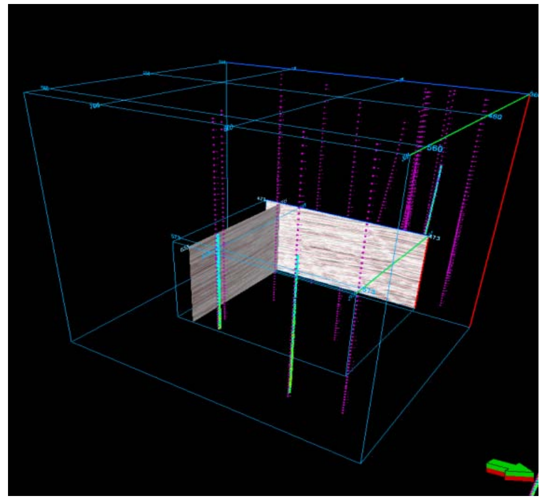

Figure 1.- Cropped Seismic Volume

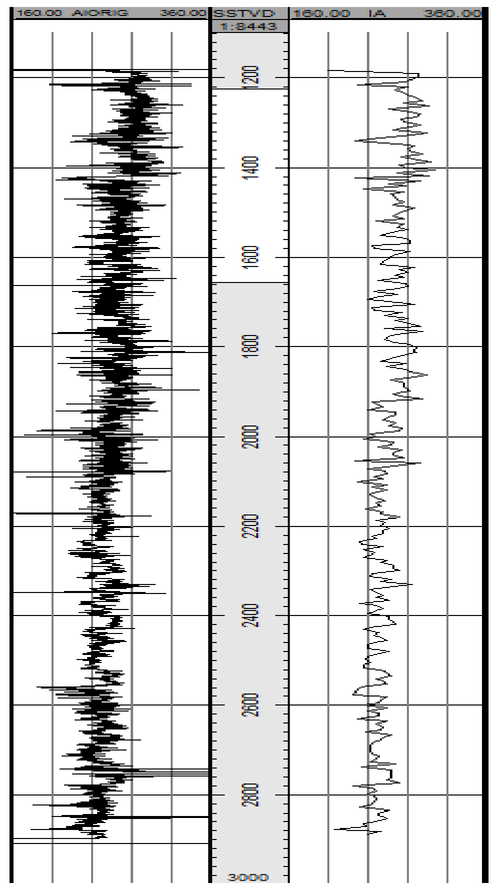

Figure 2.- Original log (left) and resample log (right)

At the end of the process the error was calculated for the entire well and for reservoir levels using cross plots as a qualitative and quantitative tool.

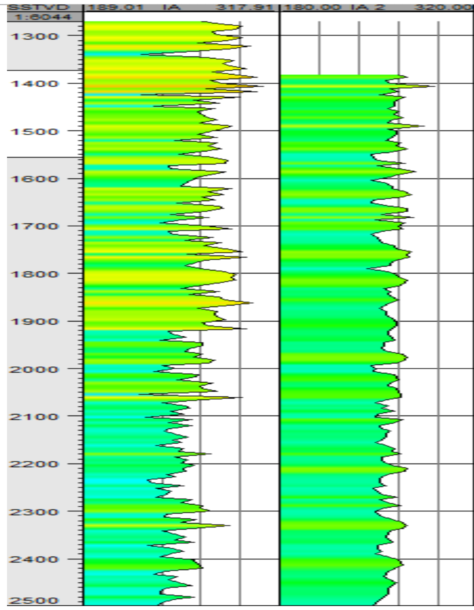

Figure 3. Pseudo log generated by the genetic inversion process in the right track, observe the original log in the left track.

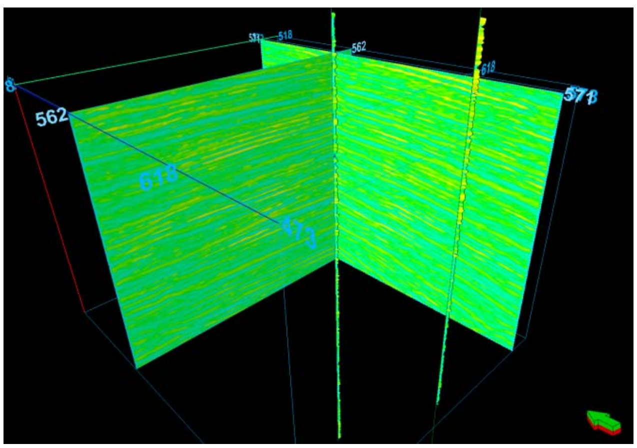

Figure 4. Acoustic Impedance volume, the wells are showing the original Acoustic Impedance.

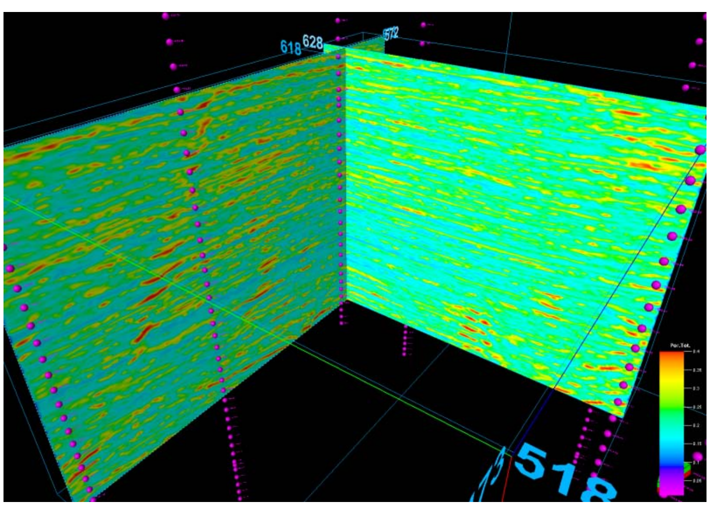

Figure 5. Porosity volume.

Results

The physical results are the property cubes, over these cubes are possible to apply opacity and transparence techniques; in this sense, it will be easily determine stratigraphic features or reservoir characteristics as show in the figure 6.

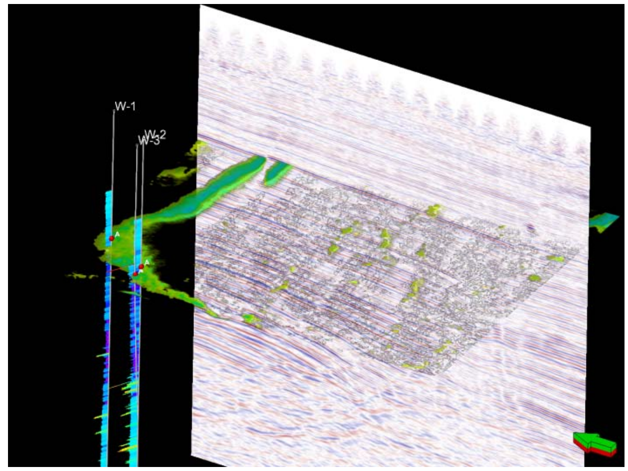

Figure 6. Stratigraphic feature determined from properties volume.

The previous figure is showing a shallow reservoir but filled by water in the three wells that drilled the reservoir (see figure 7), in a deep level (reservoir top) it is visualized the main reservoir with hydrocarbon, this reservoir level is very well imaged in the Acoustic Impedance cube as show in the figure 8.

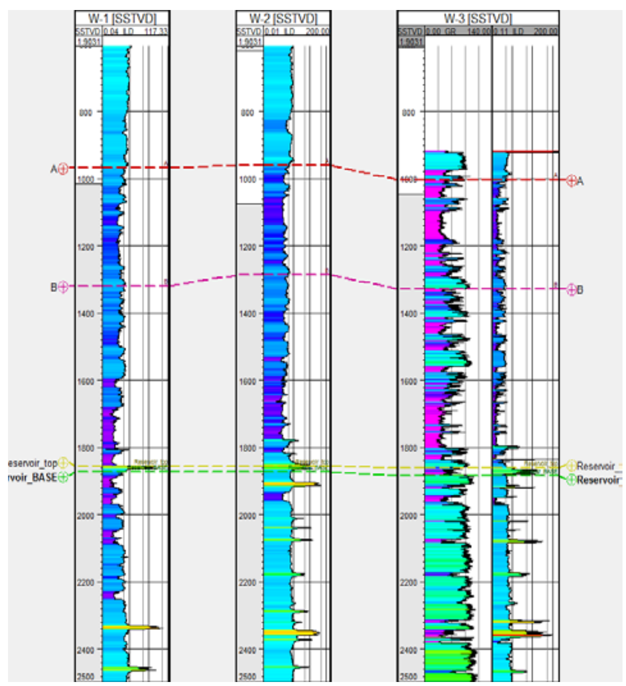

Figure 7. Well correlation based on resistivity logs showing the main reservoir filled by hydrocarbon, the gamma ray log showed in the well W-3 confirmed the presence of a fluvial channel close to the level A.

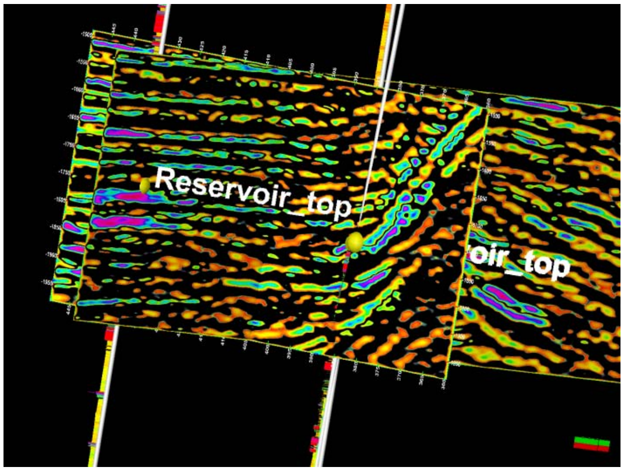

Figure 8. Acoustic Impedance Cube calculated from Genetic inversion Algorithms. Violet features show the hydrocarbon accumulation.

With the objective of determine the error of the previous cubes, cross-plots between original properties and a representative calculated log were did as observe in the figure 9, the error associate with the whole log was defined between 10% and 30%. When the error is associate with the reservoir this error is less than 15%.

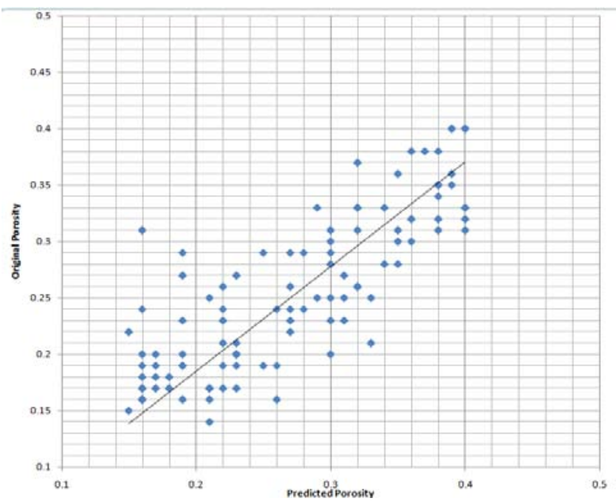

Figure 9. Cross plot between original porosity from neutron log and porosity calculated using genetic algorithms, correlation of 80%.

The last visualization, did here, is presented in the figure 10, the first track is the calculated porosity log based on Genetic Inversion algorithms; second track is the original porosity log, and the last one is the correlation between both logs showing a high correlation (more than 90%) in reservoirs with porosities from 16% to 24%. It is important to mentioned that levels that show porosities higher than 30% are related with non reservoir rocks (often neutron log's error is because lithology)

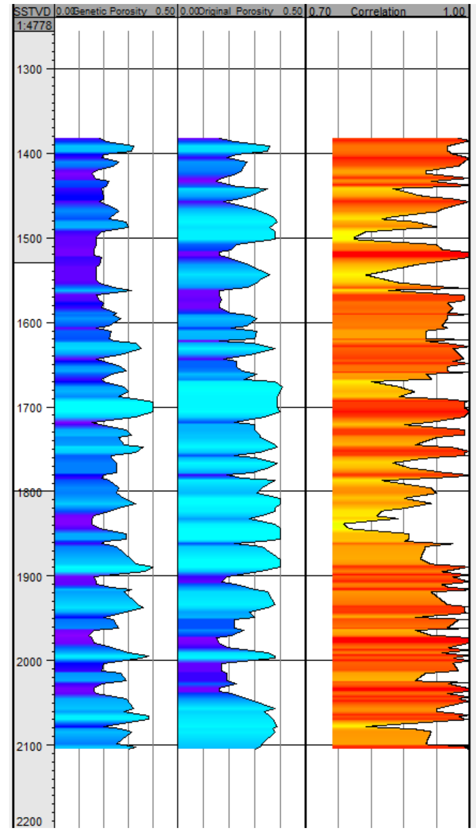

Figure 10. Comparison between Genetic Inversion Porosity log and Original Porosity log, the last curve is the correlation curve in scale from 70% to 100%.

As last consideration, this process will be improve using top and base stratigraphic horizons to control the neural network training, in this case the error could be less than 7% for reservoirs levels.

Conclusions

- Using Genetic Inversion to obtain Acoustic Impedance and porosity cubes, the error was defined between 10% and 30% in the whole log and this could be understand as the cube error; and this error is less than 15% inside reservoir levels.
- This result is very helpful to define reservoir levels, 3D facies distribution, and fluid prediction, among others; if we consider that it is possible to get a good porosity and seismic impedance cubes in few hours and in the initial phase of the exploratory project using this method.
- Involves less a-priori information compared to traditional Inversion techniques, and thus avoids model driven errors during the inversion.

References

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