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Seismic Imaging and Evaluation of Channels Modeled by Boolean Approach

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ABSTRACT

The seismic method attempts to image the subsurface architecture and has been able to significantly contribute to detect areal and vertical changes in rock properties. This work presents a seismic imaging study of channel objects generated using the boolean technique. Three channels having different thicknesses were simulated, using the same width, sinuosity and direction. A velocity model was constructed in order to allow seismic contrasts between the interior of channels and the embedding rock. To examine the seismic response for different channel thicknesses, a 3D ray tracing with a normal incident point survey was performed. The three channels were resolved and the way the seismic could image them was studied.

INTRODUCTION

Reservoir heterogeneity facies architecture manifest geometric characteristics that strongly affects oil recovery. The seismic method attempts to image the subsurface architecture and has significantly contributed to detect areal and vertical changes in rock properties. The effect of geometrical configuration of those properties yields different seismic signatures to be later interpreted based on the analysis of three-dimensional data.

This work presents a seismic imaging study of channel objects generated using the boolean technique. Three channels were simulated with different thicknesses, using the same width, sinuosity and direction. A velocity model was constructed in order to allow seismic contrasts between the interior of the channels and the embedding rock. To examine the seismic response for different channel thicknesses, a 3D ray tracing was performed with a normal incident point survey. The three channels were resolved and the way the seismic could image them was studied.

GEOMETRIC MODELING OF BOOLEAN CHANNELS

Stochastic and geometric modeling of geological objects has proven to be an efficient method to produce realizations of reservoir architecture with the same probabilities. In this paper, channel genetic unit only was used. The geometry of the channels was generated using in-house software that implements methodologies for stochastic modeling of geological objects – PetBool. A simulation domain and a set of parameters like width, thickness, sinuosity and direction are required for geometric modeling of channels. As the focus of the research is how well the seismic can image its external geometry, three channels were simulated with different thicknesses using a fixed width, sinuosity and preferred direction. Figure 1 shows the generated channels in a 2000m x 2000m domain. From left to right their thicknesses are 30m, 10m and 20m. The vertical scale is amplified 10 times. The topological surfaces of each channel were exported and visualized in Gocad.

In the boolean method, the location of each object is called germ and is randomly placed in space. The objects themselves are called grain. The sum of all grains results in a boolean model (2). The importance of the boolean model is that it may represent the geological framework. In the PetBool software, internal properties can be assigned to the objects by using classical stochastic simulation methods (Monte Carlo, Sequential Gaussian Simulation - SGS, besides deterministic methods) (1). In this work, stochastic simulation of internal properties for the channels was not performed. Instead, a deterministic velocity model to perform a seismic imaging of the channels by means of 3D ray tracing was built.

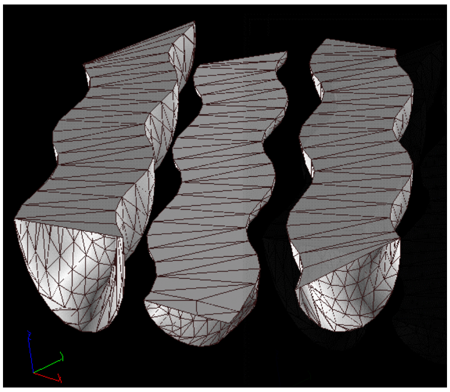

Figure 1 Genrated channels and their top and bottom surfaces.

RAY TRACING

The velocity model used in this study was made of four horizontal beds. The seismic properties of these beds were assigned in a such a way that compression velocity wave (Vp) increases from top to bottom. The channels are located into the third level. Also to characterize the geological reliability, their velocity and density are lower than those of the surrounding medium (Figure 2).

In order to analyze the seismic response for the model, a 3D ray tracing with a normal incident point survey was performed. A fast algorithm for the ray tracing by Norsar-3D WFC (3) (Wave Front Construction) was used to perform the 3D-survey simulation. The top and bottom of the channels surfaces were exploded and the arrival times were recorded, including the bed that is immediately above the channels.

Figure 4 shows three synthetic seismic sections obtained using a 3D zero offset ray tracing survey. Their location can be seen on the top view map of the channels (Figure 3).

These three seismic sections were generated with a 50 Hz Ricker pulse that could be accepted as a characteristic frequency of the seismic response in the Campos Basin. The pulse and frequency are the basic features of the seismic image to distinguish one channel from the others. From Figure 4 it can be seen the tuning effect of the seismic response of two channels that are close to each other. This seismic response can be analyzed in a 3D-interpretation platform, and can validate the channel geological model. This method is very important to characterize typical turbidite reservoirs.

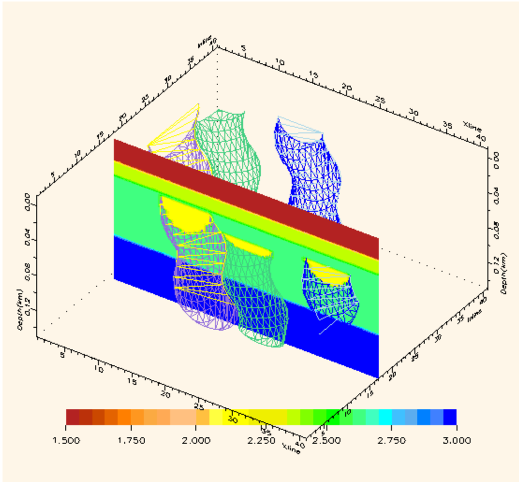

Figure 2 Three dimensional velocity model for the channels. Color bar shows the velocity scale.

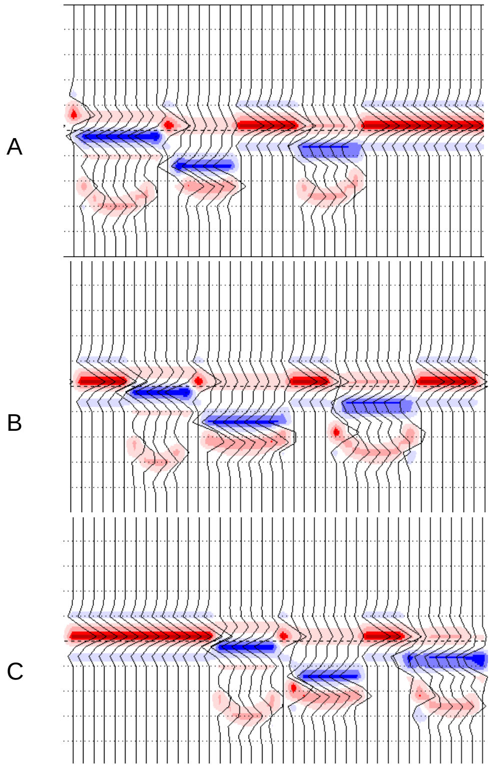

Figure 4 Seismic sections at different locations shown in Figure 3.

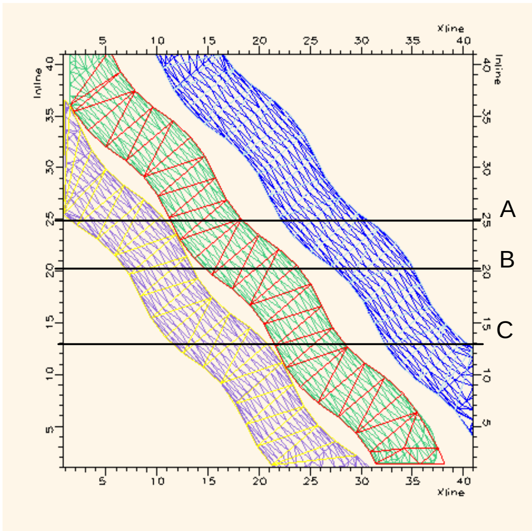

Figure 3 Map of the channels rendered as wire frame. Note the location of the three seismic lines shown left.

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VISUALIZATION AND INTERPRETATION

The 3D synthetic seismic data were imported from SEG-Y file format into the Gocad voxset format. This procedure allows the 3D visualization of the channels objects and seismic data at the same time. Figure 5 shows the channels object and a 3D seismic section. Note the differences between seismic imaging response and channels with different thickness. The left channel, which is thicker, was poorly imaged compared to the others. The borders of this channel are steeper, so the algorithm of ray tracing could not generate a seismic response of such borders. The closer to the channel borders, the less it may be visualized in seismic response. This result could occur in a real case. In the same sense, the thinner channels had their width better imaged, so this visualization can be useful as an interpretation tool.

Figure 6 shows the same previous visualization under a perspective point of view. In order to emphasize the sinuosity of the channels, a time slice was plotted. The sinuosity was well visualized even for the closer channels. The differences of seismic response in time slice for the channels are related to their varying depth. The channel most at right has brighter amplitude and the base of the channel on the left appears to be doubled. This is caused by its higher convexity and, for this channel, the time slice interception is above the talveg.

A seismic section was plotted also in Figure 6, at the same position as shown in Figure 2. Note the similar features between 3D section on velocity model and the visualized one.

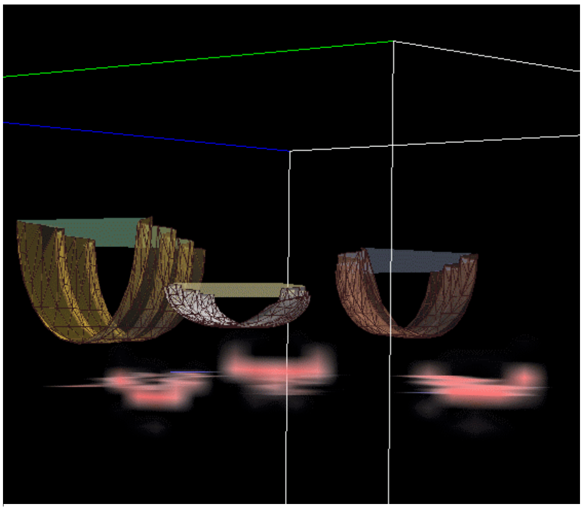

Figure 5 Synthetic seismic volume and channels visualized in Gocad.

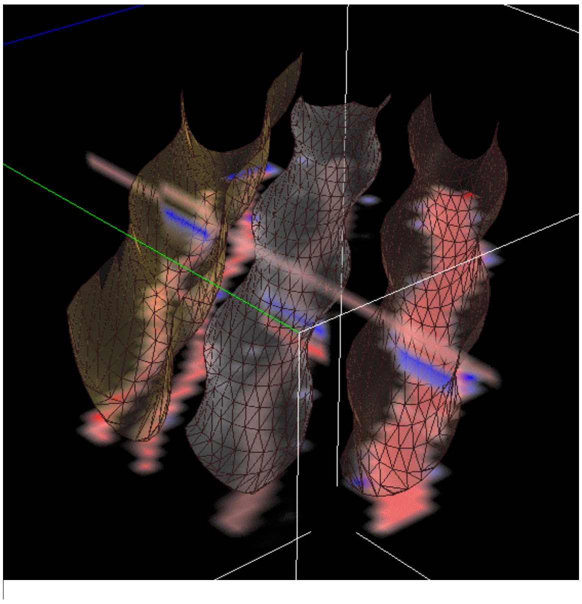

Figure 6 Base of the channel objects and time slice of 3D synthetic seismic data.

CONCLUSIONS

The methodology applied in this study shows the combination of geological and seismic modeling, generated in different software platforms and integrated in the same 3D-environment software. It has shown a potentiality as a validation tool for testing the reliability of the models. For stochastic and geometrical modeling of boolean channels, PetBool has shown its reliability to obtain realistic models. Moreover, the Gocad software has shown a good visualization and data integration platform.

The applicability of this kind of integration could be useful to identify seismic interpretation pitfalls. The control of tuning effects, for instance in synthetic model, can be treated in such 3D modelling enviroment constructing more reliable geological models. Also a complete study of reservoir characterization can be performed in a real case, integrating geological models, seismic interpretation and fluid flow simulations.

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