SUB-THRUST IMAGING: MODELLING EXAMPLE FROM THE CUSIANA OILFIELD, LLANOS BASIN, COLOMBIA

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Abstract

The Cusiana oilfield in the Llanos basin of Colombia is one of the largest in Colombia. Discovery of this field and others in Colombia was hampered by poor seismic imaging of sub-thust structures and stratigraphy. A balanced cross section, based on a seismic line over the Cusiana field, was used as a model and ray traced using 2D ray tracing program. Zero offset and common shot synthetic seismograms were generated. The zero offset synthetics were migrated using poststack Kirchhoff and FD steep dip migrations whereas the common shot synthetics were migrated using prestack Kirchhoff and prestack FD shot depth migration algorithms. The results of the modeling experiments illustrated lack of illumination in critical subthrust regions of the deformed belt and explained the poor subthrust image in the field data.

The use of raytracing modeling helped us to understand and recognize the errors in the acquisition parameters and guided us to select the best processing algorithms for reprocessing the seismic data. In areas of complex structure and poor seismic imaging, seismic modeling can be an additional tool to help constrain the interpretation.

Introduction

The foothills of the Llanos basin in Colombia is an area of rough terrain and very complex geology (Figure 1). It is also an area of large oil and gas fields. For many years in this area of complex geology, with folds, thrusts and imbricates, poststack migration has been the workhorse for seismic imaging. Implicit in poststack migration is the assumption that the stacked common midpoint trace is a zero-offset section. This basic assumption is not valid in areas of complex structure and the poststack migration will not give a true image of the subsurface (Kirtland Grech et al., 2000). In this environment, depth or time migration before stack is the only way to achieve a true image of the subsurface (Yilmaz, 1987; Gray, 1998).

The Cusiana oilfield is an unusual field. Despite being one of the largest oilfields in Colombia, it took more than 30 years of exploration activity for it to be discovered. The reserves of the Cusiana field are set at 1500 mmbo and 3.4 Tcf (Cazier etal., 1995). Poor seismic imaging was largely to blame for the difficulty in finding the Cusiana field and the poor exploration success in general in the foothills of the Llanos basin.

An interpretation of the seismic section shown in Figure 1 was made and a numerical model generated for the modeling experiments (Figure 2). Once the interfaces were corrected and the blocks generated, the material properties (Vp, Vs, density) were assigned (Figure 2). The interval P-wave velocities were taken from the Cusiana 2 and surrounding wells. The density was calculated from the P-wave velocity (Vp) in Matlab using Gardner's equation. The shear velocity (Vs) was assumed to be 50 % of the Vp. The final model was 23.6 km in length, 11 km deep, contained seven layers, two major thrust faults and four minor faults.

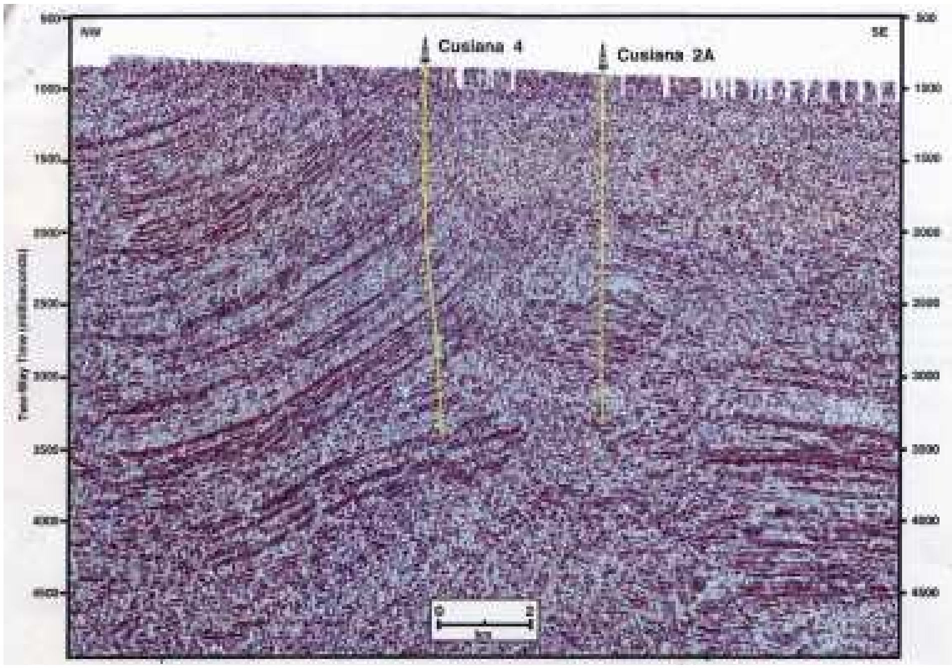
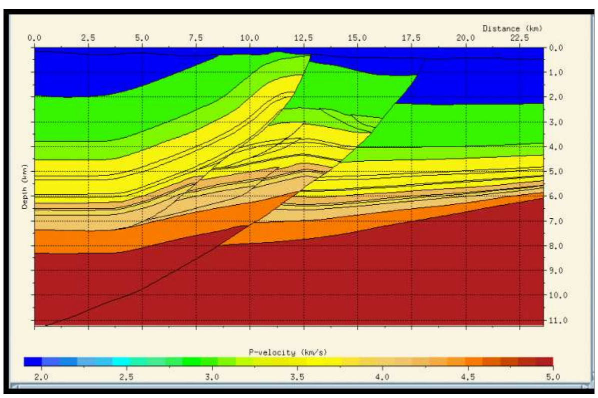
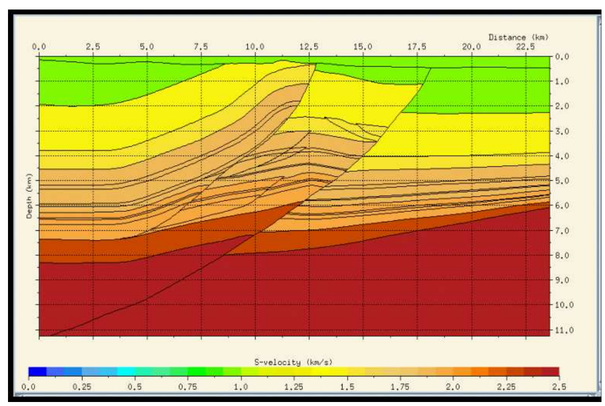


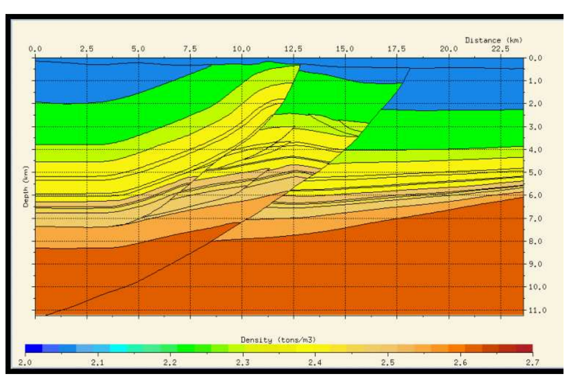
Fig 1: Seismic line T-1 across Cusiana oilfield with F-D prestack time migration



(a)



(b)



(c)

Fig 2. Material properties used in the model: (a) Vp, (b) Vs, (c) density

Common Shot Ray Tracing

The output of the common shot ray tracing was 118 synthetic shot gathers that had to be processed and evaluated. The common shot model was run with a 50 m group interval and a 200 m shot interval with a maximum offset of 8000 m and a 320 channel split spread. These parameters matched the field data acquisition of the data shown in Figure 1. As this is a numerical dataset, the usual preliminary processing steps were not needed. Q was not included in the modeling and noise was not added to the result. The model was shot from a flat datum with a uniform velocity layer so statics were not an issue. The velocity of the top layer was 1900 m/sec, the same as the replacement velocity for seismic lines in the area.

Figure 3 is the result of prestack F-D shot migration of the numerical data using the known velocity model. This algorithm performs prestack depth migration on shot gathers, using explicit finite difference extrapolators. The main advantages of this approach are good handling of vertical and laterally varying velocities and relatively steep dips.

The prestack F-D Shot depth migration gave good results and was the most precise image of the original input model. The fault planes of the major thrust faults were well imaged where there was a velocity contrast across the fault. Where like velocities were juxtaposed, there was no fault plane observed. The horizons were well defined in the areas of steeply dip, indicating that aliasing was probably not a problem on the original seismic data despite the rather large group interval(50 m). Small details from the original model have been preserved. Even the minor faults were imaged. The cut offs of the fault were improved but are not completely imaged due to the lack of complete illumination in the sub-thrust regions of the model.

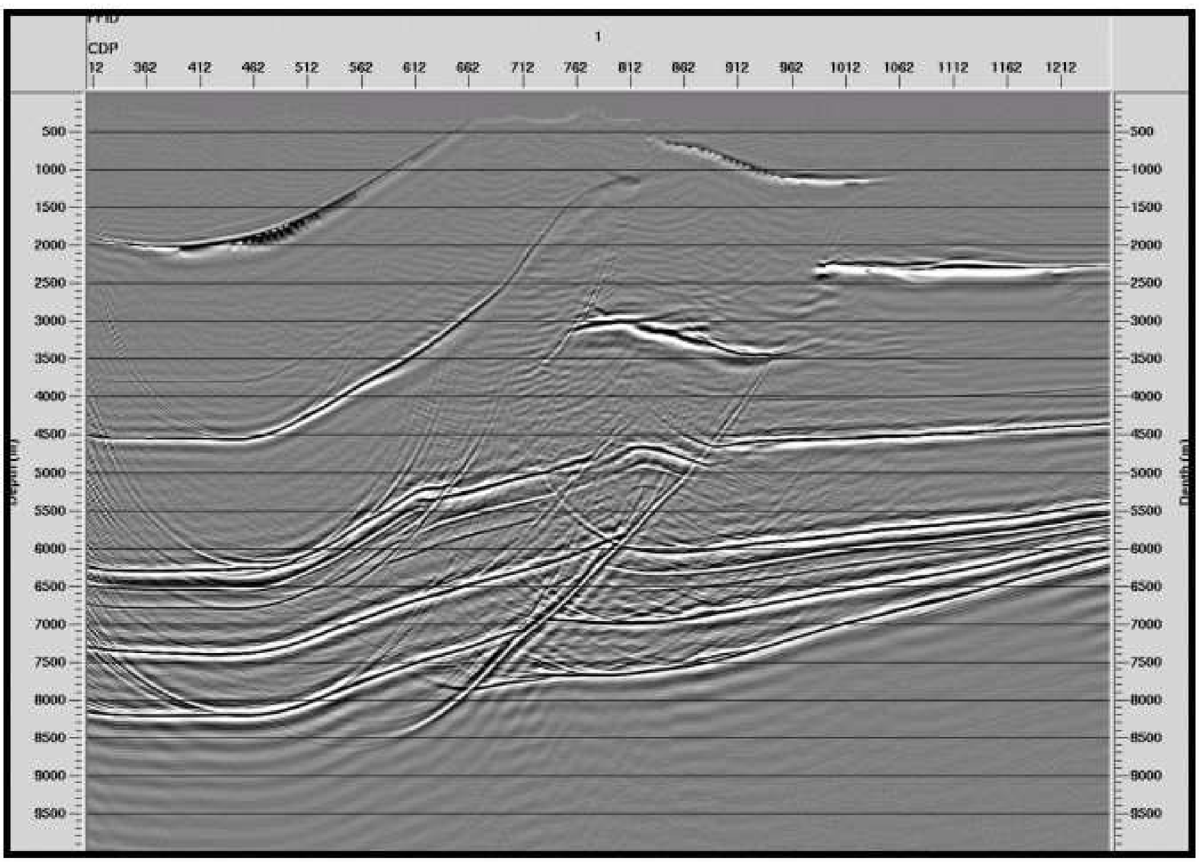


Fig. 3 Prestack FD depth migrated image of the model shown in Figure 2.

Acknowledgements

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References

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