SBGf13099

Multi-component 3D seismic pilot study in the Orinoco heavy oil belt

R. Malcolm Lansley*, Richard R. Van Dok, Mark Yale; Claude Bordenave, Abdelkader Chaouch, Jean Tachet; Total

Western Geophysical

ABSTRACT

A pilot 3-component 3D seismic survey was acquired over the Zuata Field in the Orinoco heavy oil belt of Eastern Venezuela in August of 1997. The reservoir consists of a closely interbedded series of sand bodies at very shallow depths. The goals of the 3D/3C pilot were to:
select and validate the required parameters for a subsequent 3D survey over a much larger area
evaluate the shear wave data quality
better understand the time, cost, operational, and environmental issues related to three component acquisition.
This paper will describe the key steps in the survey design, field testing, data acquisition and processing.

INTRODUCTION

When the target objectives of a 3D survey are very shallow, the source and receiver line spacings have to be reduced in comparison to surveys designed for deeper objectives. Both the environmental impact and the cost per square kilometer increase with this increased surface access. J.G.F.Stammeijer et al (1996) showed that converted wave recording could potentially provide better quality shallow information than P-wave recordings alone. If this was proved to be true for the Zuata area, then line spacings could be increased and the resulting surface access and acquisition costs could be reduced. Before commencing data acquisition of a 200 square kilometer survey over the Zuata Field, it was decided to record a small pilot survey (approx. 16 square kilometers) with 3-component geophones. This would be used to evaluate the value added (reservoir characterization, HR seismic) of converted waves in this area, and also to finalize the acquisition geometry for the full survey.
At the time when the survey was planned to be shot, there were only 1000 strings of 3C geophones available, with 6 geophones per string. This limited number of traces generated constraints on the survey design.
A number of wells had been drilled and logged (sonic, density, gamma, etc.) in the area, but no information about the shear velocities had been obtained.

SURVEY DESIGN

For the preplanning of the survey, a 3-component noise study had been recorded. P-wave reflection quality was fair, but on the PS-wave recordings, although the existence of actual converted signal was demonstrated, no identifiable reflections were interpretable. The results of this study were therefore analyzed to determine the parameters that would be applicable for P-wave recording, and these parameters were then adapted using assumed Vp/Vs ratios to permit the computation of the survey attributes for PS-wave common conversion point binning. Elastic modeling was also used to evaluate the offset ranges over which pre-critical PS-wave reflection amplitudes should be expected. This modeling was performed assuming a Vp/Vs ratio of 2, which later proved to be much less than that determined from the 3D data.

The acquisition template was 8 receiver lines of 80 receivers each, with 90 meters receiver line separation. Group interval was 30 meters. The source lines were orientated at 45 degrees to the receiver lines and were spaced 240 meters. This gave a nominal P-wave fold of 20 for the 15 meter by 15 meter bins. At an offset equal to the depth of the deepest sands of interest the fold varies from 12 to 16. Because of the limited number of geophone strings available and the size of the projected survey, a four-line roll was determined to provide a reasonable compromise between the geophysical requirements and operational efficiency.

For the determination of the converted wave binning attributes, Vp/Vs ratios from 1.5 to 2.5 were evaluated. The four-line roll causes a significant spatial variation of fold in the crossline direction, which could be reduced with a one-line roll. It was decided that any amplitude anomalies caused by this variation could be compensated for in data processing.

DATA ACQUISITION

The terrain in the survey area was gently rolling hills, with some vertical drops caused by erosion. The hills were predominantly gravel beds with a thin covering of loose, sandy soil. The geophone cases were fitted with only two spikes (one long and one short), in comparison with 3 spikes for some of the alternative geophones available within the industry, and there was concern about the quality of the geophone coupling, particularly for the horizontal elements. It was decided to verify the coupling of the geophones to the earth by conducting a test in which caps would be detonated at close range to the geophones, and then looking for evidence of "ringing" after the first arrivals. This is an indication of inadequate coupling of the geophones to the ground, and is usually most significant on the horizontal elements, but may also be seen to a lesser extent on the vertical component. After several tests of different planting methods, it was demonstrated that using a shallow trench in which to plant the geophones and packing soil around the sides to ensure good coupling was the optimum method. It eliminated the ringing while still permitting the azimuthal orientation and the leveling of the geophone to be easily verified.

Furthermore, in order to ascertain the isotropic behavior of the horizontal components, one line was acquired with two traces at each location. The second trace was constituted of geophones oriented perpendicularly to the normal orientation. The comparison of the shot gathers in the inline and crossline directions showed a perfect match, validating the x and y data for further wavefield reorientation.

Many other start-up tests were carried out to ensure the integrity of the 3C geophones: polarity test, hook up of the individual connectors for each component to the correct take-out of the cable, geophone orientation and leveling.
A major problem which arose was actually planting the geophone in the gravel layer, which varied in thickness from a few centimeters to more than 50 cms. in some locations. Whenever possible, the layout crew dug down to a more consolidated layer of sand below, and then planted the geophones in this. However, when the layer was too thick, the positioning of the geophones became very difficult. The spikes could not penetrate the gravel easily, and the geophone would become displaced from the vertical. Any attempt to reposition it resulted in the gravel becoming unconsolidated, with the result that the coupling was severely degraded. It was decided that as long as the bubble level showed that a geophone was level to 5 degrees or less, no further attempts to level it should be attempted in the gravel areas.

Although there are some areas with relatively smooth changes in elevation, many areas with rapid changes exist. In these areas, aligning the axis of the geophones with the receiver lines became very difficult as one survey stake was frequently not visible from the adjacent stake. Because of this, and also to assist in the accurate alignment of the geophones when the arrays are being contoured, a special geophone alignment tool was manufactured. This tool had a special fitting at the base that would only accept the geophone in one direction, and is fitted with a magnetic compass on the top. Once correctly calibrated to allow for the magnetic declination, it was possible to accurately align the geophones.

At least seven steps were necessary to ensure the correct planting of each geophone :

1) mark the position of the geophone within the trace
2) dig a trench
3) plant the geophone in an approximately vertical position
4) orientate the geophone
5) firmly plant the geophone and level it
6) pack soil around the geophone
7) check each phone by an independent team

The source was a small charge of biodegradable explosive (450 grams) at a depth of 10 meters.

Despite the limited number of strings of geophones and problems with cattle which chewed and disturbed the spread layout, a total of 2200 shots were recorded in 28 days, an average of close to 80 shots per day. Very rigorous field quality control was essential for ensuring that the geophone layout was optimal. A number of additional tests were performed in the field to evaluate possible changes in the acquisition parameters for future work.

DATA PROCESSING

Processing began with the P-wave data recorded on the vertical geophone, which included surface-consistent deconvolution, refraction and reflection statics, spatially-dealiased ("fat") DMO, and 3D time migration. Source deconvolution operators, total source statics, and P-wave stacking velocities obtained during this flow were all saved and utilized for the PS-wave sequence.

Initially, the PS-wave data was rotated to the radial and transverse directions. The radial component was then used for further processing assuming no azimuthal anisotropy since very little energy was observed on the transverse component. Source

deconvolution operators and statics from the P-wave processing were applied to the PS-wave data followed by a surface-consistent deconvolution using only the receiver and offset terms. Residual statics, velocities, and common-conversion point binning were iterated twice. The final pass of velocity analysis included a correction for the quartic, non-hyperbolic term in the normal moveout equation. Application of this correction significantly improved the quality of the stack section. A comparison of semblance plots from velocity analyses performed with and without this correction is shown in Figure 1.

Poststack time migration was performed using a one-pass FK algorithm and an average PS-wave velocity function. The poststack data were then positioned properly for subsequent interpretation techniques, e.g., average and interval Vp/Vs analyses for lithology discrimination.

CONCLUSIONS

The pilot study demonstrated the feasibility of acquiring a 3C/3D survey within a reasonable time frame, with minimal environmental impact, and with good safety, provided that all procedures are followed with meticulous care. It also showed that it was possible to obtain shear wave data with a reasonable signal-to-noise ratio in a land environment with difficult operational problems. Figure 2 shows shallow data from one of the lines from the 3D data volume.

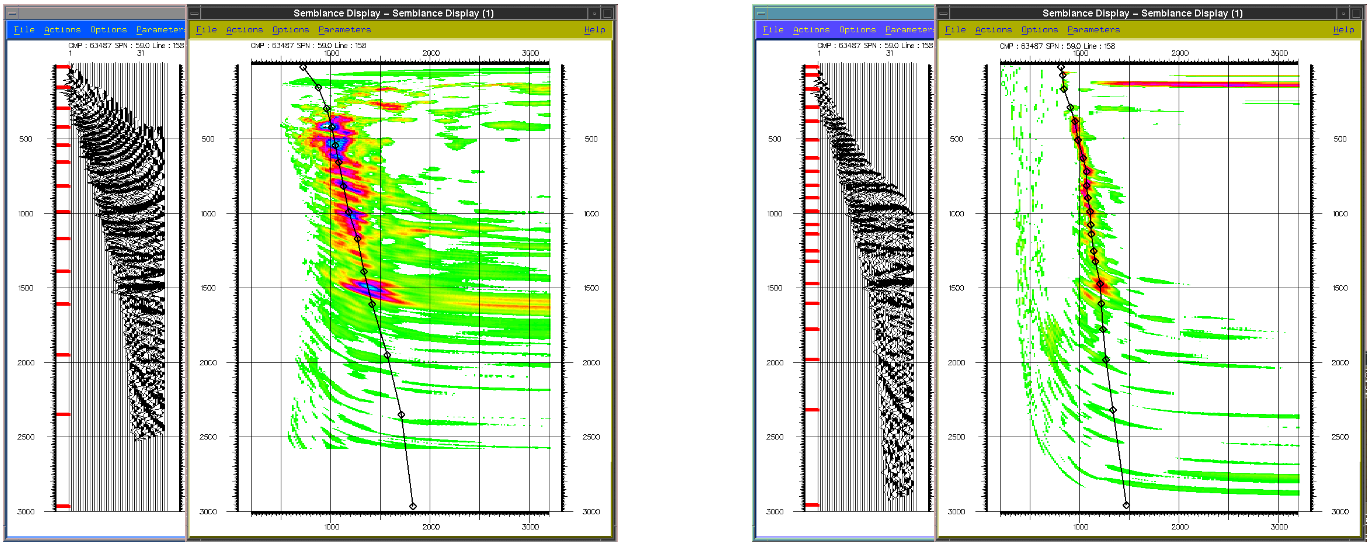
ACKNOWLEDGEMENTS

The authors would like to thank the SINCOR shareholders : Norsk Hydro, Statoil, PDV and Total for their support in this operation and for permission to present this work.

References

J.G.F. Stammeijer, J.L. Sheiman, P.K. Schruth, B Blonk, 1996, Combined processing of PP and PS data: Workshop on Advances in Multi-component Technology : Acquisition, Processing and Interpretation, 1996 EAGE Convention - Amsterdam.

A. Cordsen , D. C. Lawton, 1996, Designing 3-component 3D seismic surveys: 66th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 81-83



Hyperbolic moveout **Quartic moveout**

Figure 1: CCP gathers and velocity analysis semblance plots for hyperbolic normal moveout and normal moveout with quartic correction term.

Figure 2: Shallow data from a line extracted from the PS-wave data volume.