Multicomponent seismic surveys at Sibbald Flats, Alberta

Robert R. Stewart and Don C. Lawton

ABSTRACT

We conducted a 3C seismic survey, using vibrators, over a 5 km line in the Sibbald Flats area some 40 km west of Calgary. The line, shot in October 2003, is intended to image a Triangle Zone structure that can contain hydrocarbon reservoirs. In addition, we acquired data to test the "dragged array" concept. In these tests, we recorded numerous individual vibrators shaking at various parts of the shot interval as well as simultaneous shaking. The 3C data acquired look promising for both PP and PS analysis. Another dynamite line will be acquired at the same location in late November, 2003. This additional line should provide data to compare dynamite versus vibrators as sources for the generation of PS sections.

INTRODUCTION

Multicomponent seismic surveys on land have been undertaken primarily in areas with little structural deformation. Results from these surveys have shown considerable promise for advancing seismic analysis in lithological discrimination, mapping fluid saturants, and imaging reservoirs with low P-wave impedance. Marine multicomponent surveys, on the other hand, have been often conducted to image targets with considerable structure. The success of some of these marine efforts encourages us to apply the multicomponent seismic method to more structural areas on land.

The question of how multicomponent receiver arrays perform has also been undertaken by previous research (e.g., Hoffe et al., 2002). They found that 3C receiver arrays make little difference to the ultimate quality of a P-wave section, but actually damage converted-wave data. The damage inflicted appears to be mainly from the intra-array static variability. The investigation of sources in converted-wave data has received less attention. However, Krohn and Johnson (2003) suggested that vibrator source arrays may have both statics and NMO associated with the array. Indeed, stacking all of the sources in the array could also compromise data quality. They found that processing the individual sources, prior to stack, could considerably improve data quality. This is an interesting finding for P-wave data, but may also be important for PS data.

In September 2003, CREWES undertook a seismic acquisition program near Sibbald Flats, Alberta, about 40 km west of Calgary. The objective of the program was to collect, process, and interpret P-wave and converted-wave seismic data from an area of moderate geological structure, and to assess the application of multicomponent seismic technology for structural analysis. We also wanted to explore the effect of various source arrays on PP and PS data.

PROGRAM

The 5 km long line was oriented west-to-east and located along a Highway 1 access road at the eastern edge of the Rocky Mountain fold and thrust belt. The line crossed the apex of a regional structural trend known as a Triangle Zone. In this area, blind thrust

faults result in complex reflector geometries in the shallow section, with larger-scale duplexes at depth (Lawton et al., 1994). About 5 km to the north of the line, gas is produced from the Jumping Pound gas field. Here, the reservoir is composed of Mississippian-aged carbonates that are carried in the hanging wall of a blind thrust fault. The dominant play along the Triangle Zone has traditionally been deep carbonate reservoirs, but recently there has also been interest in shallower structural traps within Mesozoic sandstones of the Viking and Cardium formations.

The survey was undertaken for the CREWES Project and conducted by Tesla Geophysics, using the ARAM recording system and 14Hz analogue geophones. CREWES staff and students constituted the field crew for laying out geophones and surveying the line. Access was good and topographic variations were less than 30 m. Acquisition parameters for the main survey are presented in Table 1. Symmetric sampling was undertaken with source and receiver intervals both at 20 m, although some shots had to be skipped due to various cultural impediments. The entire 5 km line was live for all shots. This main line was acquired with about 12 hours of vibrating (shaking).

To test the effects of the vibrator source array, we reshot the eastern one-third of the line two more times. In the first reshoot, we used a technique called the source "drag array". In this method, the three vibrator sources shake and are recorded simultaneously. They are then moved up the line, 5m in our case, and swept again. The data from the four vibrating locations (all separated by 5m and centred at the half-station position) are stacked together. One seismogram results.

The second source test recorded all of the vibrators separately at each position of the drag array. Thus, twelve seismograms were recorded for each given vibrator point position. This separate recording will allow not only investigation into statics and NMO effects, but the non-linear coupling of the vibrators.

Table 1. Aquisition parameters for main Jumpingpound seismic survey

Source	3 x 44000 lb Hemivibes
Sweep	5 – 120 Hz over 12 seconds
Stacks	4 per VP
Receivers	3C
Receiver interval	20 m
VP interval (nominal)	20 m
Offsets	Up to 5 km

The program took 2 days to complete, in somewhat soggy conditions.

RESULTS

These 3C data are currently under analysis and fortunately there does appear to be some coherent energy on the horizontal channels (Figures 1-3). The dominant energy is at about 20Hz. We observe strong events around times at about 2200ms that may be associated with the Upper Cretaceous.

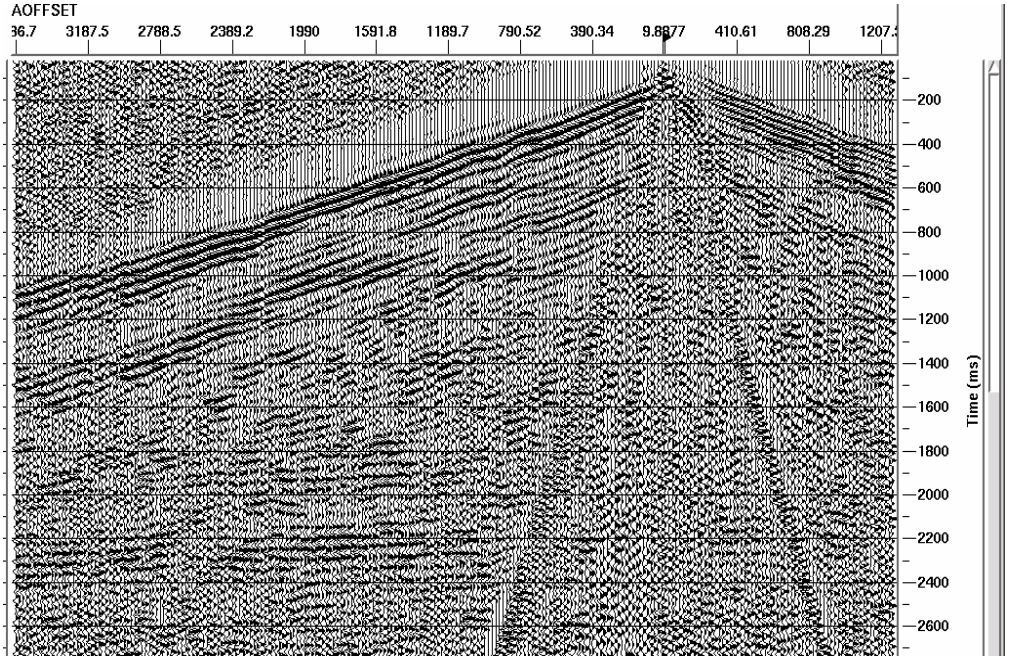

FIG. 1. Receiver gather of the horizontal 1 (nominally inline) component from Sibbald Flats 3C survey.

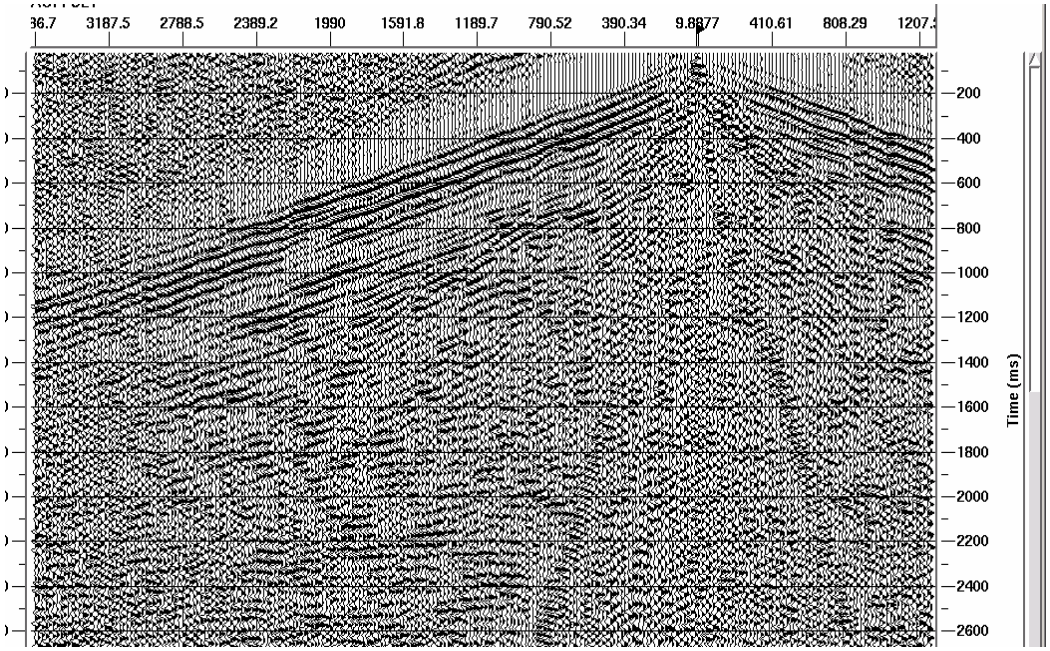

FIG. 2. Receiver gather of the horizontal 2 (nominally transverse) component from Sibbald Flats 3C survey.

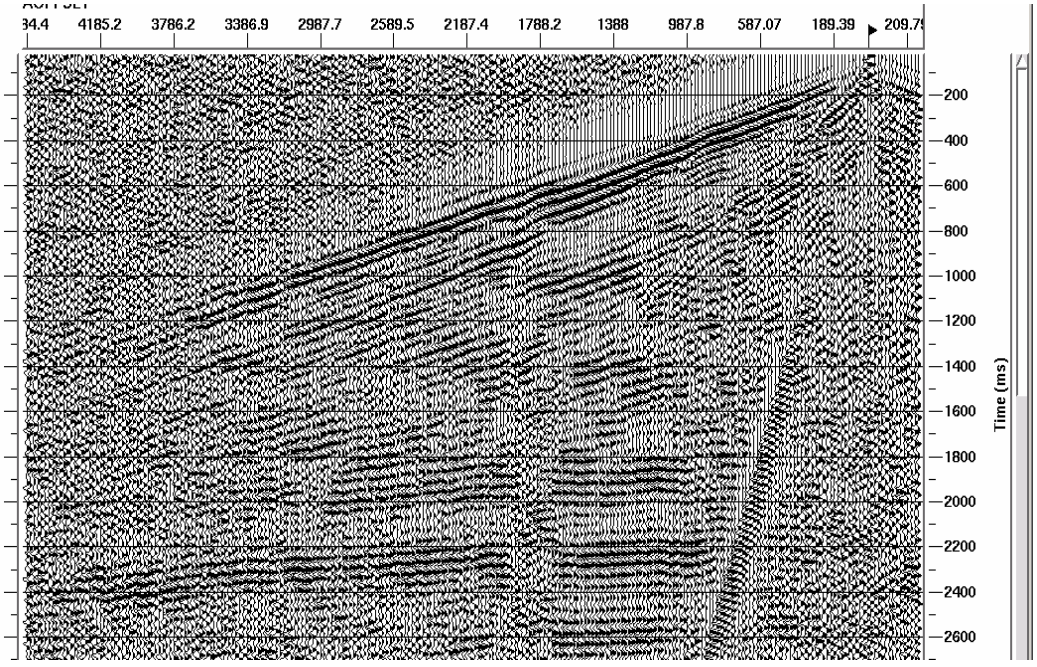

FIG. 3. Another receiver gather of the horizontal 2 (nominally transverse) component from Sibbald Flats 3C survey.

DYNAMITE AND DIGITAL RECORDING

We are planning to shoot another 3C seismic line across this same area in late November, 2003. This new line (the Copperthorpe 3C seismic survey) will use 3kg of dynamite at 18m depth. The source interval is planned to be 40m with a 10m receiver interval. We will be using the new Sercel DSU digital sensors and recording system. There is some evidence that dynamite can produce better PS sections than vibrators. If this were true, it could be a result of vibrators setting up more near-surface bound noise. This test should provide some evidence with respect to vibrators versus dynamite as a source for converted-wave surveying.

CONCLUSIONS

We conducted a 3C seismic survey, using vibrators, over a 5 km line some 40 km west of Calgary. The line is intended to image a Triangle Zone structure. The 3C data acquired look promising for PP and PS analysis. Another dynamite line will be acquired that should provide evidence for dynamite versus vibrators as sources to generate PS sections.

ACKNOWLEDGEMENTS

We thank NSERC and CREWES sponsors for funding this program, and the cooperation of Tesla in the acquisition of the data and Sensor Geophysical for processing of the primary data set.

REFERENCES

Hoffe, B.H., Margrave, G.F., Stewart, R.R., Foltinek, D.S., Bland, H.C., and Manning, P.M., 2002, Analysing the effectiveness of receiver arrays for multicomponent seismic exploration: Geophysics, **67**, 6, 1853-1868.

Krohn, C. E. and Johnson, M.L., 2003, High fidelity vibratory seismic (HFVS) II: Superior source separation: Presented at the 73rd Ann. Intl. Mtg., Soc. Explor. Geophys.

Lawton, D.C., Spratt, D.A. and Hopkins, J.C., 1994, Asymptotic tectonic wedging beneath the Rocky Mountain Foreland Basin: *Geology*, 22, 519-522.

Slotboom, R., Lawton, D.C., and Spratt, D.A., 1996, Seismic interpretation of the triangle zone at Jumping Pound, Alberta: *Bulletin of Canadian Petroleum Geology*, 44, 23-243.