Multicomponent VSP and lake-bottom cable surveys: Pike's Peak, Saskatchewan

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ABSTRACT

This paper outlines two multicomponent seismic (VSP and lake-bottom cable) surveys conducted at the Pike’s Peak heavy oilfield, Saskatchewan. The VSP survey used a 5-level 3-component tool to acquire data from depths of 515 m to 27.5 m. A 40,000 lb vertical vibrator shook at a zero-offset position as well as five offset locations from 90 m to 450 m from the well-head. The vibrator used a linear sweep from 8 Hz to 200 Hz. Very good data were recorded. The VSP tool was deployed horizontally (as a “lake-bottom cable”) in a small nearby lake. The cable was winched in to 29 locations across the lake, recording the sources at 5 locations for each cable position. The horizontal VSP geophones (now in the vertical plane) recorded reasonable data with frequencies up to about 80 Hz.

INTRODUCTION

The CREWES Project and AOSTRA in collaboration with Husky Energy Inc. are conducting a detailed study of Husky’s Pike’s Peak heavy oil field near Lloydminster, Saskatchewan. As part of this study, several multicomponent surveys were conducted in September, 2000. These efforts included a multi-offset VSP and an experimental “lake-bottom cable” survey. The survey site is shown in the photograph below (Figure 1).

Figure 1. Multicomponent VSP and “lake-bottom cable” site at Husky’s Pike’s Peak heavy oilfield, Saskatchewan.

Both the VSP survey and lake-bottom cable test used Schlumberger Canada's five-level, 3-C receiver – the ASI tool. The shuttles or 3-C receivers in the tool are separated by 15 m and magnetically clamp to the well casing (Figure 2).

Figure 2. The Schlumberger ASI tool with five shuttles each separated by 15 m and containing a 3-C geophone.

ACQUISITION

VSP acquisition

The VSP data included a zero-offset source position as well as offsets at 90 m, 180 m, 270 m, 360 m, 450 m. The 90 m offset source is shown in Figure 3.

Figure 3. Vertical vibrator at Pike's Peak offset 90 m from the VSP well.

The downhole geophones recorded 66 levels from 515 m depth to 27.5 m at a 7.5 m increment. As the shuttle spacing on the downhole tool is 15 m, it was moved 7.5 m after a shot and reclamped for another shot. After this recording, the tool was moved up 75 m to the next position and so on. We tried several non-linear sweeps with 3 db/octave and 2 dB/octave gains. However, in spectral analysis of the received signals (Figure 4), it appeared that the non-linear sweeps compromised the data in the low-frequency range (10-20 Hz) with attendant boost in the high frequencies. Thus, we used a linear sweep from 8 Hz to 200 Hz over 8 s. We also note a similar frequency band in a spectral plot from a shallower receiver depth (240 m).

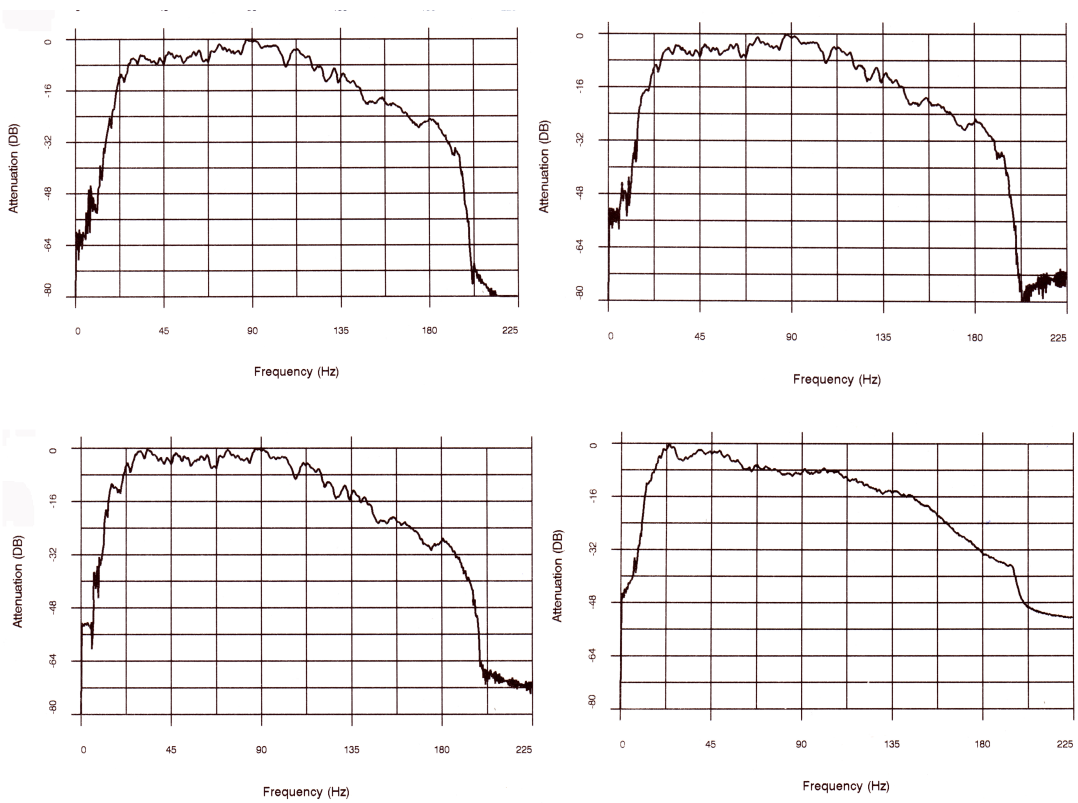

Figure 4. Comparison of geophone spectra at a depth of 515 m for non-linear sweeps: (a) 3 dB/octave, (b) 2 dB/octave, (c) linear. Plot (d) is the spectrum from a linear sweep at a geophone depth of 240 m.

The data were sampled at 1.0 ms with a 3 s listen time. The vertical channel data are shown in Figure 5 below.

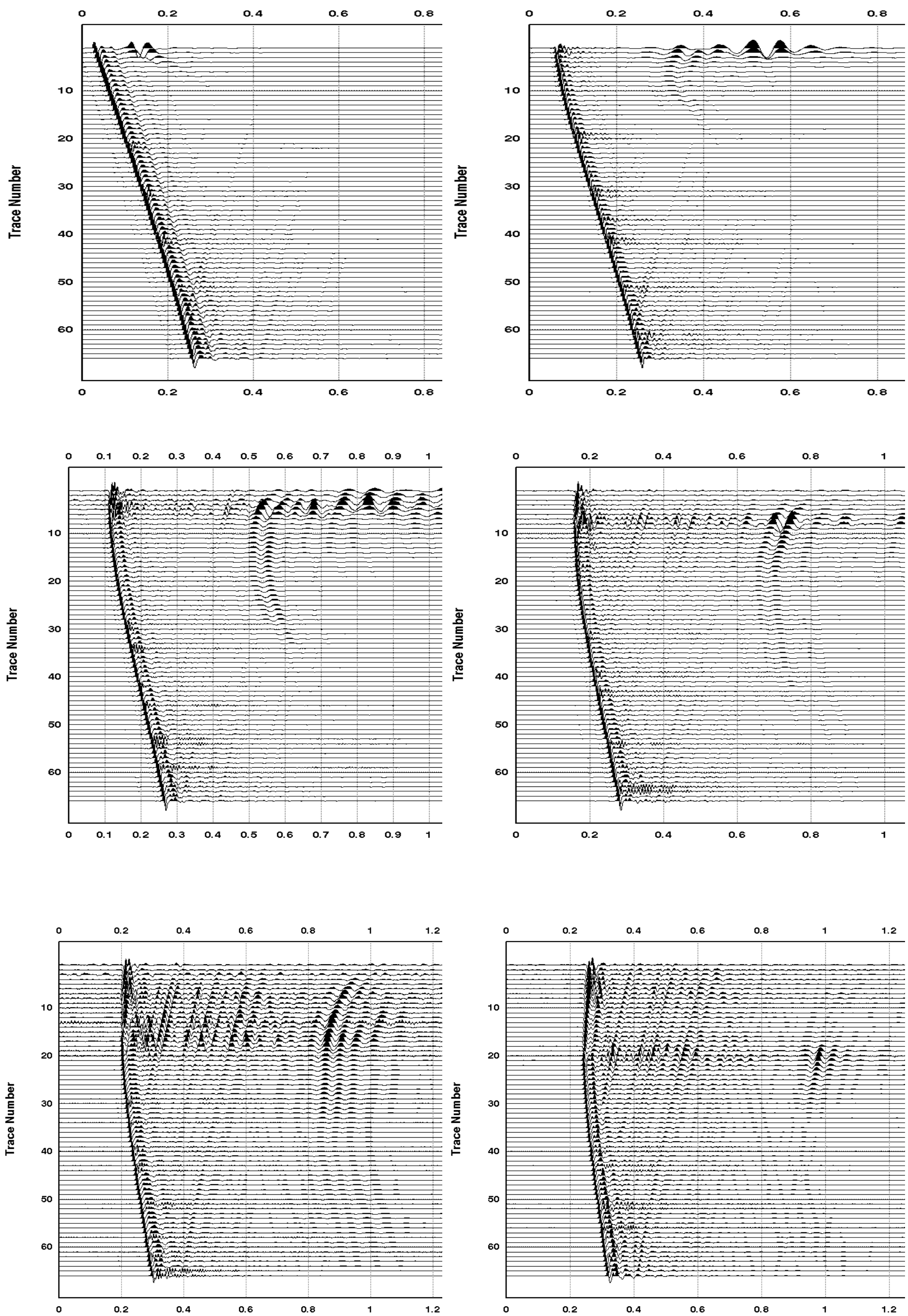

Figure 5. The vertical channel VSP data from the zero-offset, 90 m, 180 m, 270 m, 360 m, and 450 m sources.

We note that there is a consistent first arrival and evidence of upcoming reflections. Another interesting feature of these data is the low-frequency event arriving about 4 times as late as the first-breaking P-wave energy. We interpret this as a source-generated shear wave. The data indicate that there is a fairly high V_p/V_s value in the near surface

Lake-bottom cable acquisition

After the VSP survey was conducted, the five-level tool was deployed in a neighbouring small lake or slough. We accomplished the tool deployment by first floating and hand pulling the wireline across the lake. At the far end of the lake, the manual towing effort was assisted by an all-terrain vehicle. With the wireline across the lake the 60 m ASI tool was attached. The wireline truck then winched the wireline and tool back into the lake. The ASI tool subsequently acted as a five-station, lake-bottom geophone cable. The geophones in the ASI tool are not gimbaled, so we expect the vertical element to be lying horizontally and perhaps not performing optimally. The horizontal elements should be in the vertical plane orthogonal to the cable direction on the lake bottom. There were 29 cable positions recorded with five geophones spaced every 15 m. Each cable position recorded five source points that were offset from 49 m to 590 m from the recording truck. Two shot gathers are shown in Figures 6 and 7, one from about 409 m offset from the recording truck (and nearby source) and the other offset approximately 304 m. We interpret the first arriving energy as a refracted P-wave.

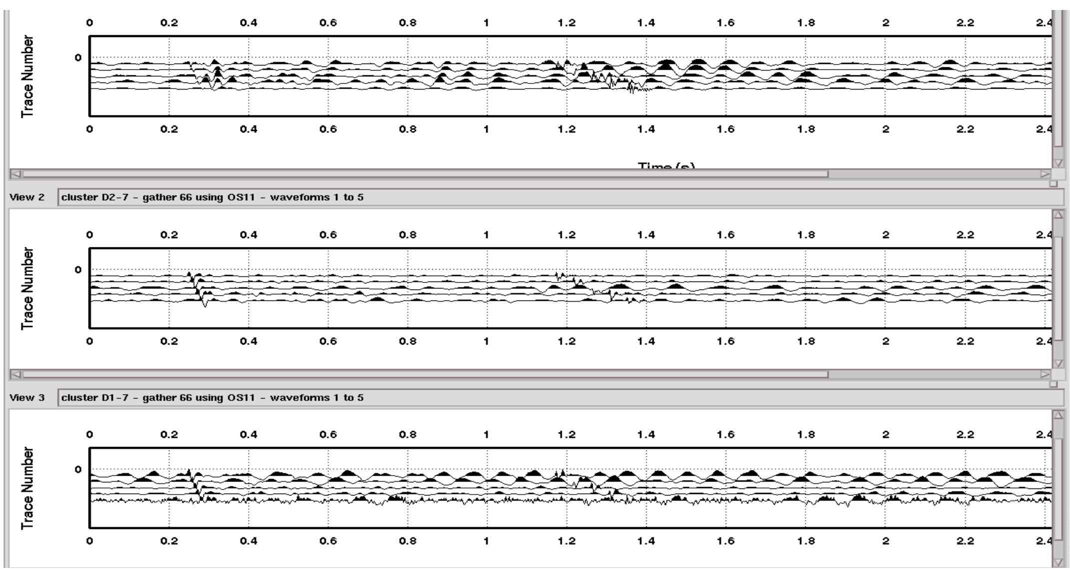

Figure 6. Shot gather records from the lake-bottom survey. The top of the receiving array is 409 m from the recording truck. The top five traces are the vertical (Z) components across the receiver while the next two groups are the horizontal components, Y and X respectively.

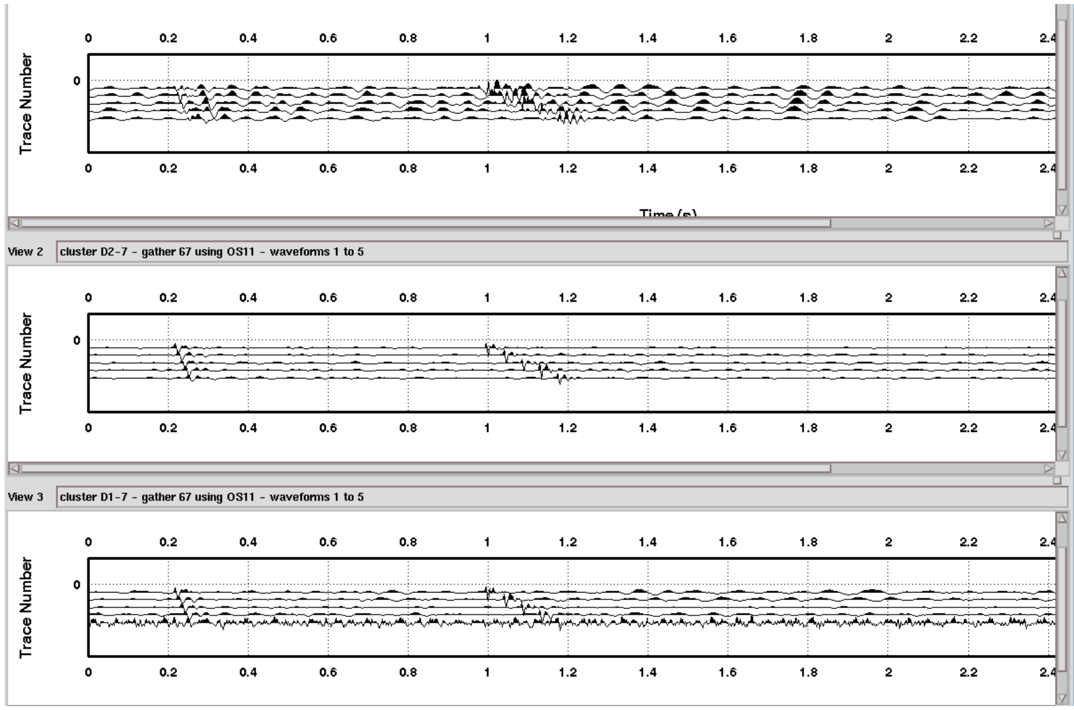

Figure 7. Shot gather records from the lake-bottom survey. The top of the receiving array is 304 m away from the recording truck. The top five traces are the vertical (Z) components across the receiver while the next two groups are the horizontal components, Y and X respectively.

The spectrum of a Y receiver at a distance 440 m from the recording truck shows frequencies up t about 80 Hz.

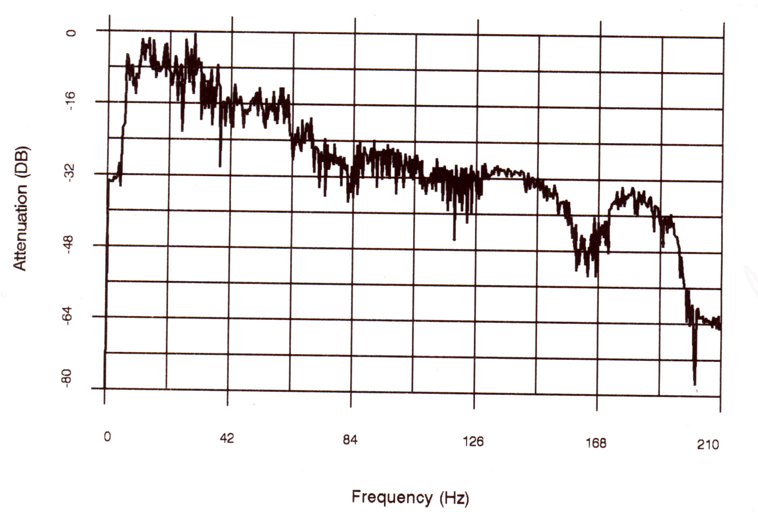

Figure 8. Spectrum from a Y-channel geophone of the lake-bottom cable at a distance 440 m from the recording truck.

CONCLUSIONS

The VSP data acquired at Husky Energy Inc.'s Pike's Peak heavy oilfield show good frequency content and consistency. The novel lake-bottom cable deployment was effective in acquiring seismic data. Both data sets remain to be processed.

ACKNOWLEDGEMENTS

We would like to thank Husky Energy Inc. for access to the Pike's Peak field and VSP well. Husky contract surveyors, Bert Cowan and Nigel Gentry, surveyed as well as courageously pulled the wireline across the slough. We also express our appreciation to the Schlumberger engineers on site including Rick Jacobs, Brad Jordan, Lyes Oualis, and Kelly Provost who patiently acquired this unusual data set. Katherine Brittle and Ayon Dey of University of Calgary ably assisted with the fieldwork.