A lake-bottom cable seismic survey: Acquisition and processing

Robert R. Stewart, Han-xing Lu, Henry Bland, and Lawrence E. Mewhort

Introduction

The CREWES Project and AOSTRA in collaboration with Husky Energy Inc. conducted a detailed study of Husky's Pikes Peak heavy oil field near Lloydminster, Saskatchewan. As part of this study, a unique experimental "lake-bottom seismic cable" survey was conducted in September, 2000. The lake-bottom cable was Schlumberger Canada's five-level, VSP tool. This 60 m long downhole tool had 3-C receivers separated by 15 m with a flexible cable between sensor levels. The basic idea of the experiment was to determine if coherent seismic energy could be recorded by the seismic sensors lain on the bottom of a lake (actually a 1 m deep slough) in the area. If successful, this type of recording could assist land-seismic exploration in summer months and might be beneficial to marine surveying using a VSP tool as an ocean-bottom cable (OBC).

Acquisition

To conduct the lake-bottom survey, we first floated and pulled the wireline from the VSP recording truck across the slough (Figure 1). At the far side of the slough, the manual towing effort was assisted by an all-terrain vehicle. When the wireline head was across the slough, we assembled and attached the 60 m long VSP tool. The truck then winched the wireline and tool back into the slough – stopping at 29 receiver locations. A vibrator walked away from the slough edge to give 10 source positions.

Figure 1. Deployment of the wireline across the "lake". The 5-level, 3-C VSP tool was attached at the far side of the lake and winched back to provide different receiver positions for the onshore vibrator.

The Schlumberger VSP (ASI) tool subsequently acted as a five-station, lake-bottom geophone cable. The "vertical" elements of the VSP tool were lying horizontally. The original "horizontal" elements should be in the vertical plane orthogonal to the cable direction on the lake bottom. There were 29 tool positions recorded with geophones ultimately configured every 15 m. Each cable position recorded five source points that were offset from 49m to 409m offset from the recording truck. Five other in-fill shots were taken.

Data Processing

The data were first vertically stacked. The total dataset included the 10 vibrator positions: 5 shot locations had 25 geophone receiving locations, while the other 5 shots have 5 geophone locations (one cable position). One of the shot gathers of three components is shown in Figure 2. From Figure 2, the data recorded on "vertical" geophone (Z) are in the horizontal direction. The other two components (X, Y) were rotated to project the maximum power to the vertical direction. The spectrum of a shot gather of vertical component shows coherent energy up to 60 Hz.

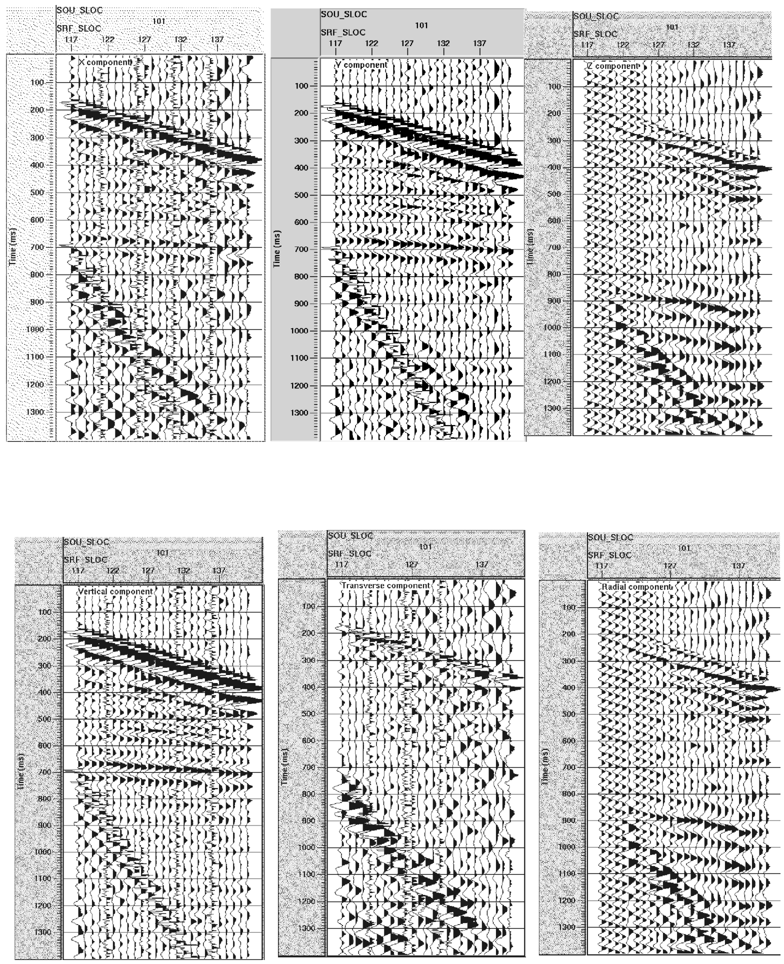

Figure 2. Shot gathers of the raw X, Y, Z components are shown above. The shot gathers of vertical, transverse and radial (V,T,R) components after orientation are shown below.

We use the new, oriented vertical component for processing the P-wave data set. A hand-static solution was applied because the short offset range did not allow other types of analysis. The CDP fold was very low (1-7 fold), so we performed the velocity analysis on the shot gathers. While not ideal, this was somewhat justified by the flat geology of the area. The preliminary result is shown in Figure 3 on the left. The main events tie reasonably well with the surface seismic events at the nearby location (Figure 4 on the right). The frequency spectrum of the previous seismic section (shot in winter) showed a very high frequency content (up to 150 Hz). To compare with the lake-bottom cable data, the previous section was bandpass filtered (6-11-30-40 Hz). This band-limited section then correlated fairly well with our lake-bottom seismic section. Our stacked section is clearly low frequency – but to us surprisingly good considering all of its limitations. The frequency content may be compromised for a number of reasons including poor source coupling (the vibrator was operating in a muddy/unconsolidated area), the receivers were just lain on the slough bottom, a water-surface ghost could attenuate the received data, and we have very low fold.

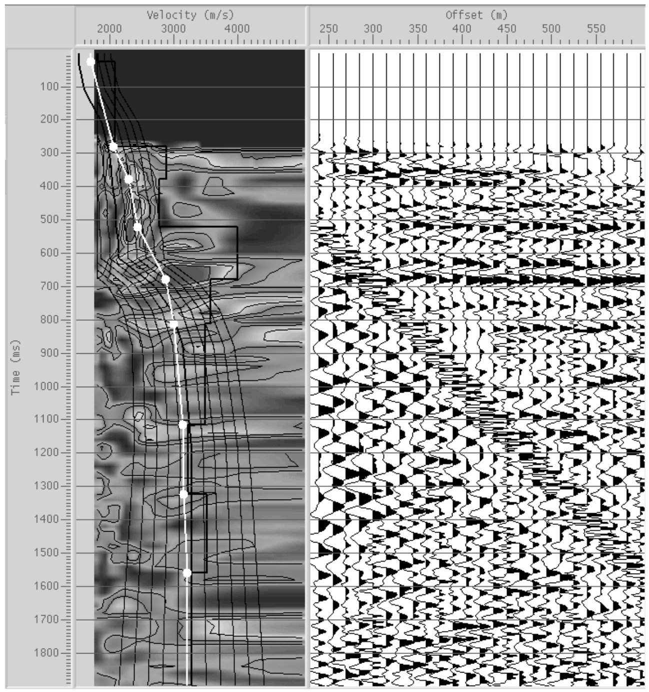

Figure 3. Velocity analysis for a shot gather treated as a pseudo-CDP gather. The white line is the picked stacking velocity, the black line indicates the velocities from the previous surface seismic line.

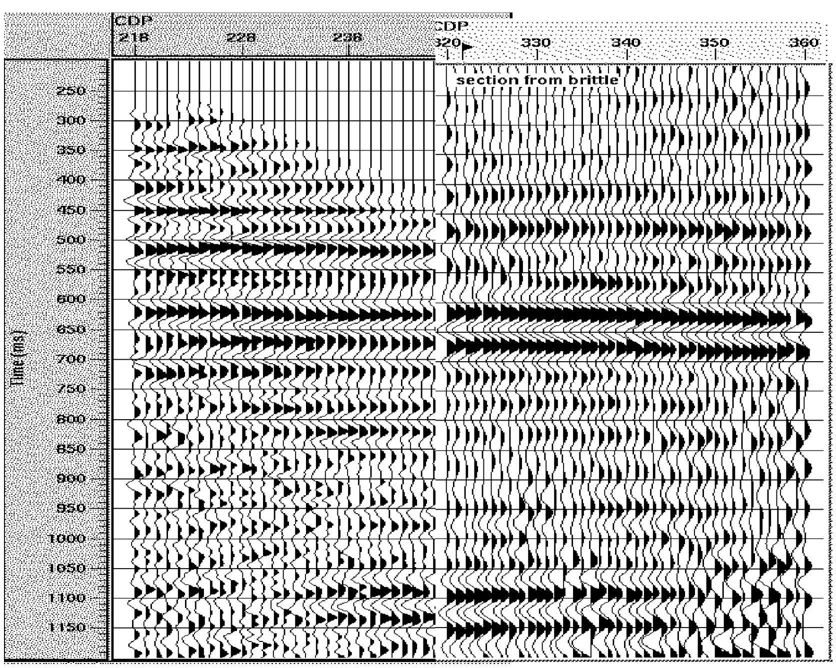

Figure 4. The stacked section for vertical component of slough data was shown on the left. The comparison of stacked section of lake-bottom cable with surface seismic section was shown on the right.

Conclusions

We conducted a "lake-bottom cable" seismic experiment by deploying a 3-C VSP tool in a slough in the Pikes Peak heavy oilfield, Saskatchewan. By winching in the tool from the wireline truck, a small line of seismic data was acquired. Coherent seismic reflections were recorded and processed. While the resultant seismic section did not contain as high frequencies as a previously recorded surface seismic line (in winter), we were able to reconstruct an interpretable section. This technique bears promise for summer lake surveying as well as marine applications.

Acknowledgements

We express our appreciation to the CREWES Project sponsors for supporting this effort as well as AOSTRA and Husky Energy Inc.