Acquisition and analysis of 3C land streamer data

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ABSTRACT

During the autumn of 2007, approximately 210 m of near-surface seismic reflection data were recorded over Priddis, Alberta as part of the University of Calgary's Geophysics Summer school program. This seismic experiment constituted the first attempt of the CREWES project to acquire seismic data using a land streamer. The 60 channel seismic land streamer consisted of 20 3C geophones with 1-m takeout spacing and a 12 lb. sledgehammer with handle trigger as the seismic source. The 2007 Priddis land streamer seismic survey produced data that imaged up to 50 m of the near surface layers, with prominent reflections at around 50-60 ms and 300 ms.

INTRODUCTION

Over the past decade, high-resolution seismic methods have become popular for resolving a wide variety of geological, engineering, and environmental problems. However, the traditional technique of planting geophones in the ground and physically moving cables in a CDP roll-along is costly, labour- and time-consuming, especially for SH-wave surveys with their requirement for smaller spatial sampling (Pugin et al, 2004). To address some of these issues, towed land-streamer systems have been in use since the 1970s.

A land streamer could be defined as an array of geophones designed to be towed along the ground. This idea comes from the seismic marine industry, where large volumes of high-resolution data are recorded using marine streamers. However the first tests on land were restricted to ice or snow (snow streamer), both of which provided smooth sliding surfaces suitable for long streamer use and a good geophone coupling (van ver Veen et al, 2001). The concept of a towed land cable was patented by Kruppenbach and Bedenbender (1975). The acquisition with the towed land streamer is similar to that of the marine streamer, where initially the streamer is kept at a fixed location, and the shot positions are moved from the back to the front of the array. Once the shot position reaches the front, it is kept at a fixed distance relative to the first receiver. Sources and receivers are shifted simultaneously after each shot. The streamer is moved up one shot interval, the shot is detonated once the streamer has been stationary for a few seconds, and the process repeated (van ver Veen et al., 2001).

Numerous successful case studies have been presented during the last three decades, helping to improve the near-surface image of the subsurface (van der Veen et al., 1998, 1999, 2001; Pugin et al., 2004; Ivanov et al., 2006; Lorenzo et al., 2006; T. Inazaki, 2006; Speece et al., 2007). Looking at these excellent results and the high potential of this near-surface acquisition technique, the CREWES Project acquired during 2007 its own land streamer system. The first experiment was done in the Priddis area located south of Calgary. The objective of this first attempt was to image the first 50 m of the subsurface and to test the capabilities of this acquisition technique.

A preliminary analysis of this dataset is presented in this study. Some of the results will allow us to evaluate the technique and proposed future improvements that need to be undertaken to achieve better quality seismic data.

Location of the Area of Study

The survey area was located close to the town of Priddis in Alberta (Figure 1). Priddis is located in the foothills of the Canadian Rocky Mountains, southern Alberta. Our geophysical test site is also home to the University of Calgary's Rothney Astrophysical Observatory.

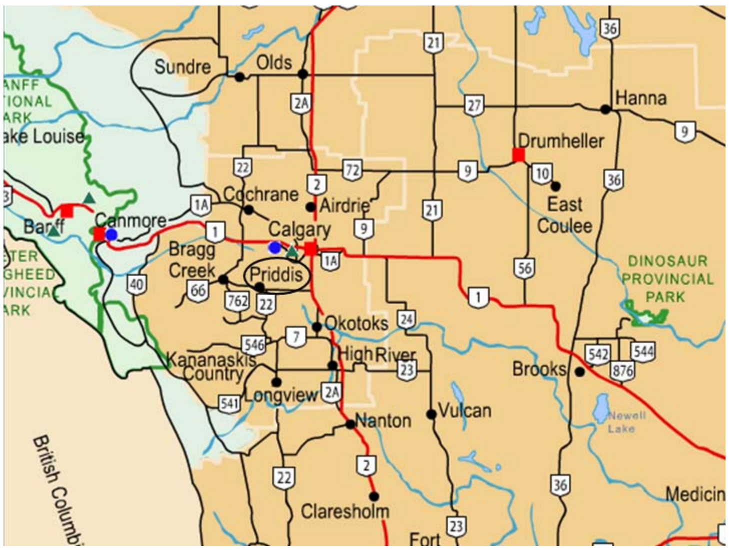

FIG. 1. Location of the area of study.

Acquisition parameters of the 3-C land streamer survey

The basic land streamer system consisted of a base plate, tow webbing, and top plate (Figure 2). It is designed to be used with our existing geophones and cables. The top plate is drilled and tapped for any make of geophone but using a 3/8- inch screw we could used our 3-C VectorSeis geophones (Figure 2). Its major characteristics are the non-stretch woven belts on which geophone units are mounted to form a multichannel geophone array, and the non-planted coupling of geophone units in contact with the terrain through metallic baseplates, which enables the geophone array to move easily up to the next position (Inazaki, 2006).

A short-spacing, short-length type land streamer configuration (1 m; 60 channels, 20 m total) was used to acquire data on a dirt road (Figure 2, 3 and 4). Our main focus was reflections at depths shallower than 50 m. The total length of the profile acquired was 210 m, with 10 m of overlap of the streamer corresponding to every time that the source point was change. Each time we recorded the entire length of the streamer (20 m), a single shot point was done, with multiple repetitions on the same location to ensure better signal-to-noise ratio (Figure 3).

In total, 38 shots were acquired, 211 receiver stations and a total line length of 210 m.

The multicomponent land streamer survey employed a vertical-impact source and multicomponent geophones (Figure 4). The source was a 12 lb. sledgehammer with handle trigger (Figure 2 and 5). The receivers were 10 Hz VectorSeis 3-C geophones that were being recorded at a 2 ms sampling rate by a Geometrics Geode recording system with 60 channels. The streamer was towed by a passenger van that was carrying the seismic recording system.

FIG. 2. Land streamer system components: land streamer basic configuration (left), geophone unit with wings to stop overturning (top right); top and bottom geophone plate and woven belt (bottom right).

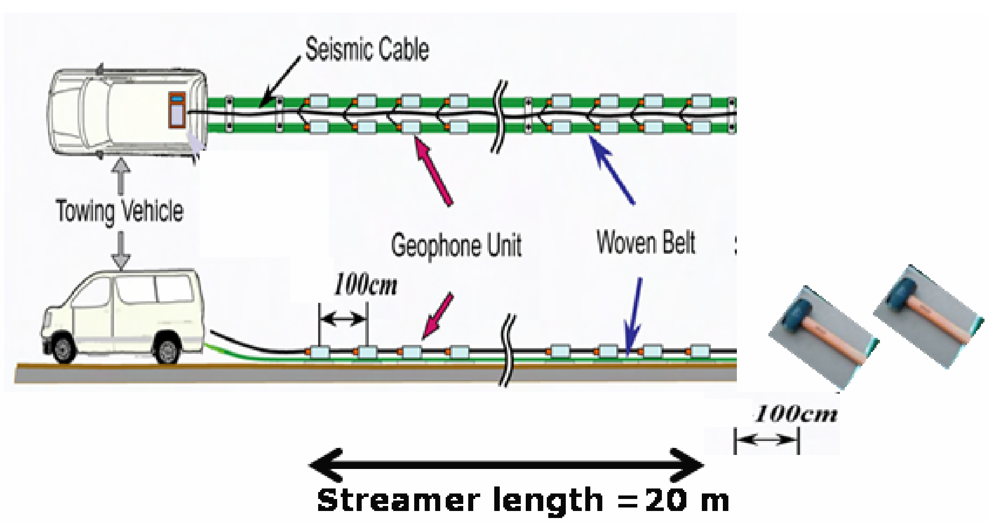

FIG. 3. Illustration of the land streamer configuration used on the Priddis seismic experiment: a 20 m streamer with 3-C geophones separated 1 m, with a sledge hammer P-wave source located at 1 m off the cable (modified from Inazaki, 2006).

FIG. 4. Actual land streamer configuration used in the Priddis experiment .Individuals shown here with the University of Calgary's Geophysycs Field School.

FIG. 5. Hammer seismic source used on the land streamer experiment.

Analysis of the data

The processing was divided into three main stages. The first stage involved fixing field problems, such as shot resampling, setting to a common trace length and renumbering the channels. The second stage involved geometry building and vertical stacking of the multiple shots that were done for the same source point. The third stage involved noise attenuation, filtering and generating a common-shot stacking section of the data.

Examples of some of the shots showing the three components can be seen in Figure 6. Figures 7 show a comparison between the raw data and band-pass filter and gain (AGC) data for the vertical and transverse component. Looking at the raw data we can notice a dominant coherent noise with a linear moveout of low seismic velocity between 100 m/s and 350 m/s. This strong noise trend suggests the application of surface-wave attenuation techniques such as F-K filters and radial filters. Another observation is that the vertical component data contains the best data, as expected.

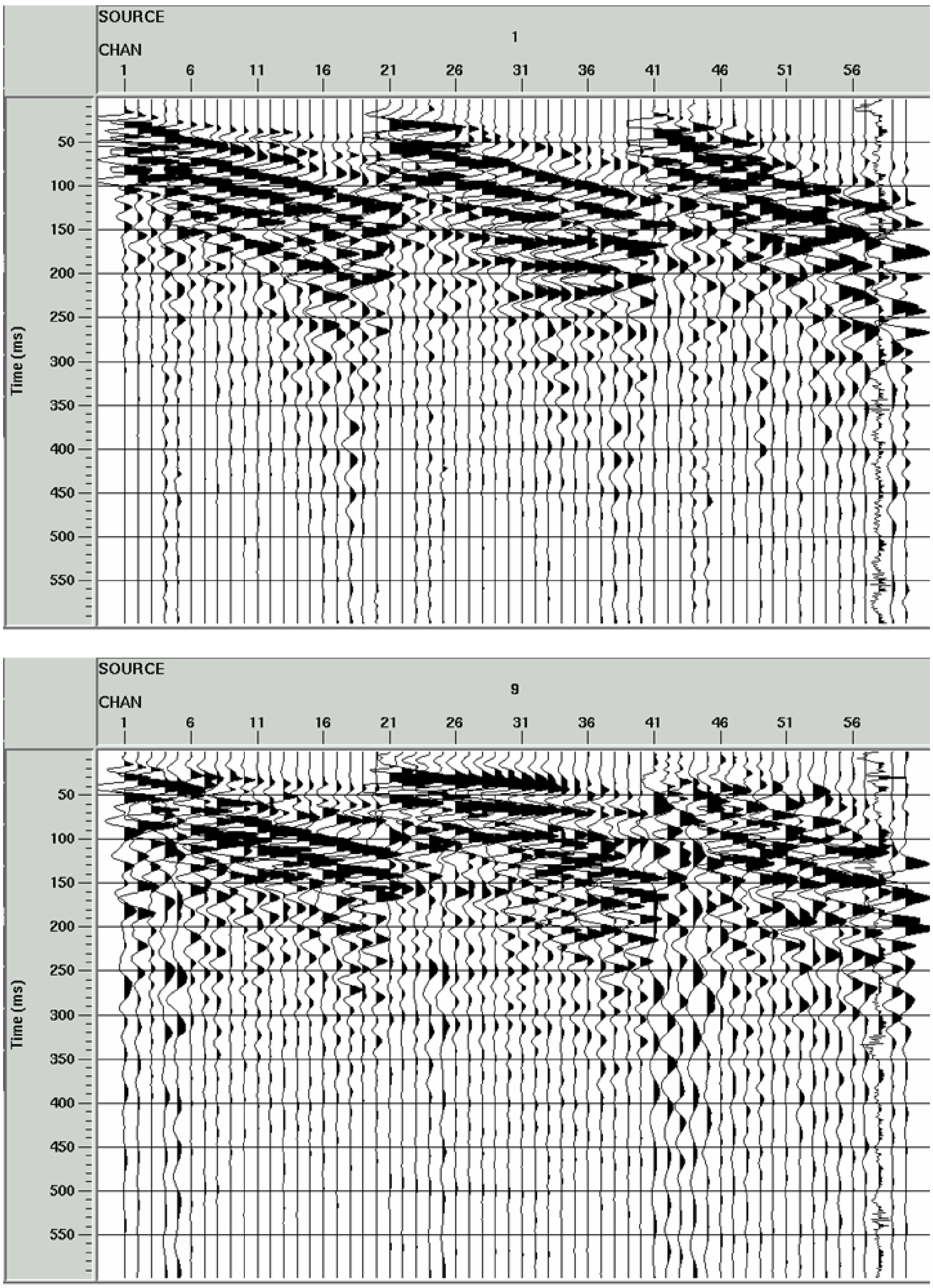

FIG. 6. Three-component shot gather: vertical component (left), transverse component (center) and radial component (right).

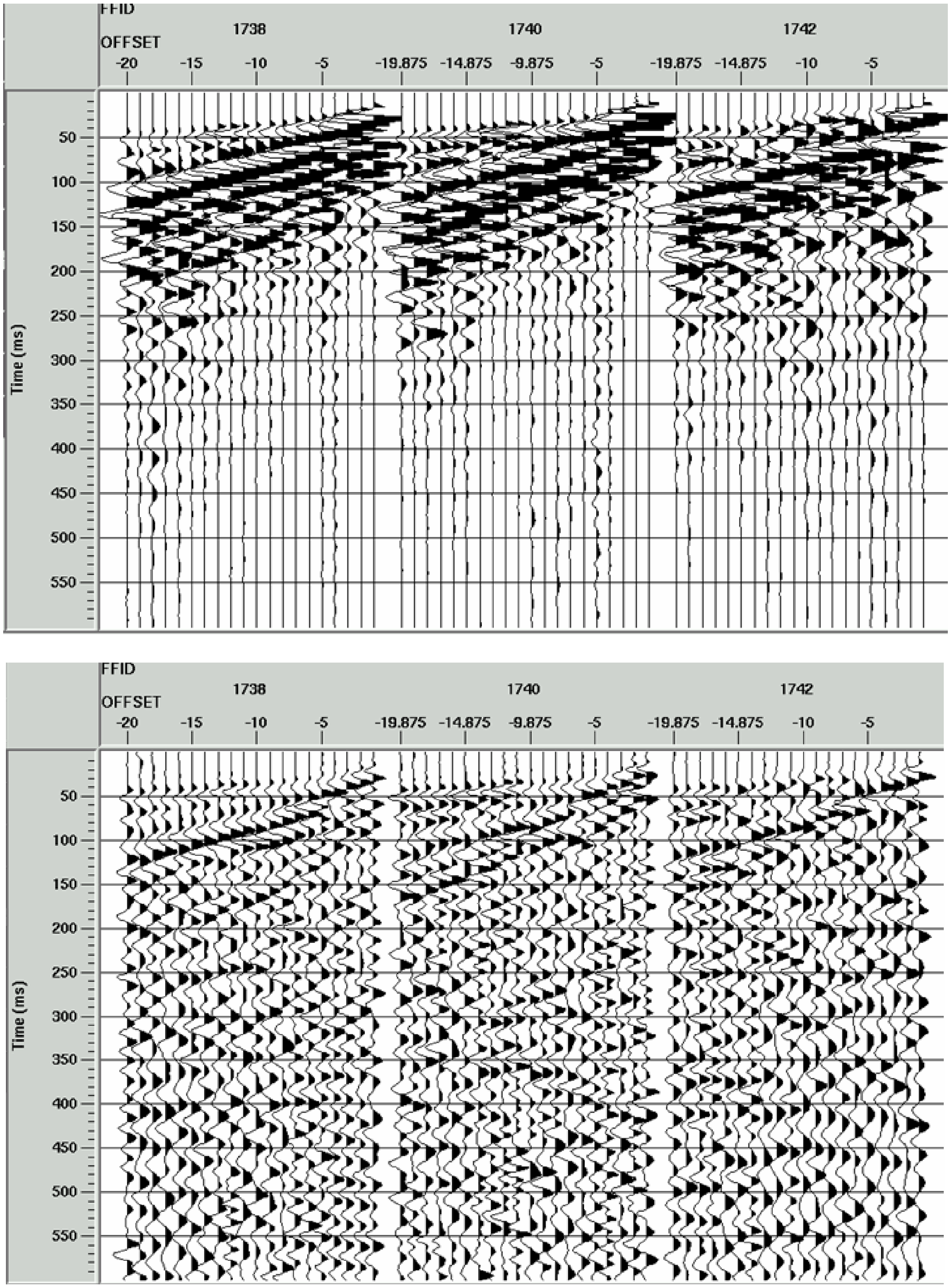

FIG. 7. Vertical component shot gathers raw (top) and band-pass filter and AGC applied (bottom).

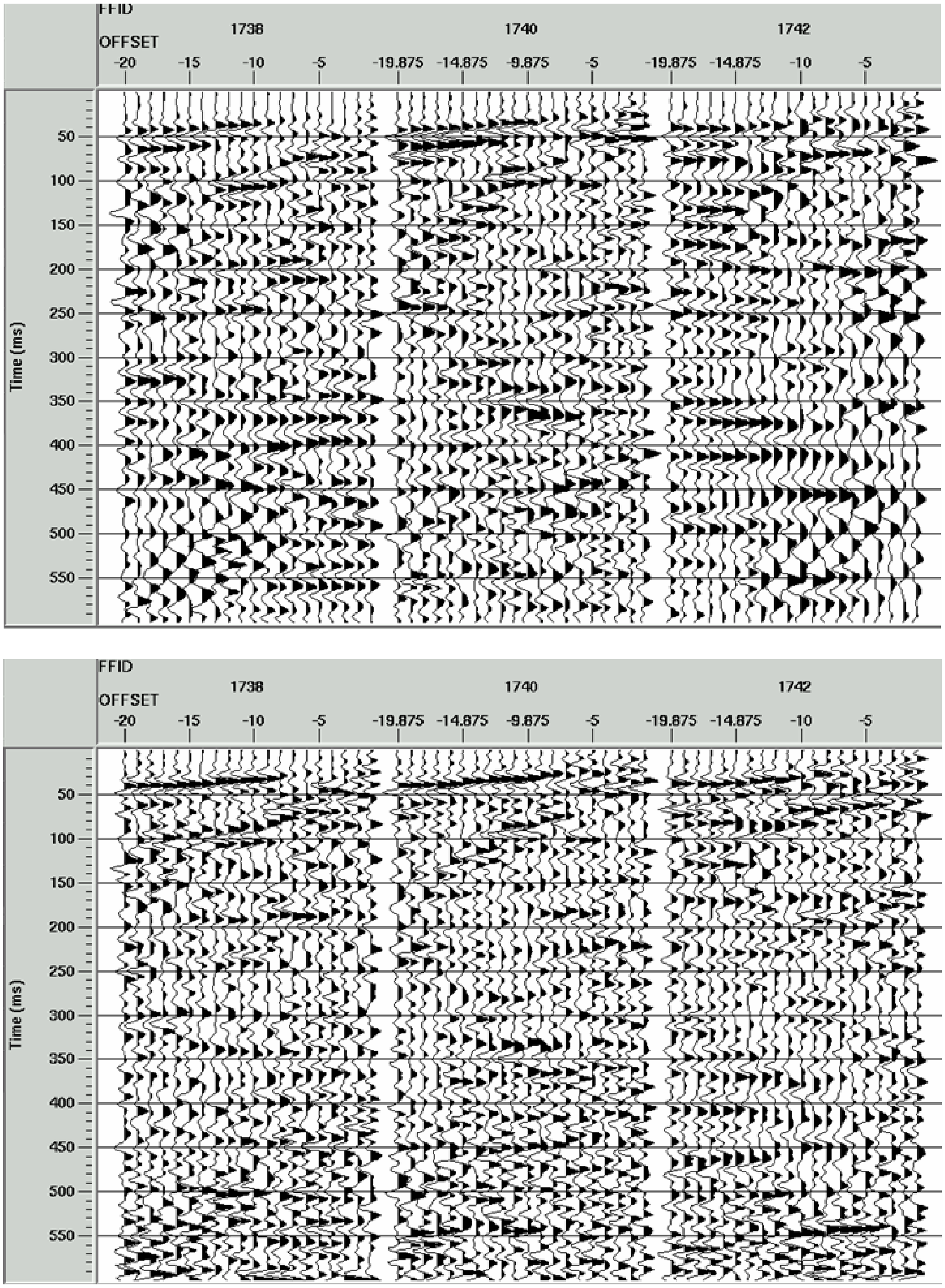

FIG. 8. Vertical component shot gathers with radial filters applied (top) and radial filters + Gabor deconvolution applied (bottom).

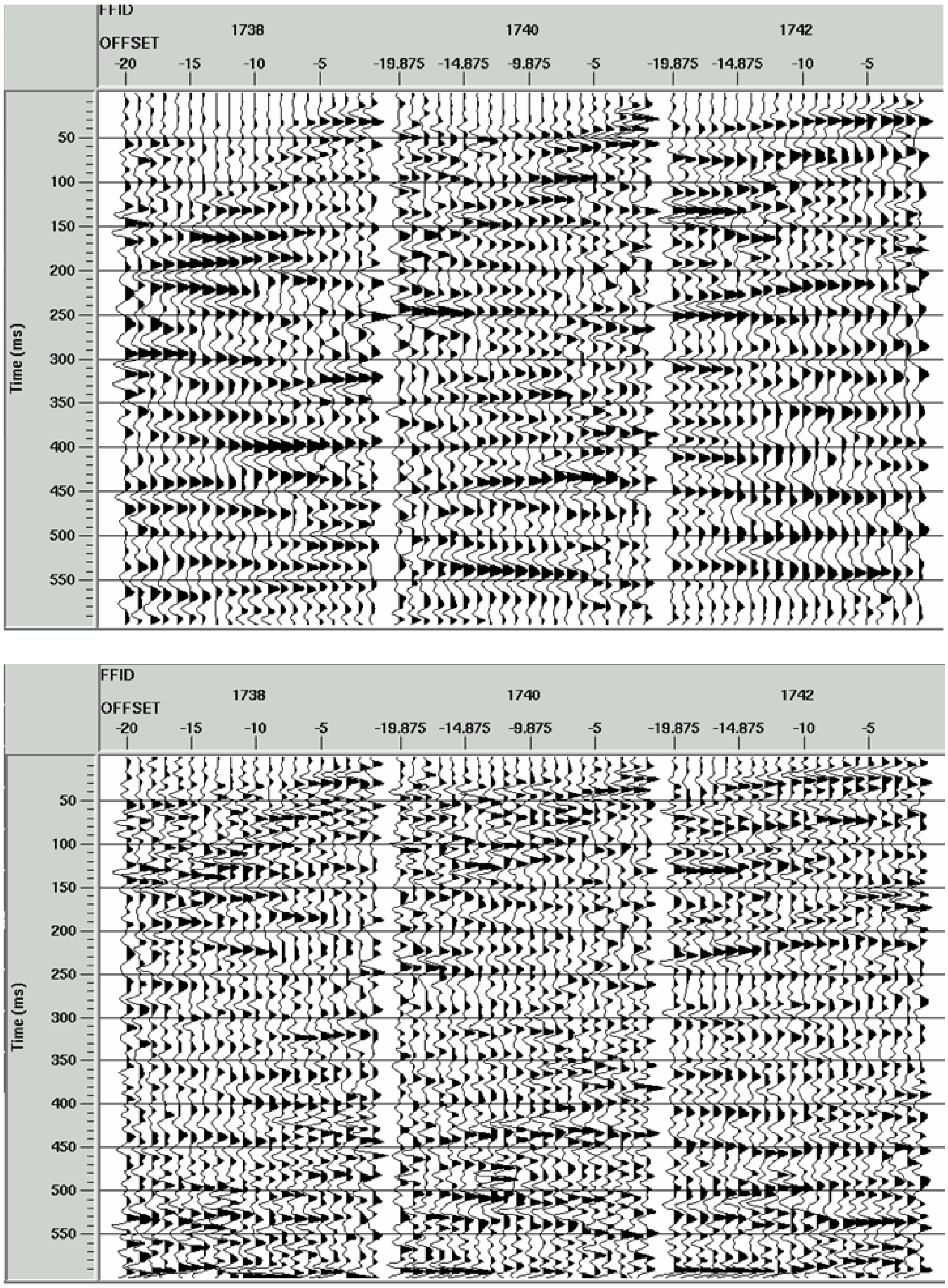

FIG. 9. Transverse component shot gathers with radial filters applied (top) and radial filters + gabor deconvolution applied (bottom).

Amplitude spectra were derived for some of the shots to analyze the frequency content and maybe the coupling quality. Figure 10 shows the amplitude spectrum for shot 1798. The response for the majority of the shots was similar to this example; with dominant frequencies on the low side around 30 Hz. Some of the possible causes for the low frequency content of the data could be coupling problems, strength of the seismic source or maybe more associated with the lithology of the weathering layer of this area (mainly conglomerates and unconsolidated material) that might be absorbing the high frequencies generated by our seismic source.

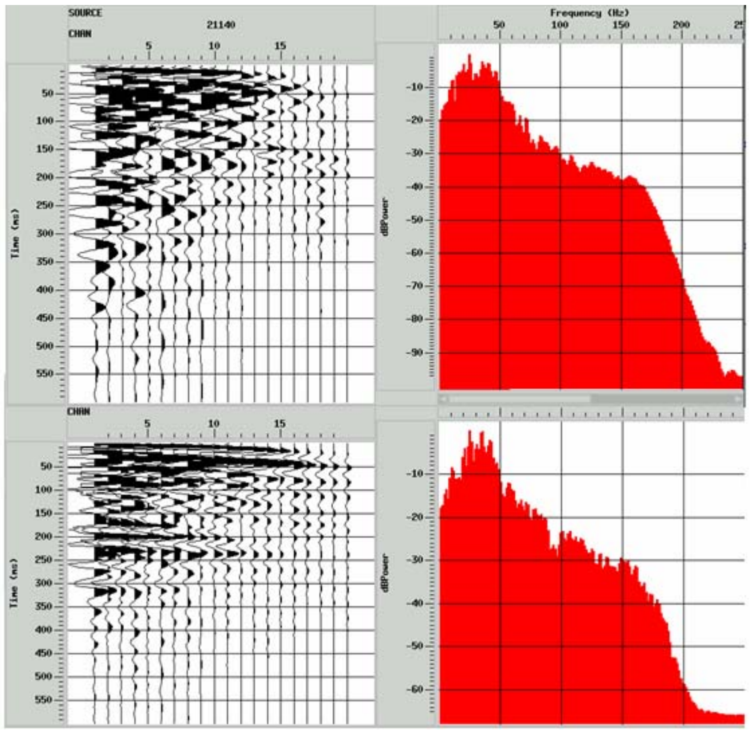

FIG. 10. Amplitude spectrum for FFID 1798 for the vertical component (top) and for the transverse component (bottom).

Radial filters with velocities on the range of 300 to 1000 m/s were applied to eliminate noise from the data in attempt to identify seismic reflections. Prominent reflections around 30 ms and 300 ms were observed on the filtered dataset (Figures 8 and 9). However, there is still coherent noise in these shots that might appear as reflections, which make necessary a conventionally acquired dataset as comparison to help us identify the near-surface seismic reflections of this area.

Some of these possible reflection events are better observed in the transverse component shot (Figure 9) if we compare it with the vertical component, such the event at 450 ms.

Constant velocity common source stacks were generated for this dataset. Figure 11 present the stacked sections for the vertical component and the inline component with velocities that ranges between 200 m/s and 900 m/s. In the 700 m/s panel; a reflection at 30 ms could be observed and at some of the panel a weak events around 300 ms could be observed.

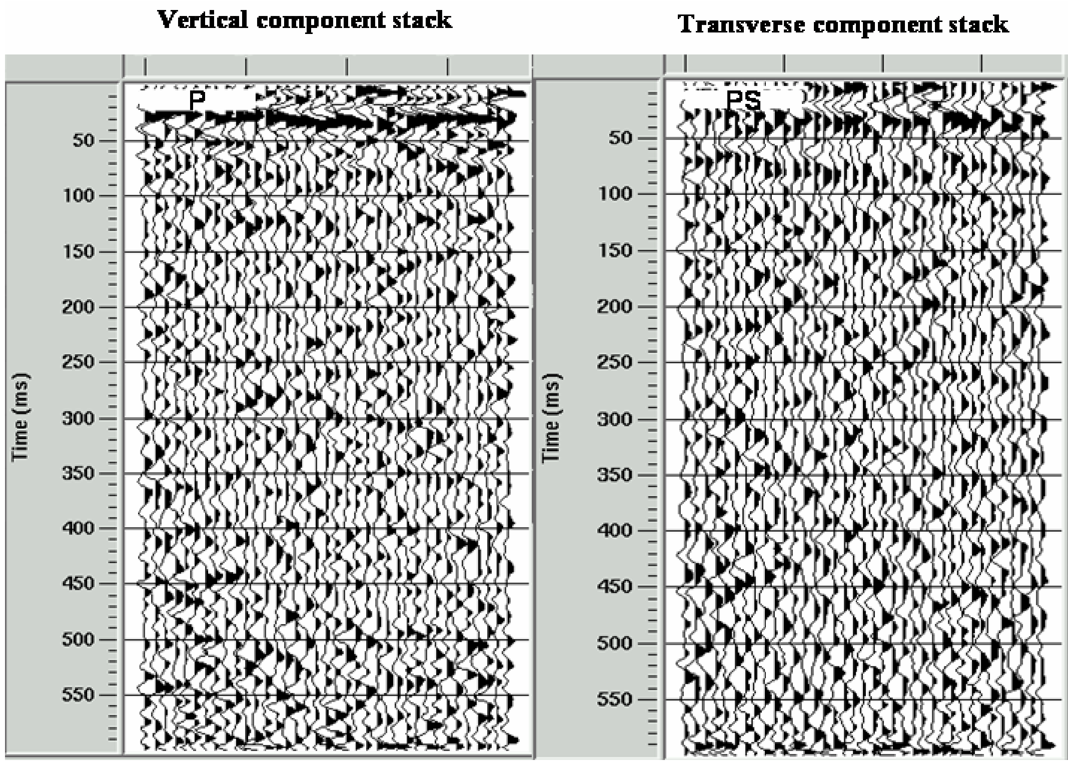

FIG. 11. Stack sections for the vertical component (left) and for the transverse component (right).

CONCLUSIONS

This dataset constituted the first experiment conducted by the CREWES Project using a land streamer system. Seismic reflections of the first 50 m of the weathering layer were observed even with the limitation of the acquisition configuration used for the Priddis area. The low frequency content of the data might suggest coupling problems or near-surface absorption of the high frequencies, as a result of the unconsolidated material characteristic of this area. However; to corroborate these theories requires further experimentation.

This first attempt demonstrates the versatility of this system and the reduction of time and labor for land seismic acquisition operations. Future improvements will involved a larger streamer with more channels and variable receiver spacings (smaller for near offsets and larger for long offsets), shots at every receiver location for every fix streamer location and a longer overlapping of the cable.

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