Quaternary buried valley characterization on the Canadian Prairies using a shear land-streamer

David G. Schieck
Echo Environmental and Geotechnical Services Ltd.
Calgary, Alberta, Canada
schieckd@echo-group.com

Robert B. Hearst*
Southern Geoscience Consultants
Toronto, Ontario, Canada
robert.hearst@sgc.com.au

SUMMARY

A 72 channel 3-component land-streamer in conjunction with an IVI Envirovibe modified with a transverse shear-pack has been constructed and tested over a known >70 m Quaternary buried valley system SE of Calgary, Alberta. Recent near surface seismic reflection developments using a land-streamer have been commercialized in the Western Canadian Prairies repurposing former exploration seismic equipment. Shear-shear reflection, P-wave reflection and multichannel analysis of surface wave (MASW) data are acquired concurrently using this cost-effective system. Processed data depicts detailed characteristics relative to cross-sections based on sparse water wells drilled to depth in this area. Real-time GPS to sub-meter accuracy, 24-bit distributed recording, advanced vibrator electronics and feedback using 3C analogue geophones all operated by a single observer while operating the Vibroseis machine is a novel approach for shallow seismic applications. This equipment and methodology demonstrate a cost-effective approach to soil investigations for near surface shear velocities, soil characterization, and detailed lithology of quaternary valleys within the Canadian Prairies to in-fill drill locations and airborne geophysical methods.

Key words: shear wave, seismic, land-streamer, Vibroseis

INTRODUCTION

Buried valleys in the Canadian Prairies are typically characterized by extensive tertiary erosional systems followed by multiple glaciations depositing glacial sediment that have infilled and buried most of the valleys today. Outcrops, water wells, exploration shot holes and petroleum wells provide most of the bases for the mapping of buried valley systems in Alberta and Saskatchewan. Most extensive valley geometries are mapped in Alberta where these data are abundant. The use of high resolution seismic reflection techniques have been used to provide critical information on glacial buried valleys in Eastern Canada and Europe. Airborne electromagnetic methods have recently been developed and used for resistivity mapping of buried valleys. For this study we have developed and demonstrated the use of a shear-shear land streamer that is cost-effective and provides continuous sub-surface imaging over a buried valley within Rockyview County, Alberta, Canada

METHOD AND RESULTS

Shear wave velocities (Vs) within consolidated rocks are typically half the corresponding compressional or P-wave velocities (Vp) or Vp/Vs ratios ~2. Within the unconsolidated overburden materials the ratio of Vp/Vs is often within the range of 5-10 which suggests that vertical resolution of shear wave data within the near surface material, even if recovered frequencies are half that of P-wave, are three to five times higher when time sections are converted to depth.

Figure 1. Survey in progress. Envirovibe with land-streamer in tow.

A 16,000 lb IVI Envirovibe was retrofitted with a 6,000 lb shear vibrator pack that can be rotated to any angle between transverse and inline orientation. ARAM lite recording system has been mounted in the cab, 72 10 Hz 3-component geophones are mounted on metal sleds spaced 1.5 m apart towed along with a Kevlar belt. Six second horizontal sweeps in the transvers orientation were conducted every 3 m to provide 36-fold P-P and S-S sections concurrently. Using these parameters, it is possible to acquire 3-4 km of data within a single day assuming eight hours of continuous pad time and limited cable moves (i.e. continuous lines). A simple data processing workflow including scaling, deconvolution, elevation and residual statics, velocity analysis and filtering yield continuous cross-sections at 0.75 m CDP. These 2D P-wave and S-wave sections were tied to known geology provided by the GSC and AER based on published public reports of the overburden within the area. Figure 1 illustrates a typical survey in progress.

Recent publication by Pugin and Yilmaz (2019) indicates that a shear wave vibrator generates not only shear waves but significant p wave energy as well. A typical shot comparison of the P-wave and transvers shear records from a single shear wave source location are depicted in Figures 2 and 3. Note the time scales of the records are adjusted ~4.5:1 to account for the difference in shear versus P-wave velocities. The shear wave records once the time scales are adjusted show the much higher frequencies and the additional detail of reflections above the bedrock not observed on the P-wave recording.

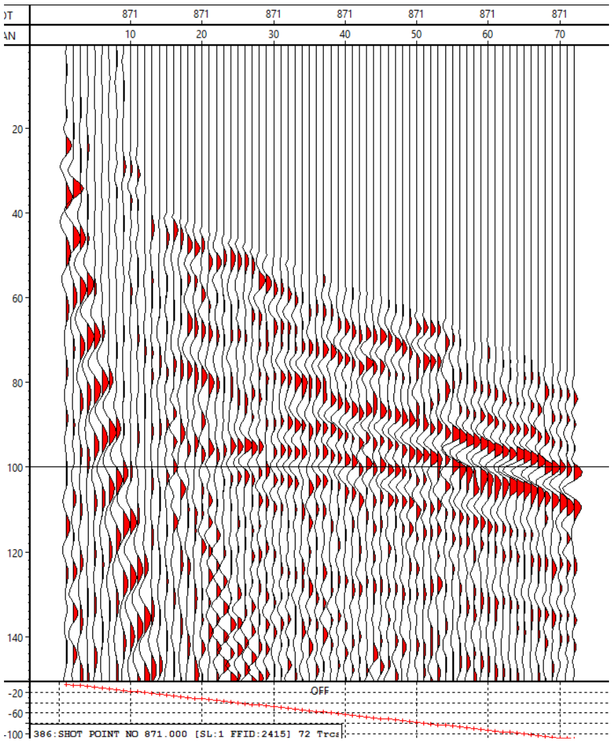

Figure 2. P-wave example data from within the 70 m deep buried channel; filtered 50/70-170/190 Hz acquired simultaneously from shear-shear source.

An impulse source was also deployed every 10th VP at the end of the tail-spread to provide a comparison with a conventional P-wave surface source and to generate ground roll signal for the multi-channel surface wave analysis (MASW).

Shear wave velocity cross-sections for the very near surface is obtained by inverting the ground roll dispersion (MASW) while the deeper velocities can be obtained from semblance analysis of the common offset stacks created as part of the reflection processing flow.

Final shear reflection section (Figure 4) depicts good correlation with nearby water wells and images layers within the buried valley such as tills and gravels.

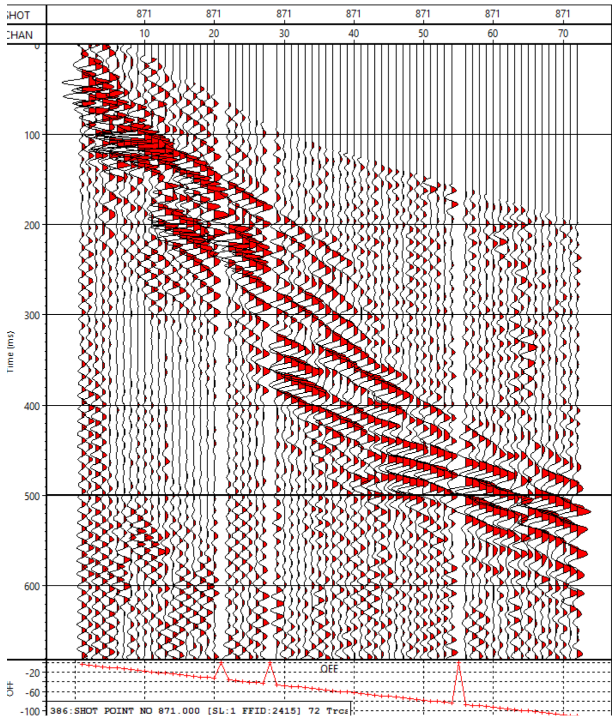

Figure 3. Traverse shear wave recording filtered 30/50-70/90 Hz acquired from shear-shear source simultaneously with P-wave.

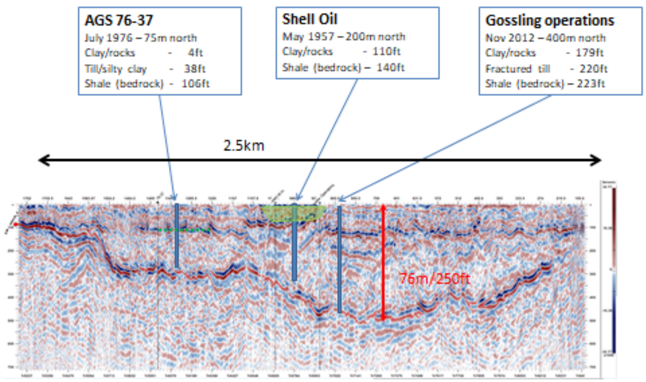

Figure 4. Shear reflection profile.

CONCLUSIONS

A shear-shear land-streamer is a cost-effective tool to continuously map detailed characteristics of Quaternary buried valley systems on the Canadian Prairies. Shear wave velocities within the near surface are 8-12 times slower than P-wave velocities enabling a larger time window to observe geologic characteristics that cause S-wave reflections within the buried valleys. Even though the frequencies of shear waves recorded are as much as half those of the P-waves this lower velocity means 4-6 times vertical resolution in depth for shear waves as demonstrated with the shot records and processed sections presented. S-waves are not affected by fluids within the soils whereas P-waves vary with velocity significantly at the water table or through fluid filled matrix. This suggests direct detection of the water table or even fluid filled channels is a possibility by comparing the concurrently recorded P and S-wave sections.

The application of this technology can allow for the rapid detection and delineation of near surface water resources and brines and the structural controls defining these reservoirs.

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