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Quaternary buried valley characterization on the Canadian Prairies using a Shear Land-streamer.

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Summary

A 72 channel 3C land-streamer in conjunction with an IVI Envirovibe modified with a transverse shear-pack has been constructed and tested over a known >70m 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 realtive 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 Vibrosies machine is a novel approach for engineering applications. This equipment and methodology demonstrates a cost-effective approach to soil investigations for near surface shear velocities, soil characterization, and detailed characterization of quaternary valleys within the Canadian Prairies to in-fill drill locations and airborne geophysical methods.

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 most 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.

Theory and/or Method

Shear wave velocities (Vs) within consolidated rocks are typically ½ the corresponding compressional or P-wave veolocities (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 ½ that of P-wave, are 3 to 5 times higher when time sections are converted to depth.

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 10Hz 3 geophones are mounted on metal sleds spaced 1.5 m apart towed along with a kevlar belt. Six (6) second horizontal sweeps in the transvers orientation were conducted every 3m to provide 36 fold P-P and S-S sections concurrently. Using these parameters it is possible to acquire 3.6km of data within a single day assuming 8 hours of contiuous pad time and limited cable moves (ie continous lines). A simple data processing workflow including scaling, decon, elevation and residual statics, velocity analysis and filtering yield continous cross-sections at 0.75m 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.

Examples

A typical shot comparison of the P-wave and transvers shear records are depicted in Figure 1. 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.

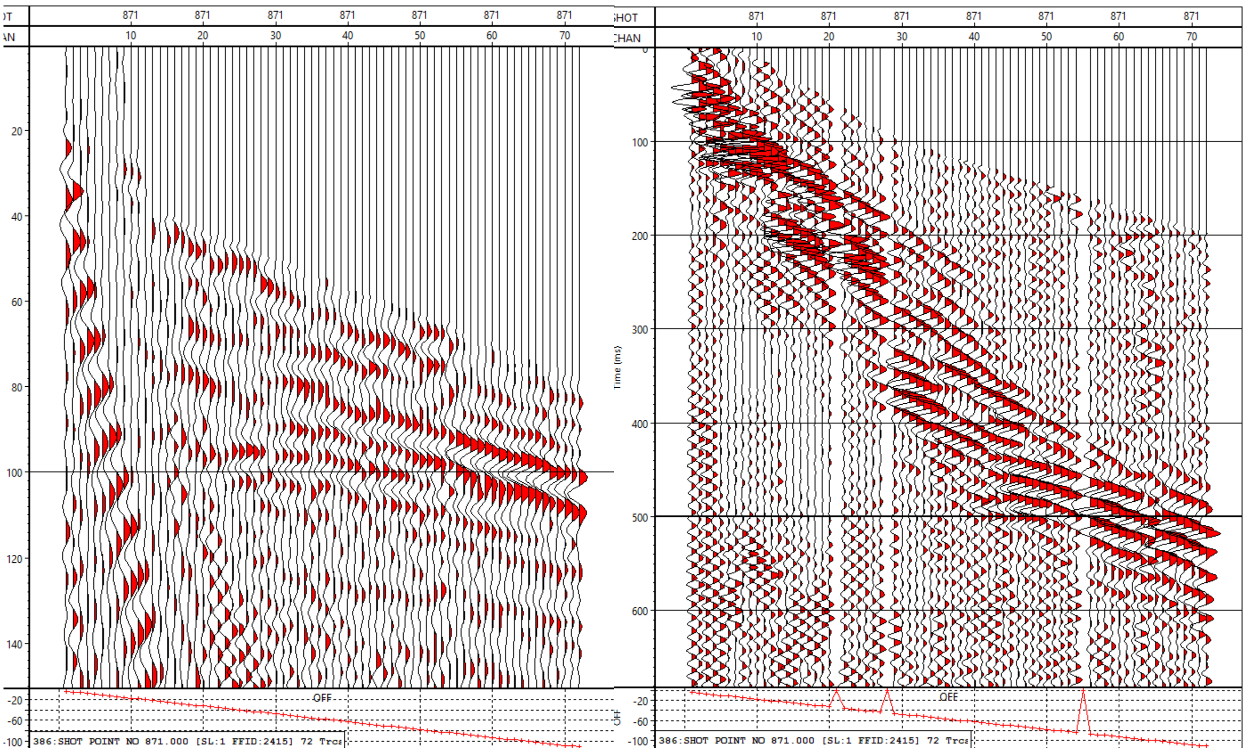

Figure 1 P-wave (left) example data, within the 70m deep buried channel, filtered 50/70-170/190Hz acquired from shear-shear source at the same time as the transverse shear recording (right) filtered 30/50-70/90Hz.

An impulse source was also deloyed every 10th VP at the end of the tailspread 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 disperion (MASW) while the deeper velocities can be obtained from semblance analysis of the common offset stacks created as part of the reflection processing flow.

Conclusions

A shear-shear landstreamer 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 5-10 times slower than P-wave vleocities enabling a larger time window to observe geologic characterisitics that casue s-wave reflections within the buried valleys. Even though the frequencies of shear waves recorded are as much as ½ those of the P-waves this lower velocity means 3-5 times vertical resolution in depth for shear waves as demonstrated with the shot records and processed sections presented. S-waves are not affected by fuilds within the soils where as 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

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References

Krawczyk, C. M., U. Polom, and T. Beneke, 2013, Shear-wave reflection seismics as a valuable tool for near-surface urban applications, The Leading Edge, 32, 256-263

Pugin, A. J.-M., Oldenborger, G.A., Cummins, D.I., Russell, A.J. and Sharpe, D.R., 2014, Architecture of buried valleys in glaciated Canadian Prairie regions based on high resolution geophysical data. Quaternary Science Reviews 86 (2014) 13-23.

Pugin, A. J.-M., K. Brewer, T. Cartwright, S. E. Pullan, D. Perret, H. Crow, and J. A. Hunter, 2013, Near surface S-wave seismic reflection profiling—new approaches and insights: First Break, 31, no. 2, 49–60.

Pugin, A. J.-M., S. E. Pullan, and J. A. Hunter, 2009, Multicomponent high-resolution seismic reflection profiling: The Leading Edge, 28, no. 10, 1248–1261.