Shallow SH-Wave Seismic for Hazard Detection and Improved Statics Analysis: Results from Saskatchewan Landstreamer Test

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Summary

Numerous studies have demonstrated the ability of Shear (SH) sources to provide seismic images of the near surface, a zone that traditional seismic is challenged to image for both practical and economic reasons. Two important aspects of the shallow near surface are therefore essentially invisible to traditional seismic: 1) Near surface hazards, such a boulders, karsts, or aquifers; and 2) The structure and velocity of the near surface, which can be important for static solutions, noise analysis and depth migration. This presentation will detail the application of such a system to the interpretation of both a near-surface hazard and its ability to effectively map the unconsolidated near surface structure and velocity.

Theory, Method, and Workflow: Acquisition and Processing

The Landstreamer system, shown below, was developed to exploit the ability of SH sources to image the near surface (Franklin, 1979; Hunter, 2022). A 17,000lb Envirovibe fitted with a transverse shear mechanism tows a 72 channel 3-component series of receiver sleds placed 1 meter apart as depicted in Figure 1.

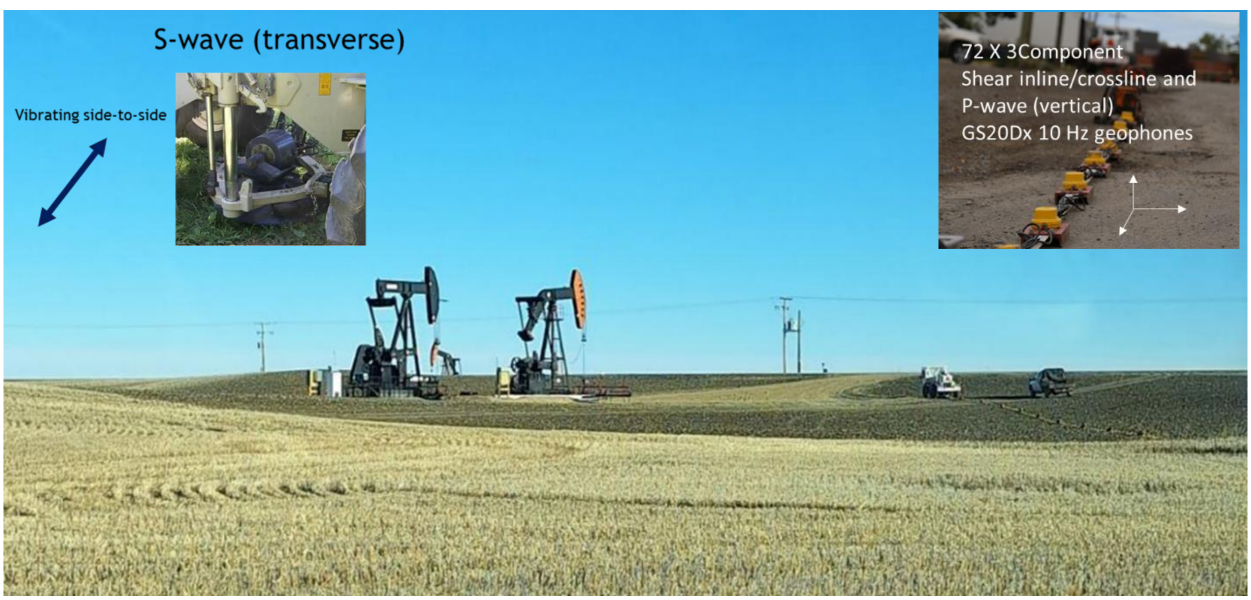

Figure 1 Oungre Line 3 land streamer in the field

SH waves are easier to distinguish from P waves and have less conversion of energy to P waves than with SV waves. The lack of response to changes in water saturation is also helpful, as shear velocity has no relationship to compressibility, only the shear strength of the medium it is travelling through. Finally, in the near surface, where Vp/Vs ratios can be in the range of 6-12, the low velocities of the SH waves suggest very high vertical resolution in depth compared to P waves. Both these data sets had shallow SH velocities in the 300 m/sec range, with frequencies of over 50 Hz, implying a wavelength of 6m and possible resolution of around 2m or less.

In conjunction with a recent conventional 3D, Vermilion Energy had the opportunity to use this system to both map a shallow hazard and test the system's ability to map shallow statics layers by comparing the results with a state-of-the art tomographic statics solution derived by Earth Signal Processing.

Data was acquired in two areas in SE is Saskatchewan: Oungre, where a previously drilled well encountered a strong water flow in the near surface that forced Vermilion to move the location before recommencing the drilling operations, and Pinto, where Vermilion was simultaneously acquiring a conventional 3D.

Shot records, shown in Figure 2, show the SH data at Oungre in raw form and after the first stage of processing, as well as the implied velocities.

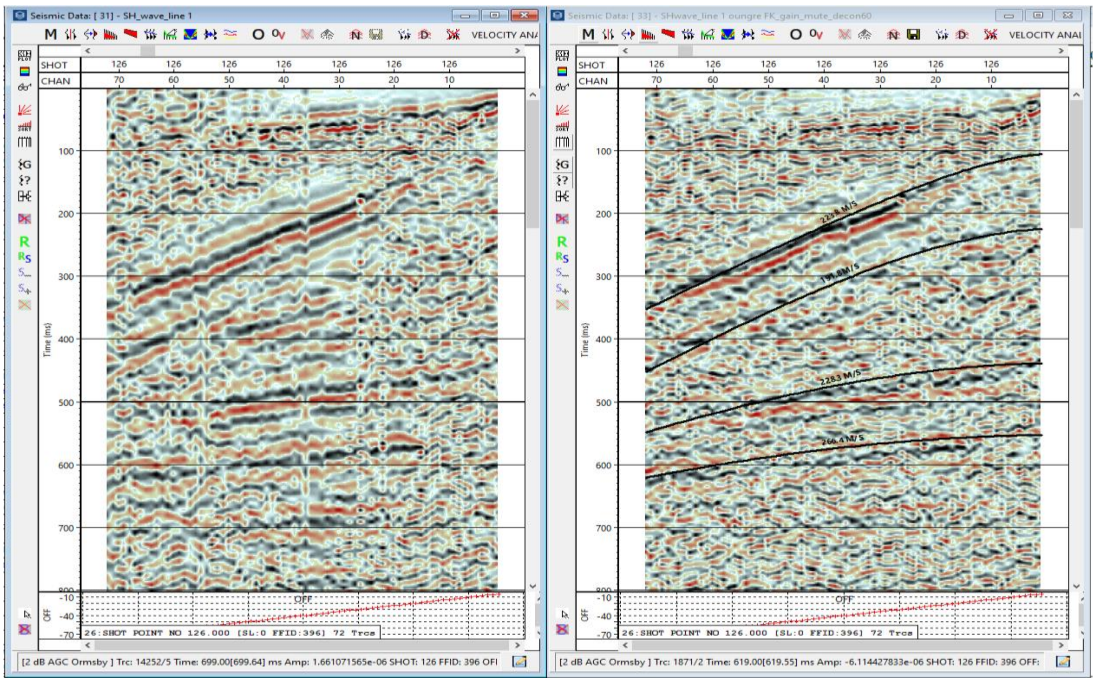

Figure 2 shot point 126 Oungre line 1 (left) left raw data and (right) after deconvolution and scaling with horizon velocities.

The conventional 3D at Pinto was processed with particularly good results by Earth Signal Processing. The conventional seismic static solution was obtained by an application of the method of Taner (Taner, 1998).

Observations: Data Interpretation and Analysis

Figure 3 illustrates a final migrated product in the Oungre area, scaled to depth. The SH velocities generated in velocity analysis, approximately 220 m/s to 550 m/s, are consistent with previously published studies of the unconsolidated surface sediments (Morrison, 2017; Hunter, 2022). This indicates that several reflectors can be identified in the 0-150m zone in both the Oungre and Pinto areas.

Figure 4 shows the interpretation and time mapping of a possible glacial channel that could be the source of the water flow.

Figure 5 illustrates a comparison of the tomographic statics solution with the corresponding SH line at Pinto. Note that the excellent tomographic solution appears to be a smoothed version of the result obtained by the SH line, confirming the idea that shallow SH acquisition can provide a method for higher resolution statics solutions.

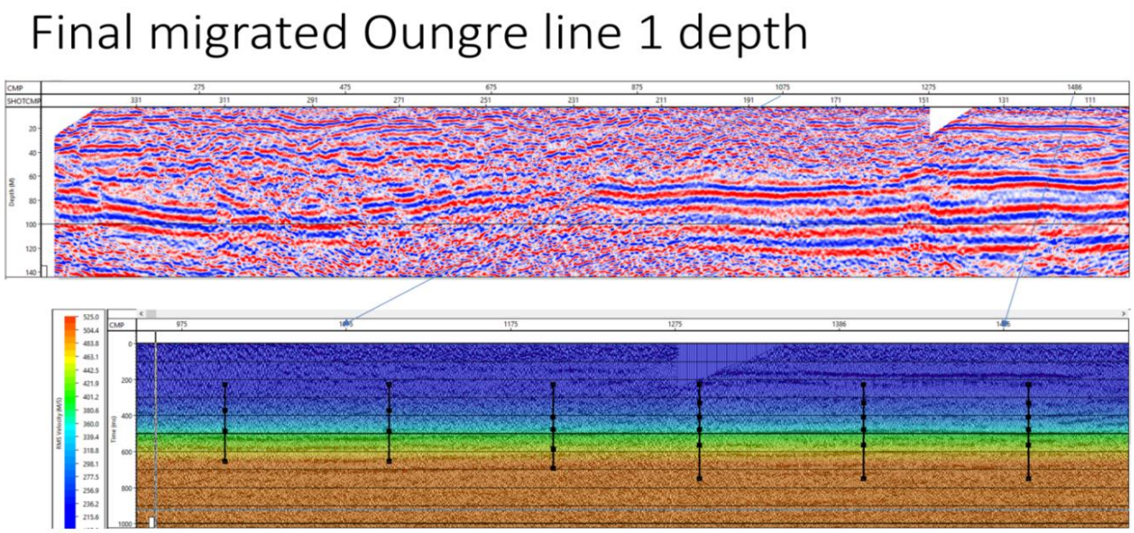

Figure 3 Oungre line 1 final processed data in depth (top) north section of data with velocity overlain in time (bottom)

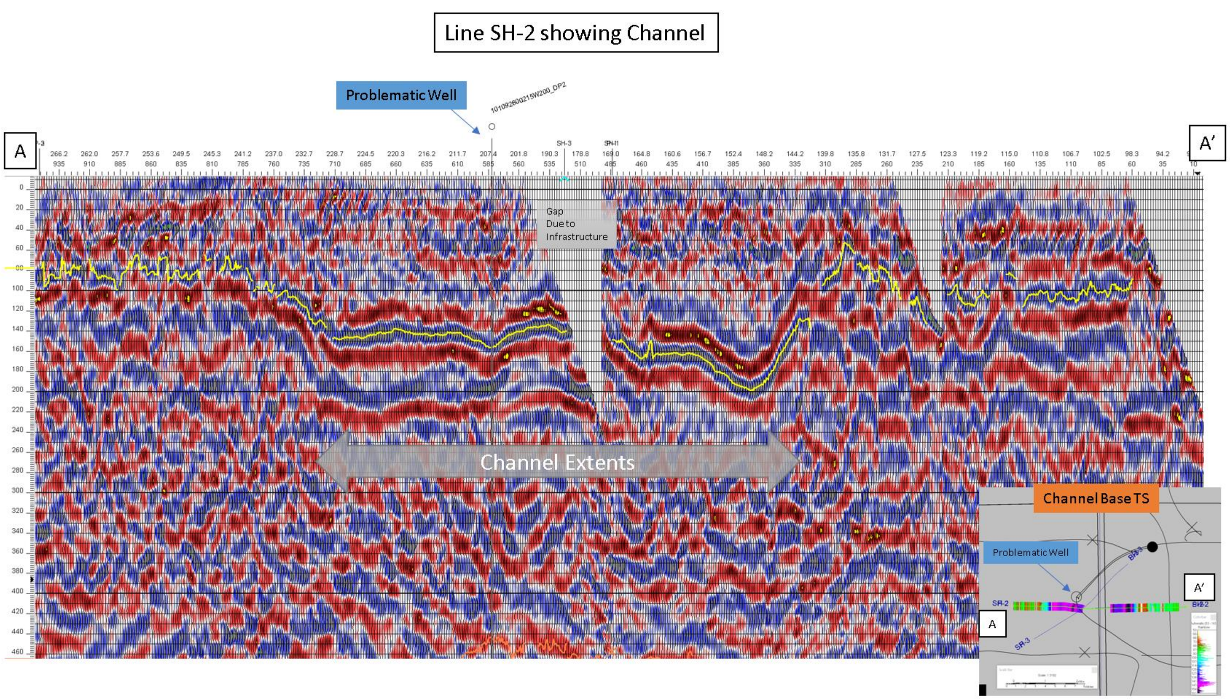

Figure 4 Oungre line 2 showing Base Channel and in yellow and map in time.

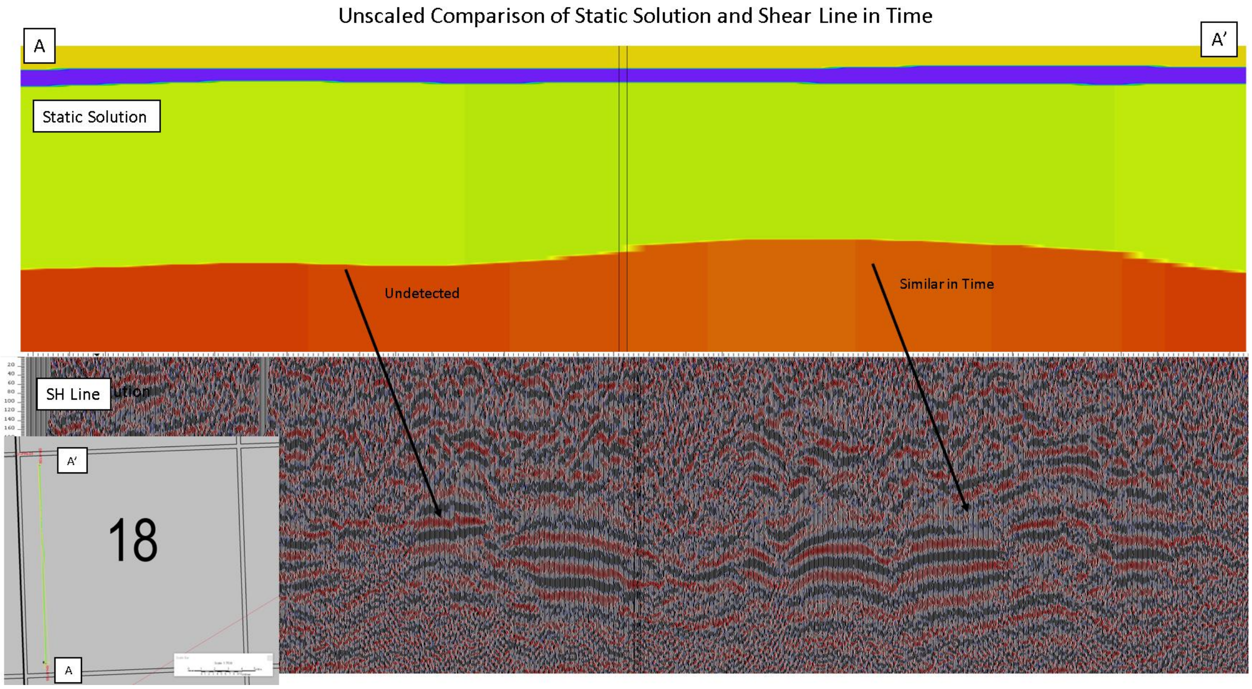

Figure 5 Pinto Showing correlations and differences between static solution on 3D and SH line in time

Conclusions

Shear data (SH) acquired using the Landstreamer system demonstrates how these waves can effectively image the shallow structure of two areas in southeast Saskatchewan. The high resolution inherent in the nature of the waves imply the ability to map important aspects of the shallow zone, including identification of shallow hazards and mapping of horizons to improve statics solutions. Although not seen on these lines, such improved imaging may also pinpoint the origin of shallow noise generating features such as shallow diffractors. There are also areas of the world where shallow structural features imaged by the SH could aid in the geologic interpretation of deeper structures.

Possible applications for this system include acquiring a set of SH lines to identify areas where shallow features cause difficulties for conventional seismic, improving the static solutions for conventional data, mapping shallow hazards, and creating velocity models for depth migration and FWI. Considerable additional investigation is required to understand how to extend and relate the results of SH data to conventional seismic.

Acknowledgments

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