A new S-wave seismic source

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ABSTRACT

Over the past year, CREWES designed and built a new shear-wave seismic source for multicomponent near-surface seismic studies. At the heart of the source is a 100 kg hammer that is accelerated by compressed nitrogen over a pressure range from 500 to 2000 psi. The source mast can be operated in a vertical mode for generating P-waves and it can rotate ± 45 degrees transverse to the longitudinal axis of the trailer, and will generate down-going P-wave and S-waves simultaneously. Pure-mode down-going S-waves are generated by subtracting records taken with the mast rotated in the positive and negative tilt modes. Initial test data generated by this source show that good quality P-wave and S-wave data can be obtained, with source-receiver offsets of several hundred meters. A vertical seismic profile experiment shows high-amplitude energy to the bottom of the well at 149 m depth.

INTRODUCTION

The source component of the system is a model A200 accelerated weight drop device manufactured by United Service Alliance Inc from Texas City, Texas. This source is mounted on a 2000 kg tandem axle trailer. The photograph in Figure 1 shows the source in operational mode in the S-wave configuration.

FIG. 1. The new CREWES S-wave seismic source in S-wave mode.

A cylinder of compressed nitrogen gas is mounted inboard on the trailer, as seen in Figure 1. The source mast can be rotated to ± 45 degrees for positive and negative S-wave polarizations.

THE S-WAVE SOURCE

The active component of the source, as delivered from the manufacturer, is shown in Figure 2.

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FIG. 2. The USAInc compressed nitrogen accelerated weight-drop source as delivered.

A pivot point can be seen just above the clawed foot in Figure 2, which enables the mast to be rotated for the generation of S-waves. The clawed foot is made of aluminum and transmits the energy into the ground.

The trailer, source configuration and all of the operational components were designed by CREWES and built in Calgary by CREWES and a fabricating shop. A pivot system was designed to enable the source to generate both P-wave and S-waves. An innovative aspect of the design are extendable legs that stabilize the trailer during source operation to minimize rotation of the trailer when the source fires. The legs are shown in the deployed position in Figure 1. A triggering system was designed to enable vertical stacks to be obtained at each source location. The source is set up to be recorded by either the 120-channel Geode system or the 600-channel ARIES recording system owned by the University of Calgary, both operated by CREWES staff.

The published performance curve for the A200 is shown in Figure 3. At maximum pressure of 2000 psi in the nitrogen spring, the source expends just over 3000 joules of energy on impact.

FIG. 3. Performance curve for the A200 source

The source foot rotates with the mast across the trailer between the axles of the trailer At the source location, a hydraulic system lowers the foot onto the ground with the hold-down mass of the trailer (2000 kg) exerted upon it. This provides excellent coupling between the source hammer and the ground. Figure 4 shows the foot in position, ready for a shot. For conventional P-wave operation, the source can be operated with the mast in the vertical position, with the hammer impacting directly downwards on the foot.

FIG. 4. S-wave source hammer and foot in contact with the ground.

MOTIVATION

The S-wave source will be used for near-surface studies of P and S waves to better define Vp/Vs in shallow layers, to understand the relationship between P-wave and S-wave statics and to measure S-wave attenuation in the near-surface. We also envisage using the source for pure S-wave surveys for shallow targets (depths less than 500 m). For multicomponent seismic data, rapid to extreme lateral variations in S-wave weathering static corrections are probably the most challenging aspect of data processing and ultimately, inversion robustness and image quality. If the travel-times of shear head-waves are pickable, then standard static methods (inversion or tomography) can be employed to calculate the receiver static corrections.

As an example of data gathered with an SH-source (not our new source), Figure 6 shows an example of first arrival traveltimes picked on a vertical component gather with a vertical source (left) and a transverse component gather with and SH source (right), illustrating the significant difference in near-surface P-wave and S-wave velocity structure (Zuleta and Lawton, 2012). These data are from a multicomponent survey in northeast British Columbia recorded with P-wave and S-wave vibrators. Figure 7 shows the resultant P-wave and S-wave receiver statics, showing very significant differences.

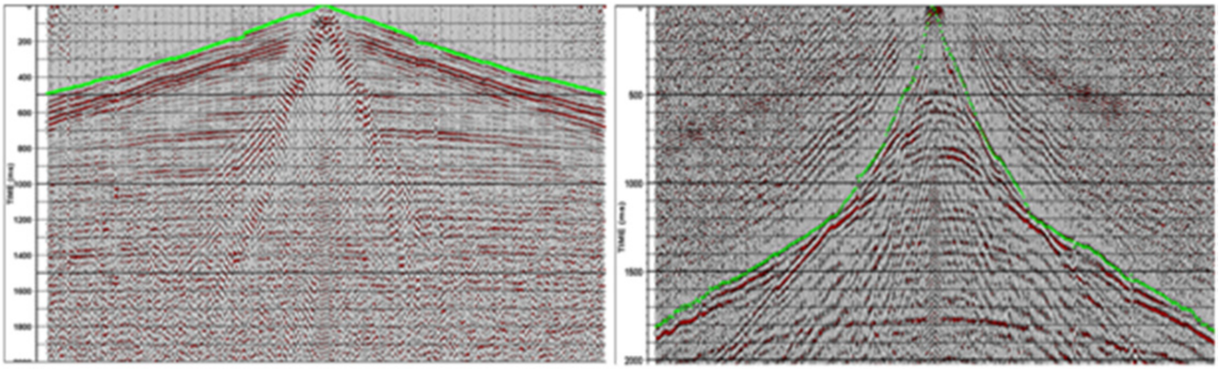

FIG. 6. Vertical component data from a P-wave source (left) and transverse component with an SH-source (right). From Zuleta and Lawton, 2012).

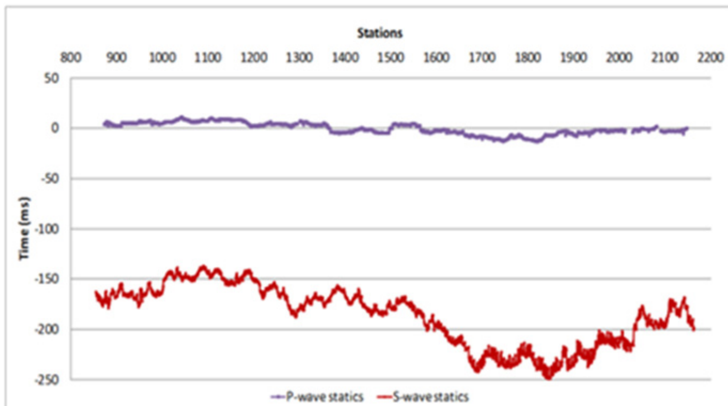

FIG. 7. P-wave and S-wave statics from the same line as the shot gathers shown in Figure 6. From Zuleta and Lawton (2012).

Often, the S-wave receiver statics can be an order of magnitude larger than the P-wave statics (e.g. Figure 7) and there may be no relationship in trend between them. If PS statics are data-limiting in the survey area, then recording an SH refraction survey along receiver lines could be an innovation to improve PS data quality. Depending on line access, these can be done quite quickly and SH first arrivals can be used to calculate receiver S-wave static corrections. However, there is no guarantee that S-wave statics corrections will be azimuthally isotropic. In order to advance this research, we plan to investigate azimuthal dependency of S-wave static corrections using this new S-wave seismic source.

PERFORMANCE

Since the new S-wave source development was completed only in September, there have been only a few field trials to evaluate its performance and reliability. One aspect of S-wave surveys that we discovered was the differential source static between each of the S-wave source polarizations at the shot-point. This arises since the pivot point is part-way up the mast, so that the foot itself will move approximately 1.2 m from one side of the trailer to the other when the mast is moved from the +45 degree tilt to the -45 degree tilt. For vertically stacked shots, we also noticed small differences in the first arrival times as the foot compacted the ground directly below it. A cross-correlation method was implemented to compensate for these small source statics (observed up to 3 ms).

To date, we have been very pleased with the source reliability, and surface seismic and vertical seismic profile (VSP) examples are displayed and discussed in other research papers in this volume (Bertram, M. et al., 2013; Asuaje et al., 2013). As an example, Figure 8 shows radial and vertical component data from a source-point near the VSP well. The vertical component data shows relatively constant P-wave velocity with depth (around 3000 m/s) whereas the S-wave data shows 2 layers with velocities of 600 m/s and 1500 m/s respectively. Also, a P-S down-going mode converted wave is visible on the radial components as well as S-wave reflections.

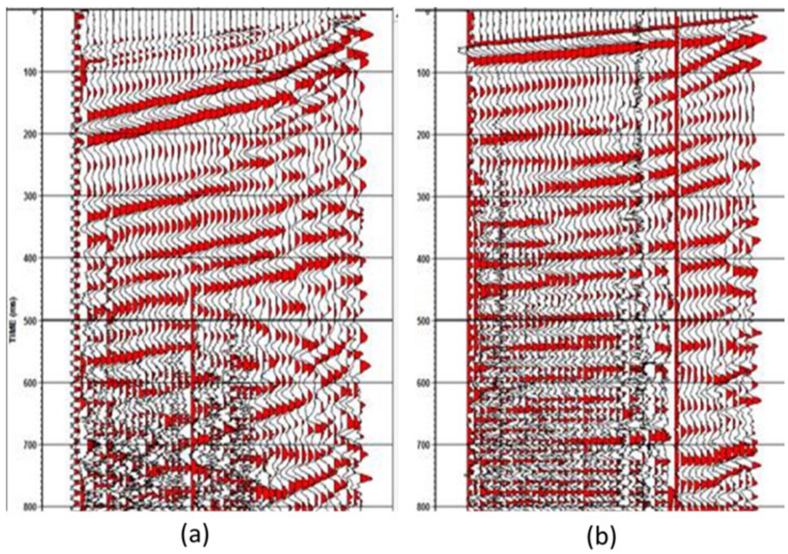

FIG. 8. (a) radial component and (b) vertical component VSP data with new source.

CONCLUSIONS

A new S-wave accelerated weight drop source has been successfully built and tested. It shows great promise for providing useful P- and S- wave velocity information in the upper several hundred meters of the subsurface.

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