Analysis of multicomponent seismic data recorded with a new hydraulic thumper source

Rafael Asuaje, Don Lawton, Malcolm Bertram, Kevin Bertram, Kevin Hall, Eric Gallant
rjasuaje@ucalgary.ca

Abstract

This research examines the performance of the new multicomponent weight drop source built by CREWES. The source was tested on the University of Calgary campus to generate P-waves and S-waves, and to provide a detailed velocity structure of the near-surface. The source generates SH-waves by orienting the source mast ±45 degrees from the vertical and subtracting records generated with opposite source polarities. This cancels P-waves and constructively adds SH waves.

The data collected show that the uppermost layer of the shallow subsurface has a P-wave velocity of 840 m/s and a SH-velocity of 215 m/s, yielding Vp/Vs of 3.90.

Survey Set Up

The survey consisted of 3 different shot locations. The beginning of the line was indicated with the flag number 101, also known as the zero mark. The thumper performed 3 sets of 10 hits for each location. After each set of hits, the recorder automatically generated a stack file for the previous 10 hits. On the first set the thumper was perpendicular with respect to the surface. This helped with the creation of the P-waves. For the second set the thumper was set to 45 degrees and was oriented in a transversal orientation with respect to the line. The third set was similar to the second set arrangement: the angle was also 45 degrees and the direction was also transversely with respect to the line, but in the opposite direction. Since the set for shots 2 and 3 were exactly opposite to each other, the plus and minus technique could be used.

Shot Gathers for P-Waves

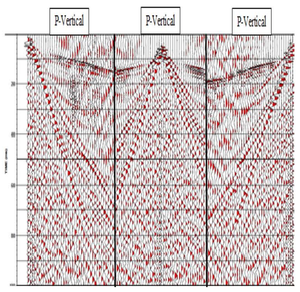

Fig 1 .Shot Gathers at all locations

Figure 1 shows vertical-component data at the 3 shot locations. Only the P-wave components are present in this figure. Despite the low signal to noise ratio in these gathers, an interpretation for the velocities was still possible.

Shot Gathers for S-Waves

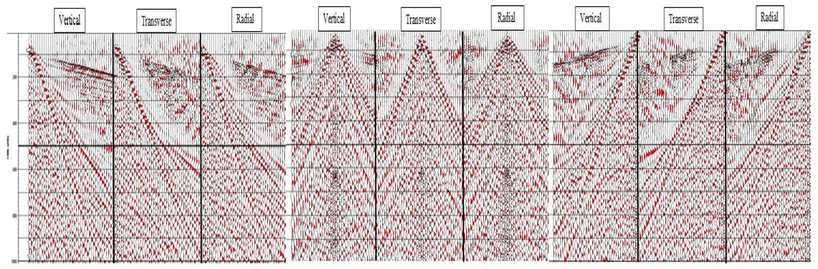

Fig 2.Shot Gathers for 101, 121, 140 locations

Figure 2 shows data taken at all shot locations. Due to some source static inconsistencies during the collection of the data, only the files that showed the best signal to noise ratios were considered for the analysis. As noted, the seismic gathers are divided into 3 areas. Three component geophones provide the data in the following order, the P-wave component in the first section and the S-wave data is shown in the transverse and the radial component in sections 2 and 3 respectively. The velocities were estimated by calculating the slopes of the refraction events. For each component there are only 40 traces.

Velocity Model for P and S-Waves

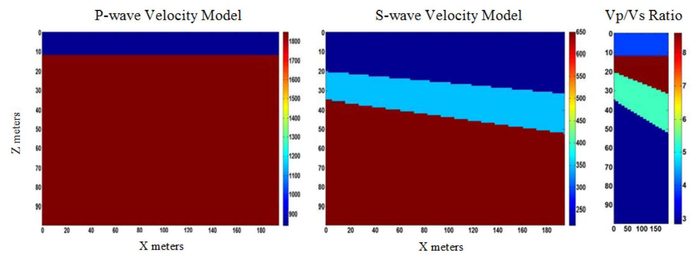

Fig 6 . Velocity models and Vp/Vs Ratio

Following the refraction velocity analysis, the thicknesses of the near-surface layers was determined from the intercept times or cross-over distances. Two layers were determined from the P-wave data and 3 from the S-wave data. The velocity and depth structure and Vp/Vs values were determined.
The average velocities analyzed at the 3 shot locations were input into this model. The averages velocities for the P velocity model were 840m/s for layer 1 and 1850m/s for the second layer. As for the S model, average velocities were 215, 350 and 650m/s for layers 1, 2 and 3 respectively. Vp/Vs appear consistent with the numbers we were expecting: higher around the shallow surfaces and decreasing with depth.

Plus and Minus Technique

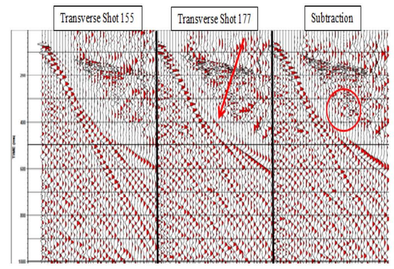

Fig 3 . Shot Gathers for data 155 and 177 at location 101.

Figure 3 shows the transverse components of data for shots at 155 and 177. The section on the right shows the subtraction of these two records. The events of the refractor are better defined after this subtraction.

In Figure 4, the data resolution is good and the subtraction process again enhances the S-wave energy. It is interesting to note that there is almost no leakage of P-wave energy onto the horizontal components.

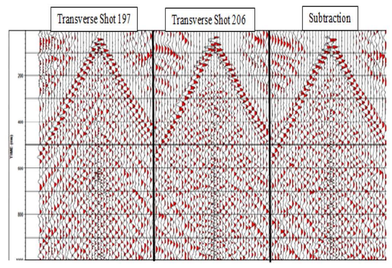

Fig 4 . Shot Gathers for data 197 and 206 at location 121.

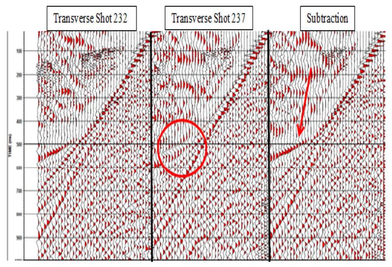

Fig 5 . Shot Gathers for data 196 and 177 at location 140.

Figure 5 shows some of the improvements from using the plus and minus method. The refractor becomes more visible at the 140 location .

Discussion

The performance of this new source thumper provided very clear gathers despite the noise encountered. The development of an accurately controllable weight drop source with very high impact energy has led to recording seismic data which is of better quality than traditional dynamite, for example, and considerably cheaper. The flexibility of the source means that source locations and source intensity can be changed dynamically, leading to better custom seismic solutions to local problems.

Acknowledgement

The authors would like to thank CREWES sponsors for providing the financial support for this research.