Tests of sand-bags to couple geophones to the earth's surface

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ABSTRACT

Sandbags were used as a means of coupling geophones to the ground as part of the Priddis testing in July of 2012. The main object was to see if better shear wave data could be obtained. Twenty older geophones were deployed at ten metre intervals along a short portion of the main test line, and their response was recorded from all the source tests that were done. A source line of dynamite charges was used to match the two data sets, but very little shear wave data could be found. The investigation was continued by comparing ground-roll data, where the sand-bag data seemed to be more consistent than the comparable spike-phone data. From this it was concluded that further tests should be done, with a larger number of geophones in an area of high data quality.

INTRODUCTION

The present standard of coupling earth motion to recorded displacement measurements is through a case with a single spike driven vertically into the earth. This method has been used and proven for pressure waves over many years. Shear wave recording has usually been done with the same technique, but its effectiveness for shear waves has not had much analysis done.

In particular, microseismic recording at the earth's surface has never given shear-wave records comparable to those acquired from boreholes (for example, see Eisner et al 2009). Part of the reason for this is that the borehole geophones are usually much closer to the energy source, but some of the reason may be the firm anchoring of the geophones to the borehole wall. This has encouraged interested people to record shear waves with permanent deeply buried geophones, or even in especially drilled shallow wells.

Before going to permanently buried geophones, testing should be done on means of temporary 'burial' at the earth's surface. The 'burial' would be effective at locking the earth and geophone together, and might even compress the uppermost soil levels so that they could conduct sound more effectively.

Spikes were left off the test geophones in case they were not able to conform to the distortion of the sheared earth. This could happen if the effective shear wave length became extremely short (compared to the spike length) and this would be caused by extremely low shear velocities at the surface.

METHOD

The 20 geophones used for the experiment were 3-component 20DM's from Oyo-Geospace. They were placed directly on the ground with minimal preparation. After the geophones were approximately leveled and oriented, a 20 pound sandbag was gently placed on top of each. They were then connected to the recording truck running a rented Aries SPML075 system, and were active for all the test sources employed.

PROCESSING

The records from some of the dynamite and minivibe sourced lines were selected from SPML075 disc files, then the flat phone traces were selected from the records. The matching records were selected from the SPML073 files, which had 3-component data recorded from a complete set of spiked geophones. The matching traces were then selected from these records. The traces were played out with several fixed gains, which in the dynamite cases were dependent on the charge sizes.

It was found that the sand-bag phones had at least 3 phones wired with the in-line and cross-line elements swapped, and at least 7 traces were reversed. These detected errors were corrected, as shown with the dynamite data records in Figures 1 and 2.

COMPARISON 1

The sand-bag data from several dynamite shots were plotted and transferred to power-point slides, along with the corresponding down-sampled records from the spiked geophones. The shift between slides could then be used to make detailed comparisons.

It was found that the higher amplitude events corresponded very closely, with character changes in nearly identical places. A general observation was that the spike-phones had a little less random noise, but also displayed slightly lower frequencies.

The only obvious difference was that the spiked in-line geophones sometimes had an extra event after the main events, which might have been leaked from the cross line elements. An example of this may be seen by comparing Figures 2 and 3. This may indicate that there may be motion of the case that transfers energy between the elements, and is one of the arguments in favour of the sand-bag data.

No reflected events on these records could be identified as shear waves. There was also little ground-roll energy, perhaps because the charges were too deep.

No events on the minivibe correlated records could be identified as shear waves or ground-roll either. Vibrator data can be expected to produce lots of ground-roll, but the correlation process is designed to suppress these events.

COMPARISON 2

It was decided to investigate ground-roll on the uncorrelated vibroseis records, and look for the combination of vertical and horizontal motion characteristics of ground-roll. Finding this type of motion would indicate that the horizontal in-line recording was working as expected, and therefore could also record shear waves if they were present.

The operator chosen to detect ground roll is given by

$$GR = U_z \frac{\partial U_x}{\partial t} - U_x \frac{\partial U_z}{\partial t} \qquad 1$$

which is a crude indication of ground-roll if the frequency content is not too high. It gives a positive response for one direction of rotation (perhaps black), and a negative response for the opposite rotation direction (white). Direct arrivals and reflections should be zero (grey). Which rotation is positive or negative depends on knowing the geophones shear wave polarity, and geophone polarities are seldom known even for the vertical component. All that can be expected is that the rotations be opposite on opposite sides of the shot, and then it can be assumed that each rotation is in the theoretical retrograde direction.

The ground-roll operator was applied to the uncorrelated minivibe data recorded on all the spike geophones overlapping the sandbag test area, and the plot is shown in Figure 4. There is a preponderance of black on the right side and white on the left, in positions where the lower frequency parts of the sweep would move out.

The same plot is shown in Figure 5, but with only those traces that correspond directly to the sandbag test traces. The same tendency is there, but it is not very obvious.

The ground-roll operator was applied directly to the sandbag traces and the result is shown in Figure 6. This display gives a wider and more convincing case for ground-roll energy in the zones where it might be expected, and is therefore also a case that more accurate shear waves were detected.

CONCLUSIONS

The experiment shown here definitely makes the case that the acquisition of shear wave data on spiked geophones can sometimes be improved upon. The arguments are indirect and don't show anything 'wrong', but they apply to groups of traces, so they are not random aberations.

A new experiment should be run with many more, better prepared geophones, and in an area where high quality data can be acquired. Hopefully, the area will then also provide some high quality shear wave reflections. It would also be prudent to experiment with some higher weight or multiple sandbags.

ACKNOWLEDGEMENTS

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REFERENCES

Eisner, L., Duncan, P. M., Heigl, W. M., Keller, W. R., 2009, Uncertainties in passive seismic monitoring: The Leading Edge, 28, 648-655.

FIGURES

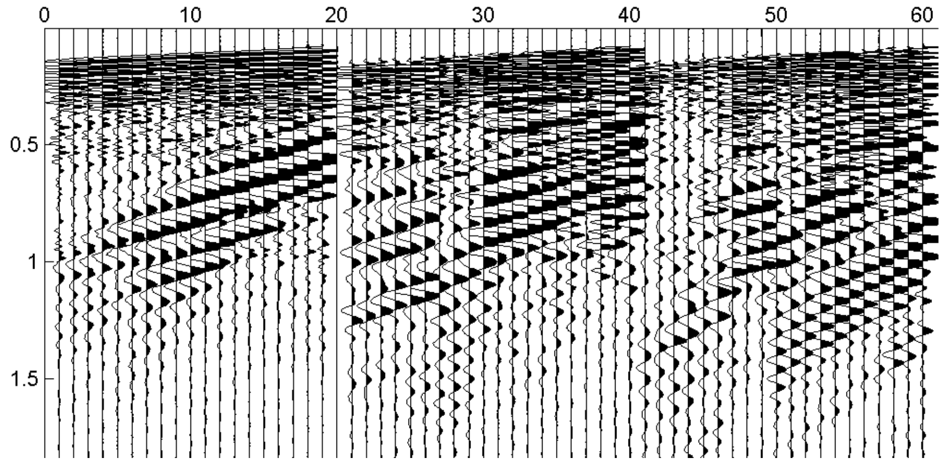

FIG 1: A record as recorded on the sand-bag phones. This source is from shot 107 on line10. From left to right, the three records show vertical, in-line, and cross line motion.

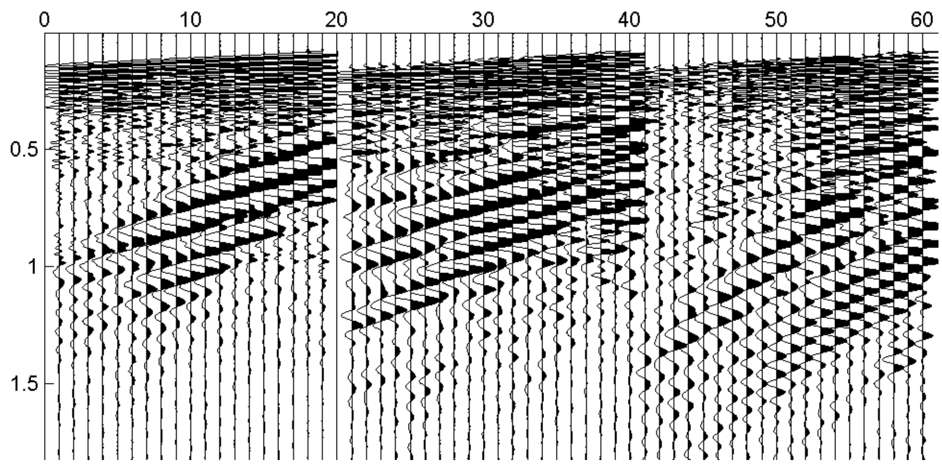

FIG 2: The record with several traces swapped between the in-line and cross-line records.

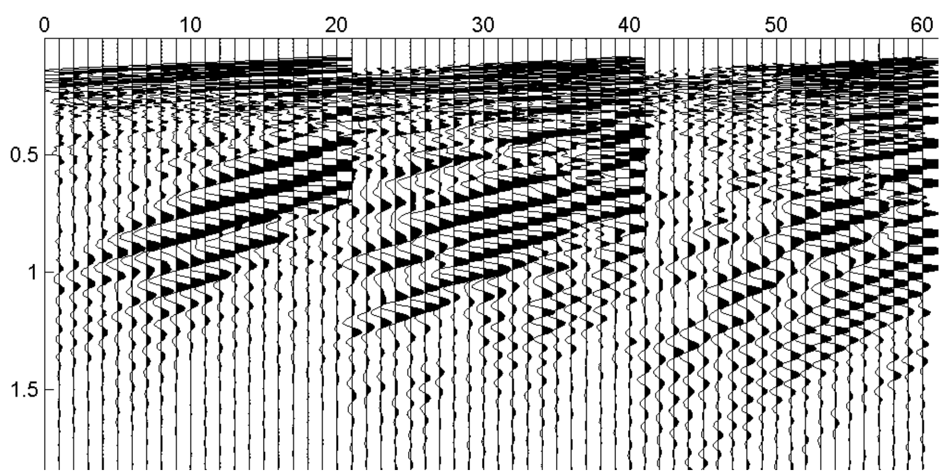

FIG 3: The corresponding record on the SM7 phones. Some energy from the third bank (cross-line) appears to have leaked to the second (in-line) bank.

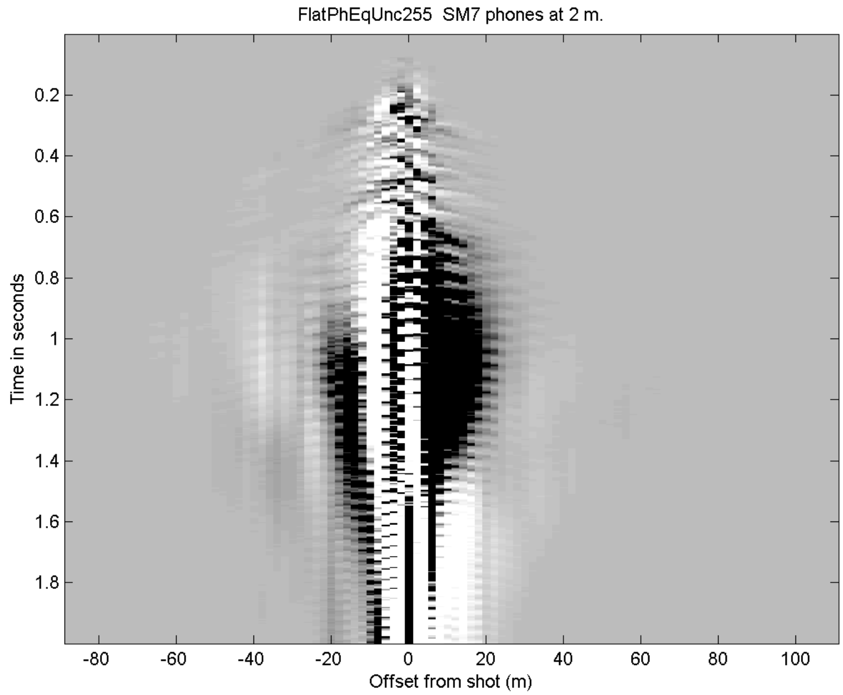

FIG 4: A ground-roll analysis plot using the SM7 geophones at 2 m. spacing, but located where the 20DM sand–bag phones were planted. The plot shows predominantly retrograde ground motion on both sides of the shot, consistent with theory.

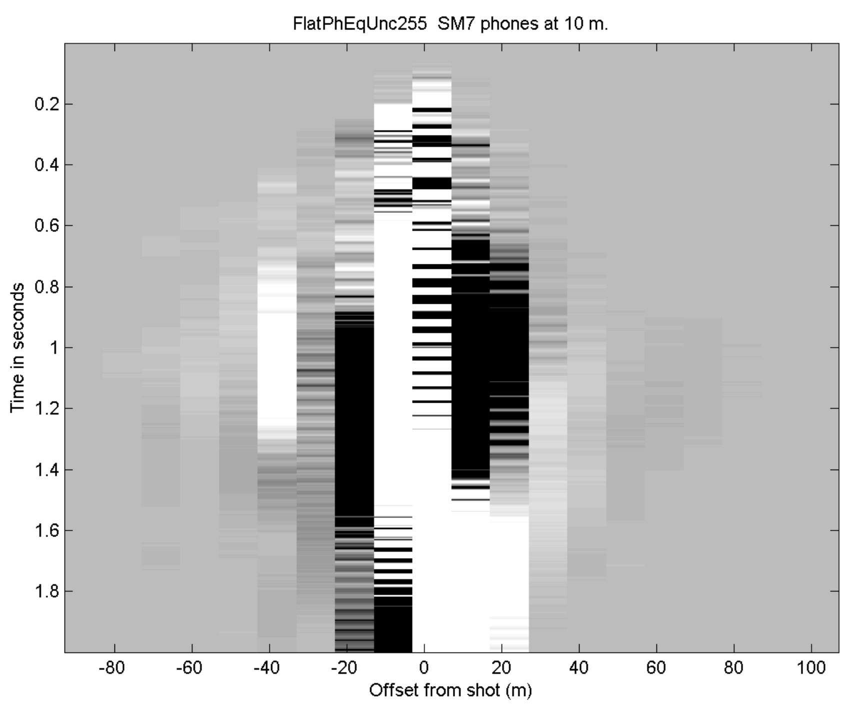

FIG 5: A ground-roll analysis plot similar to Figure 4, but only using input traces spaced at 10 metres to compare with the sand-bag geophone string. The near trace is not valid, but there is only the slightest hint of retrograde ground motion among the others.

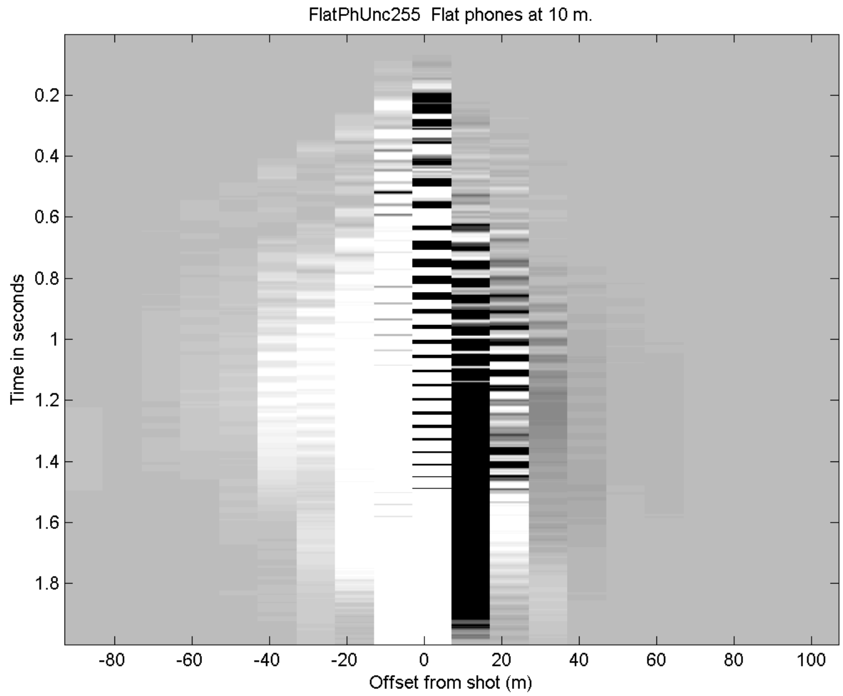

FIG 6:A ground-roll analysis plot on the 20DM sand-bag line. There is a much stronger indication of retrograde motion compared with Figure 5.