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Hurrah for Hussah! Analysis of stacked data from a low-frequency seismic data acquisition experiment at Hussar, Alberta

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Summary

The data presented in this paper were acquired at an experimental low-frequency seismic shoot at Hussar, Alberta in September, 2011. Four sources were used: a 364 vibroseis with a custom sweep that spent more time at the low frequencies than the high ("low dwell"), a 364 vibroseis with a linear sweep, a Failing vibroseis with a custom low dwell sweep, and dynamite. Each source was recorded by three receiver types: 10 Hz 3C geophones, 4.5 Hz 1C geophones and Vectorseis accelerometers.

We processed the twelve data sets with and without radial filters and Gabor deconvolution. We stacked and analysed the data. The dominant frequency of the unfiltered stacks is around 10 Hz with a steep drop off to 30-40 Hz, after which the spectra are flatter. The dynamite data show the greatest variation in power over the signal band and the least power at high frequencies.

Bandpass filtering the otherwise unfiltered data to retain only frequencies of 1-10 Hz shows the low-end spectra of data recorded by the 10 Hz and 4.5 Hz geophones to be similar for each corresponding source while the Vectorseis spectra are different. In every case there is an increase in power from 1 Hz towards 10 Hz, except for the Vectorseis dynamite data. This increase is steep up to 4 Hz and fairly linear from 4 Hz to 10 Hz for the 10 Hz and 4.5 Hz geophones. The spectra are much flatter for the Vectorseis data and the Vectorseis dynamite data is different from all the others, having a peak at 6 Hz (Figure 1).

Phase-coherence plots of stacked, unfiltered data show a dominant signal band that extends from about 10 Hz to 40 Hz for all sources and receivers, and up to near 60 Hz for the dynamite data. The dynamite stacks have more phase coherence at the high end than any of the vibroseis stacks. At low frequencies (Figure 2) there is strong phase coherence down to at least 7.5 Hz and possibly to 5 Hz in all the data.

After radial filtering to remove low frequency noise at selected velocities, the coherency analysis shows coherent events down to about 3 Hz on the 4.5 Hz geophone data (Figure 3). After additional Gabor deconvolution the very low frequency events are attenuated but there are still slight indications of coherent events below 3 Hz.

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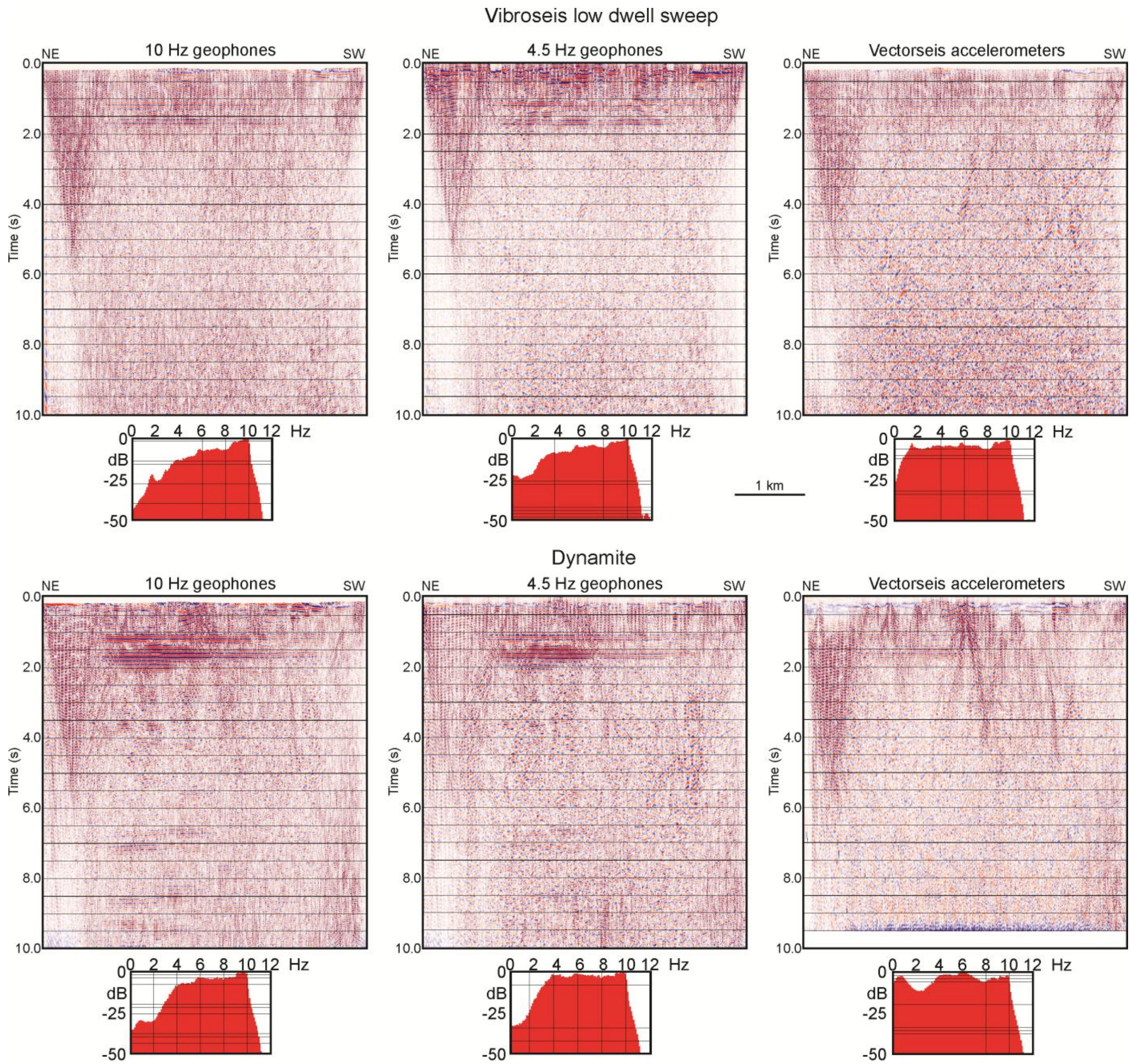

Figure 1: Bandpass filtered 0-1-10-10 Hz stacked data and spectra for two of the sources (364 Vibroseis low dwell sweep and dynamite) recorded by the three receivers. The low-end spectra of data recorded by the 10 Hz and 4.5 Hz geophones are similar while the Vectorseis spectra are different, being much flatter. In each case there is an increase in power from 1 Hz towards 10 Hz, except for the Vectorseis dynamite data. This increase is steep up to 4 Hz and fairly linear from 4 Hz to 10 Hz for the 10 Hz and 4.5 Hz geophones.

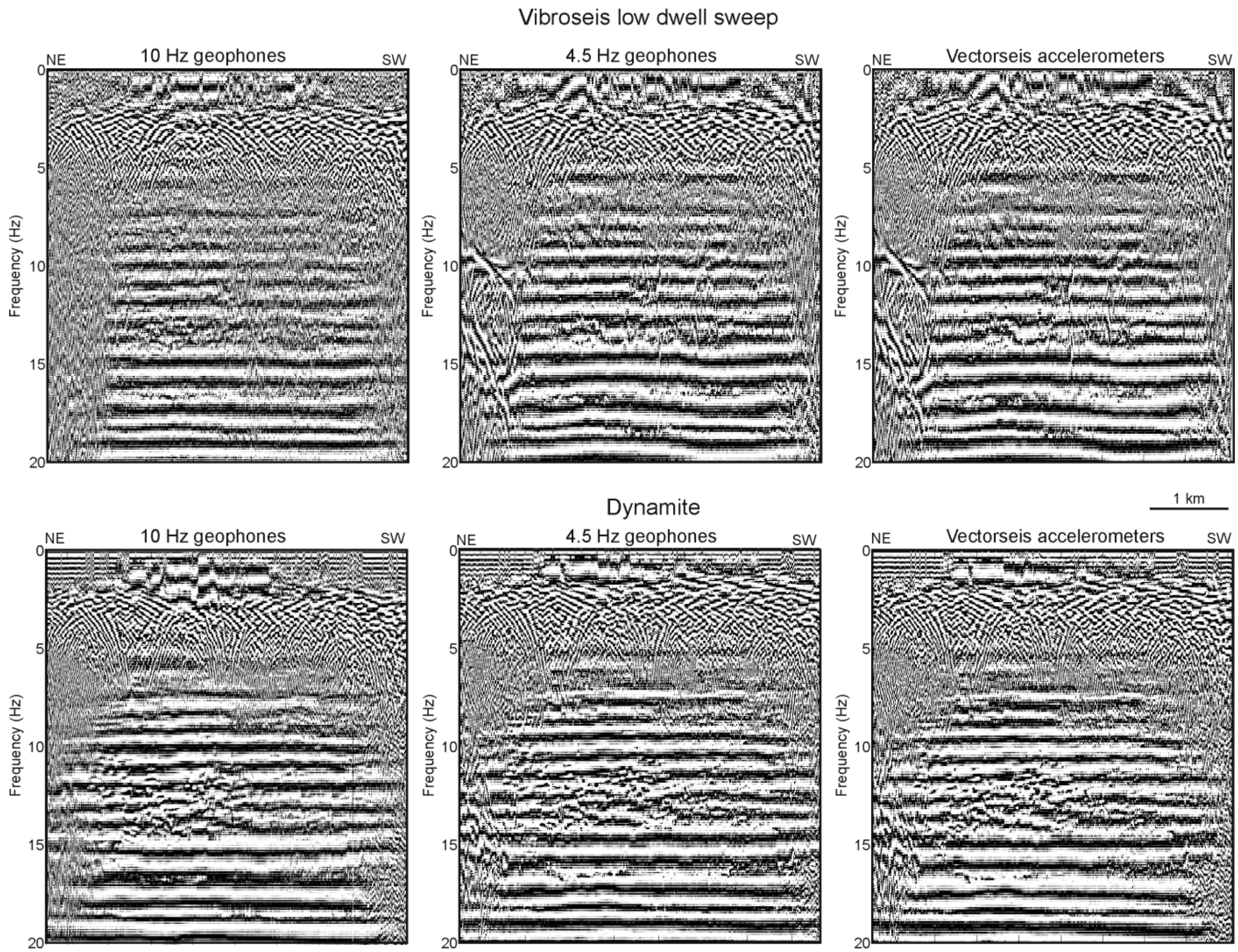

Figure 2: Coherency analysis of unfiltered, stacked data and spectra for two of the sources (364 Vibroseis low dwell sweep and dynamite) and the three receiver types. The time window is 0.5-5.0 s. There is strong phase coherence down to at least 7.5 Hz and possibly to 5 Hz. Some coherent events may be seen below 3 Hz. Are they signal or noise?

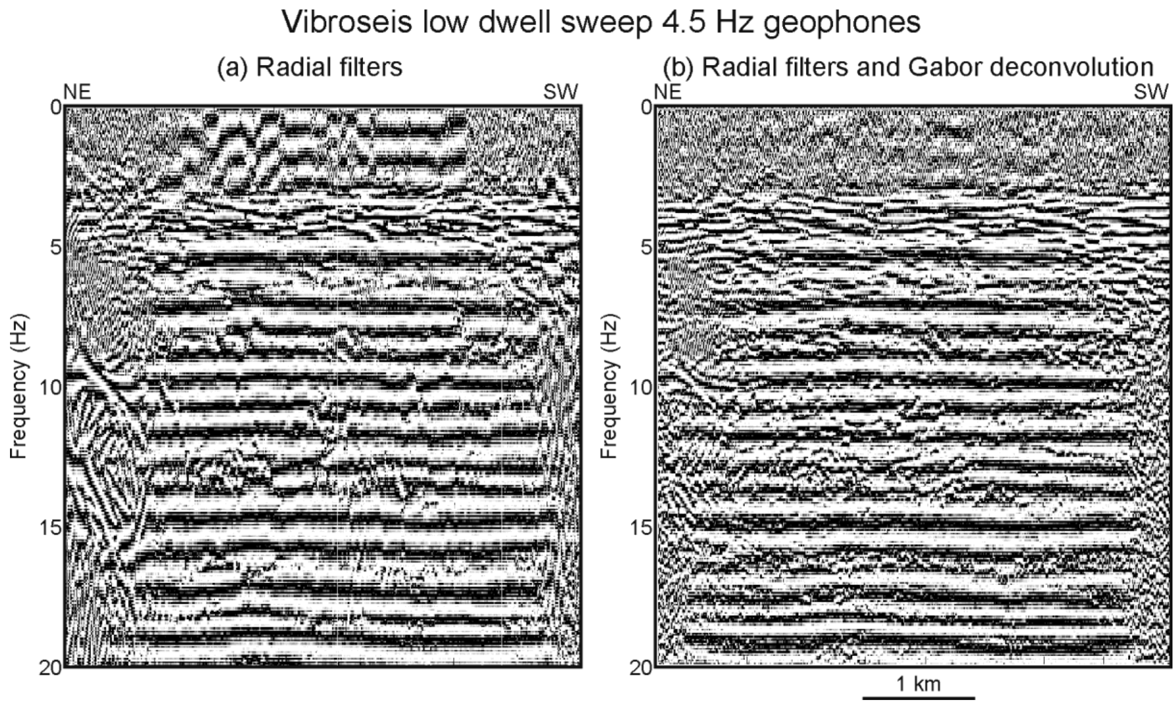

Figure 3: Coherency analysis of vibroseis data recorded by 4.5 Hz geophones after application of radial filters to attenuate low frequency noise at specified velocities and after additional Gabor deconvolution. Coherent events are seen clearly down to 5 Hz and optimistically to 3 Hz but what about the coherent events in (a) below 3 Hz? Are they actually signal or are they noise? Have we attenuated signal below 3 Hz by application of the Gabor deconvolution in (b)?

This work raises questions that we are striving to answer:

- How do we process seismic data to retain low frequency signal?
- How do we know we have low frequency signal?
- How do we attenuate low frequency noise without attenuating signal too?
- How do we know that we have not attenuated low frequency signal?

Acknowledgements

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