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# Recovery of Low Frequency Data from 10Hz Geophones

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## Summary

Increasing the bandwidth of seismic data is a desirable goal for many reasons. An example is that enhancing low frequencies improves velocity information and inversion results. In this report an analysis is made of the data from two different projects to calibrate a method to recover low frequency data from 10Hz geophones. These surveys were selected because of the ability to directly compare the enhanced spectrum from the 10Hz geophones to that from 2Hz geophones and MEMs sensors, thereby providing a measure of the effectiveness of the method. The ability to recover usable data to two octaves below resonance is demonstrated.

## Introduction

The two surveys used for this analysis are: a) the Blackfoot broadband survey recorded by CREWES in 1995 as a data set for analysis of acquisition parameters required for converted wave data, as well as providing a data set with frequencies down to 0.5Hz, and b) the Spring Coulee survey recorded by CREWES in 2008 to compare MEMs sensors (Sercel DSU3) to three component geophones (Sensor SM7) over a 6.5 Km line.

## Method

This work was prompted by a discussion about geophone response at low frequencies, and that the response of a 70% damped element can be approximated by a second-order, minimum-phase, Butterworth filter (Peter Maxwell, 2010). Such a filter, appropriate for the 10Hz geophones, was designed in Matlab, a time-domain wavelet created and inverted, then this inverse Butterworth wavelet was convolved with the 10Hz data. This provides a correction to both the amplitude and the phase of the 10Hz geophone data.

## The Blackfoot data

This survey consisted of a 4 km line recorded east of Calgary at the Blackfoot field. Geophone stations were every 20m with four different sensor types at each station. These were a single 10Hz 3C geophone, a string of 1C vertical 10Hz geophones spread over 20m, a single 4.5Hz 3C geophone, and a 2Hz vertical geophone. There were also 60 2Hz horizontal geophones planted at the centre 60 stations of the receiver spread. Shot parameters were 6 kg of dynamite at 18m depth. This study makes use of the vertical component of the single 10Hz 3-component geophones and the vertical 2Hz geophones. Figure 1 shows the raw shot gathers for these two data sets, together with the convolved 10Hz gather. The recovery of the lower frequency content in the 10Hz data is apparent. A low cut filter is necessary to trim the spectrum near DC as the inverse filter boosts the noise in this area. A remnant of this inverse filter footprint is visible at the end of the gather, but overall the record now shows good similarity with the 2Hz gather.

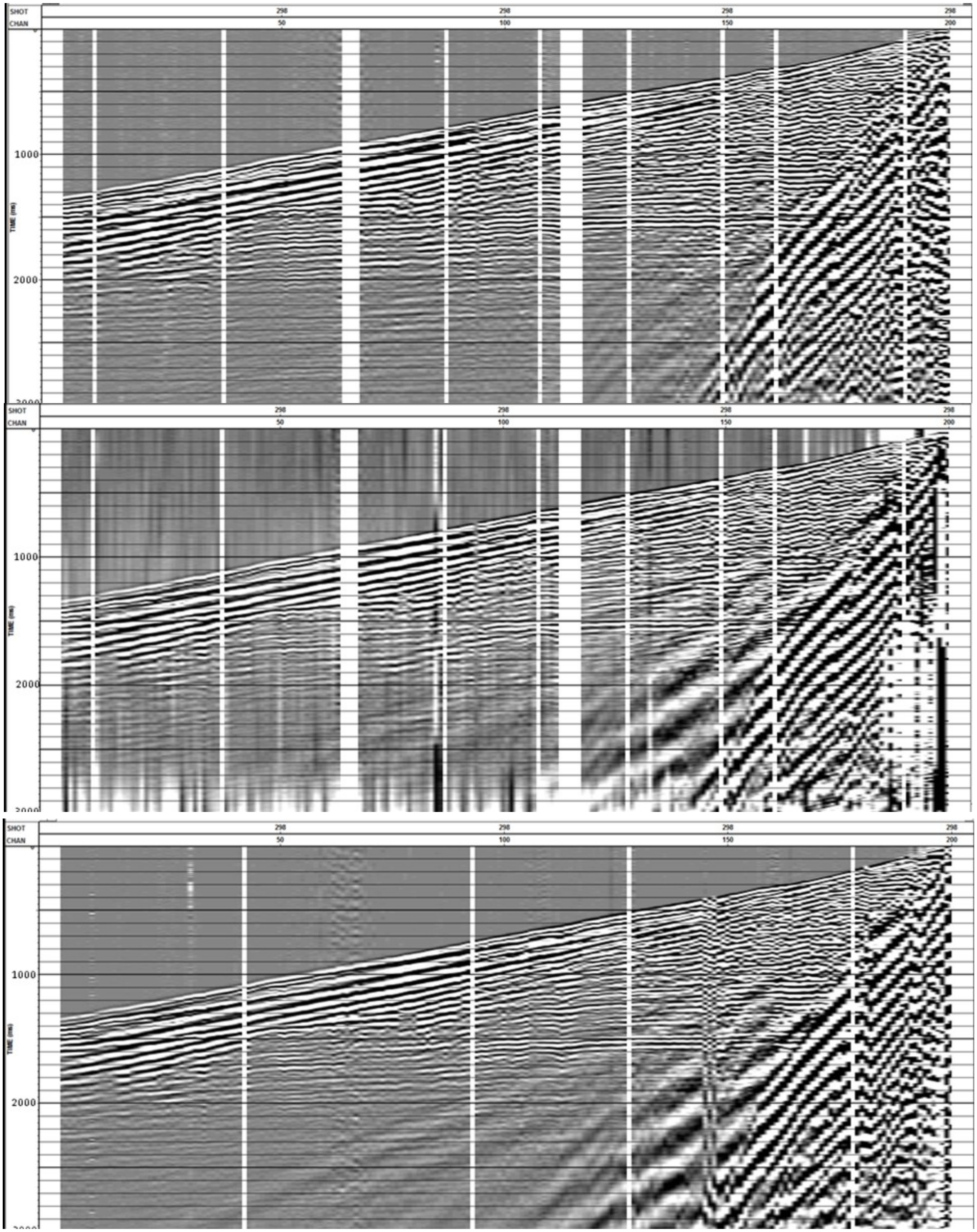


Figure 1. Shot gathers of the 10Hz (top), the convolved 10Hz (centre), and the 2Hz (bottom). A 2Hz low cut filter has been applied to the convolved 10Hz gather

## The Spring Coulee data

This survey was shot in January 2008 over a property in southern Alberta where the University of Calgary has the mineral rights. The project compared Sensor SM7 3C geophones to Sercel DSU3 MEMs sensors over a 6.5 Km line with a group interval of 10m. The whole line was shot with two 60,000lb vibrators, and a section in the centre was shot with dynamite. Since the vibrator sweep started at 8Hz, the vibroseis records have no energy in the area of interest. However, the dynamite shots (2Kg at 18m) show good bandwidth, and are used here. Figure 2 shows the average amplitude spectra for the gathers from one dynamite shot. The MEMs data was integrated to provide velocity information. In this case, the acquisition parameters included a 3Hz low cut filter on the geophone data, which shows up clearly in the average amplitude spectrum plot after convolving the data.

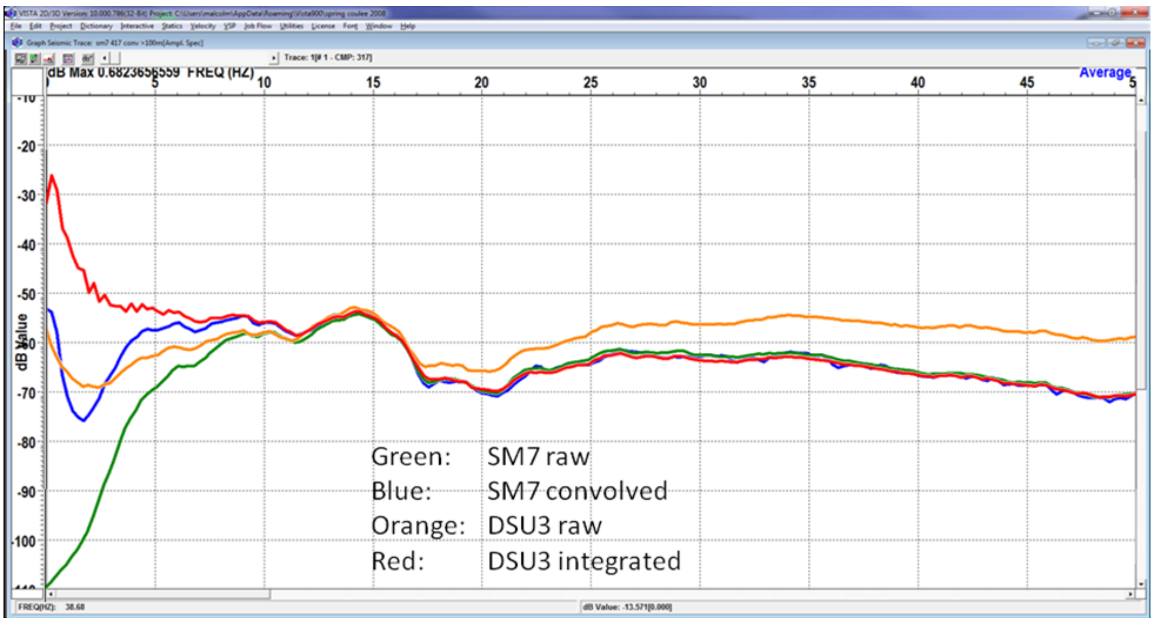


Figure 2. The average amplitude spectra for one shot.

Figure 3 shows some spectrum plots for the four data sets (10Hz geophones raw and convolved, DSU3 raw and integrated) showing the low frequency enhancement derived from the integration of the MEMs data and the application of the inverse filter to the geophone data. The effect of the 3Hz low cut acquisition filter is readily apparent on the convolved 10Hz plot.

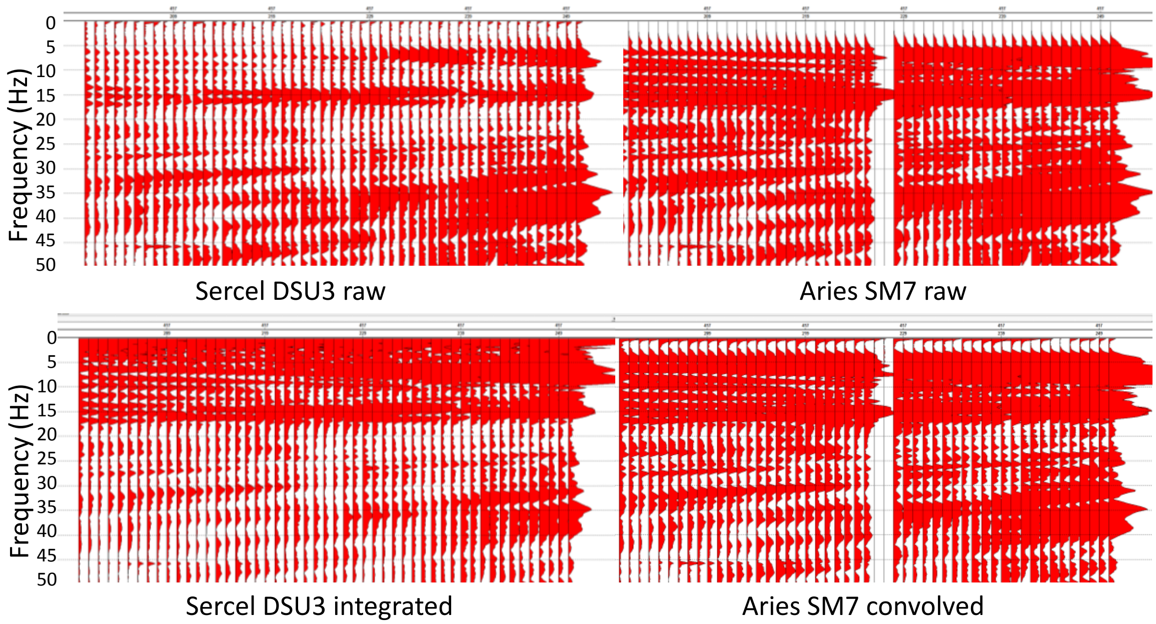


Figure 3. A spectrum plot of some traces for offsets of 600 to 1000m for 0 to 50Hz.

## Conclusions

Both cases presented here indicate that using this method of data enhancement shows a great deal of promise. However, care must be taken to establish if there is information to recover by inspecting the low frequency content of the original data, and being careful to take the signal-to-noise decrease due to offset into consideration. Beware that many acquisition systems apply a 3Hz low cut filter by default, meaning that recovery of data below this is unlikely. The ability to compare the inverse filtered spectrum directly to another data set from either the 2Hz geophones or the MEMs sensors provides a high level of confidence in the application of this filter as an accurate method of data recovery for frequencies below geophone resonance.

## Acknowledgements

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#### References

Bertram, Malcolm B., 1995, Acquisition instrument performance from the Blackfoot broad-band survey: CREWES Research Report Volume 7.

Ferguson, Robert J. and Gary F. Margrave, 1996, A simple algorithm for band-limited impedance inversion: CREWES Research Report Volume 8.

Maxwell, P., 2010, What receiver will we use for low frequencies?: SEG Low-Frequency Workshop, Snowbird, Utah.

Maxwell, P., 2010, Personal communication.