Analysis of the low frequency content of seismic data acquired during an experiment at Hussar, Alberta, Canada

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Summary

Seismic reflection data acquired by CREWES at an experimental low frequency shoot at Hussar, Alberta, Canada, in September 2011 were processed to attenuate unwanted noise and other wavetrains and to retain or even enhance the low frequency signal content. We analyzed the stacked data by creating plots of lateral phase-coherency versus frequency. The initial unprocessed data show strong coherency down to 7.5 Hz and weak coherency to 5 Hz but little coherency below that.

The data were processed with various noise reduction and signal enhancement techniques, such as coherent noise attenuation, spiking deconvolution and amplitude scaling. After processing the data show good coherency at the lowest frequencies of 1-5 Hz. Effective noise attenuation appears to be the greatest factor in attaining high coherency reflection data at these low frequencies.

We find that the phase-coherency plots are affected by processing procedures such as AGC and the amount of muting before stack. AGC adversely affects the coherency and gives misleading results while a standard harsh mute, designed to improve resolution, appears to remove desired frequency content in the stacked sections.

Introduction

In September, 2011, CREWES carried out an experimental low-frequency seismic shoot at Hussar, Alberta, Canada (Margrave et al, 2011). Although we acquired both vibroseis and dynamite data using various types of receivers, in this abstract we present the analysis of dynamite data recorded by 3C 10 Hz geophones. The dynamite source was 2 kg at a depth of 15 m. The seismic line is 4.5 km long with a receiver station spacing of 10 m and a source spacing of 20 m.

The data were processed by CREWES and CGGVeritas to attenuate low frequency groundroll, noise from external sources, and other unwanted wavetrains with the objective of producing seismic data containing low frequency signal and thus suitable for poststack impedance inversion, full waveform inversion or similar processes. We analyzed the low frequency signal content of the data by making phase-coherency displays that plot reflection strength and continuity against frequency.

Data analysis

Phase-coherency plots (Margrave, 1999) show spatial coherence where signal is dominant and incoherence otherwise, making then a useful tool for quick analysis of the frequency content of signal in seismic data. Figure 1 shows the phase-coherency plot of unprocessed (a) and processed (b) dynamite data analyzed over a window of 0.5 – 5.5 s. All statics and a full trace length AGC were applied to the data before stack and we were very careful to mute any nmo stretch that might influence the results.

The frequency content of the unprocessed data (Figure 1a) is very good down to 7.5 Hz and fair to 5 Hz. Below 5 Hz there is considerable noise and we see no lateral coherency. The criss-crossing pattern seen between 2 and 5 Hz is caused by groundroll.

Various noise reduction and signal enhancement techniques, such as coherent noise attenuation, surface consistent amplitude scaling, spiking deconvolution, semblance weighted dip filter noise attenuation and spectral balancing were applied to the seismic data. After this processing, there is coherency even at the lowest frequencies (Figure 1b).

Application of a harsh mute, as commonly used to increase resolution, appears to remove desired low frequency signal (Figure 2) while AGC before stack gives erroneous results (Figure 3). These processes, although not routinely applied to unstacked data, affect the phase-coherency analysis of stacked data and should not be applied.
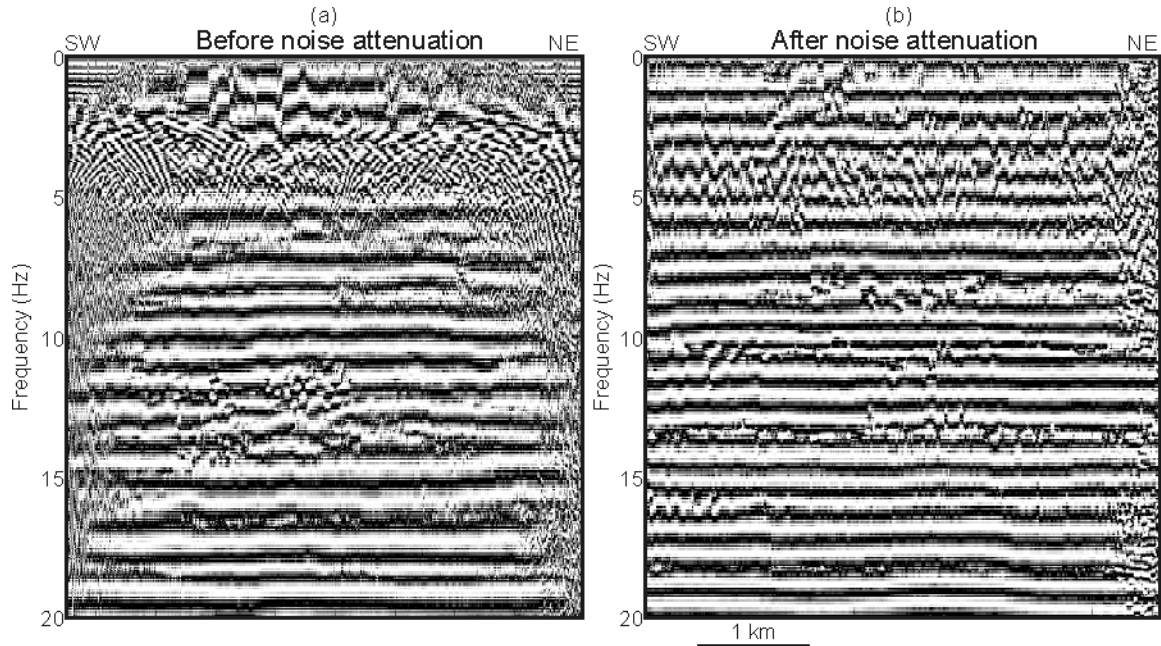

Figure 1: Phase-coherency plot of unprocessed (a) and processed (b) dynamite data.

Conclusions

We are learning how to process seismic data to retain any low frequency signal content while still attenuating the unwanted groundroll and other undesired low frequency events in the data.

Phase-coherency analysis of seismic data from the experimental low frequency shoot at Hussar, Alberta, Canada, allows us to assess the frequency content of the data at different stages of data processing, to observe which processes enhance the desired low frequencies and, perhaps more importantly, to avoid those processes that degrade the desired low frequencies.

The initial unprocessed data show strong coherency down to 7.5 Hz and weak coherency to 5 Hz but nothing below that. After processing, stacks display phase-coherence at the lowest frequencies of 1-5 Hz,

suggestive of reflection signal content. Efficient noise attenuation appears to be the greatest factor in attaining high coherency at the lowest frequencies.

We find that the phase-coherency plots are adversely affected by processing procedures such as AGC and the amount of NMO stretch muting before stack, which can give misleading results.
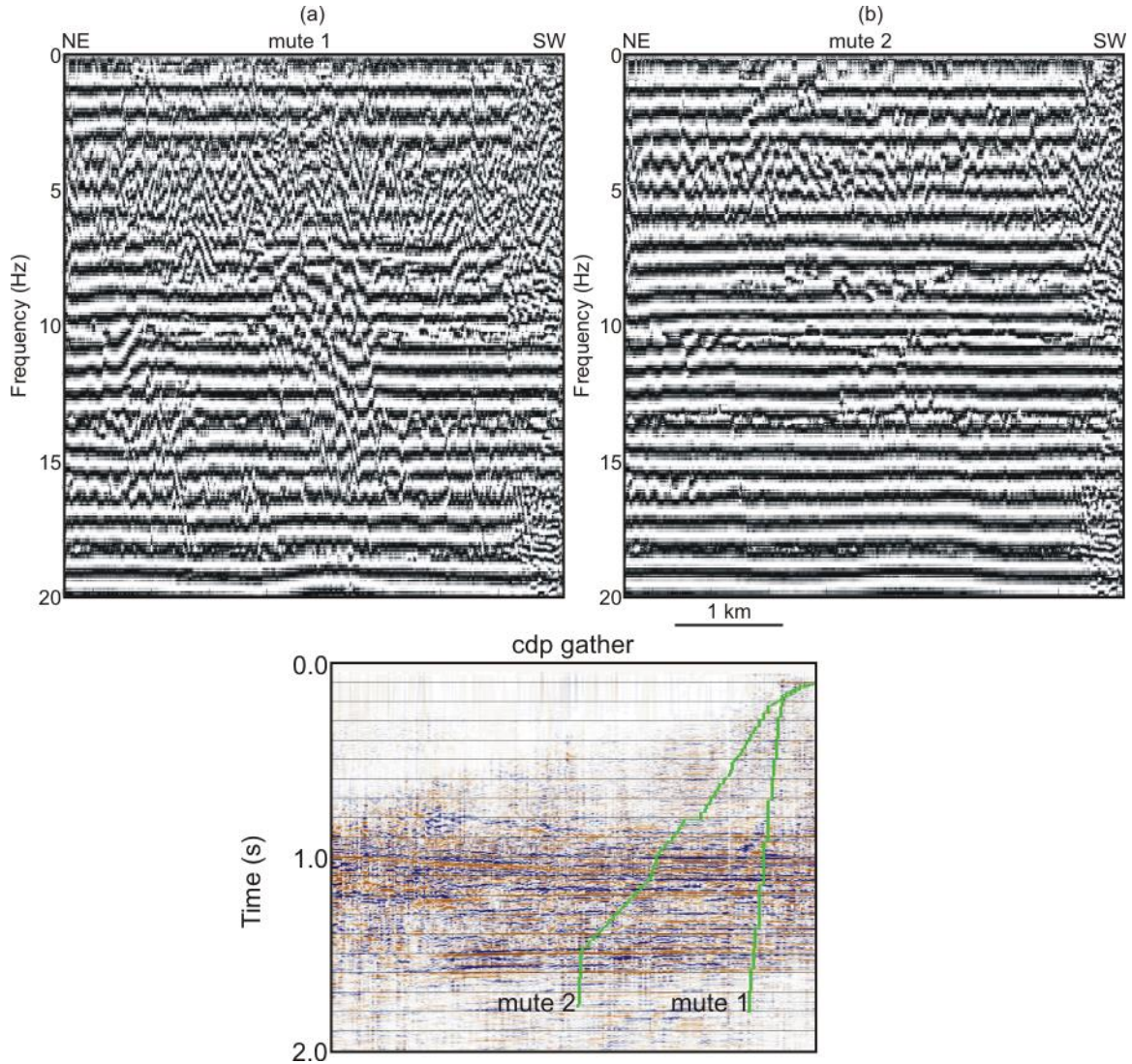

Figure 2: Applicaton of a harsh mute (a) affects the apparent low frequency signal content of the data, especially between 2 and 8 Hz, and is not recommended.
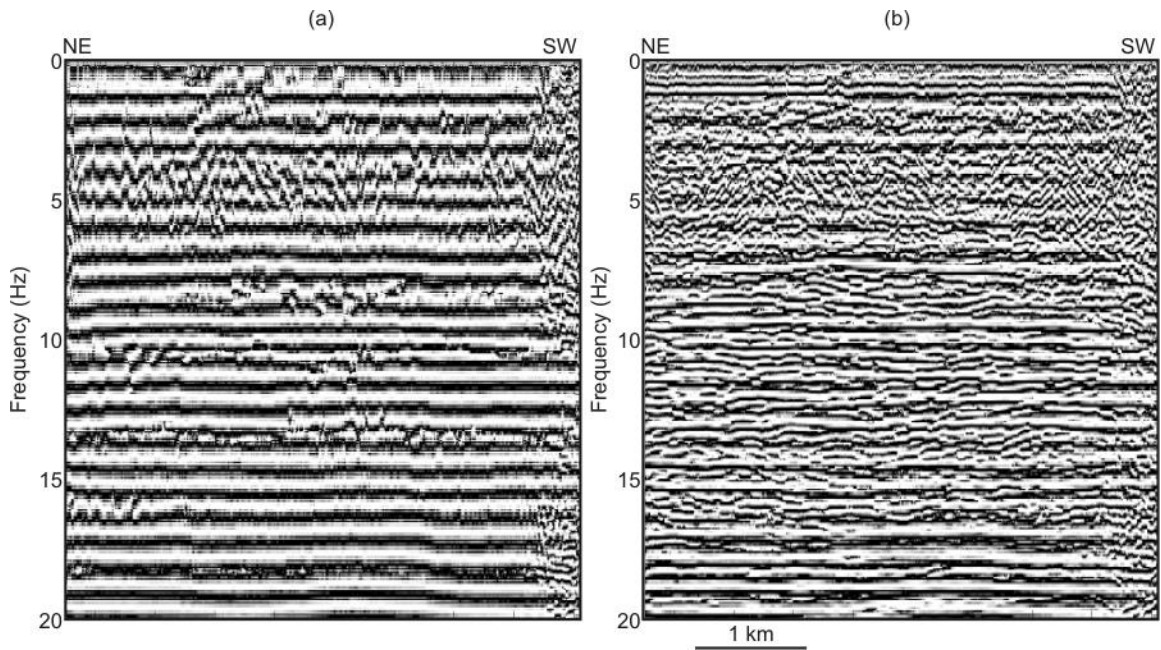
Figure 3: Processed data stacked without (a) and with (b) prestack AGC. The AGC adversely affects the apparent signal frequency coherency and is not advised.

Acknowledgements

References

Margrave, G. F., 1999, Seismic signal band estimation by interpretation of f-x spectra: Geophysics, 64, 251-260.

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