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Increasing Seismic Resolution by Decreasing Receiver Spacing

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Summary

In 2008, we conducted a small seismic field experiment in which we tested the benefits of very closely spaced geophones *recorded individually*. Using 3C geophones spaced 1m apart, we demonstrated the benefits of seismic acquisition techniques which accurately record the coherent noise, with no significant aliasing, thus enabling its effective removal. Our 2D survey imaged the near-surface geology of our Priddis field test site with unprecedented resolution.

Introduction

Now that the University of Calgary has its own seismic acquisition system, to which CREWES has access, we are able to experiment with various aspects of seismic data acquisition. One of our interests has been to extend the limits of spatial and temporal resolution. Beginning with an experiment in 2006 in the Longview area (Henley et al, 2007), we began to explore the benefits of seismic recording using a single phone at each receiver station, with stations spaced closely enough to properly sample most coherent noise. We chose 2.5 m as the spacing for the vertical component geophones in that experiment and subsequently showed that recording the survey with the independent single phones allowed us to produce a seismic section with higher resolution, both spatially and temporally, than a section created from the same data, but with the raw traces summed into geophone groups, emulating more conventional acquisition. Even with 2.5 m receiver spacing, however, higher frequencies of some of the coherent noises were visibly aliased, particularly those with apparent velocities at or below air velocity. Therefore, we decided in 2008 to conduct another experiment, this time at our Priddis field site, in which we shortened the receiver spacing to 1 m in hopes of reducing aliasing even further. In addition, we decided to use 3C geophones in order to explore the resolution of any converted waves, an aspect of the experiment still under investigation.

The experiment

As part of the development of a permanent field experiment site at the University property near Priddis, an experimental 3D survey was conducted in 2007 (Lawton et al, 2008) in which shallow, dipping reflecting horizons were successfully imaged using the University's acquisition equipment, including the Enviro-Vibe as a source. The 3D acquisition grid consisted of orthogonal source and receiver lines, both spaced 50 m apart, with source and receiver spacing of 10 m on their respective lines. During the survey, it was noted that coherent noise is a major issue at this site, and a significant portion of the low-frequency seismic band was discarded (40 – 60 Hz low cut) in order to attenuate the source-generated noise. We expect significant contribution to the earth spectrum in this frequency range, however, so one objective of our 2008 survey

was to sample the coherent noise field finely enough to enable our coherent noise attenuation and deconvolution techniques to attenuate noise without sacrificing as much of the low-frequency spectrum.

Our 3C-2D survey consisted of 200 3C geophones planted at 1 m intervals, to form a receiver spread 200 m long. The source line was parallel to the E-W oriented receiver spread, but offset to the north 5 m. In addition, it was 400 m long and centred on the receiver spread, so that maximum source-receiver offsets, and the CDP line length, were both 300 m. The source was the Enviro-Vibe, sweeping a frequency range of 5-250 Hz. The vibrator points were spaced 10 m apart along the source line, and each was occupied 10 times by the vibrator, to enable us to conduct a concurrent experiment with a landstreamer, whose length of 20 m required it to be moved nine times in order to cover the same profile as the fixed geophone spread. The ten shot records at each source point were vertically stacked prior to further processing.

Results—vertical component only

Figure 1 shows a typical long offset vertical component shot gather from the Priddis 1 m experiment. As can be seen, no reflections are visible due to the high level of coherent noise. Fortunately, however, all the coherent noise on this gather appears to be well sampled, with no *visible* aliasing.

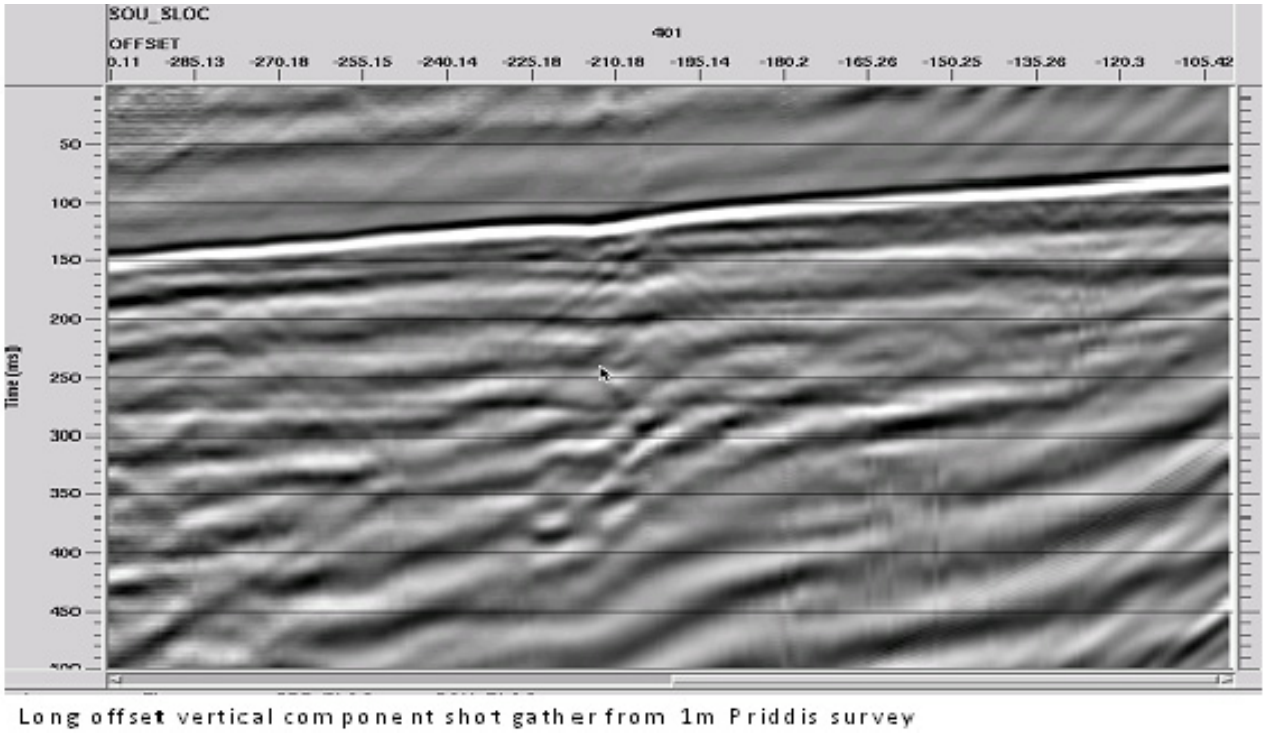

Figure 1: Vertical component shot gather from the Priddis 3C-2D experiment with 1 m receiver spacing. None of the coherent noise on this gather *appears* to be aliased.

Applying our procedure of step-wise radial trace filtering for coherent noise attenuation (Henley et al, 2006), we removed most of the coherent noise from the gather in Figure 1. The fine spatial sampling allows us to use filtering parameters that preserve spectral components down to at least 25 Hz (our radial trace filters had equivalent low-cut filters of 20-25 Hz). Following the radial trace filtering, Gabor deconvolution (Margrave et al, 2002) was used to whiten the trace spectra. The results are shown in Figure 2, where many reflections are revealed, from very near the surface, down to at least 500 ms. High frequencies have been boosted by whitening, so aliasing of the higher frequency components of residual noise is now visible, for events propagating at lower velocities. This implies that even 1 m spacing is too coarse, if we want to remove coherent noise at all velocities and all seismic frequencies, including those which may be enhanced by whitening.

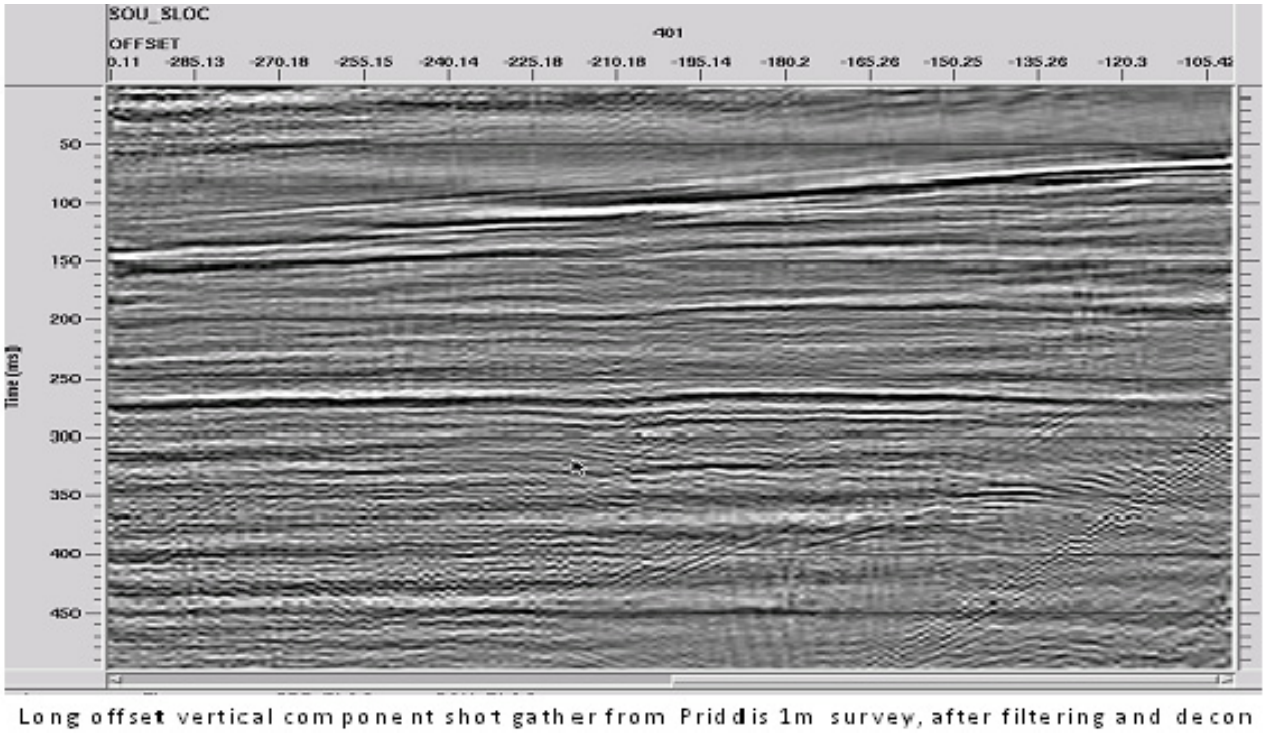

Figure 2: Vertical component shot gather from the Priddis 3C-2D experiment with 1 m receiver spacing. Several passes of radial trace filtering have been applied to attenuate coherent noise; and Gabor deconvolution has been subsequently applied to whiten the spectrum. Because of the whitening, aliasing now appears for residual noise propagating at air velocity or less.

From the filtered gathers (as shown in Figure 2), we were able to determine NMO velocities for the various reflectors. After removing NMO, we stacked the *unfiltered* shot gathers (like those in Figure 1) over CDP to produce Figure 3. Due to the power of stacking, we can see reflections as deep as about 300 ms; although they are greatly obscured by the coherent noise. We see no detail above about 100 ms, however, and the low frequency amplitude variations in the shallow section are obvious artefacts.

Figure 4 shows the CDP stack of the same shot gathers, but *after noise attenuation and deconvolution.* The comparison between this figure and Figure 3 shows the effectiveness of the noise attenuation and deconvolution procedures used on these data. We emphasize that ***in order to analyze and filter the noise this effectively, the noise must be adequately sampled spatially during acquisition***.

Conclusions

We show that fine receiver spacing and pre-stack coherent noise attenuation and deconvolution can result in very high resolution stack images (note the distance and depth scales on Figures 3 and 4. There is evidence that even 1 m spacing is not fine enough for properly sampling noise when deconvolution is intended.

Acknowledgements

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References

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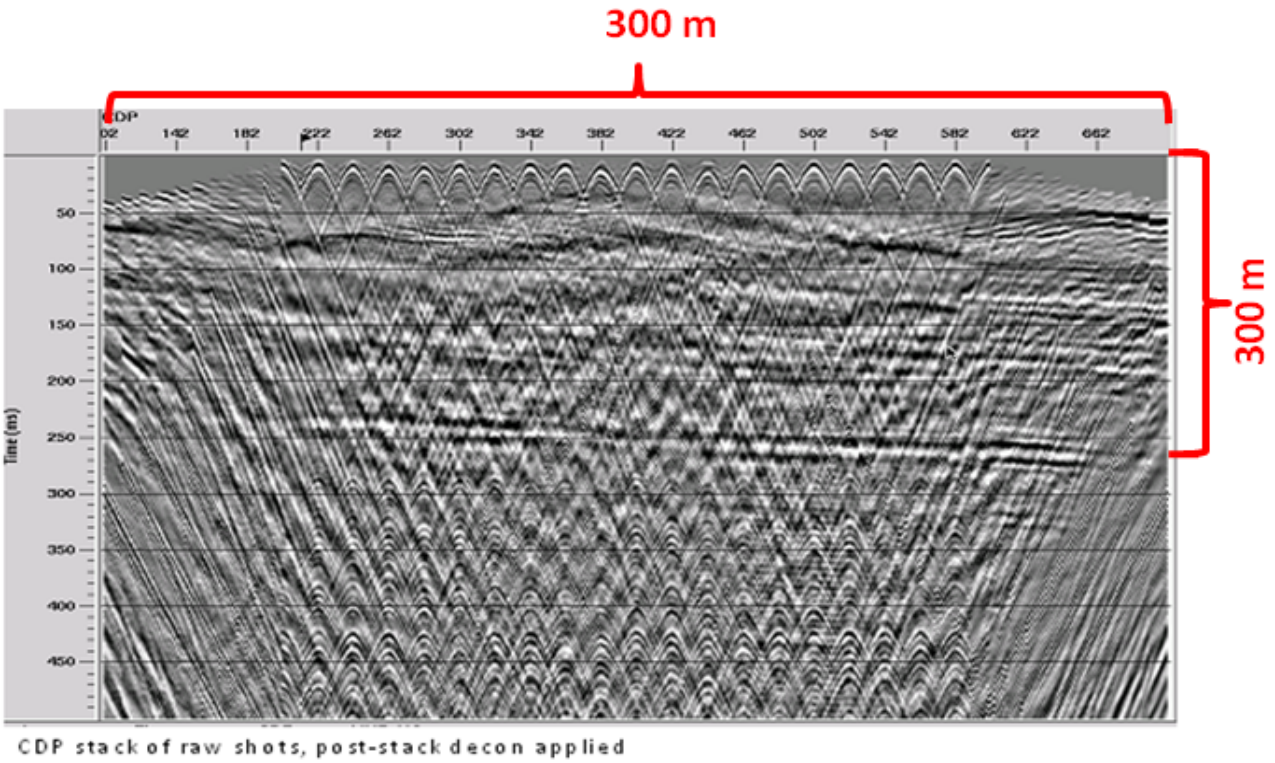

Figure 3: Vertical component brute CDP stack from the Priddis 3C-2D experiment with 1 m receiver spacing. The high-fold stack allows us to see reflections, but the noise is quite overwhelming.

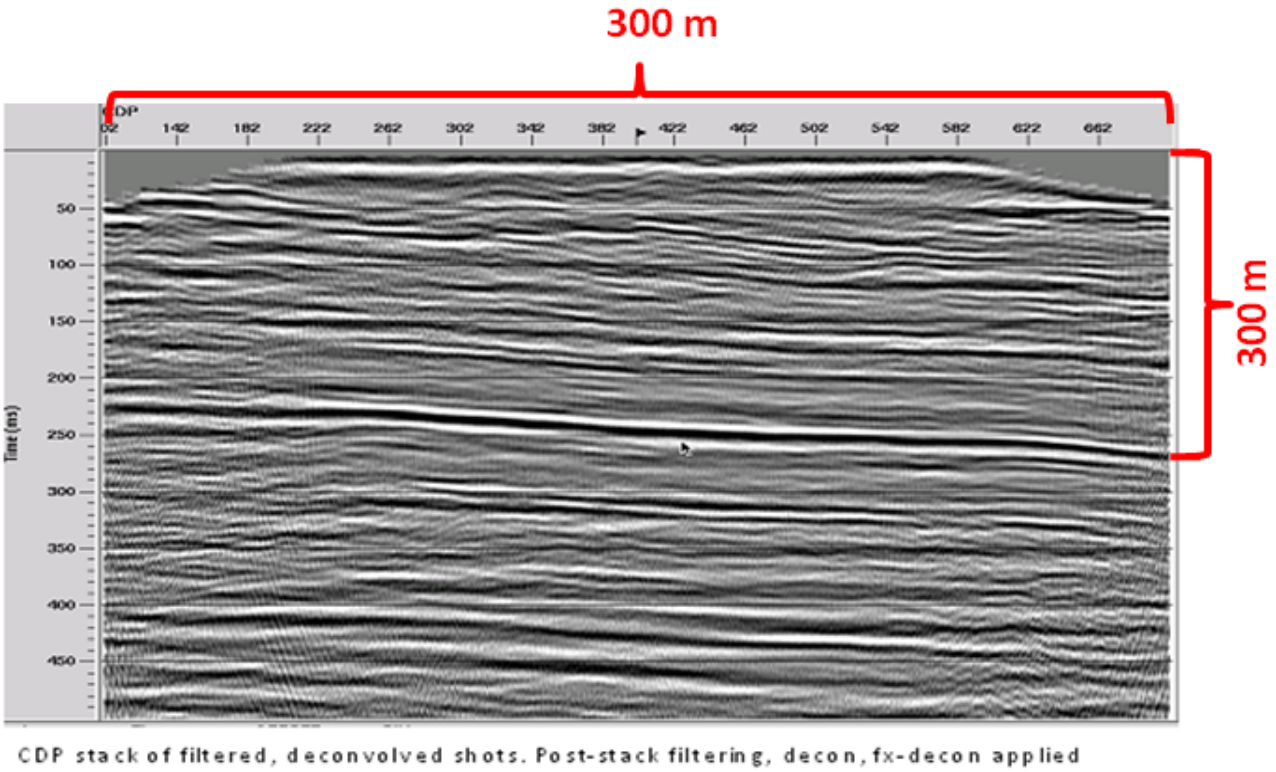

Figure 4: Vertical component CDP stack from the Priddis 3C-2D experiment with 1 m receiver spacing. Pre-stack coherent noise attenuation and deconvolution have cleaned up the image and broadened the bandwidth of reflection events. This image could not be formed without our fine receiver sampling and the filtering procedures enabled by the sampling.