

“High-Effort” Seismic Acquisition: Improving Image Detail*

David C. Henley¹, Kevin Hall¹, Henry Bland¹, Eric Gallant¹, Gary Margrave¹, and Malcolm Bertram²

Search and Discovery Article #41568 (2015)

Posted February 23, 2015

*Adapted from extended abstract prepared in conjunction with a presentation given at CSPG/CSEG 2007 GeoConvention, Calgary, AB, Canada, May 14-17, 2007, CSPG/CSEG/Datapages © 2015

¹CREWES, University of Calgary, Calgary, AB, Canada (dhenley@ucalgary.ca)

²Department of Geology and Geophysics, University of Calgary, Calgary, AB, Canada

Abstract

In seismic exploration, there is always a trade-off between the quality of the seismic data acquired and the resources and “effort” committed to obtaining the data. For most routine seismic surveying, the acquisition geometry is designed to sample the anticipated subsurface features without spatially aliasing their structure, and to provide some amount of noise attenuation, while still allowing acceptable daily production rates. Noise attenuation is usually provided by horizontally summed geophone arrays whose antenna pattern preferentially admits vertically travelling reflection wavefronts, rather than non-vertical coherent noise wavefronts. Recent equipment advances, however, allow us to record individual geophones in sufficient numbers that we can eliminate arrays and reduce receiver station intervals dramatically. Doing this allows us to accomplish two objectives: the lateral resolution of a survey can be greatly improved, and various multi-channel processing tools, in addition to conventional horizontal summation, can be employed for noise attenuation. An earlier example of single phone acquisition relative to arrays is discussed for multi-component acquisition by Hoffe et al (2002).

Although we describe the close-spaced, single geophone recording technique as “high effort”, the actual number of geophones per survey does not necessarily increase from that used in a conventional survey. What does increase is the number of phone/cable connections that must be made and broken during layout and pickup of the survey, as well as the density of source stations, since we typically shoot every other station, at the reduced station interval. There are three objectives for our proposed technique: improved lateral resolution of reflection events; increased stack fold for higher S/N; and proper spatial sampling, not only of reflection features, but also of all coherent noises, so that these noises can be effectively attenuated using multichannel processes.

The Experiment

In August 2006, several members of CREWES, and staff from the department of Geology and Geophysics conducted a small seismic survey on a 1 km portion of a section line road intersecting secondary road 543, east of the town of Longview, Alberta. The experiment was intended as a shakedown test of the University’s new seismic acquisition system prior to the 2006 department field school, as well as a test of the “high-effort” method for high-resolution surveys. Because of promising results from an earlier experiment using 5 m geophone spacing, the new

survey was designed for 2.5 m spacing. The spread was 937.5 m in length, with 376 single geophone stations. For this survey, shots were spaced every 5 m along the line, which was shot from one end to the other without moving any portion of the spread. The source was the University's new mini-vibrator, emitting four sweeps per shot location, each sweep being 8 seconds, 10-200 Hz. Listening time was 10 seconds, and the data were diversity-stacked and correlated in the field. With a field crew consisting of four experienced and four inexperienced hands, the profile was acquired in one ten hour day: three hours for spread layout, five hours for acquisition, and two hours for spread pickup.

The Analysis

Creating data sets with coarser station spacing

The strategy for exploring the possible benefits of high effort seismic techniques was to first process the complete data set, taking every possible advantage of the short receiver interval to detect and remove noise, and to determine statics and velocities from this complete data set. Next, we created four other data sets by using all of the same original shot gathers, but decimating the receiver stations to simulate shot gathers with receiver intervals of 5 m, 10 m, 20 m, and 40 m. The decimation was done by applying appropriate trace mixing to the input gathers before decimation, to simulate using the original geophones in arrays, just as would typically be done in the field. For these artificial data sets, although we used all the original shot gathers, we also effectively decimated the shot spacing, as well, using some creative re-binning. This means that all the traces of the original survey were used in creating each decimated data set, and that the stack fold at each decimated CDP was the same as the stack fold of the corresponding CDP in the original data set.

Noise removal and deconvolution

The processing flow for each of the data sets was identical, except that parameters obtained from visual examination of a particular data set were not used to help process any other data set. Processing parameters depending upon receiver and/or CDP interval were individually assigned for each data set, but all other parameters were fixed at the same values for all data sets. The shot gathers were first analysed for coherent noise. All visible noises were sequentially estimated and subtracted using radial trace filtering (Henley, 2003). Single trace mode Gabor deconvolution was then applied to the shot gathers after noise attenuation (Margrave and Lamoureux, 2002). Single trace mode Gabor deconvolution was also applied in the radial trace domain to all the source gathers in each data set to remove residual air blast, reduce short period multiples, and equalize reflection strength over angle (Henley, 2004).

Moveout velocity and statics

NMO Velocity analysis and statics derivation were the only two processing operations that were performed only on the 2.5 m data set and shared with the other sets, in the interest of providing comparable stack and migrated images in which the simulated receiver array geometry would be the only significant difference between the data sets.

Stacking, migration, and display

Each data set was CDP stacked with the common velocity function, using the newly decimated CDP bins created for each data set. In order to create displays with comparable appearance, the four decimated raw stacks were interpolated to the same trace density as the original 2.5 m stack before plotting with variable density. FX phase spectra were computed for each raw stack, at the original lateral resolution of each individual stack, in order to identify the highest coherent frequency for each stack, and hence to guide the selection of migration parameters. These parameters were determined for each data set individually, so that the migration algorithm did not attempt to migrate aliased frequencies or dips. In order to honour the simulated spatial resolution of each data set, the raw stacks were migrated with a post-stack Kirchhoff algorithm, at their original simulated CDP resolution. Then, as with the raw stacks, the migrated sections were interpolated to the same final trace density before display.

Results

[Figure 1](#) displays a raw shot gather at full 2.5 m lateral resolution as well as the same shot gather at a simulated 10 m lateral resolution. Coherent noise almost totally obliterates any reflection energy on these records. In addition, many noises that are properly sampled at the finer resolution are badly aliased at the 10 m spacing, or not even visible. In the lower part of the figure, the same gathers are shown after noise attenuation and deconvolution. Even at this early stage of processing, it can be seen that the 2.5 m data have greater bandwidth and higher S/N than the 10 m data. [Figure 2](#) shows the ultimate comparison between stacked, migrated data for both resolutions of seismic data. The differences are obvious and striking. Surprisingly, the data sampled at 2.5 m not only have greater lateral resolution, but also greater vertical bandwidth, after all processing.

Conclusions

Sampling a seismic wavefield with closely spaced geophones, recorded singly, allows coherent noise to be recorded without aliasing, thus enabling its estimation and removal. The same fine spacing also leads to increased lateral resolution in the reflection image, and, unexpectedly, to increased vertical resolution, as well. We conjecture that the differences would not be as dramatic for seismic data with a lower level of coherent noise, but that significant image resolution improvement would result for most seismic data acquired with the “high effort” configuration.

Acknowledgements

The authors acknowledge CREWES sponsors for their support, the University of Calgary for use of the seismic acquisition system, and an enthusiastic field crew, which included Joe Wong, Hanming Gu, and Zuolin Chen.

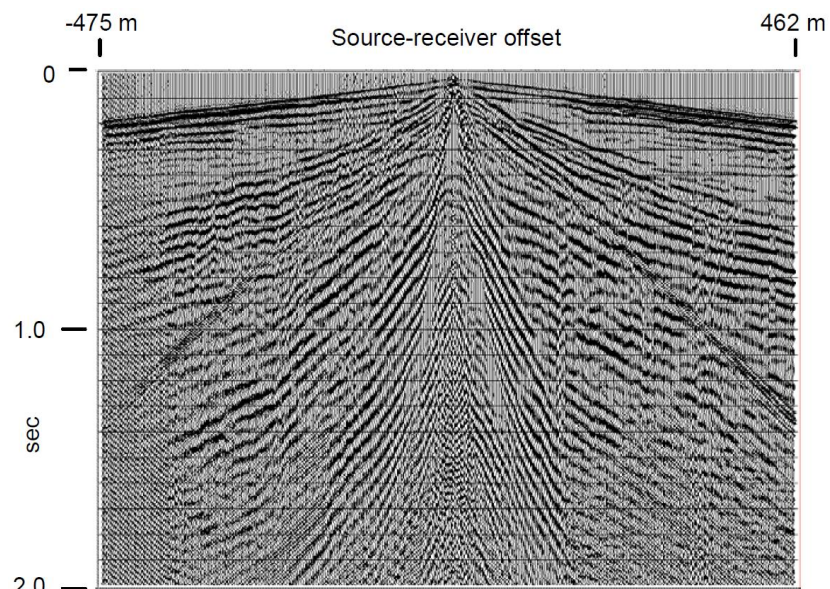
References Cited

Henley, D.C., 2003, Coherent noise attenuation in the radial trace domain: *Geophysics*, v. 68/4, p. 1408-1416.

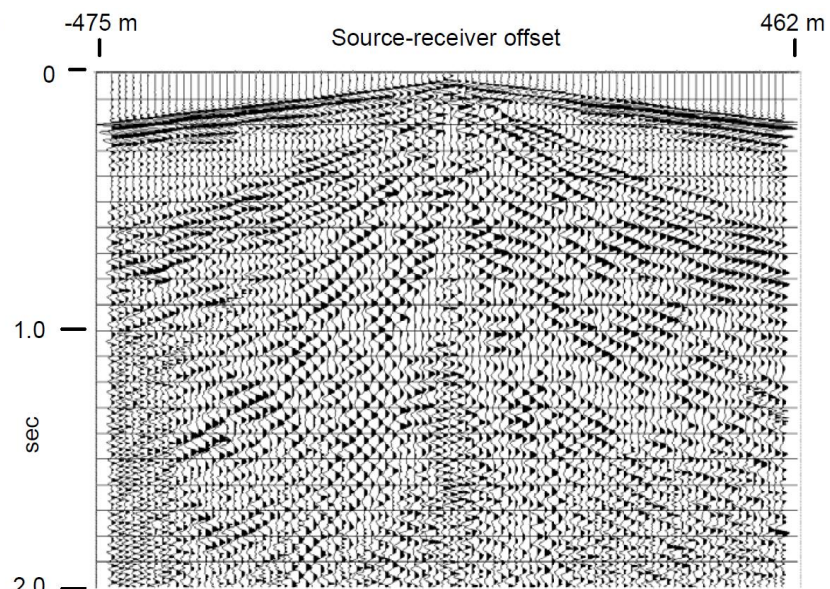
Henley, D.C., 2004, More processing in the radial trace domain: 2004 CSEG annual meeting, expanded abstracts, Web accessed February 1, 2015, http://cseg.ca/assets/files/resources/abstracts/2004/003S0122-Henley_D_Processing_Radial_Trace.pdf.

Hoffe, B.H., G.F. Margrave, R.R. Stewart, D.S. Foltinek, H.C. Bland, and P.M. Manning, 2002, Analyzing the effectiveness of receiver arrays for multicomponent seismic exploration: *Geophysics*, v. 67/6, p. 1853-1868.

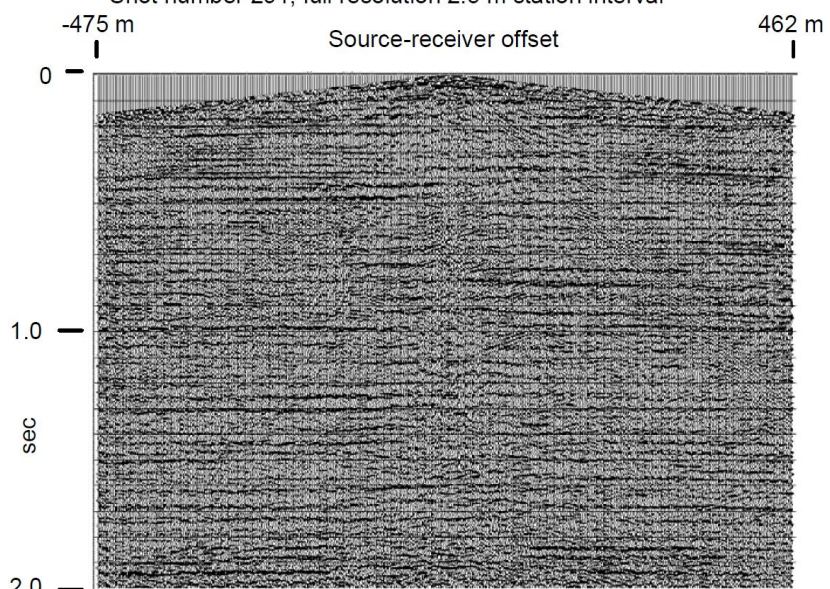
Margrave, G.F., and M.P. Lamoureux, 2002, Gabor Deconvolution: 2002 CSEG annual meeting, expanded abstracts.



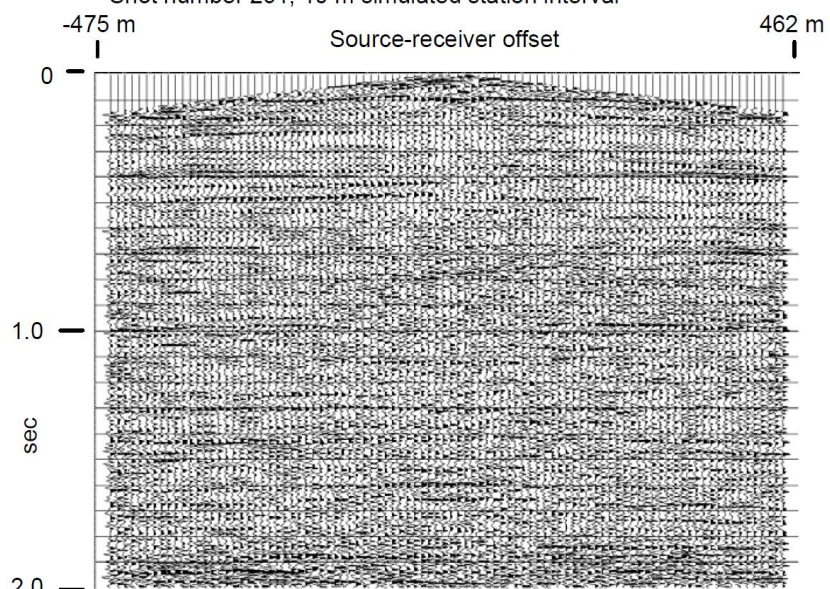
Shot number 291, full resolution 2.5 m station interval



Shot number 291, 10 m simulated station interval



Shot number 291, 2.5 m station interval, radial filtered, 1 pass XT domain Gabor decon, 1 pass RT domain Gabor decon



Shot number 291, 10 m station interval, radial filtered, 1 pass XT domain Gabor decon, 1 pass RT domain Gabor decon

Figure 1. Typical raw shot gather at full 2.5 m station resolution (above left) and simulated 10 m station resolution (above right). The same gathers are shown below after noise removal and deconvolution.

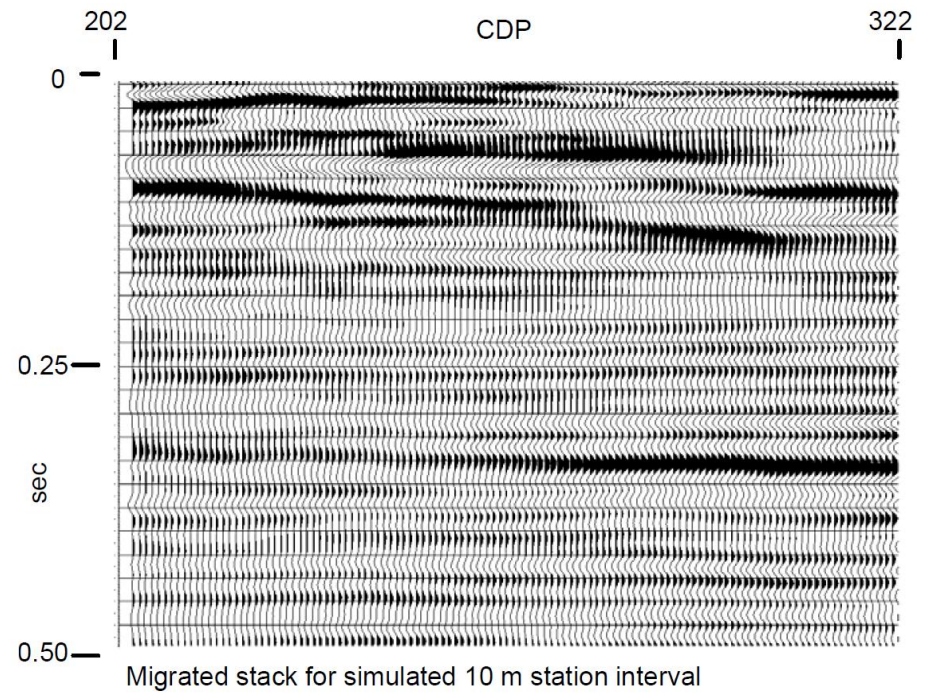
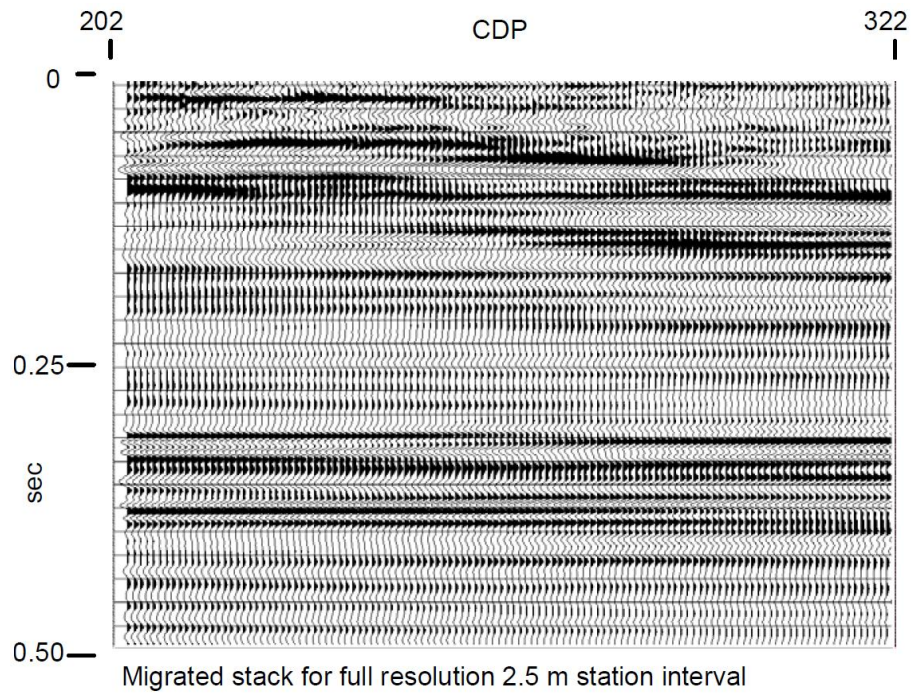


Figure 2. Detail of stacked, migrated section for 2.5 m sampling (left) and 10 m sampling (right).