GC Benefits of Reduced Bin Size*

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General Statement

Ideally, seismic data should be acquired at high spatial and temporal sampling, so that the small subsurface features of interest can be clearly seen on the seismic display. Such interpretation is easiest when the geological features of interest are uniformly illuminated, which in turn is possible by recording the scattered seismic wavefield on a uniform surface grid. The "nominal grid" is defined by the source-to-source spacing within a shot line and the geophone-group-to-geophone-group spacing within a receiver line.

One also can increase the trace density by reducing the spacing between shot lines and between receiver lines. Once acquired, data processing workflows are designed to retain the highest possible lateral and vertical resolution of the geologic target. Because of the different ray paths, dense acquisition (closer source and receiver lines) provides greater leverage against backscattered ground roll and interbed multiples, as well as decreased migration artifacts. Uniform acquisition results in increased lateral continuity of amplitudes that otherwise may be contaminated by acquisition footprint.

Method

In reality, economic, permitting and physical access constraints result in 3-D seismic data that are not uniformly sampled in all directions. Vibrators require access along roads or open country, while geophones easily can be placed in forest or cultivated farmland. For this reason, "shot lines" may be more coarsely spaced than "receiver lines," resulting in rectangular rather than square bins. Obstacles such as ponds, roads, buildings and archaeological sites give rise to holes in an otherwise uniform acquisition grid.

Such non-uniformity in offsets and azimuths introduce additional artifacts in the final image. This non-uniformity also affects the performance of the processing algorithms – and so could lead to sub-optimally processed data, affecting subsequent data interpretation.

In principal, any processing algorithm can be modified to handle sparse data. In practice, it is much easier to write an accurate 5-D interpolation algorithm, and thereby precondition the seismic data such that well-calibrated (and perhaps more complicated) algorithms such as prestack migration and prestack inversion work well.

While there is no substitute for acquiring good quality seismic data that has the above-mentioned qualities, it is possible to mimic or address some of the problems that crop up due to the sub-optimum parameterization used in the acquisition, during processing of the data. In the June 2013 Explorer, we described the advantages of regularizing the offsets and azimuths of the input seismic data during processing by way of 5-D interpolation, which then aids the computation of seismic attributes.

Regularization of seismic data has proven to be a successful method – not only for superior imaging of post-stack data but for prestack analysis as well, such as AVO (amplitude versus offset) or AVAz (amplitude versus azimuth). The advantages accrue from the enhanced spatial and azimuthal sampling of the 3-D seismic data.

After doing the trace edits, amplitude recovery, refraction statics, preliminary velocity analysis and trim statics, one can run 5-D interpolation to "regularize" the data to have a uniform coverage of offsets and azimuths, thereby conditioning them for more detailed velocity analysis, noise rejection, prestack time migration and prestack impedance inversion. In our June 2013 article we showed how such 5-D interpolation reduced artifacts in amplitude as well as in coherence and curvature attributes, but somewhat reduced the lateral resolution.

Example

In this article we demonstrate the results of reducing the bin size of the seismic data as part of the 5-D interpolation process. The source and receiver spacings are both 40 meters, giving rise to a nominal bin size of 20 meters by 20 meters. The primary use of 5-D interpolation is to fill in missing shots, receivers, offsets and azimuths corresponding to the nominal grid.

However, there is nothing preventing us in postulating a denser 10-meter by 10-meter grid and interpolating the corresponding unmigrated surface data. This smaller bin size is the interpolated equivalent of a (four times) more densely acquired survey. We then use the same processing and prestack migration procedure applied to the interpolated data on the 20-meter by 20-meter grid.

The results we show are from a land seismic data volume from western Canada. We used 5-D interpolation to build missing traces for both 20 by 20 and 10 by 10 bin sizes.

In Figure 1 we show a comparison of coherence horizon slices generated from data with 5-D interpolation at the nominal 20-meter by 20-meter bin size and at the "dense survey" 10-meter by 10-meter bin size. Notice the enhanced resolution of the faults and the suppression of the NE-SW trending acquisition footprint.

A comparison of the seismic amplitude data before and after bin size reduction is shown in Figure 2. In the dashed box we notice somewhat clearer seismic signatures corresponding to the channel features that can be seen on the coherence phantom horizon slices comparison shown in Figure 3.

Conclusion

Although the distributary channel system seen on the coherence slices is well imaged at the nominal grid size, the interpolated surface data provide much sharper individual channel limbs. Such enhanced quality imaging of data in terms of suitable seismic attributes helps squeeze out more information from the seismic data – and contributes in a generous way to the overall interpretation of the data as well.

Acknowledgments

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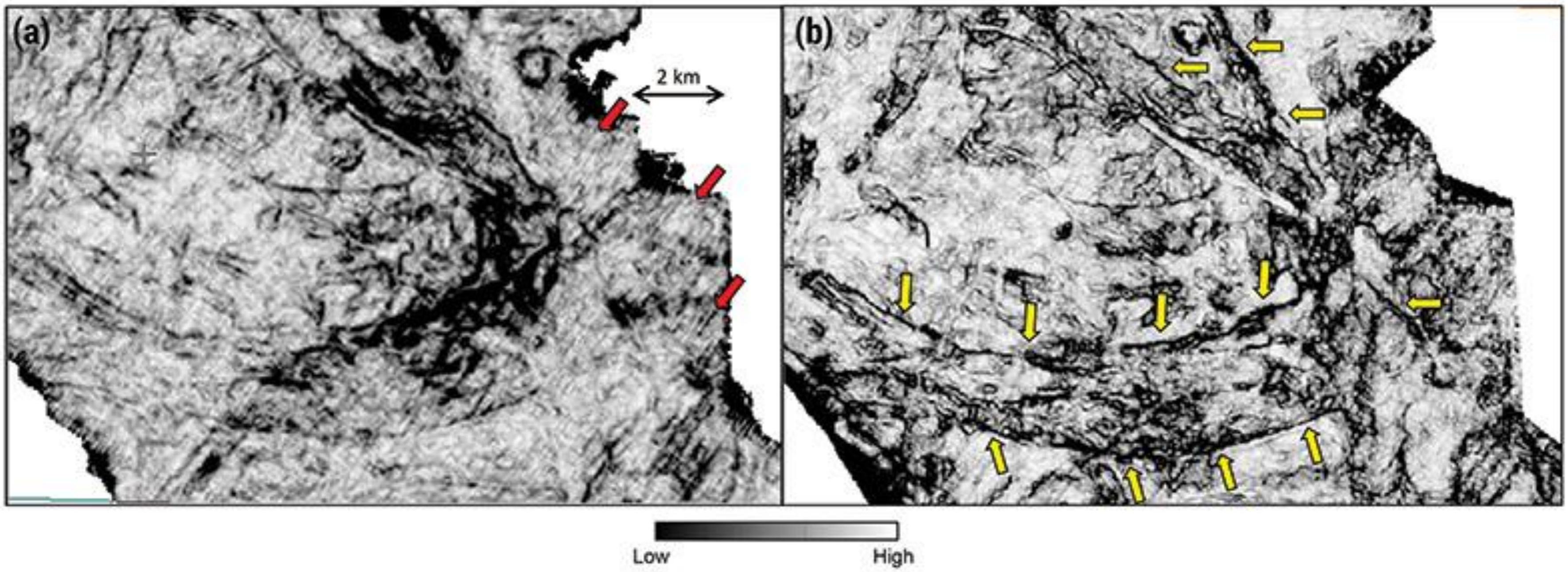

Figure 1. Stratal slices through coherence volumes close to a shallow marker horizon at t=600 ms generated from 5-D interpolated data at (a) nominal 20 m by 20 m, and (b) finer 10 m by 10 m bin size. Red arrows indicate a pervasive footprint. Yellow arrows indicate features at higher resolution.

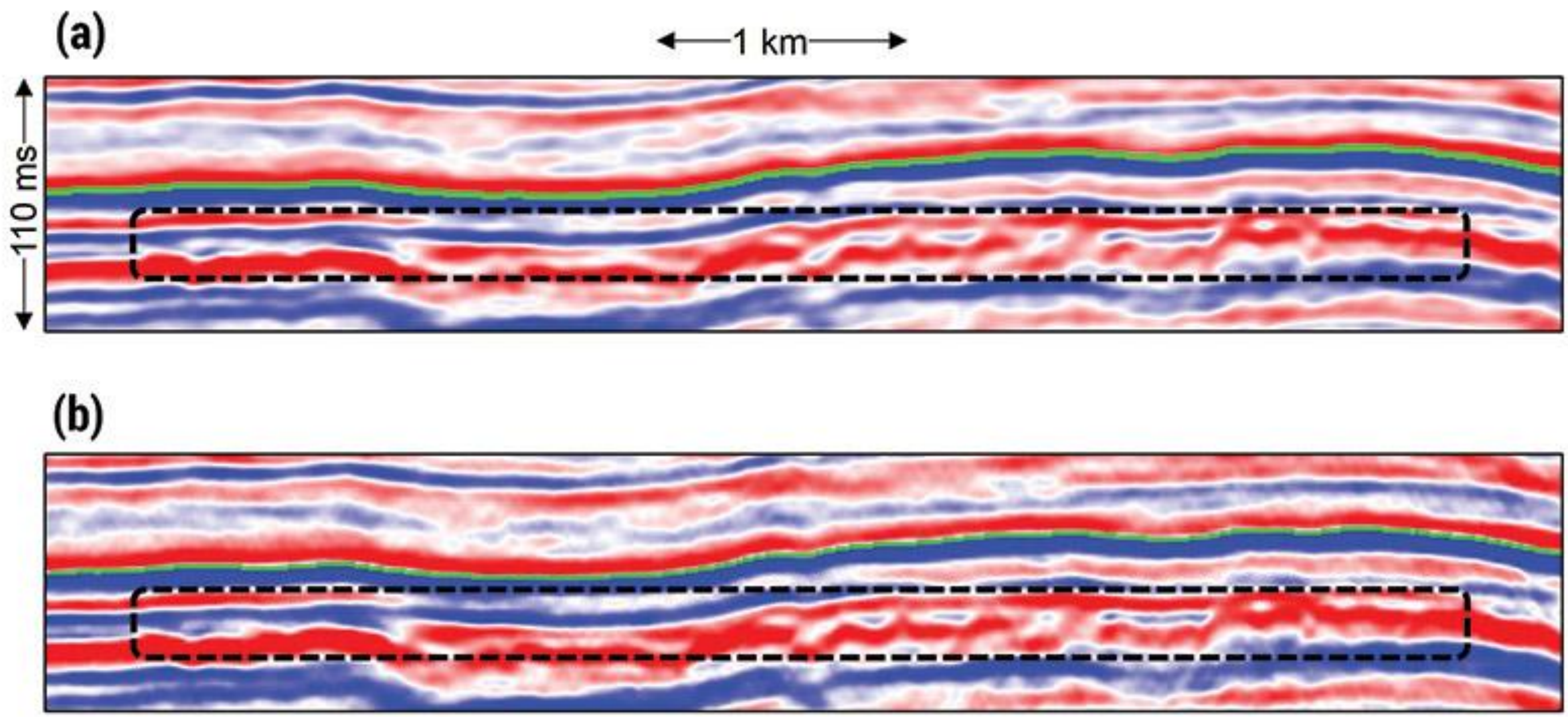

Figure 2. Vertical slice corresponding to the blue dotted line shown in Figure 3 through seismic amplitude volumes generated using 5-D interpolation generated from 5-D interpolated data at (a) nominal 20 m by 20 m, and (b) finer 10 m by 10 m bin size. Black box indicates channels delineated by coherence in Figure 3.

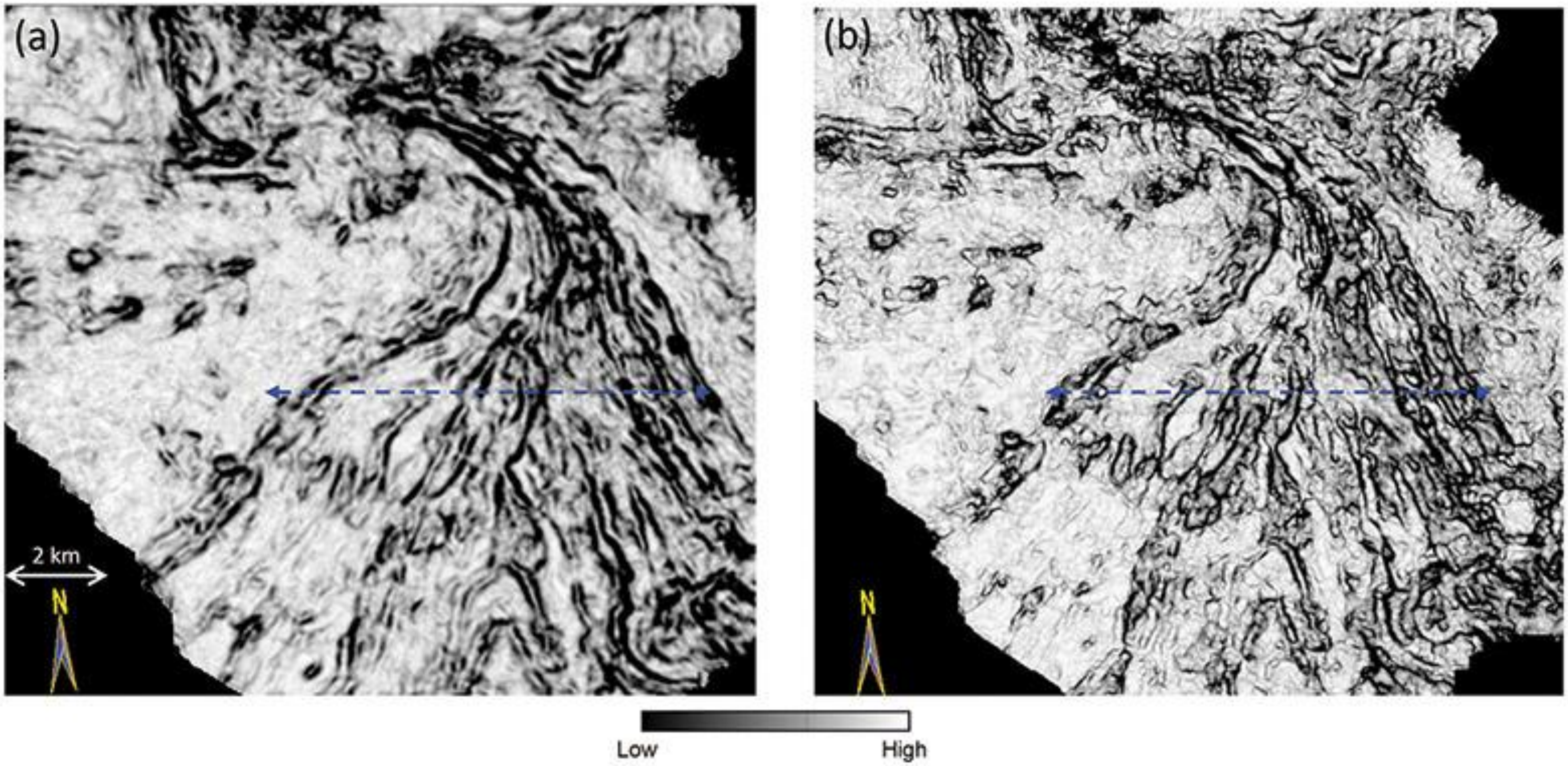

Figure 3. Phantom horizon slices 20 ms below the green horizon shown in Figure 2 through coherence volumes generated from 5-D interpolated data at (a) nominal 20 m by 20 m, and (b) finer 10 m by 10 m bin size. Blue line corresponds to vertical slice shown in Figure 2. Notice the crisp definition of the limbs of the distributary channel system.