GC Acquisition Footprint Removal for Better Fault and Curvature Attributes*

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General Statement

Seismic attributes are particularly effective for extracting subtle geologic features from relatively noise-free seismic data. However, seismic data are usually contaminated by both random and coherent noise, even when the data have been migrated reasonably well and are multiple-free. As you can see here, certain types of noise can be minimized during interpretation through careful structure-oriented filtering and post-migration suppression of data-acquisition footprints.

Another problem sometimes encountered by interpreters is the relatively low frequency bandwidth of seismic data. Although significant efforts are made during data processing to enhance frequency content of reflection signals, such efforts often fall short of the objective. Thus suitable ways need to be adopted to achieve improved frequency content of reflection data during data interpretation. We discuss both of these problems here – the suppression of acquisition footprints from seismic data, and frequency enhancement of data before final interpretation is done.

Noise Suppression

Suppression of Random Noise

Mean filters and median filters are commonly used during interpretation to suppress random noise. One valuable application is the use of dip-steered mean or median filters, which enhance laterally continuous events by reducing random noise yet does not suppress details consistent with geologic structure. Such a filter spans a defined number of data samples (N) within an aperture that follows local dip and azimuth and replaces the amplitude of the central sample with the median value of all N amplitudes spanned by the filter. Median filters can be applied iteratively, reducing random noise at each successive iteration, but they do not significantly increase the high-frequency geological components of the surface along which they operate.

Dip-steered mean filters work well on prestack data in which discontinuities appear as smooth diffractions, but they tend to smear faults and stratigraphic edges on migrated data. Dip-steered median mean filters work somewhat better, but they too can smear faults. Structure-oriented filters operate parallel to reflectors and do no filtering or smoothing perpendicular to a reflector.

Suppression of Acquisition Footprint

An acquisition footprint is defined as any amplitude or phase anomaly observed in seismic data that correlates to surface data-acquisition geometry rather than to subsurface geology. Spatially periodic changes in stacking fold, source-receiver azimuths and source-receiver offsets cause spatial periodicity in enhanced seismic signal and in noise rejection. Most seismic attributes react to these periodic changes in seismic data quality and create artifacts that mimic the source-receiver geometry.

One of the simplest methods for suppressing data-acquisition footprints is to apply kx-ky filters on seismic amplitude time slices. We show an example of this type of noise suppression on Figures 1a and 1b, where much of the vertical striping seen on the amplitude data exhibited on Figure 1a is removed on Figure 1b. Attributes calculated from seismic data that have no acquisition footprint do not display acquisition geometry artifacts and provide more accurate geologic interpretation. As an example, notice vertical receiver-line imprints that appear on the time slice of the most-positive curvature attribute on Figure 1c are not seen on the equivalent time slice in Figure 1d after the data-acquisition footprint is filtered from the amplitude data.

Frequency Enhancement

Thin-bed spectral inversion is a process that removes time-variant wavelets from seismic data and extracts reflectivity to image bed thicknesses far below seismic resolution. In addition to enhanced images of thin reservoirs, these frequency-enhanced inverse images are useful for mapping subtle onlaps and offlaps, thereby facilitating the mapping of parasequences and the direction of sediment transport.

In addition to viewing spectrally broadened seismic data in the form of reflectivity, data also can be filtered to any desired frequency bandwidth that allows useful information to be better seen for interpretational purposes.

Depending on the quality of data being interpreted, as well as access to the methods discussed here, data need to be preconditioned to optimize noise removal (whether the noise removal involves random noise or unwanted acquisition footprints) and to achieve optimal frequency-enhancement before attributes are computed. Once such data preconditioning is done, attribute computation then yields attribute maps devoid of artifacts and allows a more accurate geologic interpretation.

To illustrate the importance of data preconditioning, Figure 2 shows stratal slices from coherence volumes run on (a) input data, (b) input data with inverse Q filtering, (c) spectrally whitened input data, and (d) input data transformed to filtered thin-bed reflectivity inversion.

Notice these coherence slices show increased resolution in this a-b-c-d order of data preconditioning, with the highest lateral resolution seen for coherence computed from filtered thin-bed reflectivity inversion.

We emphasize that computation of attributes is not a process that involves pressing some buttons on a workstation, but requires careful examination of input seismic data in terms of signal-to-noise ratio, noise contamination, and frequency content.

Conclusions

In our studies, we find that:

- Attributes calculated from seismic data that have a high signal-to-noise ratio and that are processed for acquisition footprint suppression exhibit geological features clearly without any masking.

- Enhancement in the frequency content of data volumes occurs in the order shown on Figure 2.

Some of these data-conditioning methods may not be available to an interpreter; we hope these examples assist in decisions about how seismic interpretation software and workstation capabilities may need to be adjusted to improve data interpretations.

Acknowledgment

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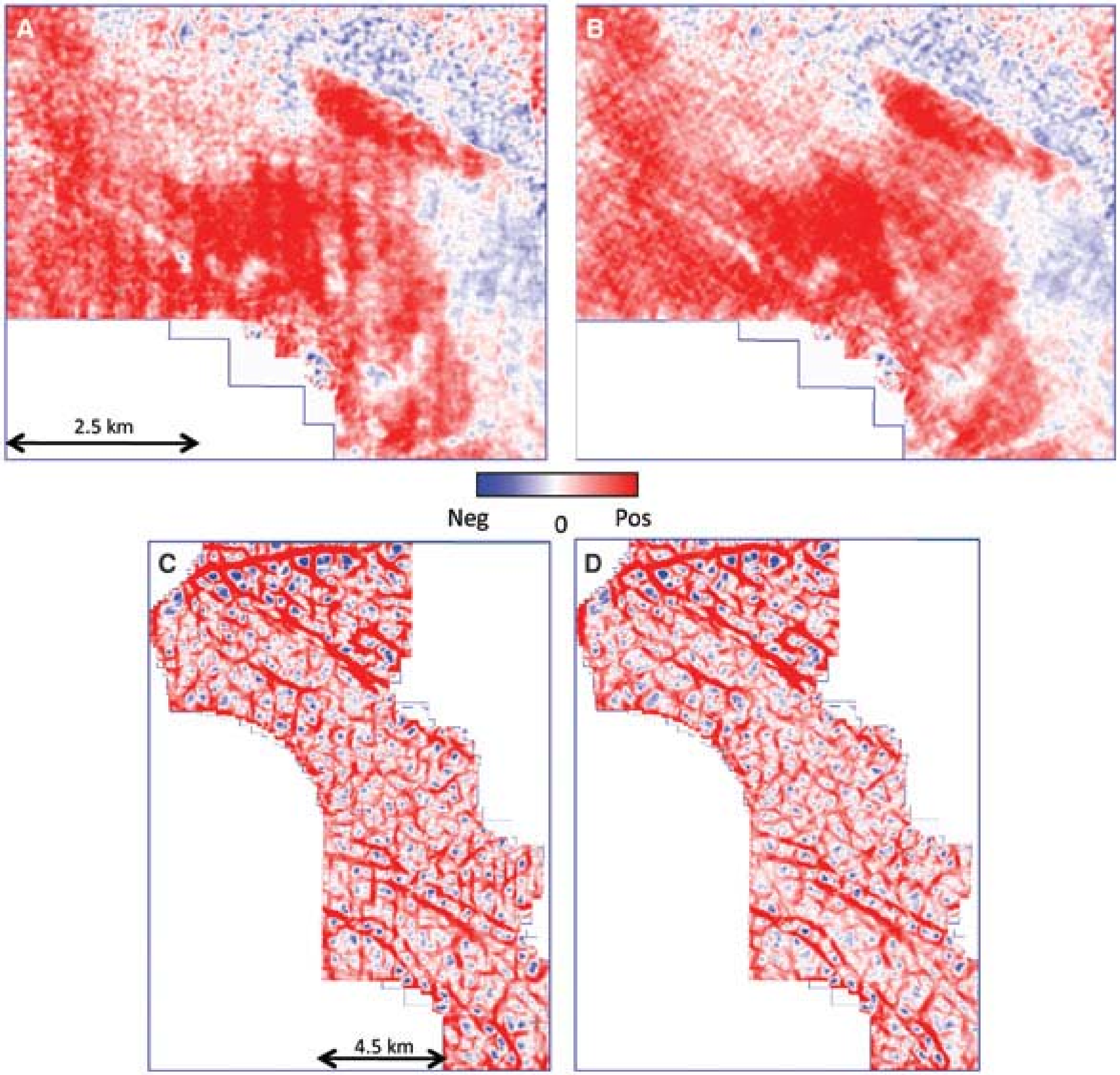

Figure 1. Time slices of reflection amplitude at 769 ms (a) without, and (b) with kx-ky filtering for suppression of acquisition footprint. The vertical striations (acquisition footprint) seen on panel a are removed on filtered panel b. Stratal slices of most-positive curvature calculated from data (c) before, and (d) after footprint filtering. Numerous vertical trends seen on panel c are eliminated on panel d.

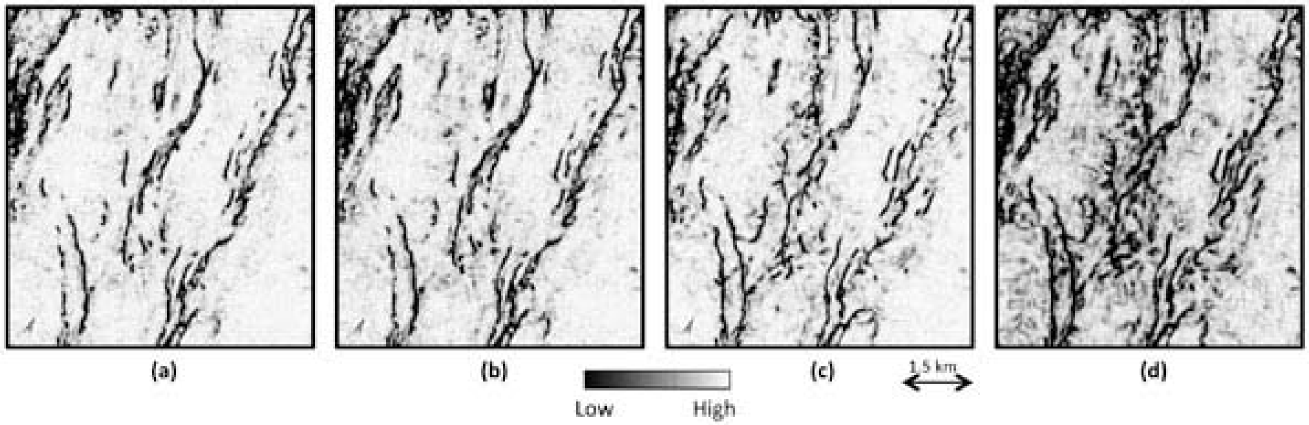

Figure 2. Stratal slices from coherence attribute calculated (a) from input data, and after (b) Q compensation, (c) time-variant spectral whitening and (d) filtered thin-bed inversion. More detail is seen as data conditioning steps progress from a to d.