The interpretational value of mega-merged reprocessed legacy data volumes.

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ABSTRACT

Since its introduction in the 1980s, 3D seismic surveys blanket more and more of Midcontinent of the USA and are not only used by geophysicists at large oil companies but also by geologists and engineers in small partnerships. Many of these non-geophysical seismic interpreters are unfamiliar with concepts of migration aperture and advances in seismic processing. Even for those well versed in seismic technology, they need to justify the purchase of merged, reprocessed data to their business colleagues. We provide a case study of such a financial investment illustrating the value through improved attribute images.

INTRODUCTION

The Watonga survey was acquired by Amoco in three stages (1993, 1994 and 1996) with the main objective of imaging the Red Fork interval within the Anadarko Basin. The Watonga survey is of particular interest because it served as the first published application of 3D spectral decomposition analysis (Peyton et al., 1998). Chesapeake Energy bought the Amoco property and associated seismic data in the late 1990s. In 2009, Chesapeake and several other companies licensed their 3D surveys to CGG-VERITAS to form a "mega-merge" survey (Figure 1 and Table 1). Missing areas were shot to form more continuous coverage. To further facilitate the geologic interpretation of this area, these newly acquired and legacy pre-stack volumes were then reprocessed together with newer technology including the noise attenuation and migration algorithm shown in Table 2, such that one survey helps imaging adjacent areas in previously separately processed, but adjoining surveys. Comparing the amplitude spectrum of the 'mega merged" and the Watonga surveys, we observed that the mega merged survey is better amplitude spectrally balanced than Watonga survey in the zone of interest (Between Pink Lime to the Novi Formations) (Figure 2).

ATTRIBUTE SENSITIVITY TO REPROCESING

3D seismic attributes enable the interpreter to better visualize subtle subsurface geological structures. In the Red Fork interval, channel patterns can be delineated using edge- and facies-sensitive attributes such as coherence, Sobel filter similarity and most positive and most negative curvature. Lateral changes in amplitude and thickness can be mapped using spectral component attributes . Acquisition footprint as well as other seismic artifacts are present in the Watonga survey, severely contaminating seismic attributes such as curvature. Reprocessing and merging adjacent legacy surveys, better delineates previously hidden geologic features.

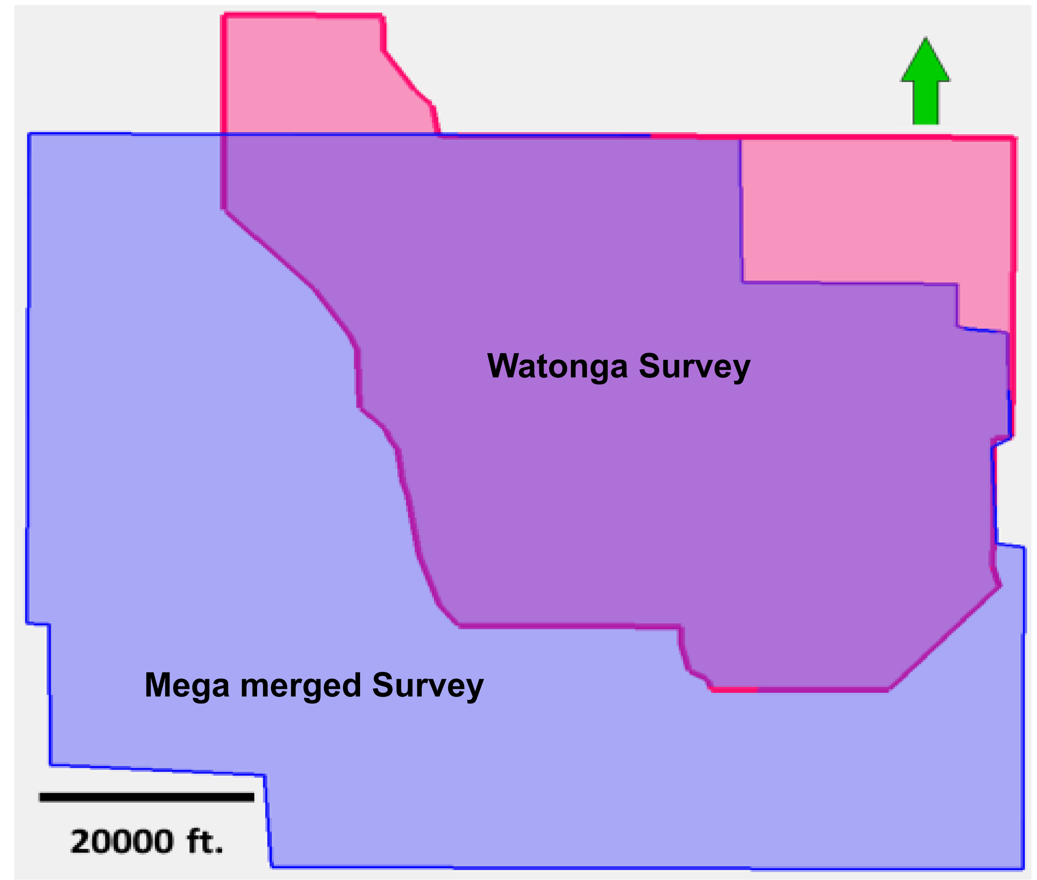

Figure 1. Base map of the mega merged survey (blue) and Watonga survey area (magenta).

	Mega merged survey	Watonga survey
Bin size	110ft*110ft	82.5ft*82.5ft
Inline direction	N-S	W-E
Crossline direction	W-E	N-S
Total number of inlines	872	886
Total number of crosslines	721	923
Seismic area	244.6 mi^2	136 mi^2

Table 1. Acquisition geometry of the mega merged and Watonga surveys

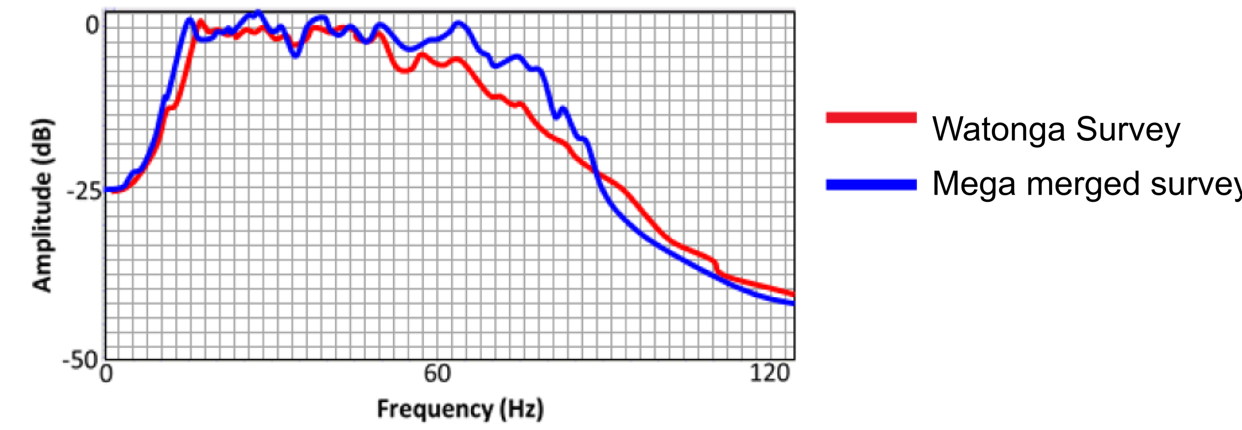

Figure 2. Amplitude spectrum of the Watonga and mega merged surveys. Note how higher frequencies are preserved on the mega merged survey.

Demultiplex/reformat (3D geometry and manual trace edits): Geometry QC: Binned 110ft by 110ft
Spreading gain recovery type: T^2 (Phase Matching)
Noise burst attenuation (not on Watonga surveys)
Surface consistent deconvolution (Operator length 160 ms, prewhitening= 10%)
Surface consistent gain: Spiking Deconvolution: Operator length=160 ms. Consistency Scaling: Line/Shot/Receiver terms
Tomographic refraction statics (Datum: 1900 ft. Offset 0-10000 ft, replacement velocity=8500ft/s)
Velocity analysis, phase matching, surface consistent residual statics
Velocity analysis, noise burst attenuation, spectral whitening 4/8-115/130 Hz
Phase matching, surface consistent residual statics
FX Noise attenuation – shot domain, velocity analysis
Surface consistent gains, CDP Trim statics, 1500 ms pre-stack gain
Pre-stack time migrated Flexi-binning
Pre-stack time migrated velocity analysis
Pre-stack Kirchhoff time migration
Residual velocity analysis, NMO, mute application and tomographic long wavelength

Table 2. 2006 processing sequence applied to the mega merge survey, which included five input surveys.

CURVATURE: When extracting structural curvature attributes through the Red Fork Formation, two main curvature responses can be interpreted over the channels features. For narrow channels, we observed high most-positive curvature on the edges and high most-negative curvature values along the channel axis or thalweg. For wide channels, high most-positive curvature on the edges and high most-negative curvature values on the channel base edges and zero curvature on the bottom channel plane. Note how the curvature attributes over the 1993-1996 vintage Watonga survey are less detailed than over the newer mega-merge survey. The channel associated with the Red Fork Formation are better delineated by the attributes extracted over the mega-merged survey.

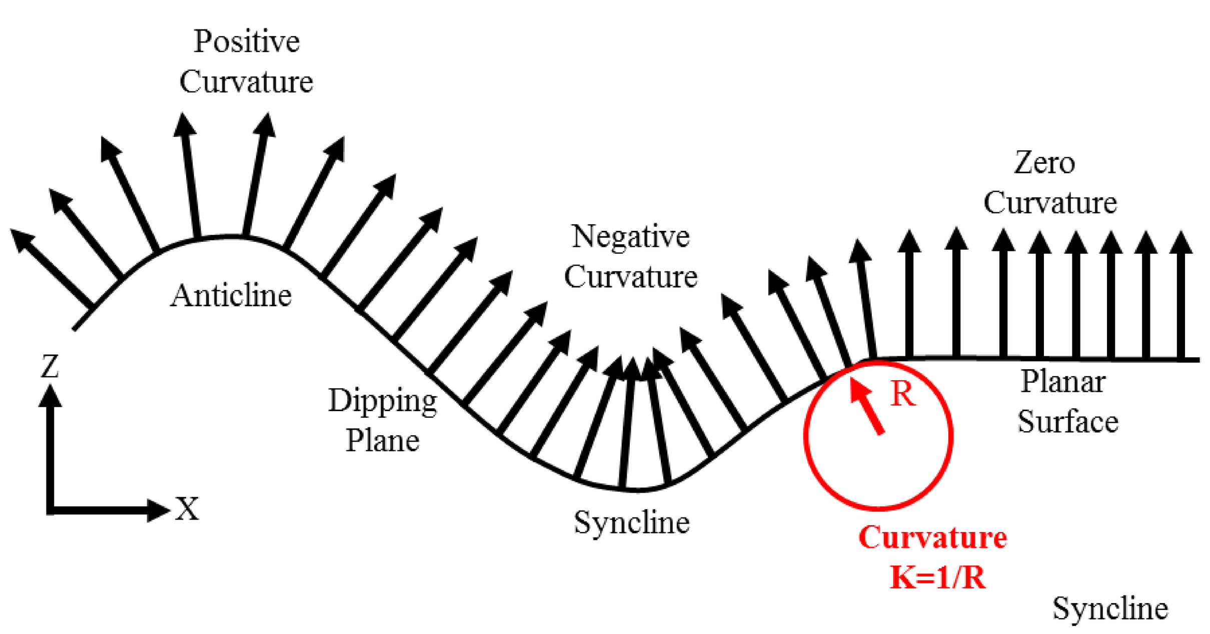

Figure 3. 2D curvature (K) of a two-dimensional line defined. Anticline features have positive curvature, synclinal features have negative curvature and planar features (horizontal or dipping) have zero curvature (After Roberts, 2001).

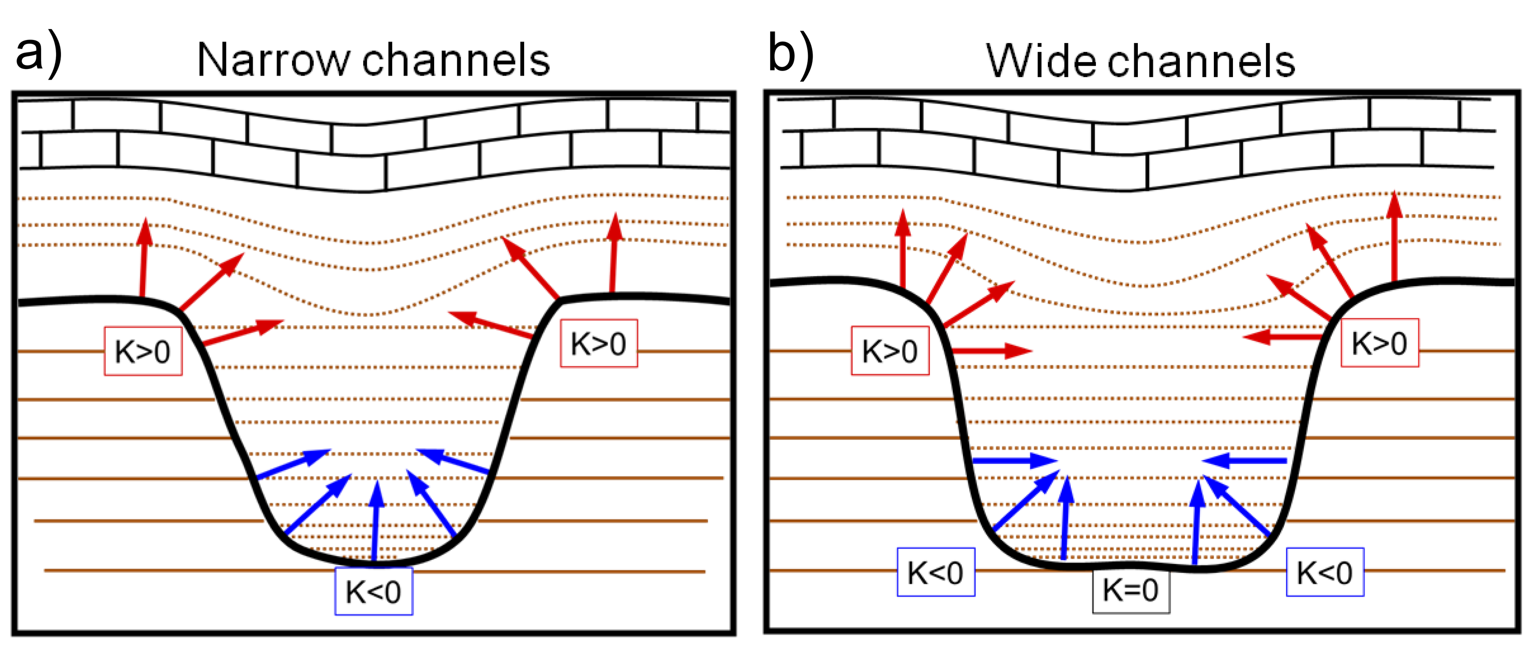

Figure 4. Curvature response of the Red Fork Formation channels. a) Narrow channels are expected to have high most-positive curvature on the edges and high most-negative curvature values on the channel's thalweg. b) Wide channels are expected to have high most-positive curvature on the edges and high most-negative curvature values on the channel base edges and zero curvature on the thalweg plane. Both may give rise to differential compaction anomalies in overlying sediments.

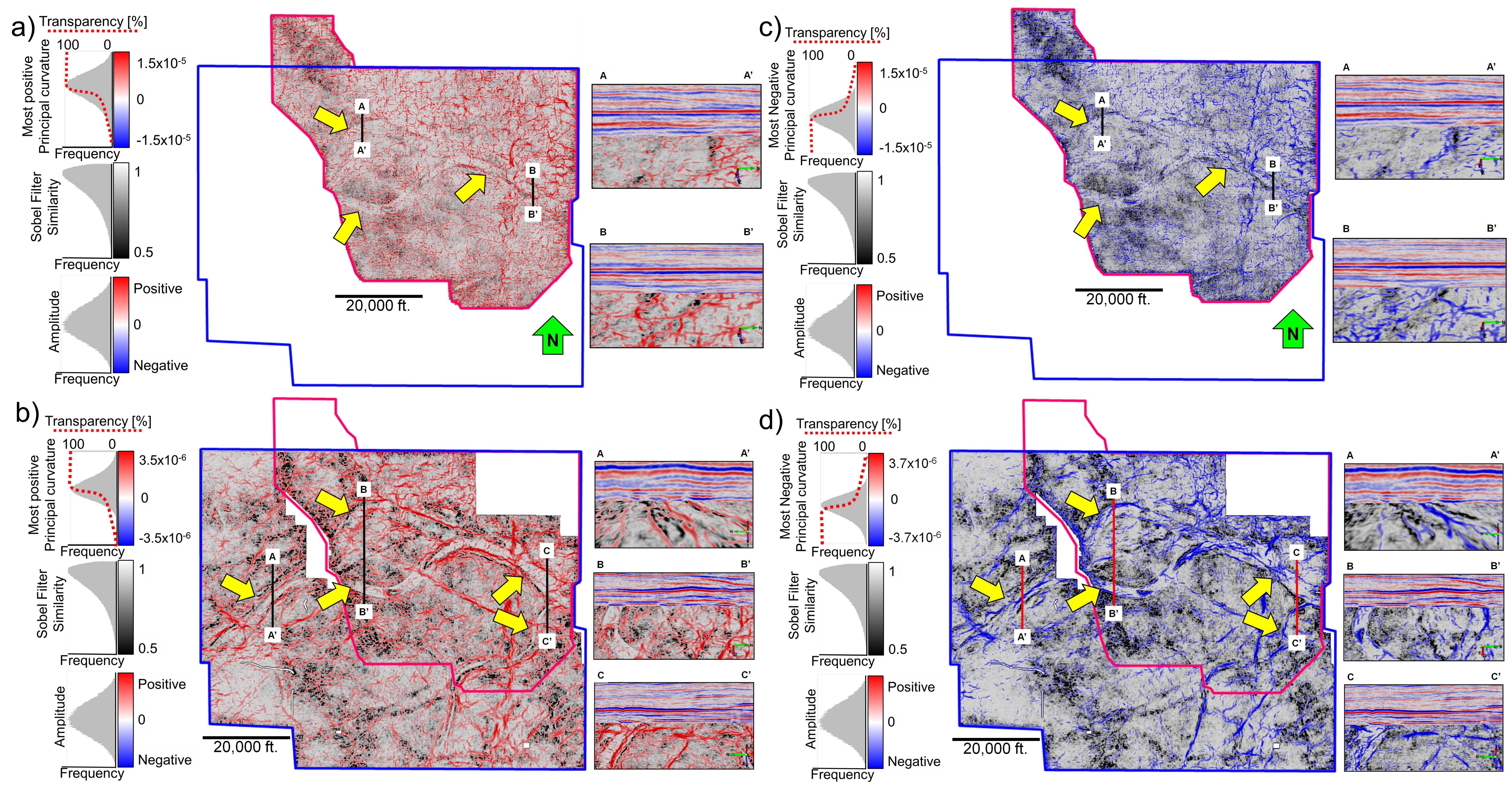

Figure 5. Phantom horizon slice 12 ms below the Pink Lime horizon through the most positive principal curvature co-rendered with the Sobel filter similarity volume on the (a) 1993-1996 vintage Watonga and the (b) mega merged survey. Same phantom horizon most negative principal curvature co-rendered with the Sobel filter similarity volume on the (c) 1993-1996 vintage Watonga and the (d) mega merged survey. Yellow arrows indicate incised channels. Notice the better delineation of the edges of the channels by the Sobel filter similarity and the highest values of most positive curvature. A-A', B-B' and C-C' vertical sections through the main valley fill in the Red Fork Formation.

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COHERENCE: Coherence attributes are useful in delineating channel edges when those channels are thick enough to cause measurable changes in the form of the wavelet (Chopra and Marfurt, 2010). We used energy-ratio similarity volumes (the ratio of the energy of the Karhunen-Loeve filtered data over the energy of the original unfiltered data) to illustrate the impact of reprocessing. Sobel filter similarity measures lateral changes in amplitude (Chopra and Marfurt, 2010). Depending on geology and data quality, Sobel filter similarity may delineate subtle edges not seen by energy ratio similarity, particularly for features below one fourth (¼) wavelength resolution. The greater acquisition footprint is due to lack of careful amplitude balancing in the Watonga Survey using the original processing sequence (Figure 6).

SPECTRAL DECOMPOSITION: Spectral decomposition is sensitive to subtle interference patterns, such as thin-bed tuning associated with channels in a plan view (Chopra and Marfurt, 2010). Since the data were previously spectrally whitened during the seismic processing stage, the spectral components exhibit the tuning effects of the geology with different channel thicknesses and infill exhibiting different spectral responses. In general, thinner beds will be better displayed with higher frequency components, and thicker beds with lower frequency components.

In Figures 8, the 14 Hz, 34 Hz and 54 Hz spectral components are co-rendered along a horizon slice extracted 12ms below the Pink Lime Formation. Stages of fill are defined by the different frequencies.

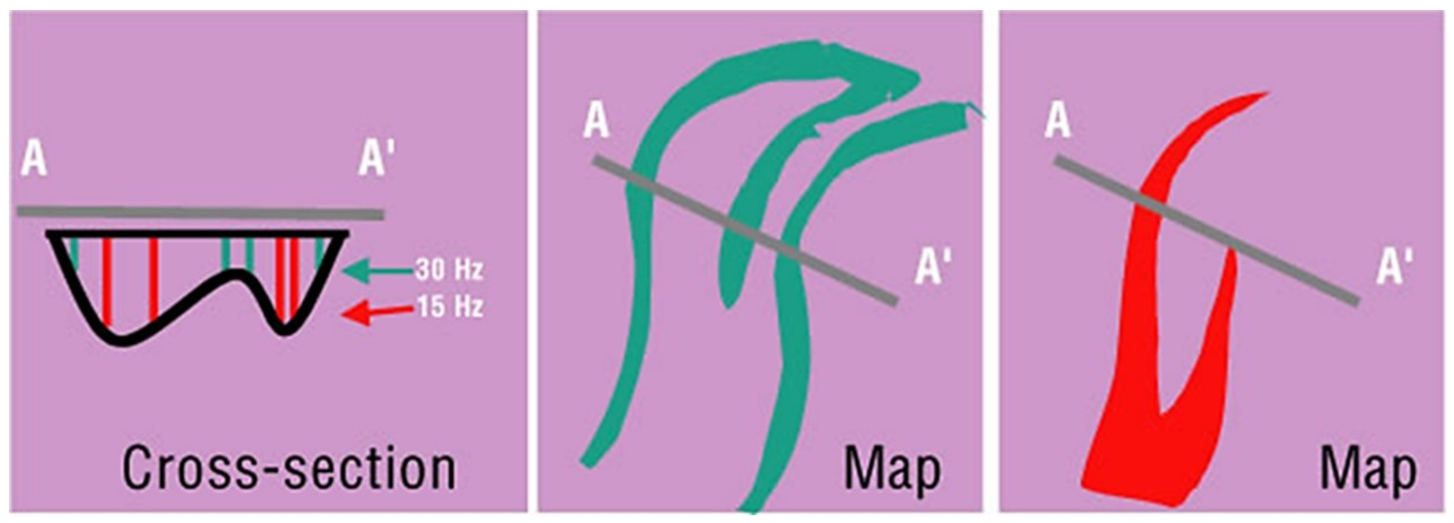

Figure 7. Schematic diagram showing the effect of thin bed tuning analyzed using different frequencies (After Laughlin et al., 2002).

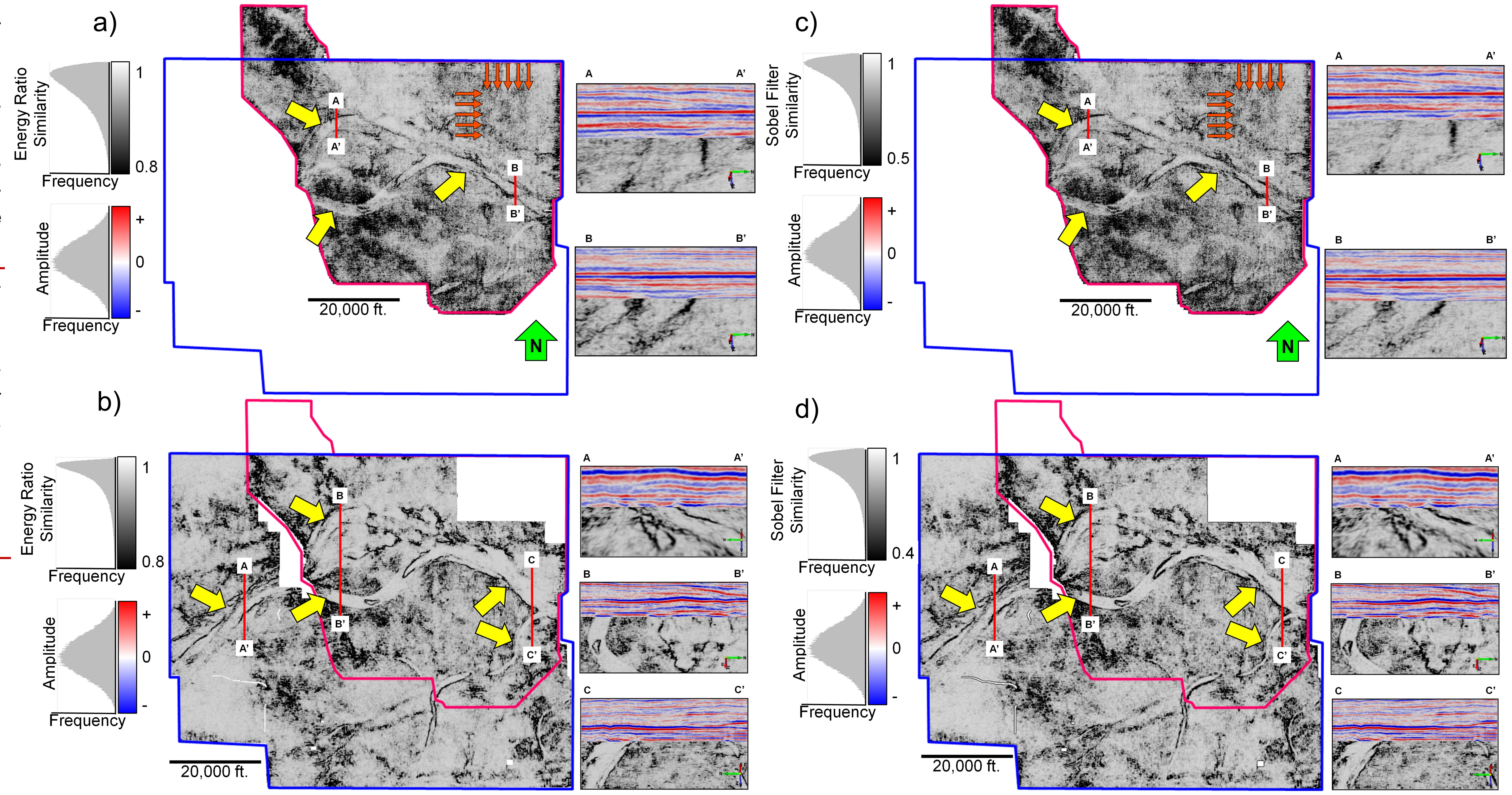

Figure 6. Phantom horizon slice 12 ms below the Pink Lime through the energy ratio similarity (coherence) volume computed from the (a) 1993-1996 vintage Watonga and (b) mega merged survey. Same phantom horizon slice 12 ms below the Pink Lime through the Sobel filter similarity volume computed from the (a) 1993-1996 vintage Watonga and (b) mega merged survey. Yellow arrows indicate incised channels. Notice the reduction on the footprint. A-A', B-B', and C-C' vertical sections through the main valley fill in the Red Fork Formation.

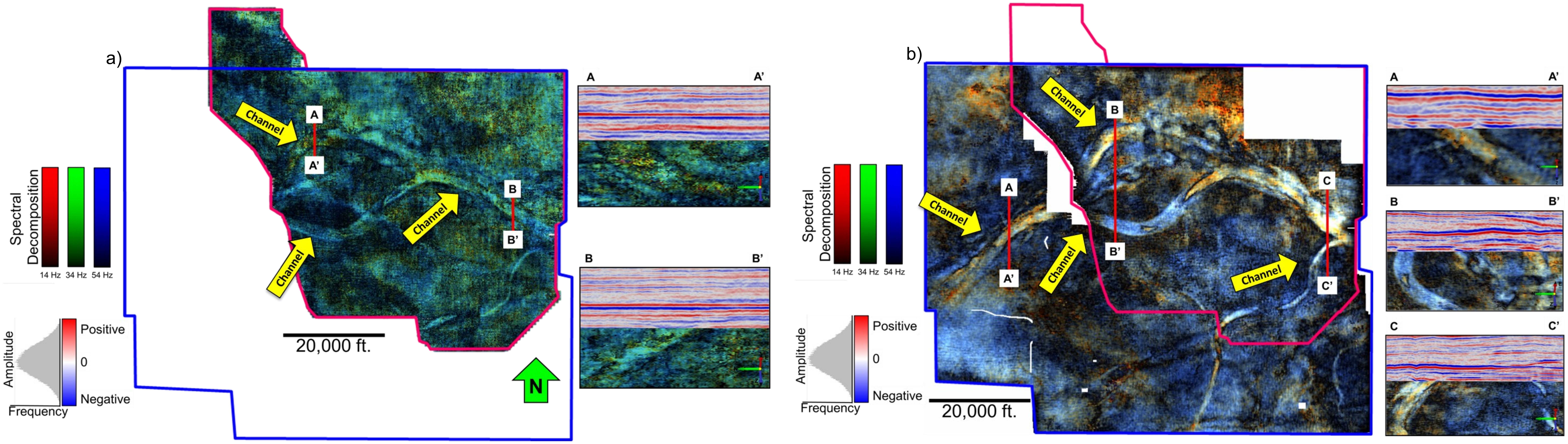

Figure 8. Phantom horizon slice 12 ms below the Pink Lime displaying the Red Fork Formation channel features highlighted by three spectral frequencies at 14 Hz (red), 34 Hz (green), and 54 Hz (blue) on the (a) 1993-1996 vintage Watonga survey and (b) mega merged survey. Yellow arrows indicate incised channels. A-A'and B-B' vertical sections through the main valley fill in the Red Fork Formation. Note that A-A' corresponds to B-B' and B-B' to C-C'.

CONCLUSIONS

Carefully re-procesing of legacy seismic data can significally improve the delineation of geologic features such as the Red Fork incised valleys.

Careful trace balancing diminishes acquisition footprint, which dominates not only edge-sensitive coherence and curvature attributes, but also spectral components and impedance inversion.

Merging multiple surveys not only improves the delineation of geology at the survey edges, but also by providing a larger view, places the acreage of interest into a larger depositional environment context.

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