Improving fault segmentations using maximum entropy based multispectral coherence

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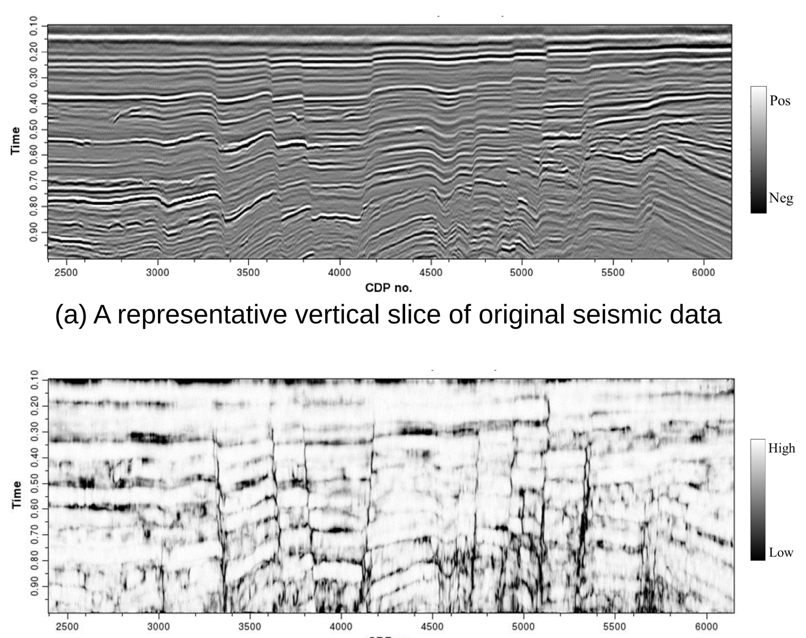
Introduction

Seismic coherence followed by smoothing, sharpening, and skeletonization has significantly improved fault images. However, if there are relatively similar reflectors juxtaposing across the faults, the coherence images of faults computed from the full-bandwidth seismic data often appear segmented as coherence gaps. We developed a maximum entropy based multispectral coherence method to improve these fault segmentations. Because the phase is different for different spectral components, alignment effects occur for only a few spectral components not all components, which helps to improve the fault segmentations due to the similar reflectors across faults. We evaluate the method with the Opunake 3D seismic survey acquired in the offshore Taranaki Basin, New Zealand.

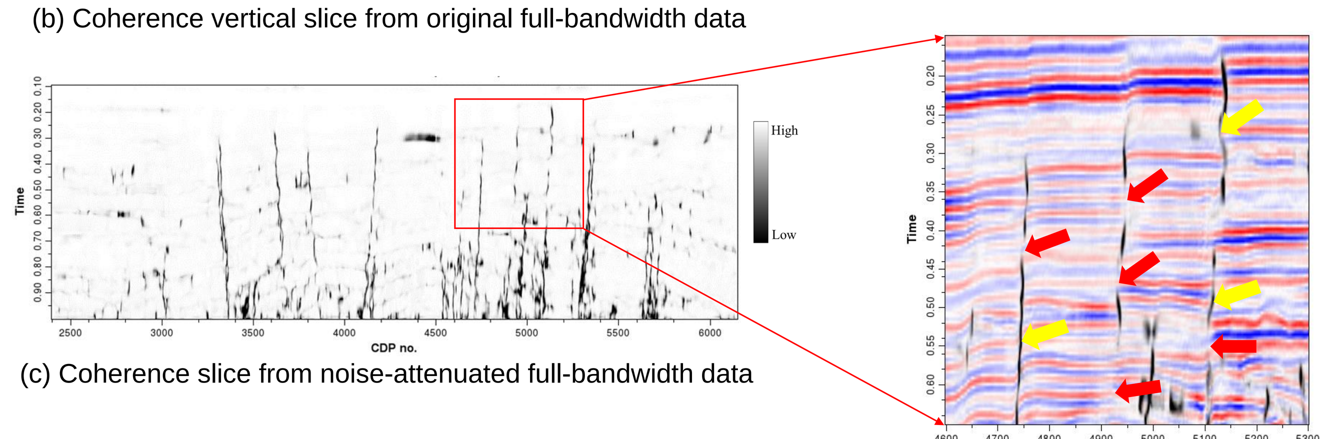
Limitation of full-bandwidth coherence



(a) A representative vertical slice of original seismic data

(b) Coherence vertical slice from original full-bandwidth data

The coherence image (Figure 1b) computed from original full-bandwidth seismic data (Figure 1a) suffers from serious noise, including either seismic noise (low amplitude shale-on-shale reflections overprinted by larger amplitude noise) or geologic noise (condensed sections or other unconformities). Noise attenuation could effectively suppress artifacts in full-bandwidth coherence image (Figure 1c), but we still face the challenge of coherence segmentations in presence of juxtaposition of relatively similar reflectors across faults (Figure 1d).

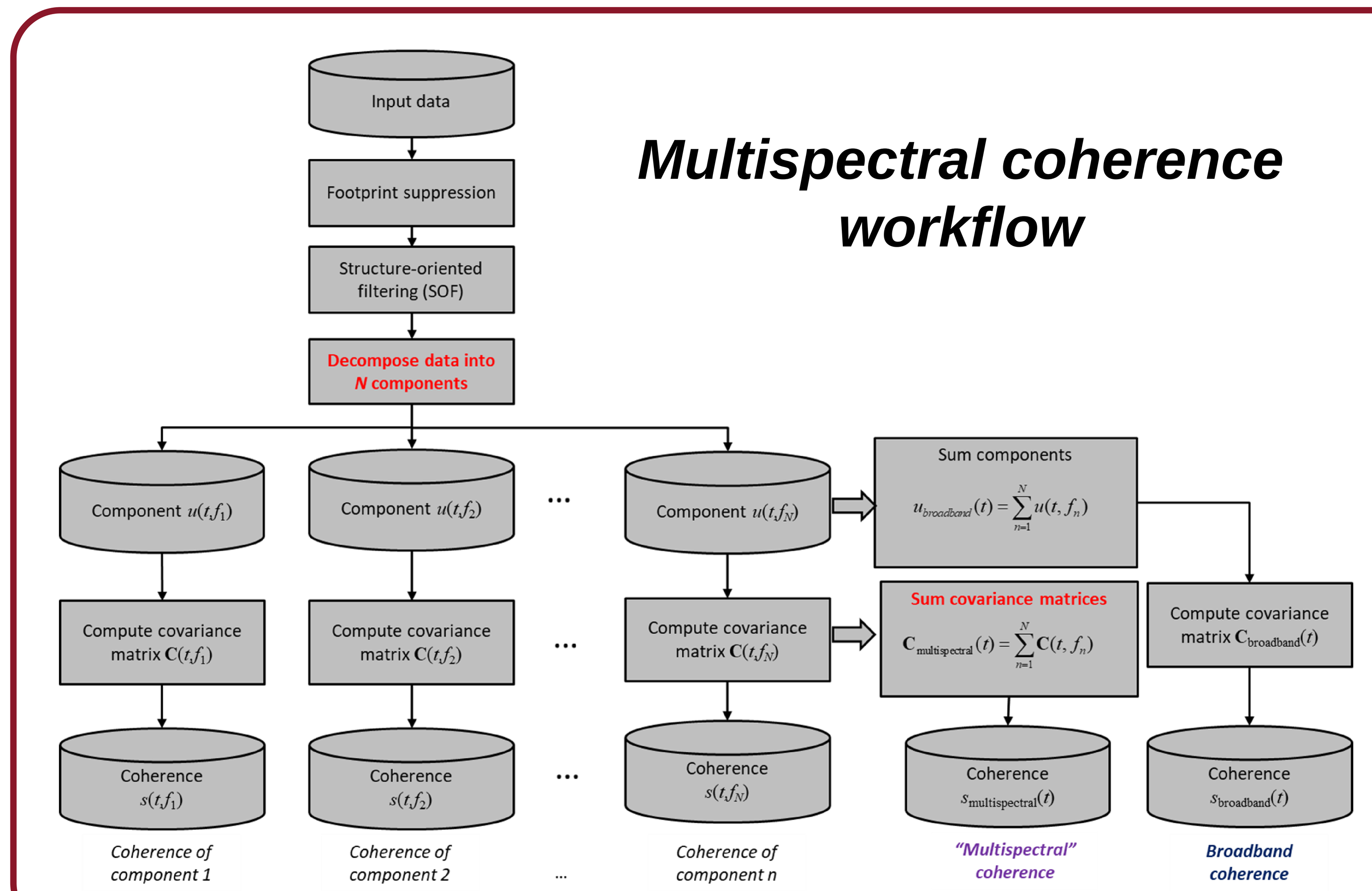


(c) Coherence slice from noise-attenuated full-bandwidth data

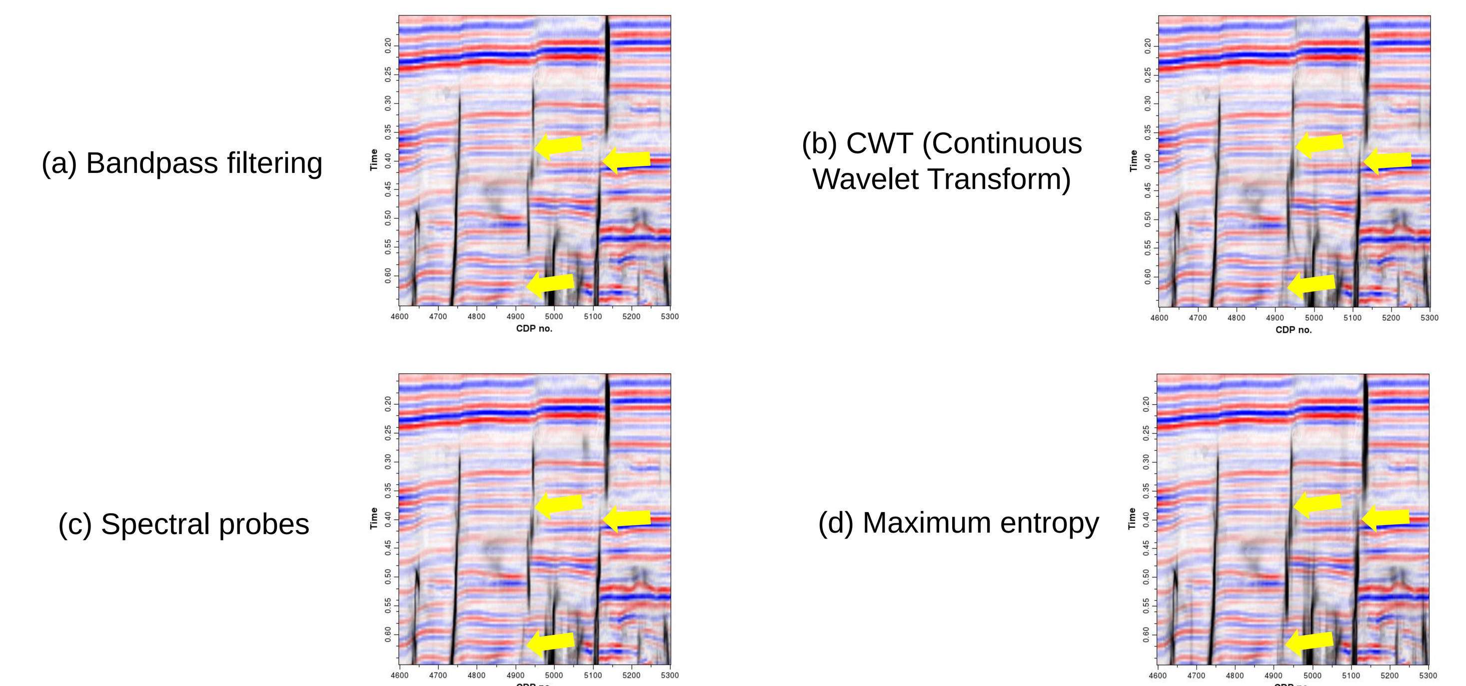
(d) Coherence co-rendered with amplitude

Figure 1: Coherence images from full-bandwidth data

Multispectral coherence workflow



Which spectral decomposition should we choose?



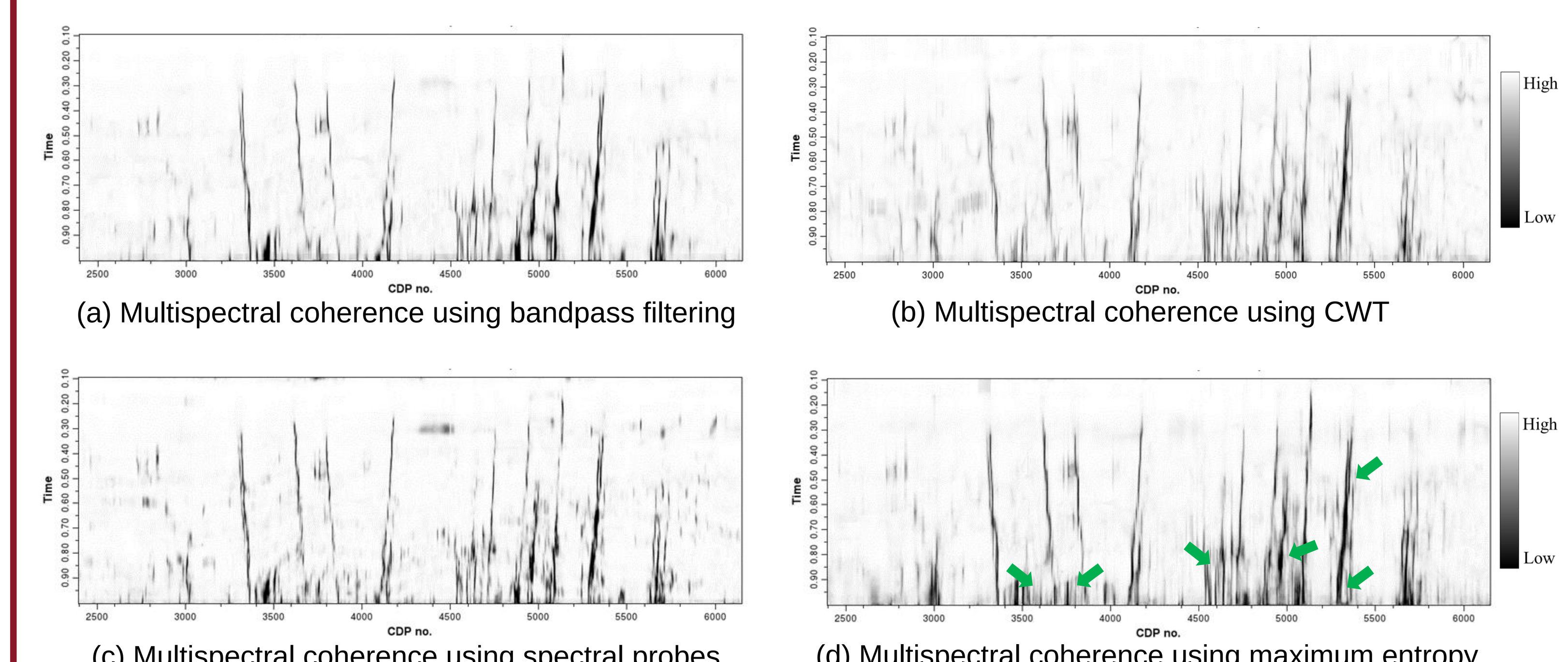
(a) Bandpass filtering

(b) CWT (Continuous Wavelet Transform)

(c) Spectral probes

(d) Maximum entropy

Figure 2: Maximum entropy based multispectral coherence provides the most continuous coherence image of the faults compared to other spectral decomposition methods



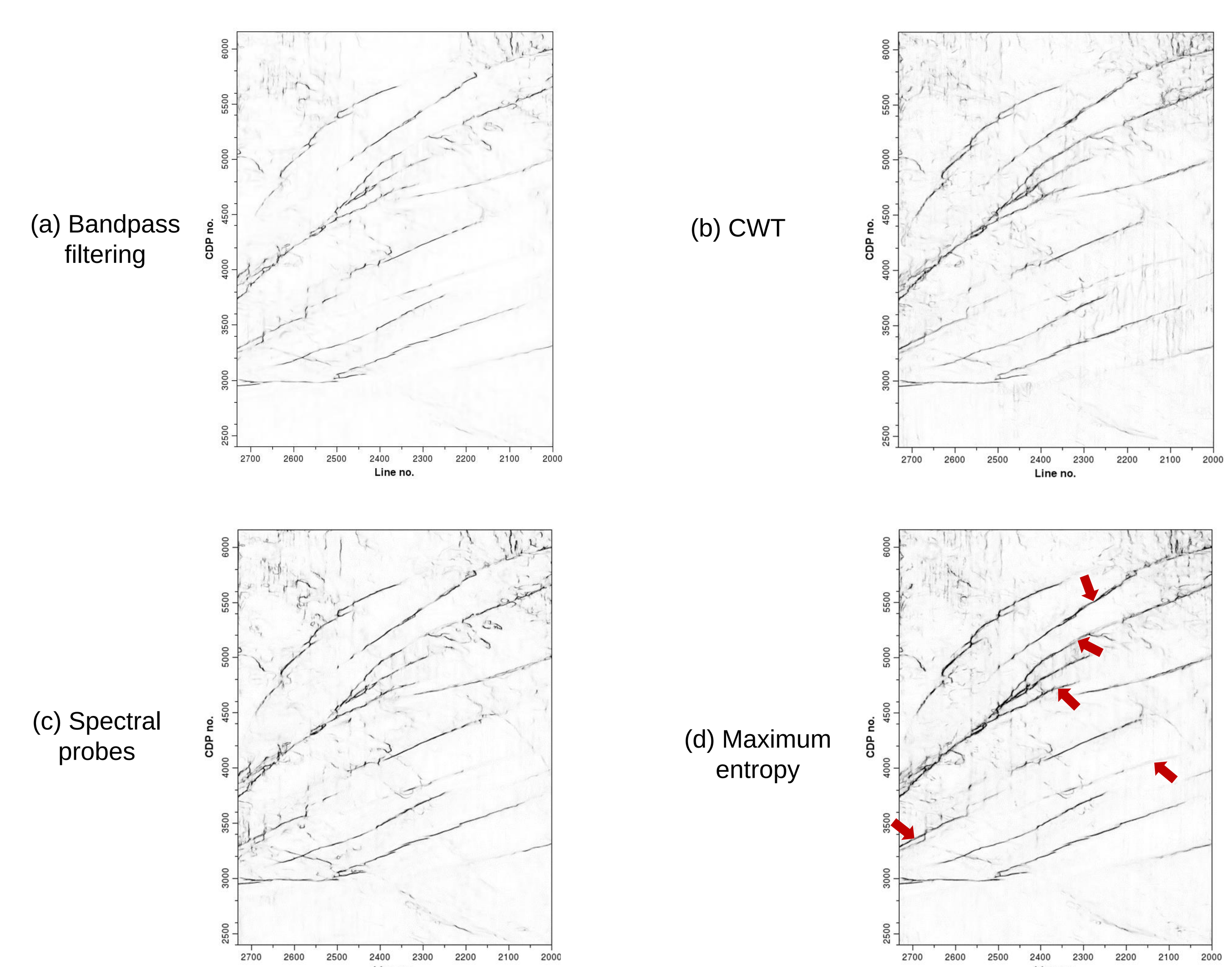
(a) Multispectral coherence using bandpass filtering

(b) Multispectral coherence using CWT

(c) Multispectral coherence using spectral probes

(d) Multispectral coherence using maximum entropy

Figure 3: Multispectral coherence vertical slices using different spectral decomposition methods. Note the improvement of lateral resolution using maximum entropy method, highlighting small-scale discontinuities.



(a) Bandpass filtering

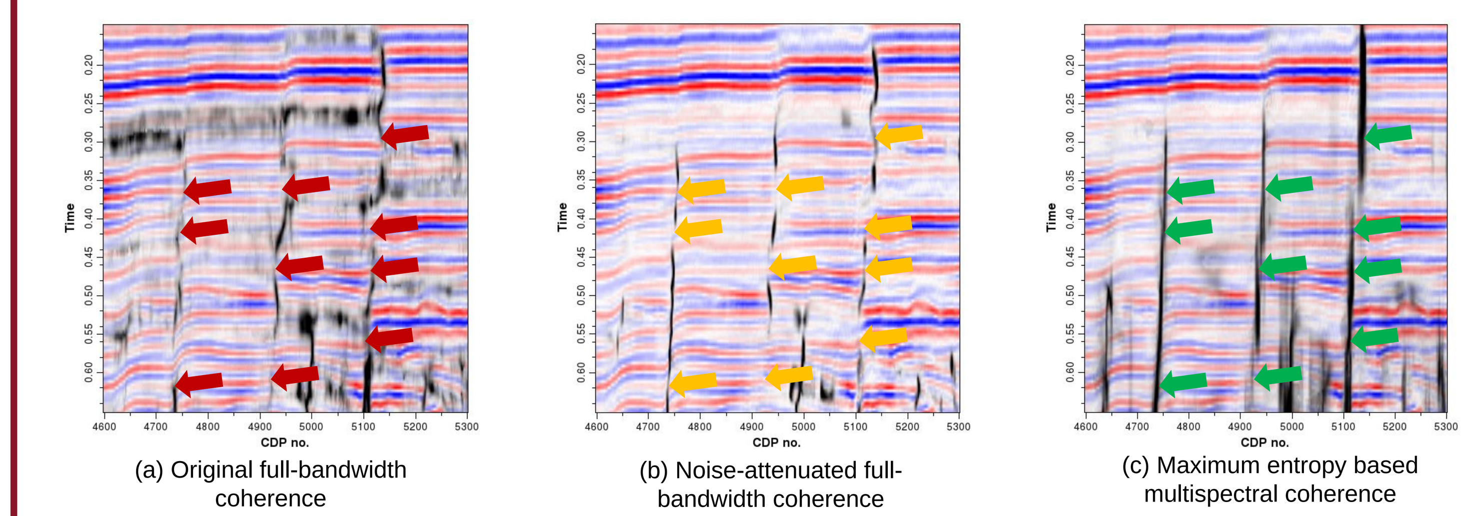
(b) CWT

(c) Spectral probes

(d) Maximum entropy

Figure 4: Multispectral coherence time slices (0.4s) using different spectral decomposition methods. Note the improvement of continuity of fault imaging using the maximum entropy method.

Improvement of fault segmentations



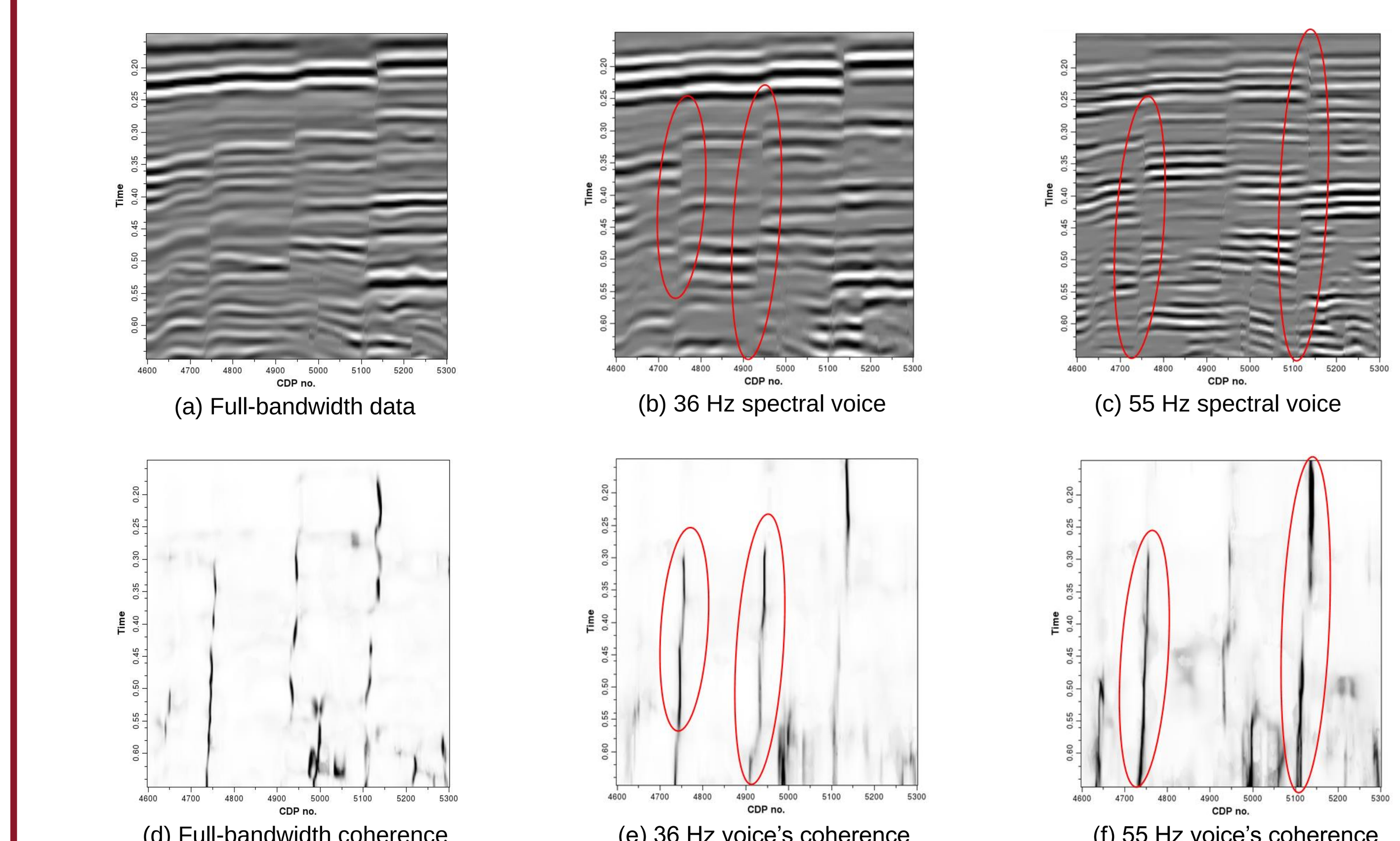
(a) Original full-bandwidth coherence

(b) Noise-attenuated full-bandwidth coherence

(c) Maximum entropy based multispectral coherence

Figure 5: The full-bandwidth coherence computed using the noise-attenuated seismic data improves the quality of fault imaging over the original full-bandwidth coherence. Maximum entropy based multispectral coherence further improves the fault segmentations.

Why the method works?



(a) Full-bandwidth data

(b) 36 Hz spectral voice

(c) 55 Hz spectral voice

(d) Full-bandwidth coherence

(e) 36 Hz voice's coherence

(f) 55 Hz voice's coherence

Figure 6: Coherence computed using full-bandwidth seismic data appears segmented due to the similar reflectors juxtaposing across the faults. However, because the phase is different for different spectral voices, alignment effects occur for only a few spectral voices not all components, which helps to fill the coherence gaps.

Conclusions

- Coherence images from full-bandwidth seismic amplitude volume behave segmented (high coherence) if relatively similar reflectors juxtapose across the faults, even after careful noise attenuation.
- Maximum entropy based multispectral coherence effectively improves the fault segmentations in coherence images, helping fault detection.

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References

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