A multistep fault enhancement workflow

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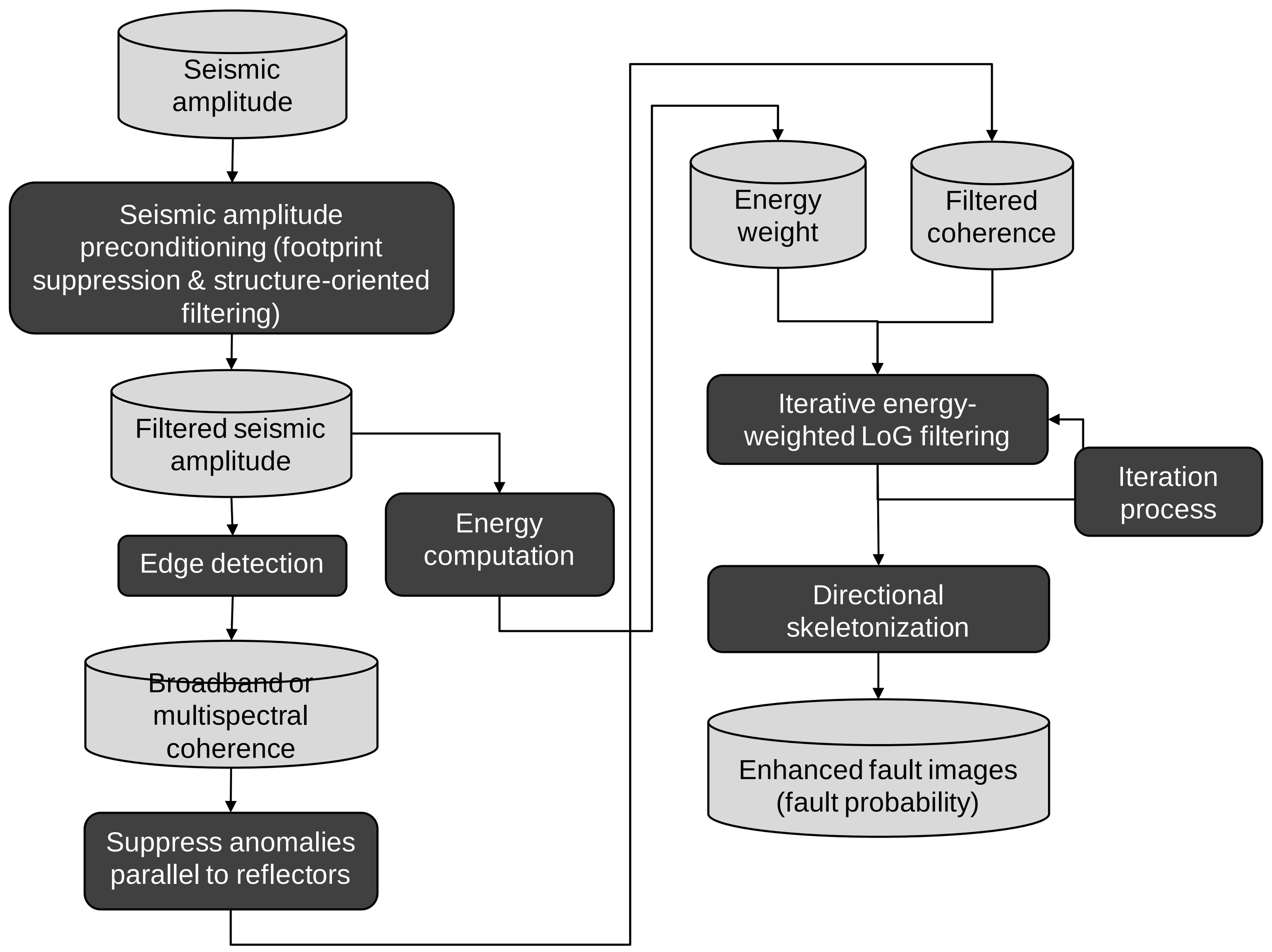
Summary

We propose a fault attribute workflow which contains footprint suppression, structure-oriented filtering, attribute computation, "unconformity" suppression, and our new iterative energy-weighted directional Laplacian of a Gaussian (LoG) operator. In general, tracking faults that exhibit finite offset through a suite of conformal reflectors is relatively easy. Instead, we evaluate the effectiveness of this workflow by tracking faults through an incoherent mass transport deposit, where the low frequency contribution of multispectral coherence provides a good fault image. Multispectral coherence also reduces the "stair step" fault artifacts seen on the broadband data. Application of statistically filtering can preserve discontinuity's boundaries and reject incoherent background. Finally, iterative application of an energy-weighted directional LoG operator provides improved fault image by sharpening low coherence anomalies perpendicular and smoothing low coherence anomalies parallel to fault surfaces, while at the same time attenuating locally non-planar anomalies.

Fault enhancement workflow



The limitations of coherence in fault definition

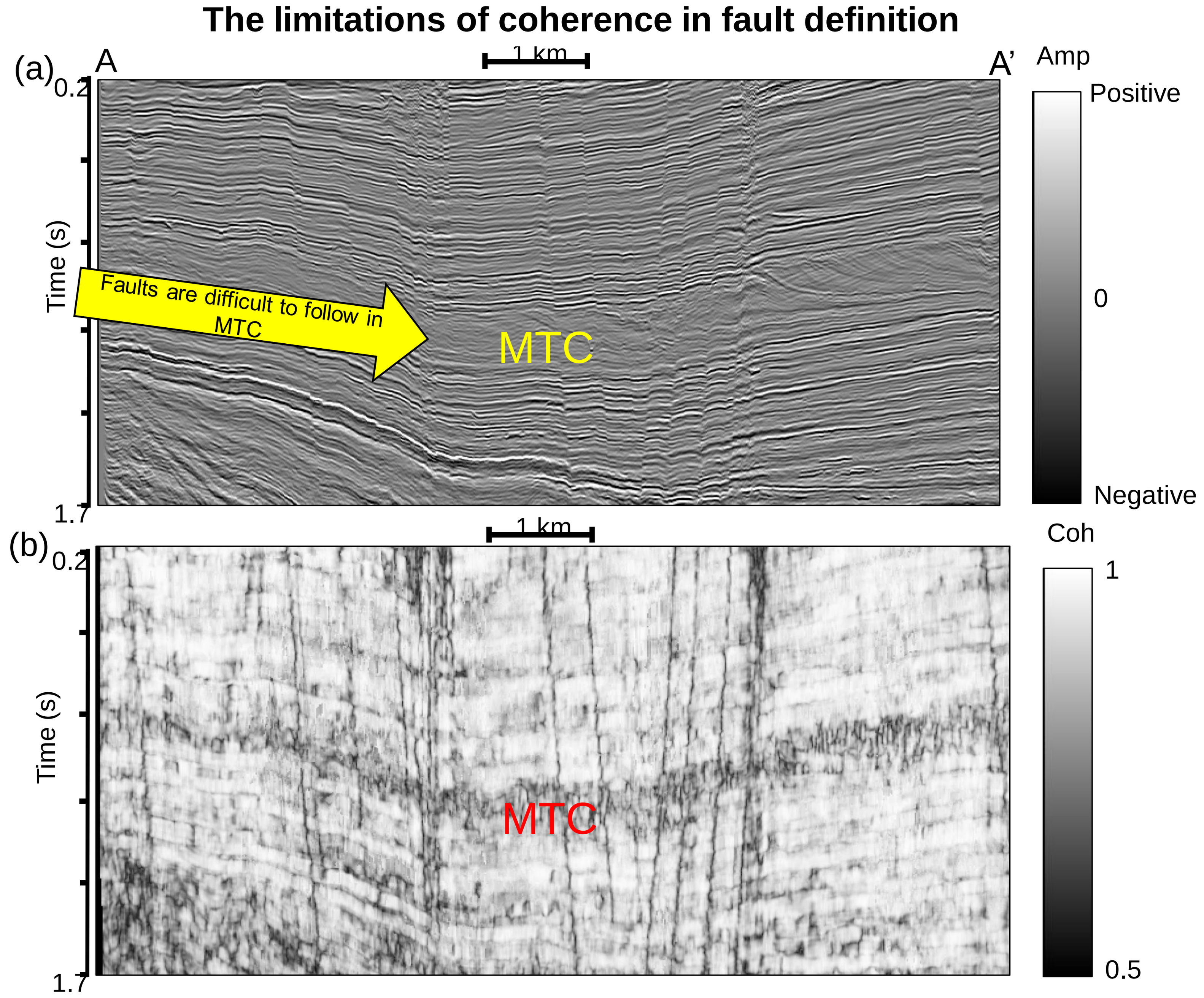


Figure 1: (a) A representative vertical slice through the seismic amplitude volume. Major faults are visible above and below the mass transport deposit but are difficult to track through it. (b) Vertical slices through coherence computed from the original data. Analysis window: 3 trace by 3 trace by 11 samples ±25 m , ±25 m, ±10 ms.

Footprint suppression and structure-oriented filtering

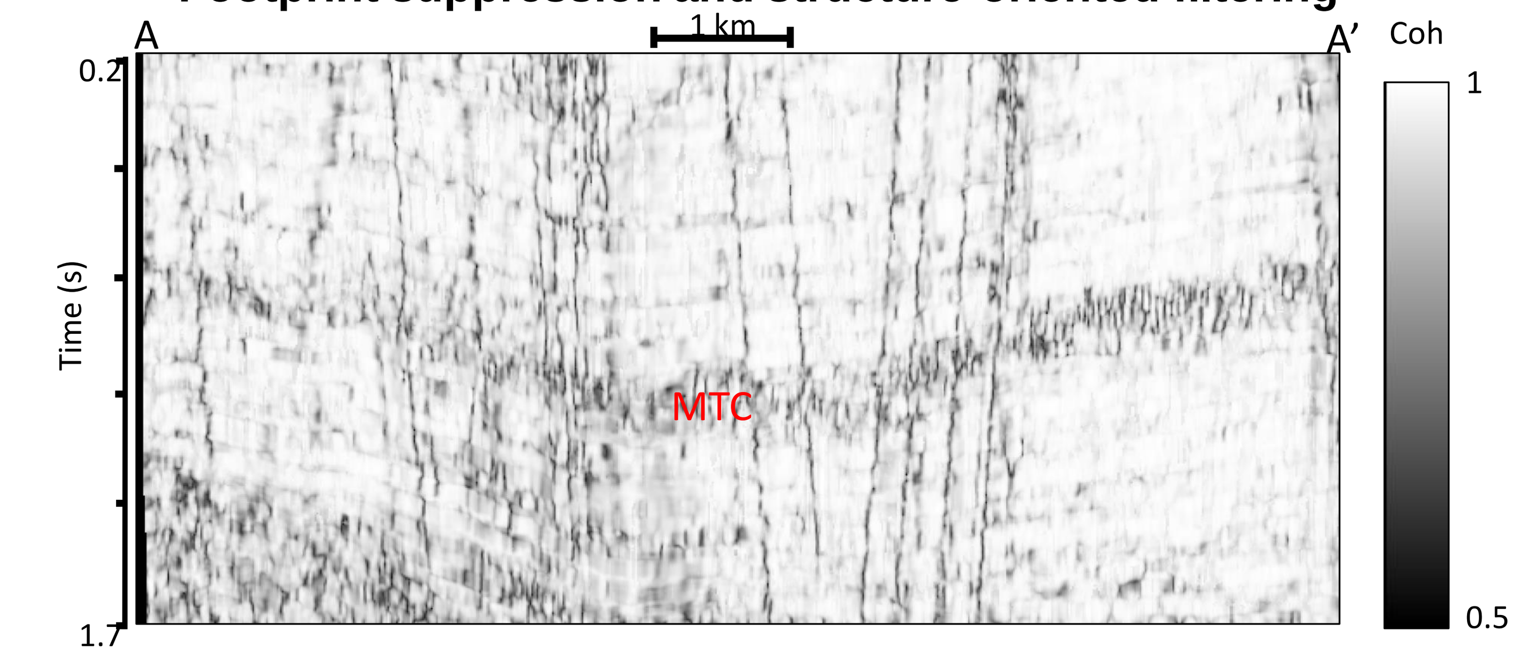


Figure 2: Coherence after footprint suppression and structure-oriented filtering. Coherence after noise rejection exhibits a better signal-to-noise ratio. Faults and other discontinuities are more easily interpretable within and through the mass transport deposit zone.

Multispectral coherence

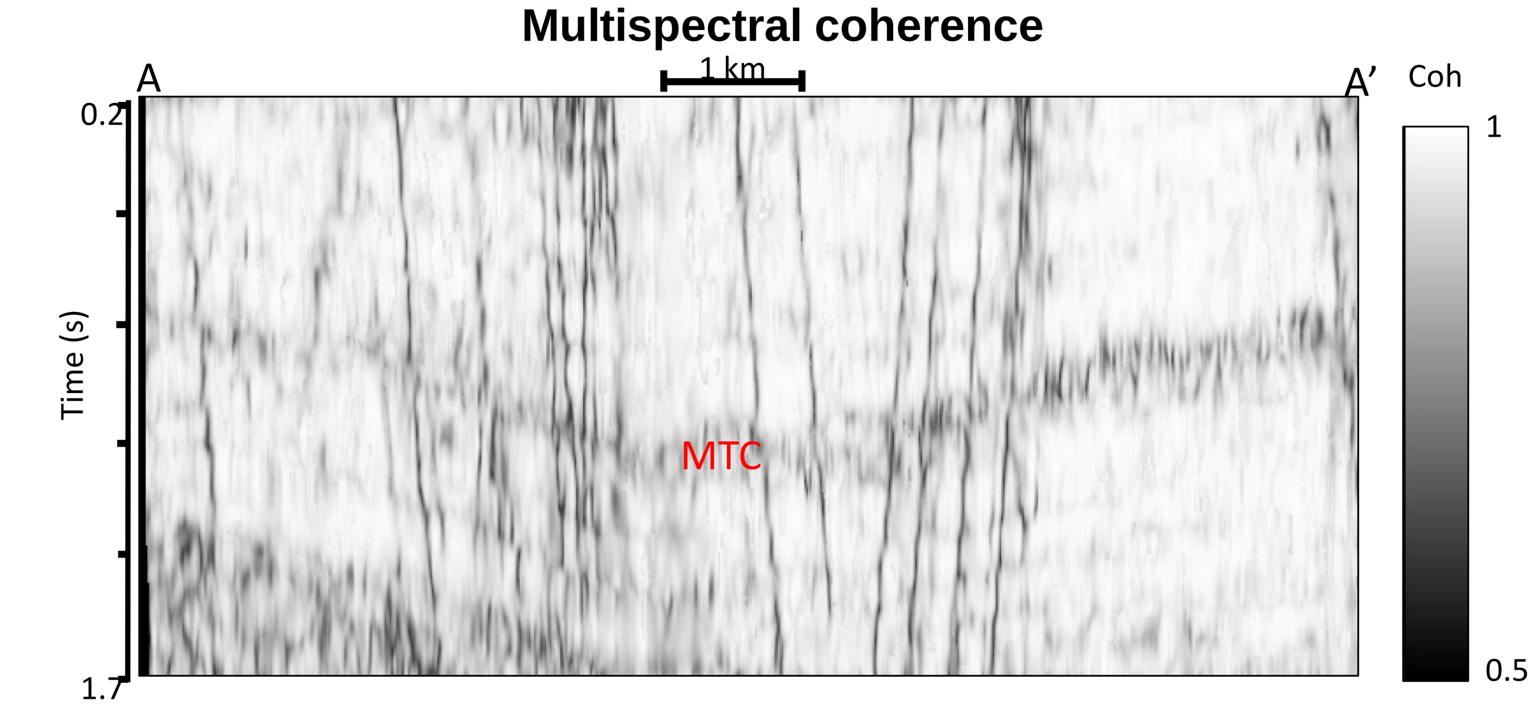


Figure 3: A vertical slice through multispectral coherence. Note that, faults are more continuous, and exhibit fewer "stair step" artifacts than seen on the broadband coherence

Fault enhancement

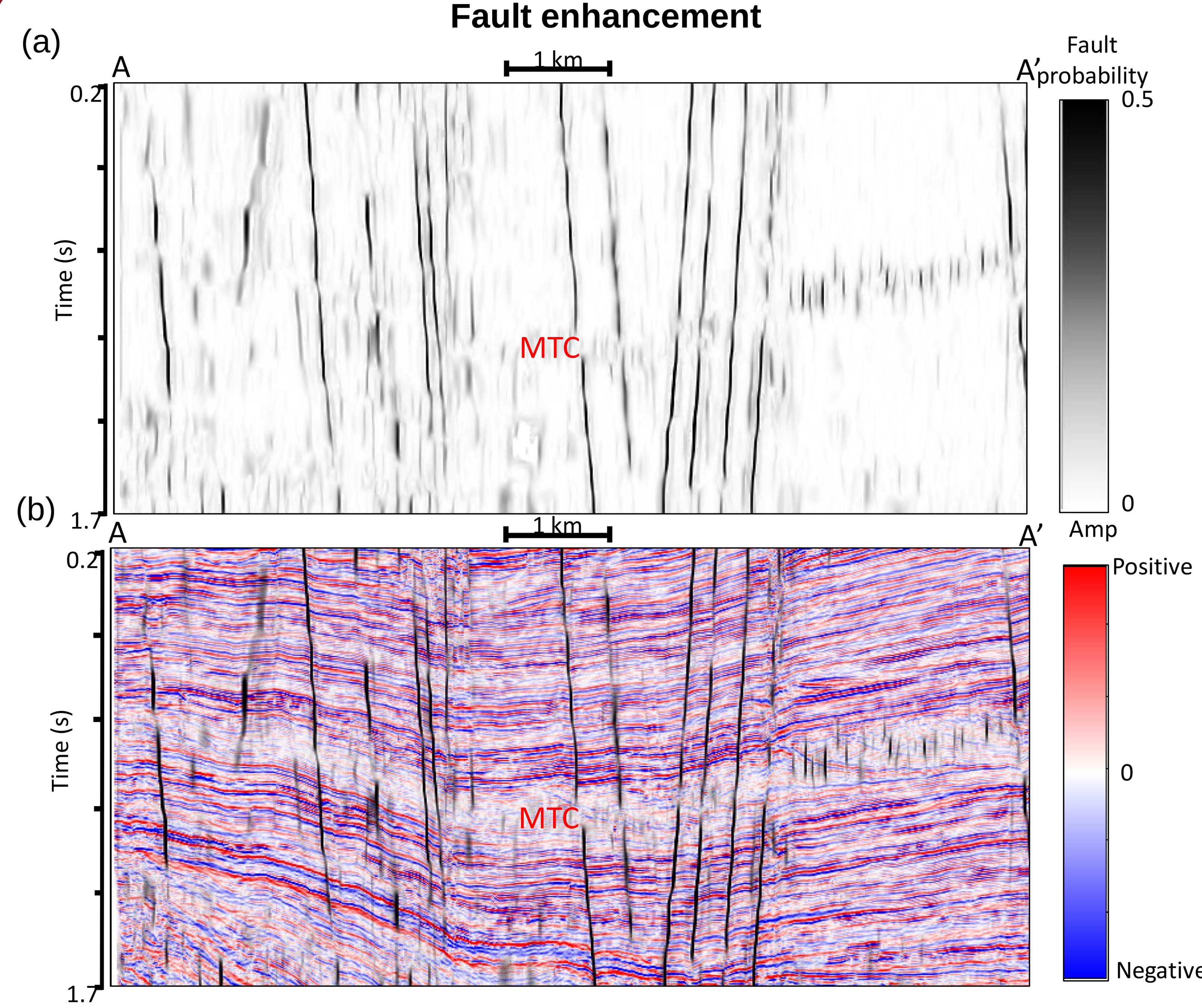


Figure 4: (a) Vertical slices through LoG fault probability, and (b) vertical slices through the seismic amplitude volume co-rendered with fault probability. Note that, the fault probability computed from the filtered coherence exhibits fewer isolated noise. Use of the energy weight results in faults exhibiting fewer "stair step" artifacts, and smoother fault surfaces.

Fault enhancement

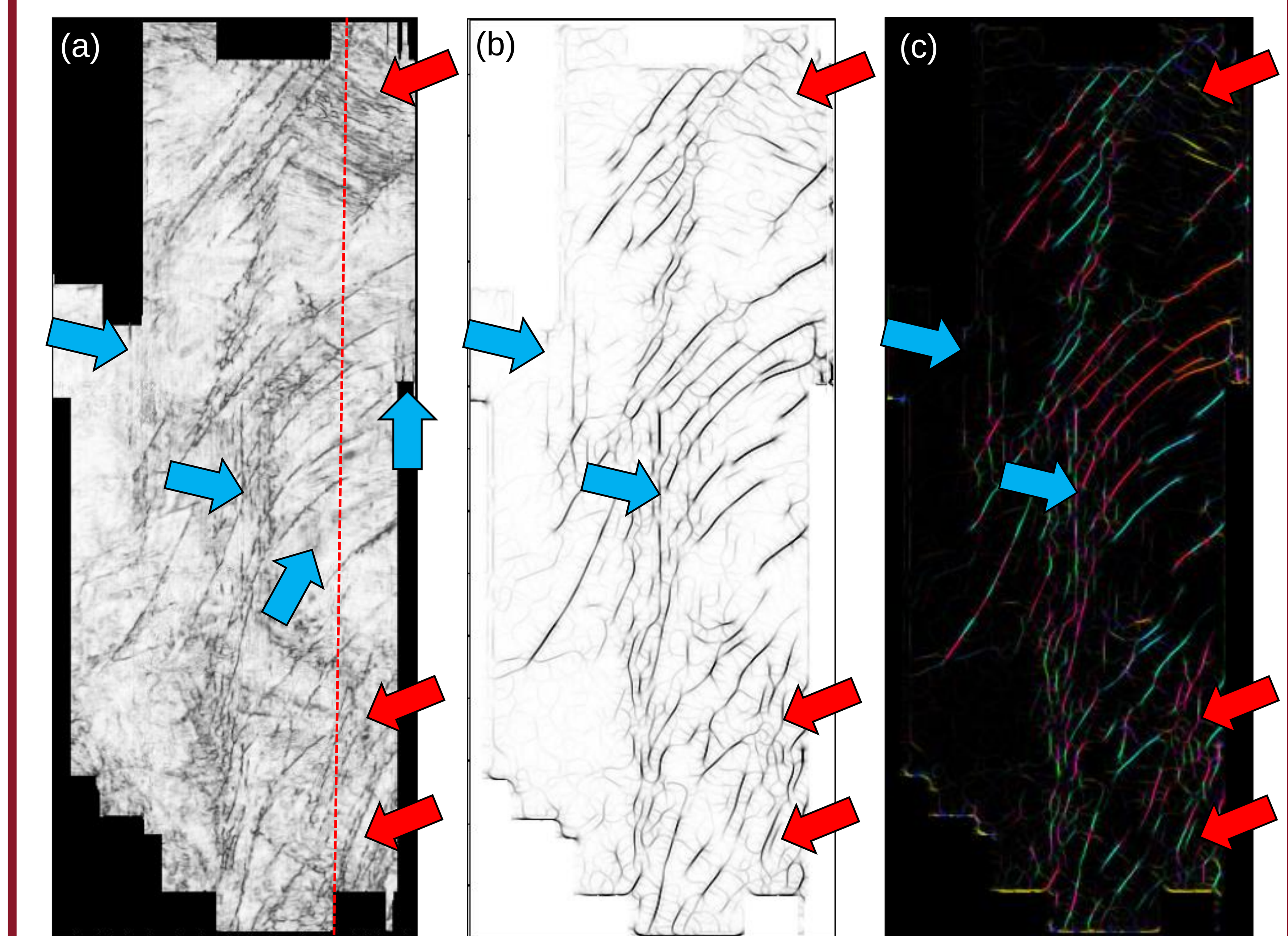


Figure 5:Time slices at t=0.8 s through (a) original coherence, (b) fault probability, and (c) fault probability co-rendered with fault dip magnitude and fault dip azimuth. Note that, the coherence before our workflow and variance exhibit strong acquisition footprint. Red arrows indicate the edges of rotated fault blocks in the mass transport deposits, which appear as parallel discontinuities. Blue arrows indicate acquisition footprint that can't be suppressed.

Automatic fault extraction using fault probability

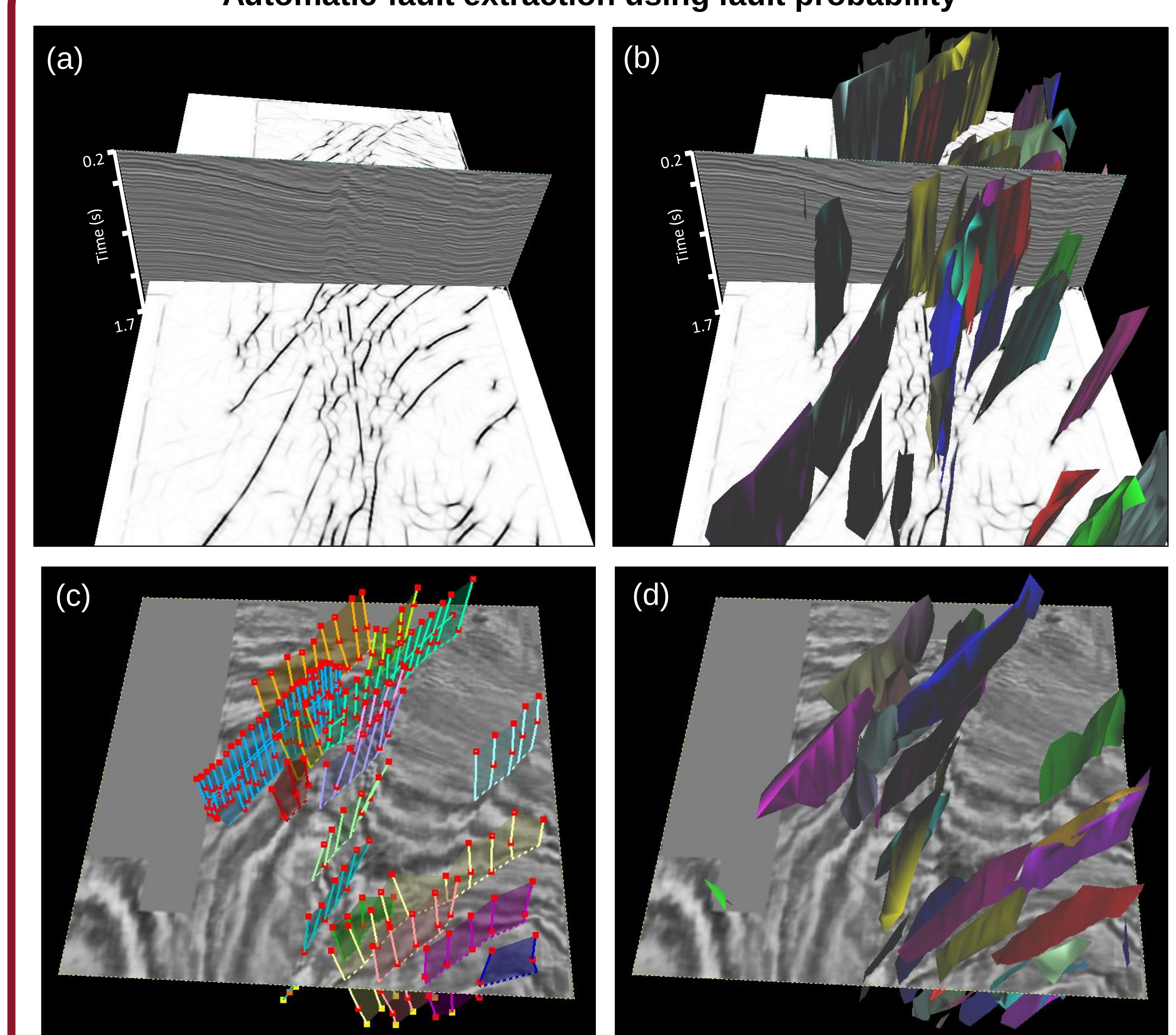


Figure 6: 3D view showing (a) a vertical slice through seismic amplitude volume with a time slice through the fault probability, and (b) the automatically extracted fault patches with fault probability as input, (c) a time slice through a cropped seismic amplitude volume with interpreter picked faults, and (d) the fault patches with the fault probability as input. Note that, the fault patches are as accurate as the interpreter picked faults.

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