GC Nemaha Strike-Slip Fault Expression on 3-D Seismic Data in SCOOP Trend*

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General Statement

Fault interpretation is an important step in seismic structural interpretation and has a bearing on the quantitative interpretation that may eventually be carried out. This requires the meaningful recognition of the faults within the proper geological context of the area. In Oklahoma, we see wrench faulting with strike-slip faults and other associated features.

In the case of a strike-slip fault, the maximum and minimum principal stress directions are horizontal, and the intermediate stress is vertical. Large strike-slip faults are also called “wrench faults”. In many cases, branches and step overs might form with two or more through-going faults instead of one, and offset one another. This results in complicated fault patterns. Wrench faults are usually characterized by near vertical fault planes, along which the strike-slip motion takes place, and might produce positive and negative flower structures, in response to compressional and extensional driving forces respectively. Evidence of strike-slip movement along the fault plane usually manifests in additional fault and fracture patterns. A continental-scale zone of deformation produced by strike-slip movement is sometimes referred to as a megashear fault.

In the central and eastern United States, such faults typically root into igneous basement (about 1.5 billion years ago in Oklahoma). Displacement within the basement produces characteristic fault structures in the sediments above. Strike-slip movement and relatively low strains result in Riedel (R) faults as well as faults in the R’ and, P orientations. Riedel fault segments will commonly get linked to P fault segments. Such combinations can give rise to en echelon fault patterns in the direct vicinity of the main fault or a zone of intense strike-slip deformation with complicated vertical offsets, i.e. positive and negative flower-type structures. Three prominent faults in Oklahoma are marked in Figure 1. The Nemaha Fault, striking nearly north-south through the state is a wrench fault rooted in the deep crust (past the basement).

There are two thoughts on its formation, one is that it is related to the deep-rooted tip of the mid-continent rift; the other is that it could have formed due to a gentle counter-clockwise rotation of an intra-continental block lying between two bounding, left-lateral megashears, namely the Oklahoma megashear to the south (Figure 1) and the Central Plains Megashear in Nebraska. It is perpendicular to the regional maximum horizontal principal stress (SHmax) orientation, which is a consistent 80-degree north/90-degree east orientation through much of Oklahoma, except in the southern part, where it deviates to approximately 50 degrees northeast. The Meers Fault is steeply dipping oblique-slip fault, which formed as part of the Wichita Uplift system. Finally, there is the Wilzetta Fault, a long north-northeast trending strike-slip fault.

Nemaha Fault Zone

The 400-mile-long Nemaha Fault zone extends from southeastern Nebraska through northeastern Kansas and across Kansas and Oklahoma and terminates in central Oklahoma. As wrench faults form because of a horizontal shear couple, which in this case is likely basement rooted, compressional and tensional forces are generated in the overlying sediments. Such forces may provide additional signatures, such as en echelon faults and fractures that could be utilized as a means of interpreting them.

We study the seismic expressions of such faults and fractures and try to interpret them on a 3-D seismic volume from the SCOOP area of Oklahoma, and its location is shown in Figure 1. The quality of the seismic data seems to be very good as seen on a segment of a seismic section from the 3-D seismic volume shown in Figure 2 and Figure 4. Notice the basement reflection tracked in purple. The Nemaha Fault marked on the section penetrates beyond the top of the basement. In fact, it is the Nemaha Fault zone that can be seen there, and its spatial disposition is seen clearly on the stratal slices in Figure 3 between the Mayes and the Hunton markers from the coherence and most-negative curvature attribute volumes. The fault lineaments are seen better defined on the curvature than the coherence. The Nemaha Fault appears to be in the form of a zone rather than a single fault, as indicated by the two black arrows. Another fault zone is also seen to the left of the Nemaha Fault zone as indicated with the cyan arrows.

Conclusion

In addition to these two fault zones, there is another fault lineament pattern in the northeast-southwest orientation that seems overlaid on the display. The observed basement fault patterns are consistent with the tectonic history of the Mid-Continent and may provide explanations for deformation observed in the shallower sediments. As the Precambrian basement of the Mid-Continent is only exposed in a few places and limited in aerial extent, studies using seismic attributes on robust 3-D volumes provide a critical tool for understanding how deep structures and deformation may influence the overlying sediments.

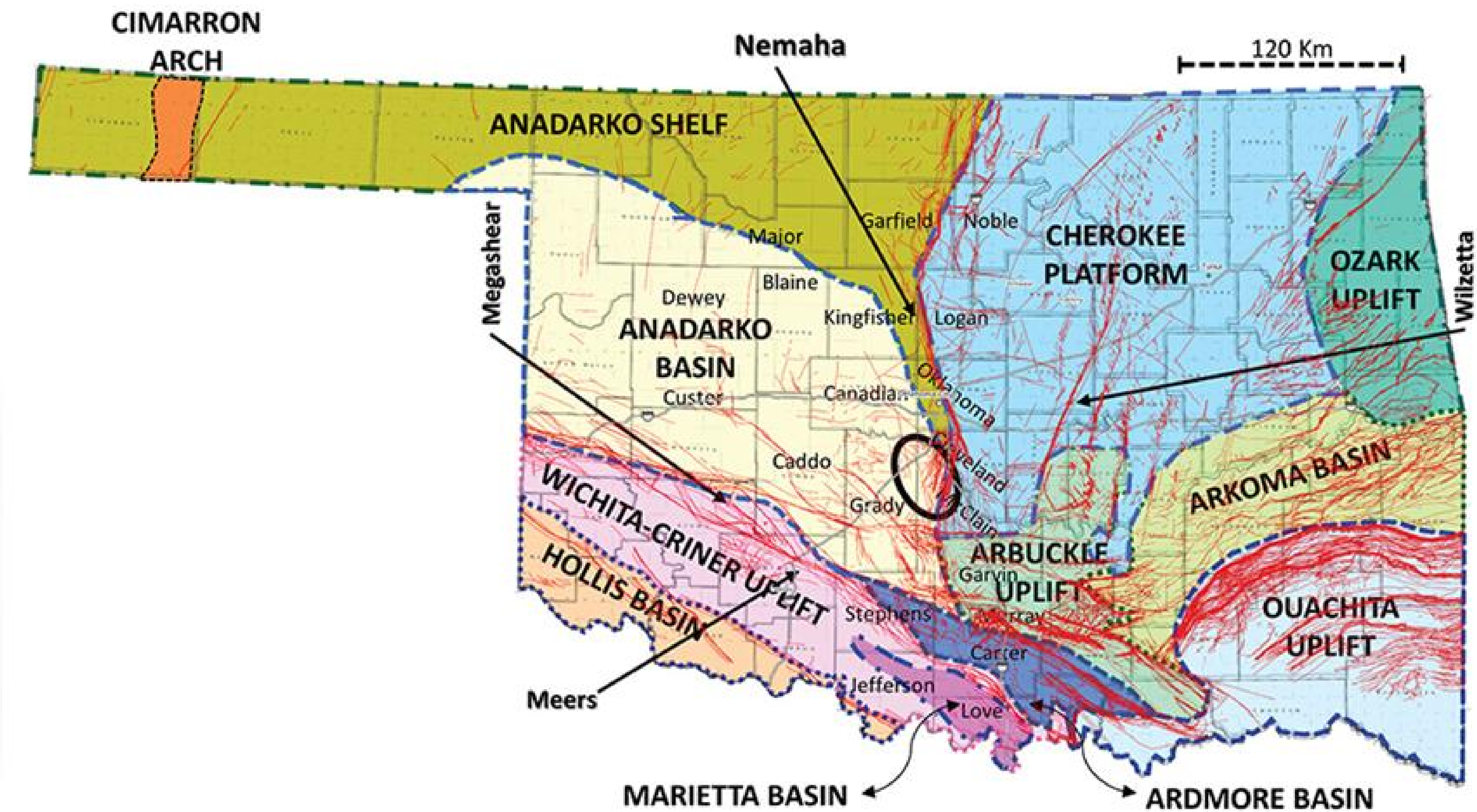

Figure 1. Map of Oklahoma showing the major geologic provinces. (Modified from Oklahoma Geological Survey map by R.A. Northcutt and J.A. Campbell, 1998). Some counties have also been annotated as well as the location of the 3-D seismic survey under study. The comprehensive fault lineaments overlaid over the map have been taken from the document by March and Holland, 2016, website accessed June 22, 2018, www.ou.edu/content/ogs/data/fault.html. The three main faults, namely the Nemaha, Meers and the Wilzetta on this image, as well as the megashear trend are also indicated.

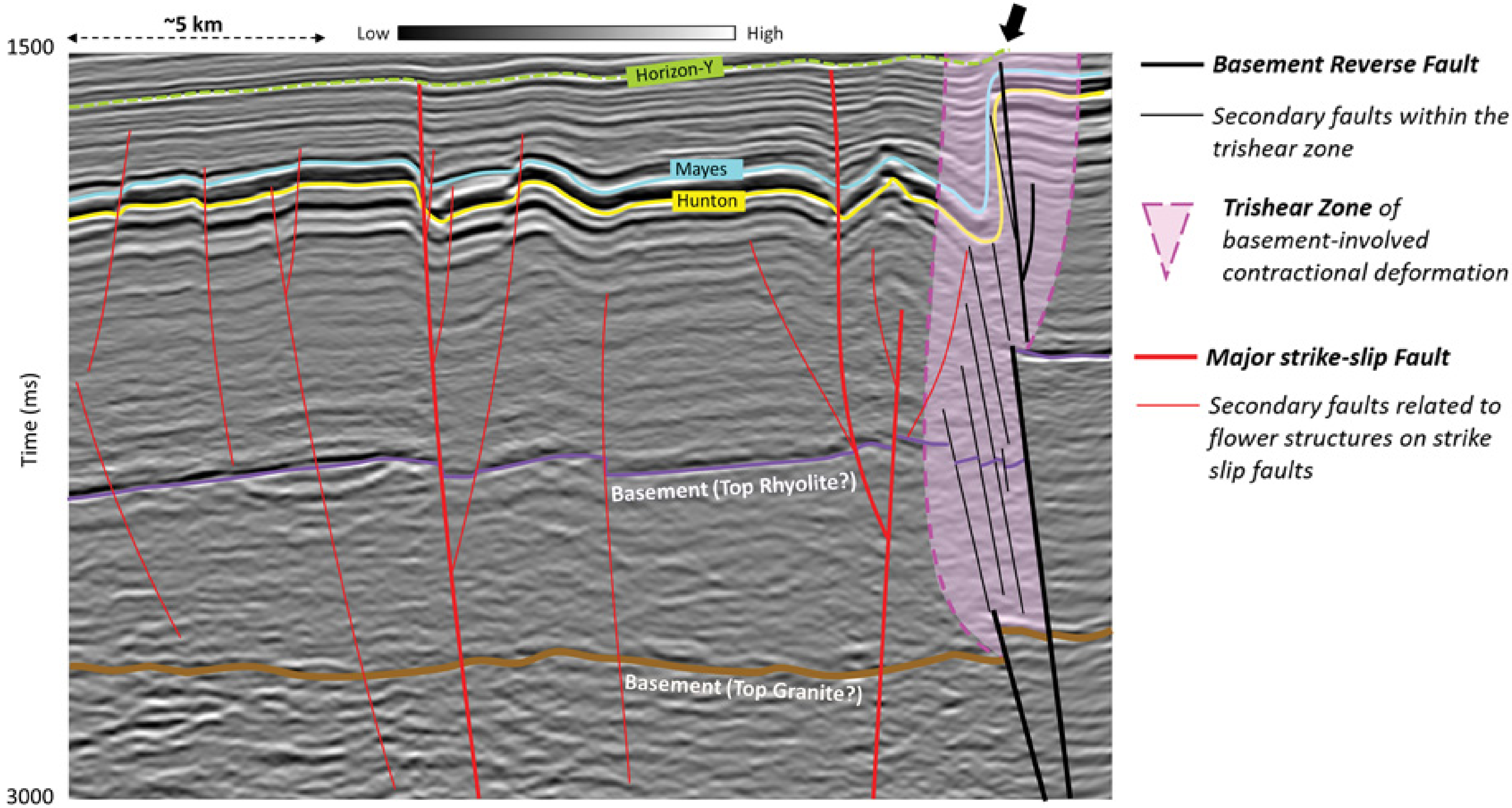

Figure 2. Segment of a seismic section from the 3-D seismic volume from the SCOOP area. The main Nemaha Fault is seen to the right (black arrow), and its large throw is prominent. It goes down all the way to the basement (in purple) and beyond. The prominent horizons and the fault interpretation have been marked on the section. The legend to the right explains the different colored fault segments. Data courtesy of TGS, Houston.

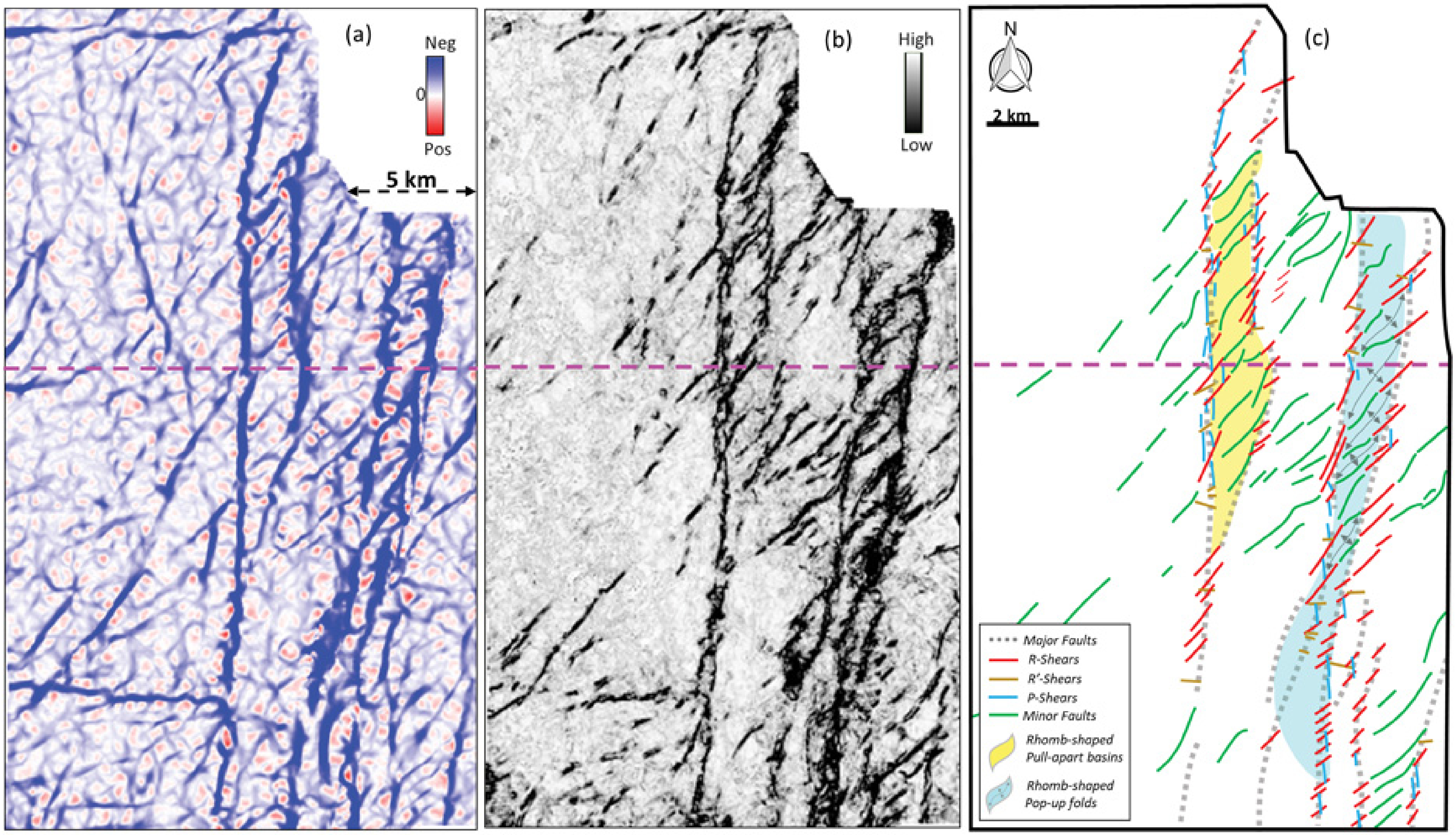

Figure 3. Stratal slice midway between the 'Mayes' and the 'Hunton' markers from the (a) energy ratio coherence volume, and (b) most-negative curvature (long-wavelength) volume. Interpretation of different types of faults (as described in the text) carried out on the stratal displays in (a) and (b) is shown in (c). Data courtesy of TGS, Houston.

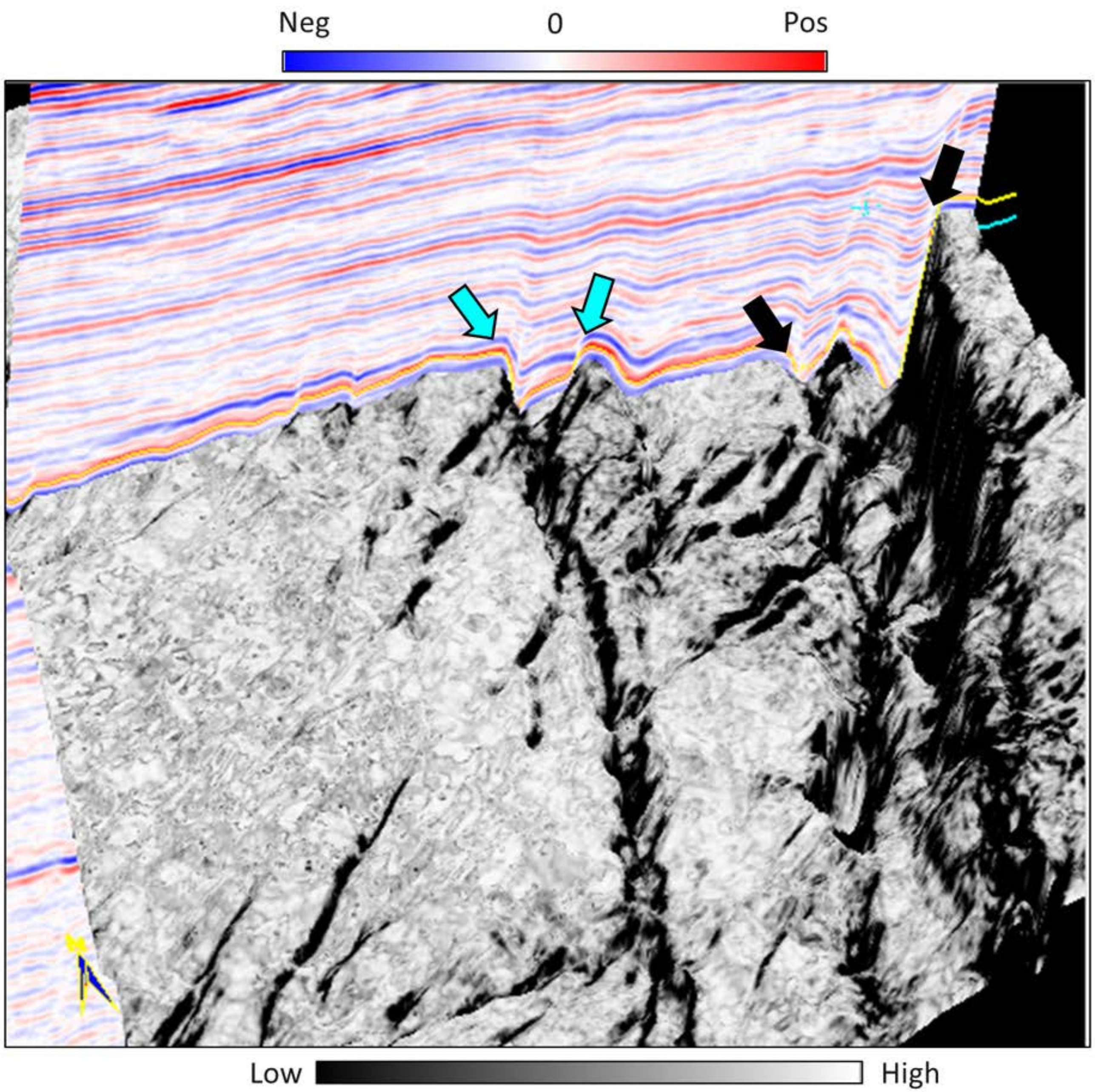

Figure 4. A chair display showing the energy ratio coherence stratal slice shown in Figure 2 as the horizontal display and an inline from the seismic volume as the vertical display. Data courtesy of TGS, Houston.