Seismic reprocessing and interpretation of a shallow "buried-hill" play: Texas Panhandle

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① Introduction and Geologic Setting:

The study area is located on the western flank of the Amarillo-Wichita uplift and is a part of the Panhandle-Hugoton field, a giant oil and gas field in the North America (EUR: 1400 million barrel of oil and 75 trillion cubic feet of gas). Hydrocarbons migrated from deeper layers in the Anadarko basin (including the famous Woodford Shale), through the granite wash and a system of fracture inside the basement toward the south, where they were trapped by the Permian evaporite (Sorenson, 2005) (Figure 1).

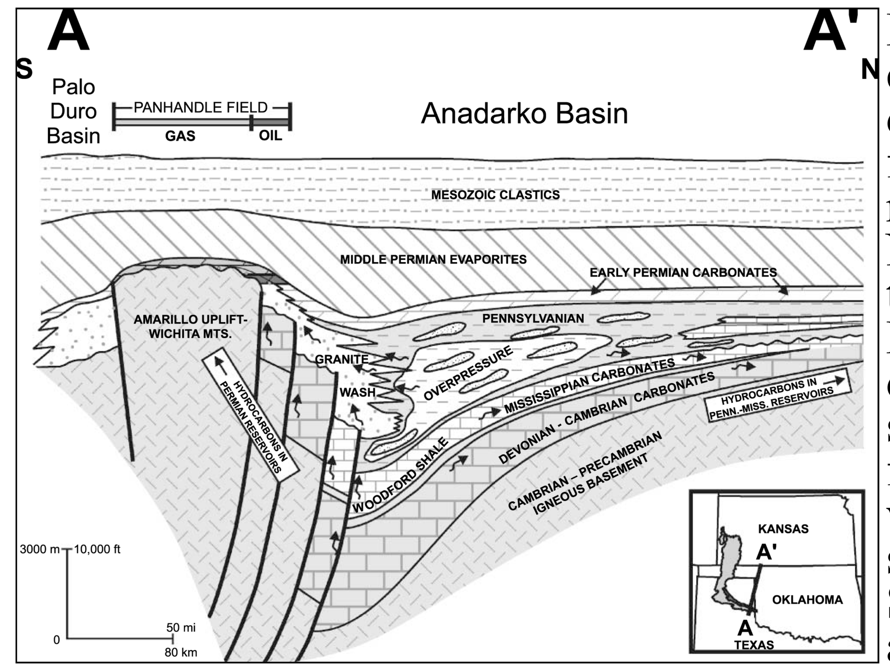

Figure 1. Regional geological cross-section through the Panhandle field (Sorenson, 2005). The field is located on top of the Amarillo-Wichita uplift, bounded to the NE by the Anadarko basin and to the SW by the Palo Duro Basin. Hydrocarbons migrated from deeper layers in the Anadarko basin (including the famous Woodford Shale), through the granite wash and a system of fracture inside the basement toward the South, where they were trapped by a thick layer of Permian evaporite.

② Seismic Reprocessing:

This is the main step to improve seismic image quality. Figure 2 shows my processing flow chart. The most important task is velocity analysis, followed by linear noise suppression and prestack time migration. The improvements of the reprocessing are shown in Figures 3-7. The reprocessed data has less noise, better correlation, higher resolution, and much less acquisition footprint than the original vendor-processed data.

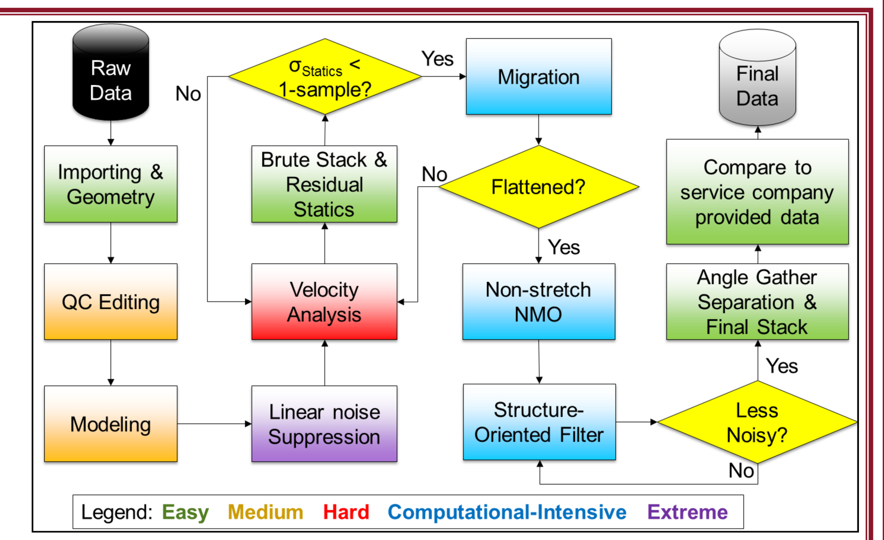

Figure 2. Seismic processing flow chart.

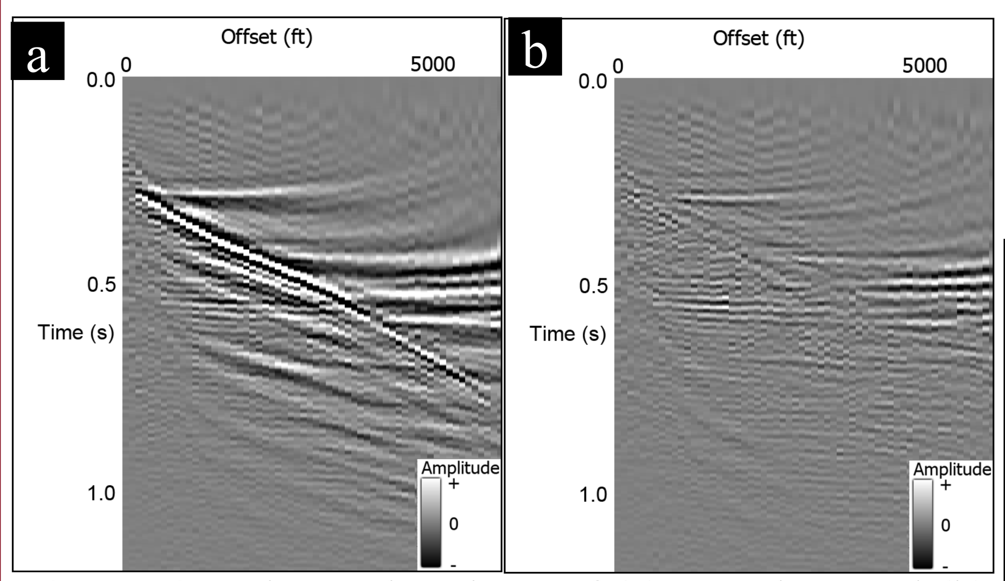

Figure 3. Migrated gathers of (a) raw data and (b) data after the final noise suppression. Signal is much more visible in (b).

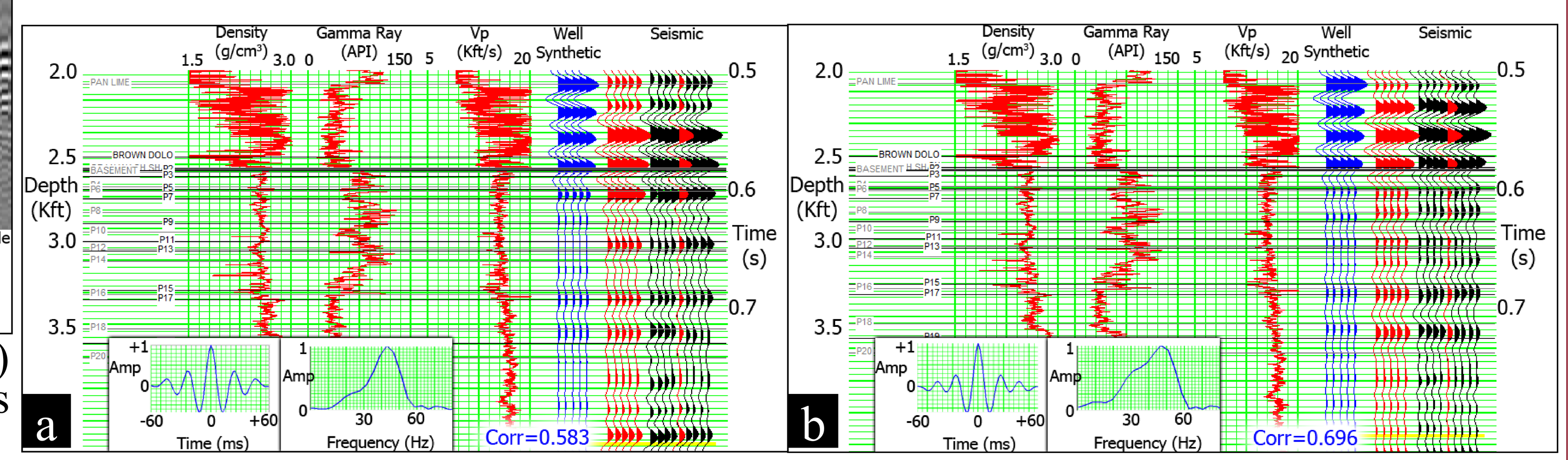

Figure 4. Well-tie with (a) the original data and (b) the reprocessed data. Blue traces represent synthetic seismic traces derived from the well's P-wave velocity log and density log. Red traces represent the average trace of seismic data close to the well location. The reprocessed data has higher correlation coefficient and higher frequency content than the original data.

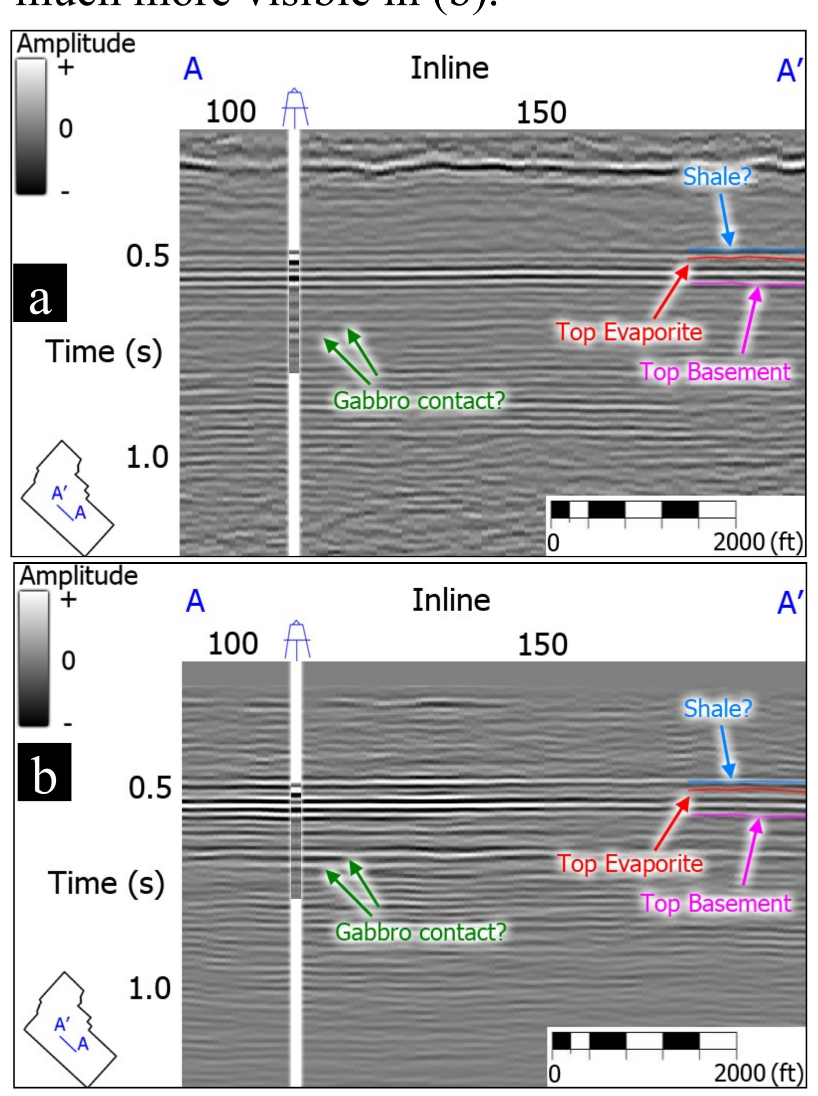

Figure 5. Vertical slices through (a) the original and (b) the reprocessed data. A reflection above the evaporite (possibly shale) is brighter and more focused in the reprocessed image. Green arrows indicate possible granite-gabbro contacts.

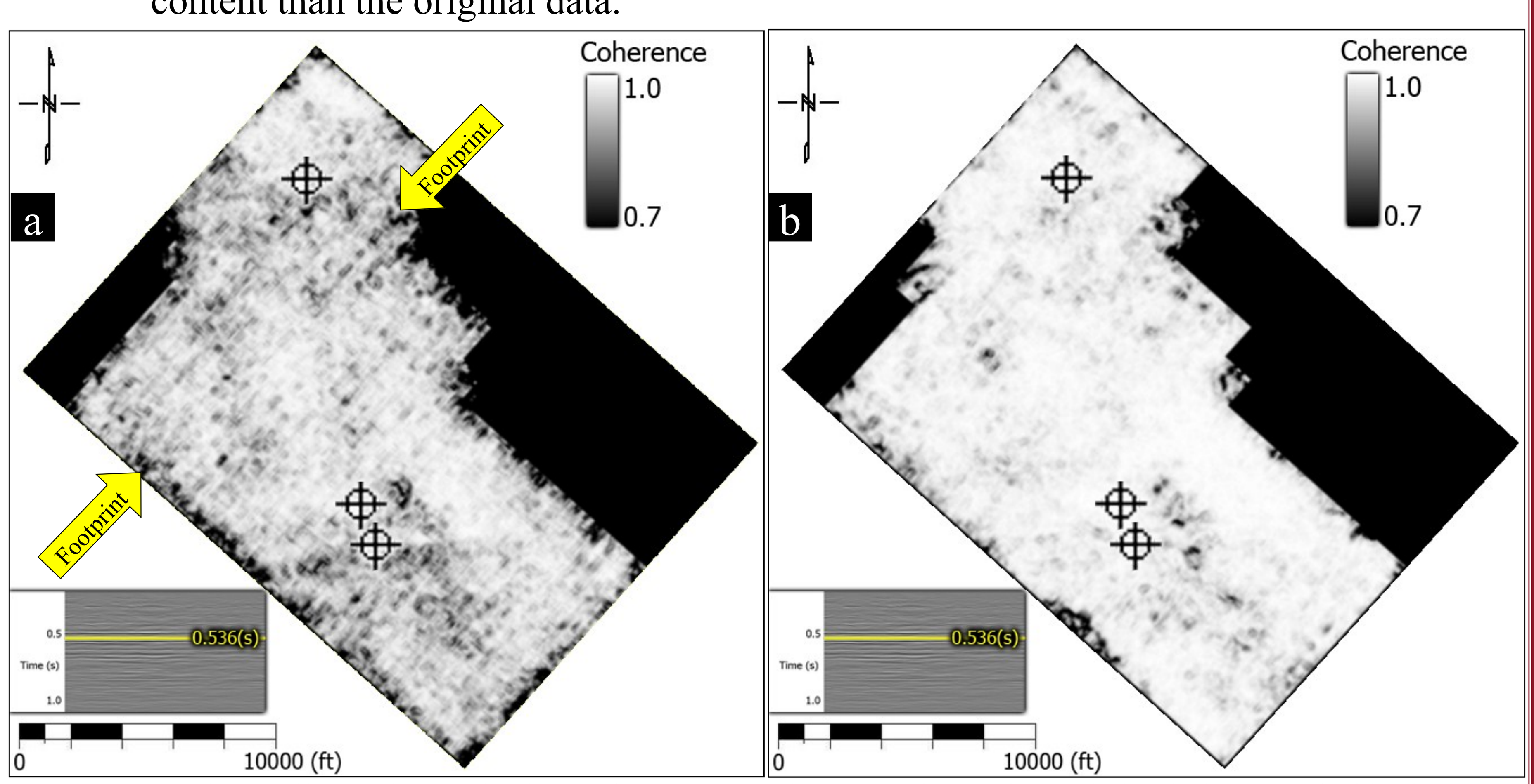

Figure 6. Time slices through the coherence volumes of (a) the original data and (b) the reprocessed data. Acquisition footprint is visible in the original data, which overlaid geologic feature, making it difficult to interpret. In the reprocessed data, acquisition footprint is suppressed.

③ Attributes, Inversion, and AVAz:

To interpret the data, I calculate geometric attributes (coherence and curvature), apply inversion, and perform AVAz analysis. A major but small-displacement fault can be seen in the co-rendered map of coherence, most-positive curvature (k_1), and most negative curvature (k_2) along the top basement (Figure 7). In cross-sectional view (Figure 8), the fault exhibits the pattern of a theoretical normal fault with drag on both sides. Within the basement, there are high impedance, horizontal anomalies (Figure 9) that could be interpreted as gabbro sills (horizontal intrusions of gabbro into granite) (Barnes et al, 2002). Smaller fractures (i.e. joints) can be illuminated by the P-impedance curvature map (Figure 10). High anisotropy, low impedance, NNW-SSE trending anomalies in the center and eastern part of the survey (Figure 11) suggest areas of open fractures that are parallel to the compressional stress during the late Pennsylvanian uplift.

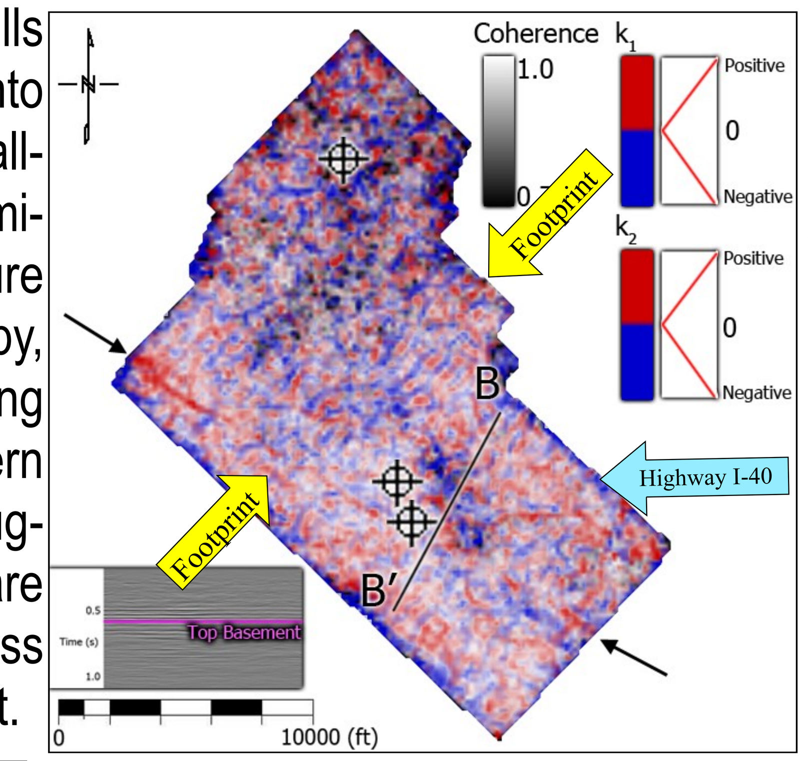

Figure 7. Co-rendered image of k1, k2, and coherence along the top basement horizon. Black arrows indicate a fault. Some NW-SE lineaments are possibly remnant of acquisition footprint. The k1 lineament is displaced ~200ft to the south of the k2 lineament. An E-W anomaly is caused by the lack of seismic sources and receivers along highway I-40.

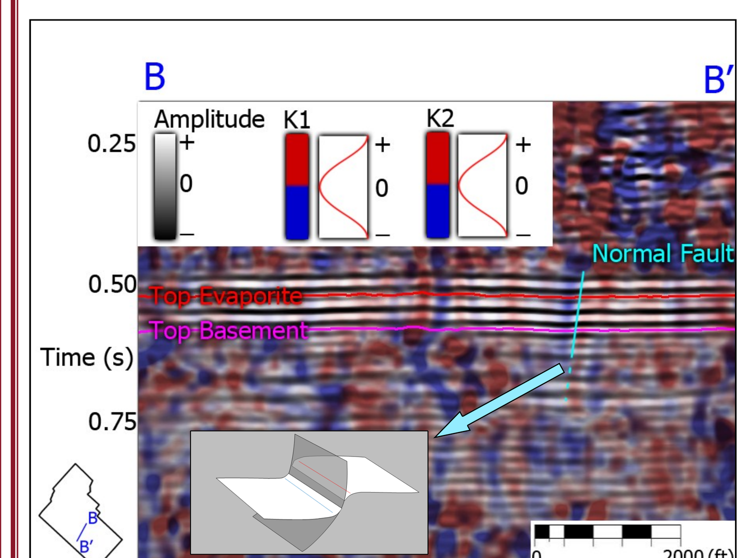

Figure 8. BB' cross-section through seismic amplitude volume, co-rendered with k1 and k2. The anomaly exhibits similar curvature pattern to a theoretical normal fault with drag on both sides.

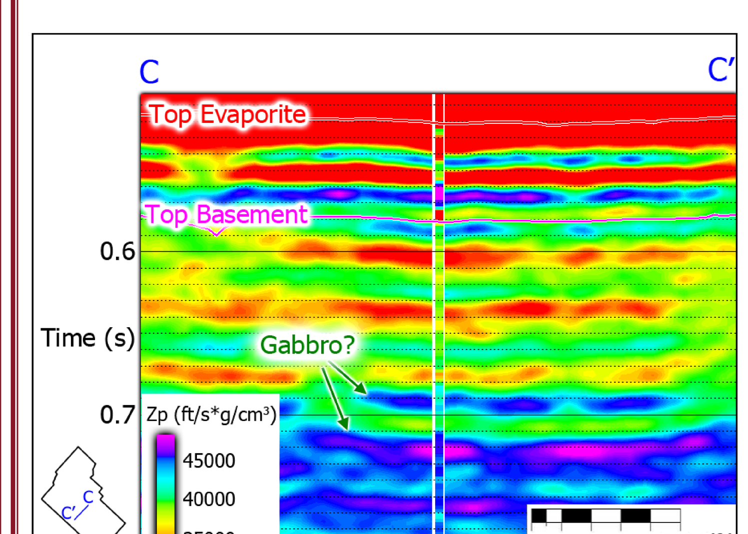

Figure 9. CC' cross-section through P-impedance volume. Green arrows indicate high P-impedance anomalies, suggesting that denser and higher-velocity rock (such as gabbro) exists within the basement.

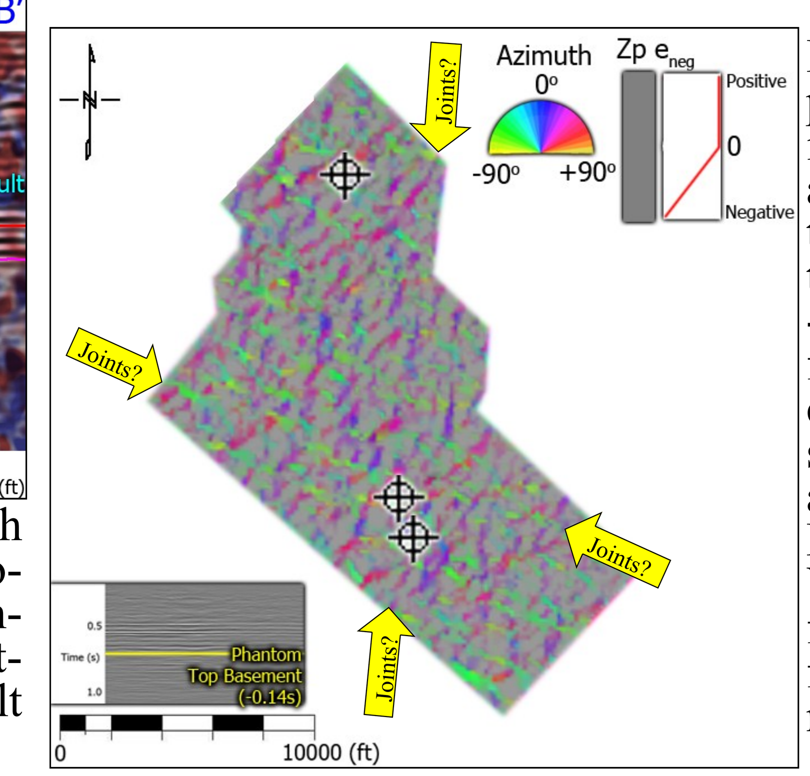

Figure 10. Co-rendered negative amplitude curvature (e_{neg}) of P-impedance and azimuth of e_{neg} along a phantom horizon 0.14s below the top basement. Strong negative curvature corresponds to local minima of P-impedance. The colors are bright and fresh where there is strong negative curvature. Yellow arrows indicate two sets of linear anomalies, one trending almost N-S, and one trending WNW-ESE (which is the same with the Wichita uplift trend). I interpret these features to be two sets of conjugate fractures (or joints) that are approximately 60° apart.

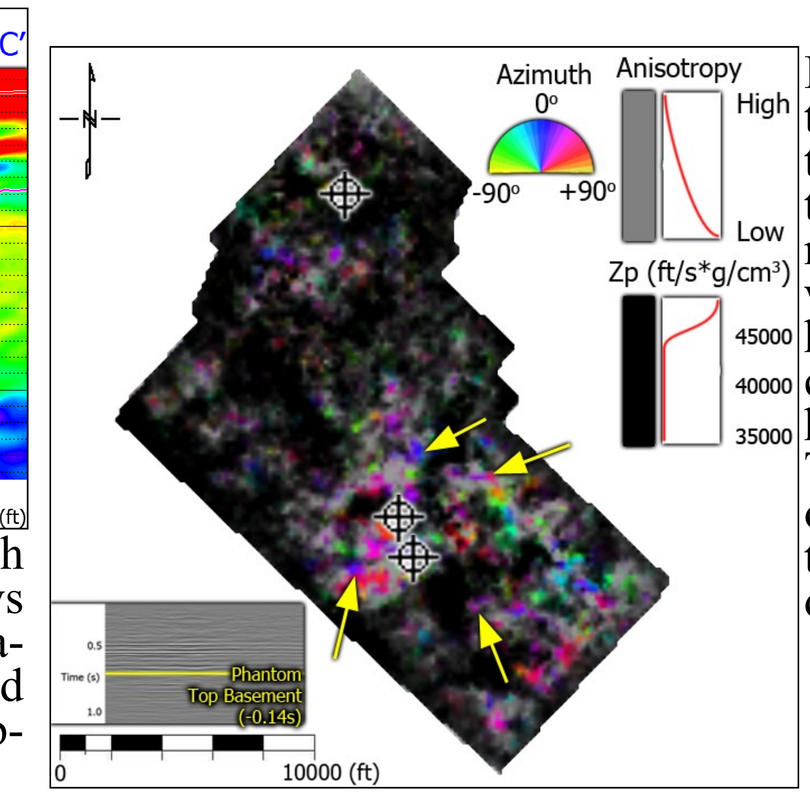

Figure 11. Co-rendered anisotropy intensity, maximum anisotropy direction, and P-impedance along a phantom horizon 0.14s below the top basement. The colors are bright and fresh where there is low P-impedance and high anisotropy. Yellow arrows indicate arrears of low impedance and high anisotropy trending NNE-NE. Those areas exhibit the characters of open fractures that formed parallel to the direction of compressional stress during the late Paleozoic uplift event.

④ Conclusion:

With a great deal of pain, I can generate better images of shallow "unconventional" basement targets. Among the processing steps, careful velocity analysis and coherent noise suppression are key factors to improve seismic images. Reflections within basement are signal, tying basement impedance logs. Those reflections are probably granite-gabbro contacts. Impedance curvature shows a network of lineaments trending 25° to the acquisition grid. Together with AVAz, potential open fractures can be interpreted as low impedance, high anisotropy areas in the center and eastern part of the survey.

References: Available upon request..

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