Complex Fault Network Characterization on the North Slope, Alaska

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1. SUMMARY

The deeper formations on the North Slope, Alaska presents a structurally complex geologic system. The complex system contains a number of reservoirs with large amount of hydrocarbons, many of which are fault-controlled. An ensemble of volumetric seismic attributes are computed on a large 3D seismic reflection survey to interpret different sedimentary horizons and investigate the structural complexity in a few key intervals, such as the Kekiktuk, Shublik, and Kuparuk formations. Second-order (curvature) and third-order (aberrancy) derivatives at long and short wavelengths are extracted on each of the intervals to better understand the faulting styles, geometries, and infer the multi-phase deformation history. The results from the most-positive and most-negative curvature attributes show that there are mainly two types of faults in the study area, which includes WNW-trending steep faults and N/NNE-oriented gentler conjugate faults. It is inferred that the WNW-oriented faults are controlled by the pre-existing basement structures, the influence of which decreases in the upsection. The conjugate faults display single-tip and double-tip abutting relations with the pre-existing WNW-trending faults. The deepest Kekiktuk horizon shows the presence of mostly WNW-oriented faults, whereas the shallower Shublik and Kuparuk

2. GEOLOGY OF THE STUDY AREA

Figure 1. Study area showing the location on the North Slope, Alaska (modified after Bird and Houseknecht, 2002). The blue polygon indicates the approximate 3D seismic survey area ("Storms 3D"), and the black dash line inside the polygon indicates a NW-SE oriented crossline (a seismic

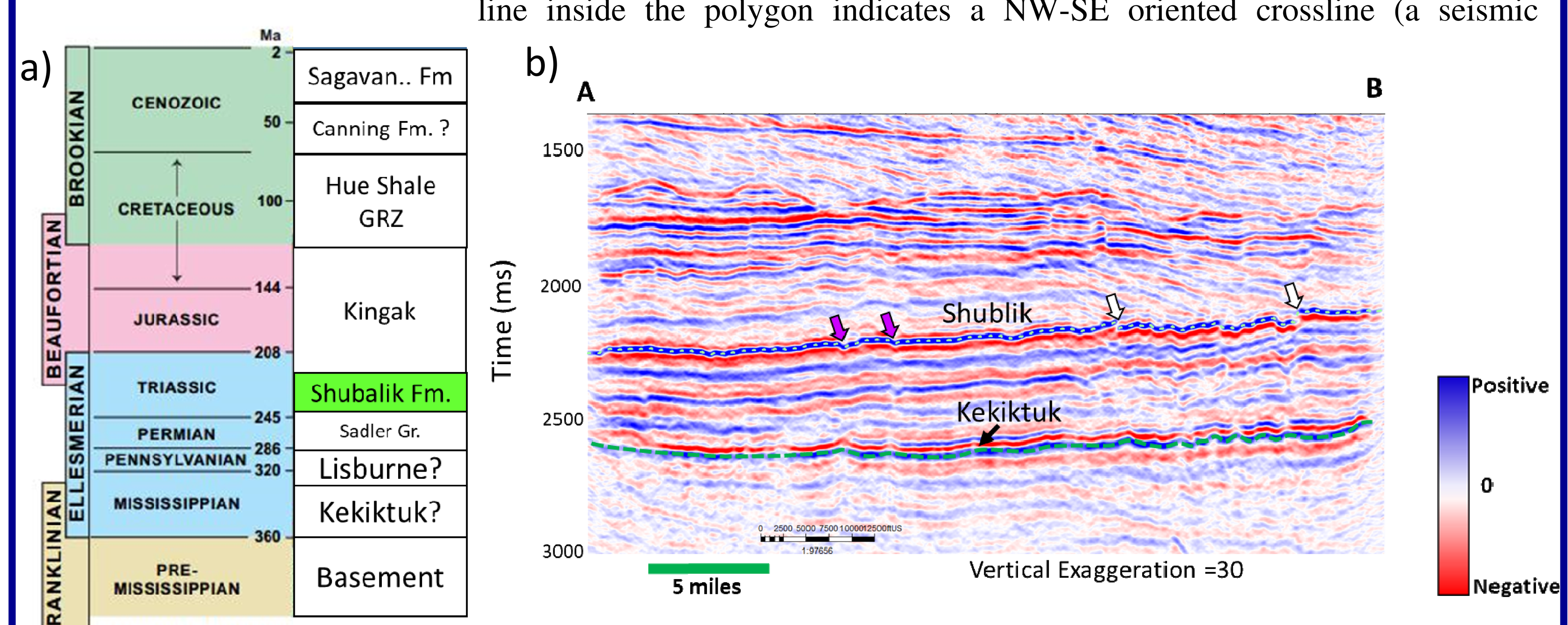


Figure 2. (a) Stratigraphic units and petroleum system on the North Slope (modified after Garrity et al., 2005). (b) seismic section along NW-SE showing the interpreted horizons such as the Kekiktuk, Shublik, and Kuparuk. The Kekiktuk and Kuparuk formations are hydrocarbon-producing reservoirs, whereas the Shublik

3. SEISMIC ATTRIBUTE STUDY

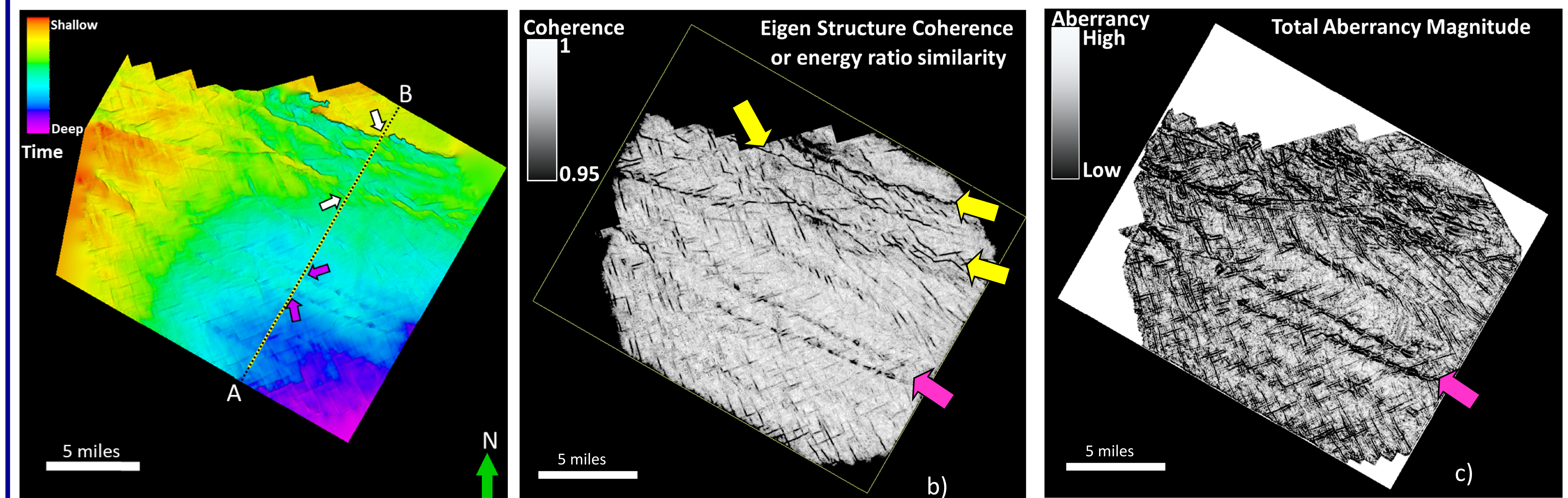


Figure 3: (a) Time structure maps of the Shublik. Note the black dash line indicates the NW-SE oriented crossline seismic section in Figure 2b. (b) Coherence and (c) aberrancy slice along the Shublik surface. Notice that the coherence values are really high, the range is limited to 0.95 to 1. In the southern part, impression of orthogonal faults are, barely visible in coherence, whereas very clearly seen aberrancy. The magenta arrow shows basement related fault structure. The faults in the northern part of the survey indicated by yellow arrows are visible in both coherence and aberrancy.

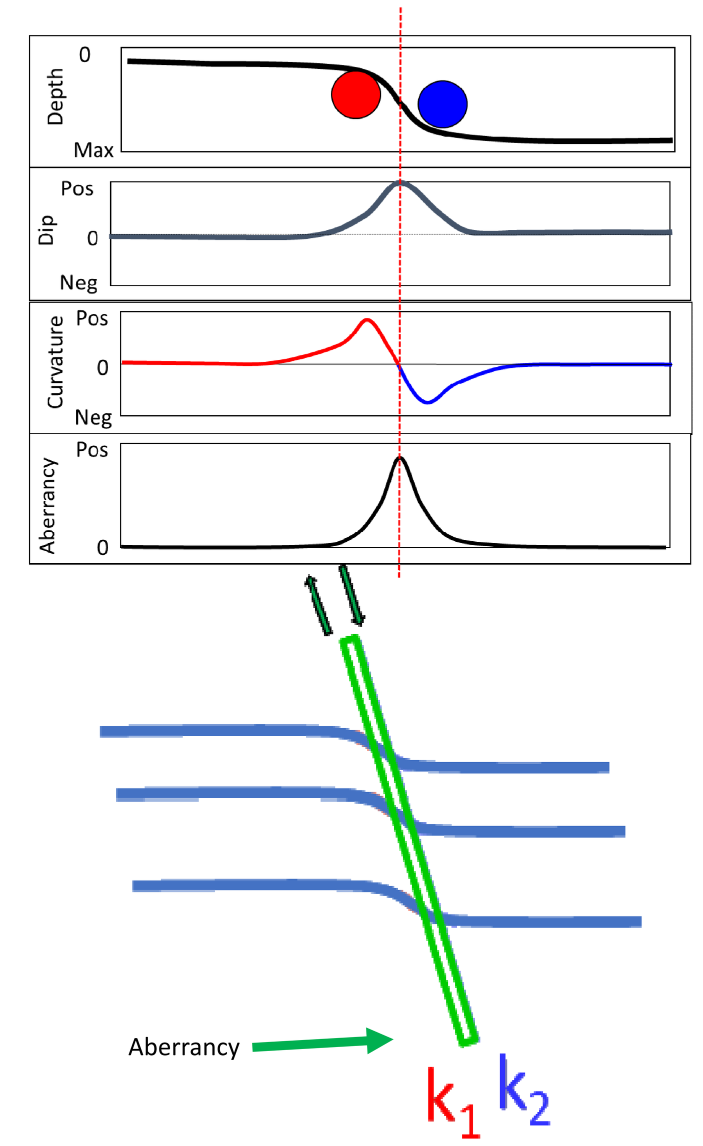


Figure 5: Top– concept of curvature and aberrancy on a curve (modified after Qi and Marfurt, 2018). The red circle indicates peak, and the blue circle indicates trough. Bottom– small offset faults, are seen as a continuous reflector by seismic with a little flexure. So, such faults are not visible on the coherence, but are clearly seen on curvature and aberrancy.

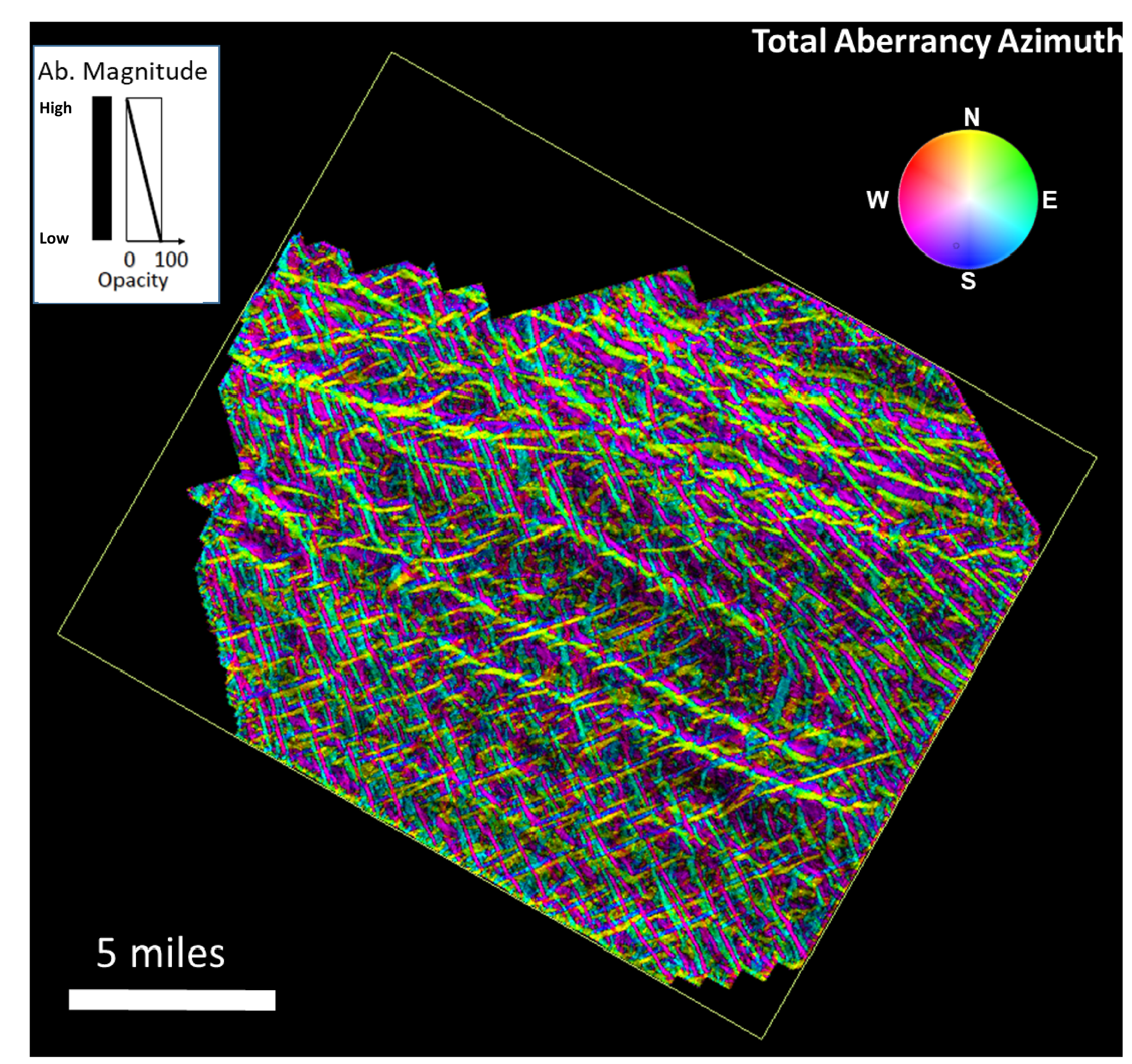


Figure 6: Total aberrancy azimuth modulated with total aberrancy magnitude along the Shublik Shale surface. The bright areas indicate high flexure or aberrancy values. The A set of conjugate faults can be observed abutting against the older basement-related WNW faults. Relatively high values of aberrancy can be seen near the abutting tips due to localized strain development. Note: Coherence (Figure 3a), was not useful here for faults with minimal offset, gentle flexures, and insignificant variation in amplitude as well as seismic waveform shape along the seismic reflectors. Whereas the aberrancy and curvature which can see very small amount of flexure

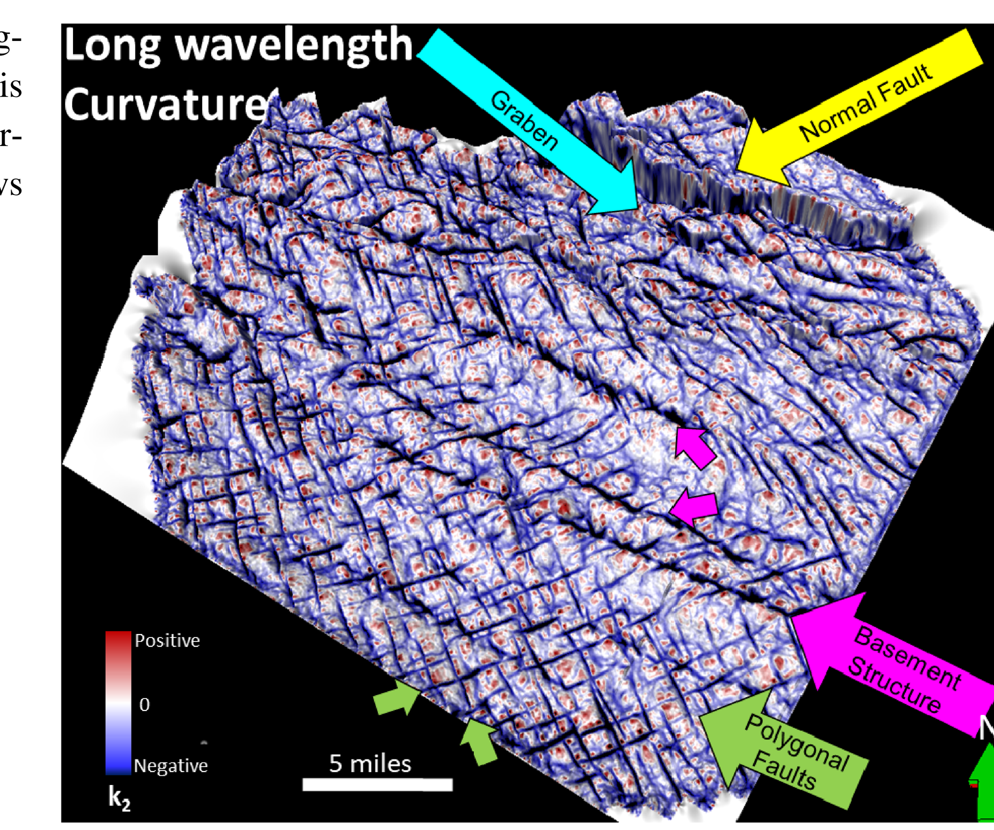
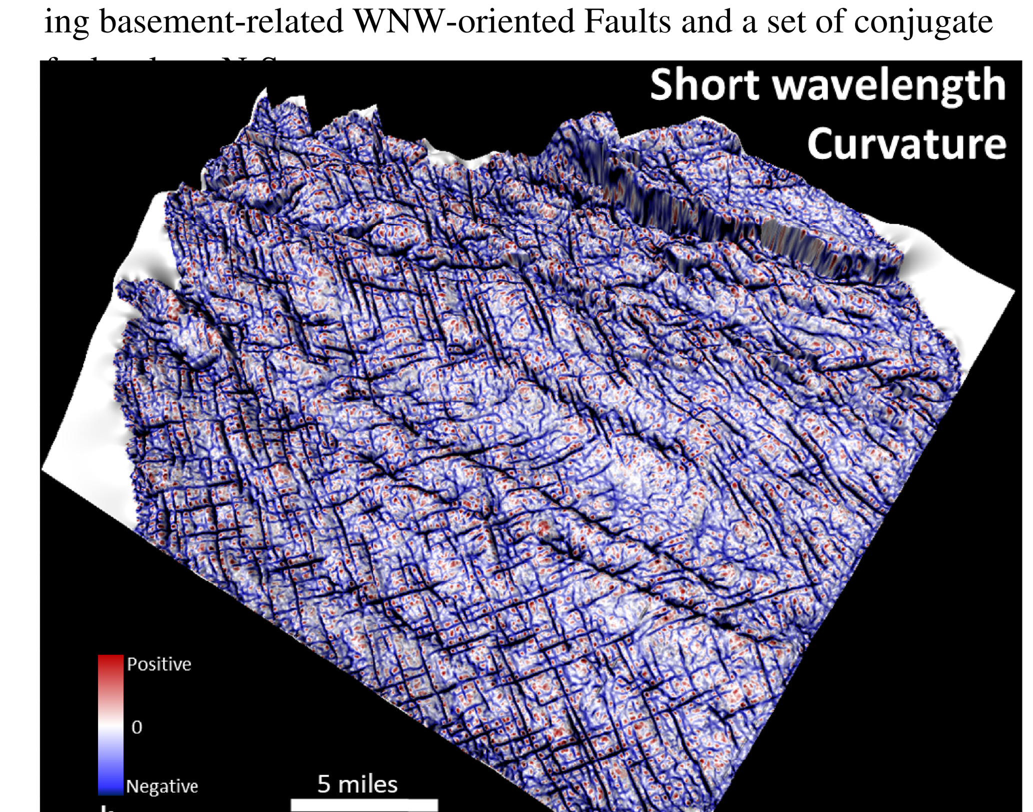


Figure 4: Interpreted structures on the Shublik surface with most-negative curvature (k_2)attribute, top– long wavelength k_2 and bottom– short wavelength k_2 in 3D (vertical exaggeration 25). Two dominant types of faults can be observed on the attributes, including basement-related WNW-oriented Faults and a set of conjugate



5. REFERENCES

Bird, K.J., and Houseknecht, D.W., 2002, U.S. Geological Survey 2002 Petroleum Resource Assessment of the National Petroleum Reserve in Alaska (NPRA), USGS factsheet, 6 p.

Garrity, C., Houseknecht, D.W., Bird, K.J., Potter, C.J., Moore, T.E., Nelson, P.H., and Schenk, C.J., 2005, U.S. Geological Survey 2005 oil and gas resource assessment of the Central North Slope, Alaska: play maps and results, Open-File Report 2005-1182, 29 p.

6. ACKNOWLEDGEMENTS

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4. CONCLUSIONS

Shublik contains WNW-oriented basement-influenced structures, as well as a conjugate set of faults oriented N-S and E-W, and normal fault along NW-SE. Coherence was not useful here for faults with minimal offset. Curvature and aberrancy illuminated the complex faults. Older faults might have been reactivated during or after deposition of the Shublik formations.