Geometric attributes to characterize the complex fault styles on the North Slope, Alaska

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1. SUMMARY

The North Slope, Alaska has a complex fault system in the subsurface due to different episodes of tectonics. The most-producing reservoirs are fault-controlled. Our study area lies in the south of the well-known Prudhoe Bay and Kuparuk oil fields. The Triassic-aged Shublik Shale, which is the most prominent source rock, has gone through three stages of extensional tectonic activities during the Jurassic, Cretaceous, and Eocene. To understand the complex fault system, we computed an ensemble of volumetric seismic attributes, including coherence, curvature, and aberrancy, and studied them along the Shublik Shale surface. In this study, we have divided the structures into three types based on seismic signature, 1. significant fault throw on vertical seismic section, 2. insignificant fault throw but clearly visible flexure, 3. insignificant fault throw and very weak flexure. We observed type 1 faults on the vertical seismic section, and seismic attributes which trends in WNW direction, these faults have large lateral extent. The type 2 faults have similar orientation as type 1. The type 2 faults are clearly visible on the curvature and aberrancy attributes. Although, the type 3 structures have no visible throw on vertical seismic, but it can be seen as two fault lineations (which are orthogonal to each other) on curvature and aberrancy attributes. Based on our attribute analysis and regional geologic understanding, we think that, the type 1 and type 2 fault sets are of Jurassic age, whereas the two faults of the type 3 were formed in Cretaceous and Eocene with an orientation of nearly east-west and north-south orientation. These type 3 faults display cross cutting, single-tip and double-tip abutting relations with the older west-north-west striking faults.

2. GEOLOGY OF THE STUDY AREA

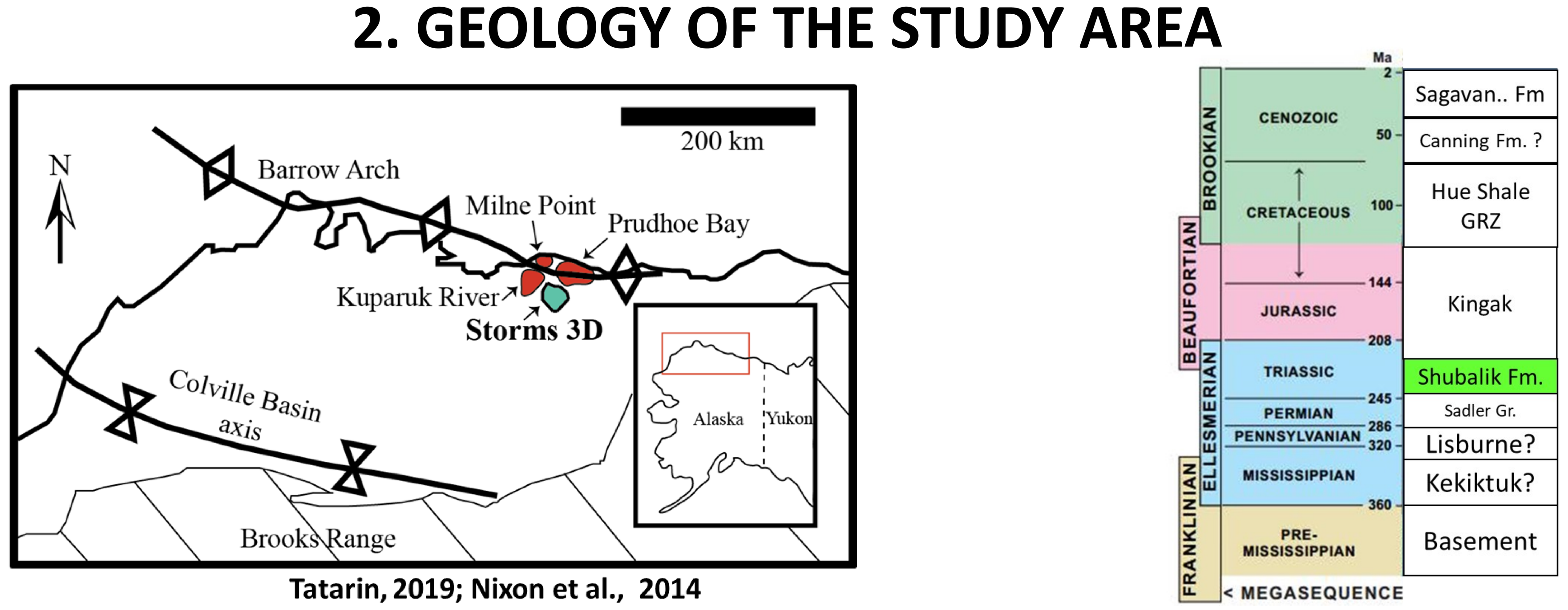

Figure 1. Study area showing the location on the North Slope, Alaska (modified after Bird and Houseknecht, 2002). The blue polygon indicates the approximate 3D seismic survey area ("Storms 3D"), and the black dash line inside the polygon indicates a NW-SE oriented crossline (a seismic section) that will be shown in Figure 4. (b) Stratigraphic units and petroleum system on the North Slope .

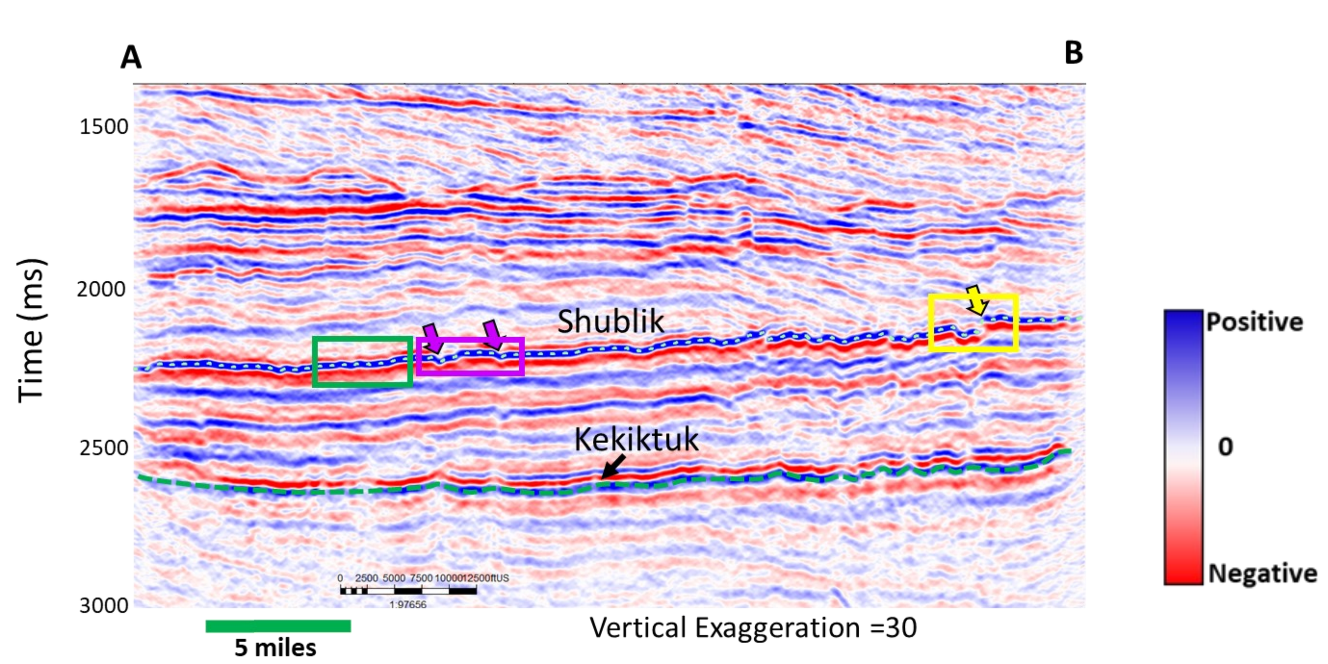

Figure 2. seismic section along NW-SE showing the interpreted horizons such as the Kekiktuk, Shublik, and Kuparuk. The Kekiktuk and Kuparuk formations are hydrocarbon-producing reservoirs, whereas the Shublik Formation acts as both source and cap rocks on the North Slope.

3. SEISMIC ATTRIBUTE STUDY

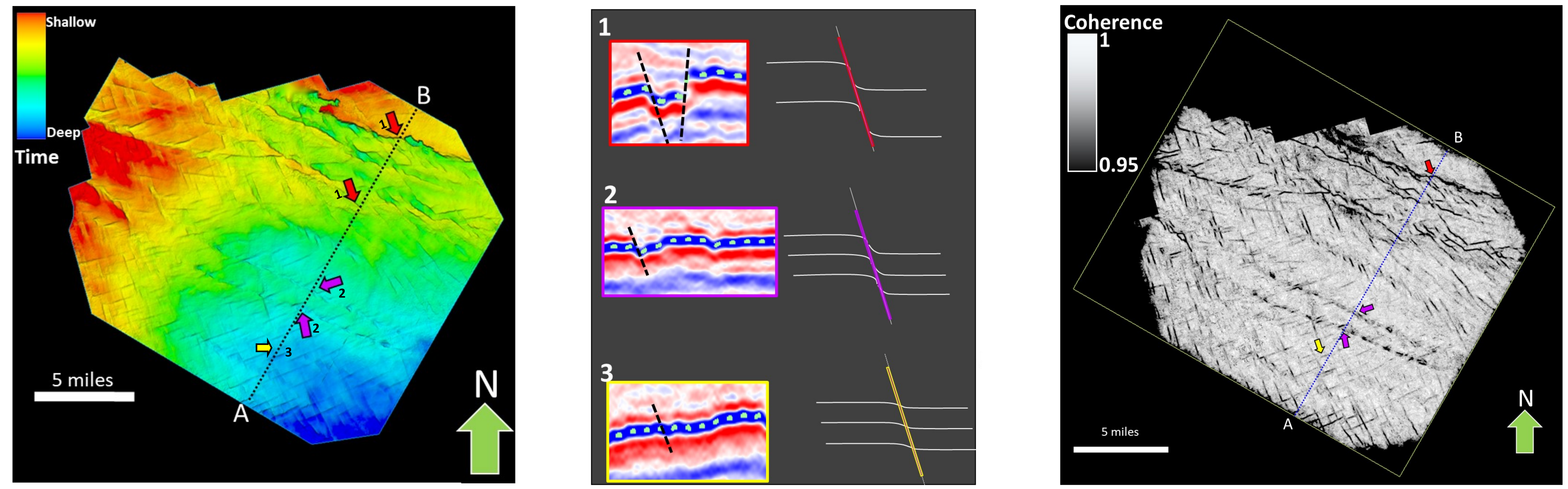

Figure 3: (a) Time structure maps of the Shublik. Note the black dash line indicates the NW-SE oriented crossline seismic section in Figure 2b. (b) zoomed seismic section for, 1. indicated by a red arrow on Figure 3a, which has a significant fault throw on vertical seismic section; 2. indicated by a magenta arrow on Figure 3a, insignificant fault throw but clearly visible flexure, 3. indicated by a red arrow on Figure 3a, insignificant fault throw and very weak flexure. (c) Coherence extracted along the Shublik surface. Notice that the coherence values are significantly high, the range is limited to 0.95 to 1. The In the southern part, the yellow arrow indicates the impression of orthogonal faults, where no coherence anomaly is visible. The magenta arrow shows basement related fault structure. The faults in the northern part of the survey indicated by red arrows, and also the faults indicated by magenta arrow in the middle part of the survey are visible in coherence.

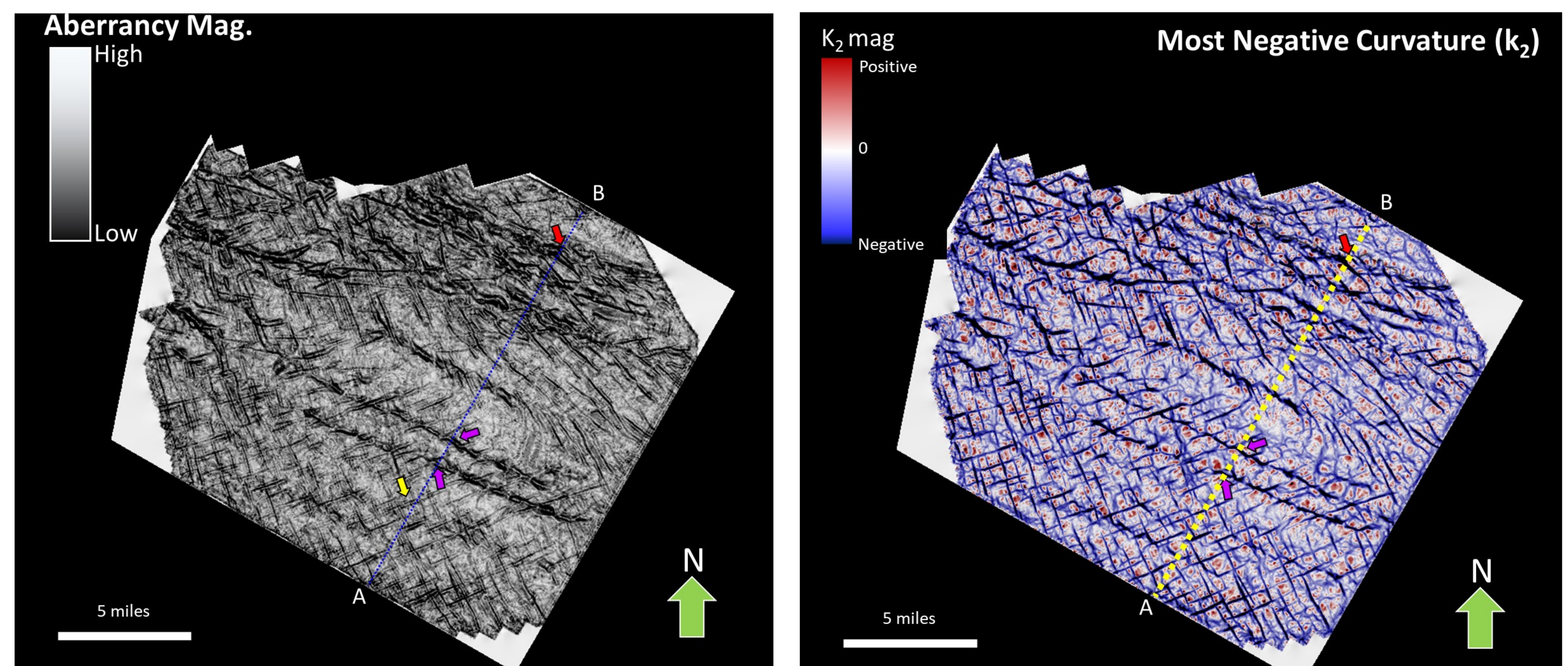

Figure 4: (a) Aberrancy and (b) most-negative curvature (k_2) attribute extracted along the Shublik surface. All three types including 1. red faults, 2. magenta faults and 3. yellow lineation show a aberrancy and curvature anomaly. In the southern part, the impression of the faults is barely visible in coherence, whereas very clearly seen on the curvature attribute.

5. REFERENCES

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3. SEISMIC ATTRIBUTE STUDY

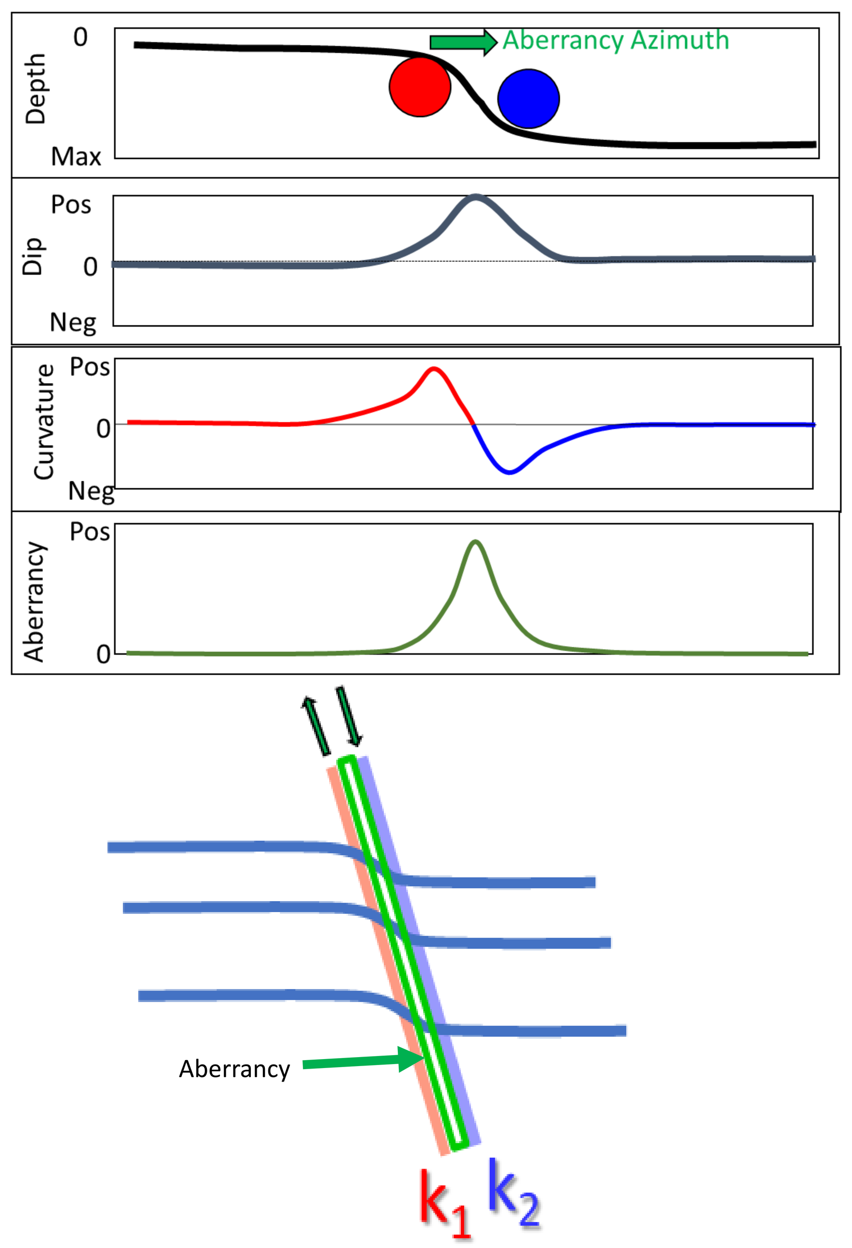
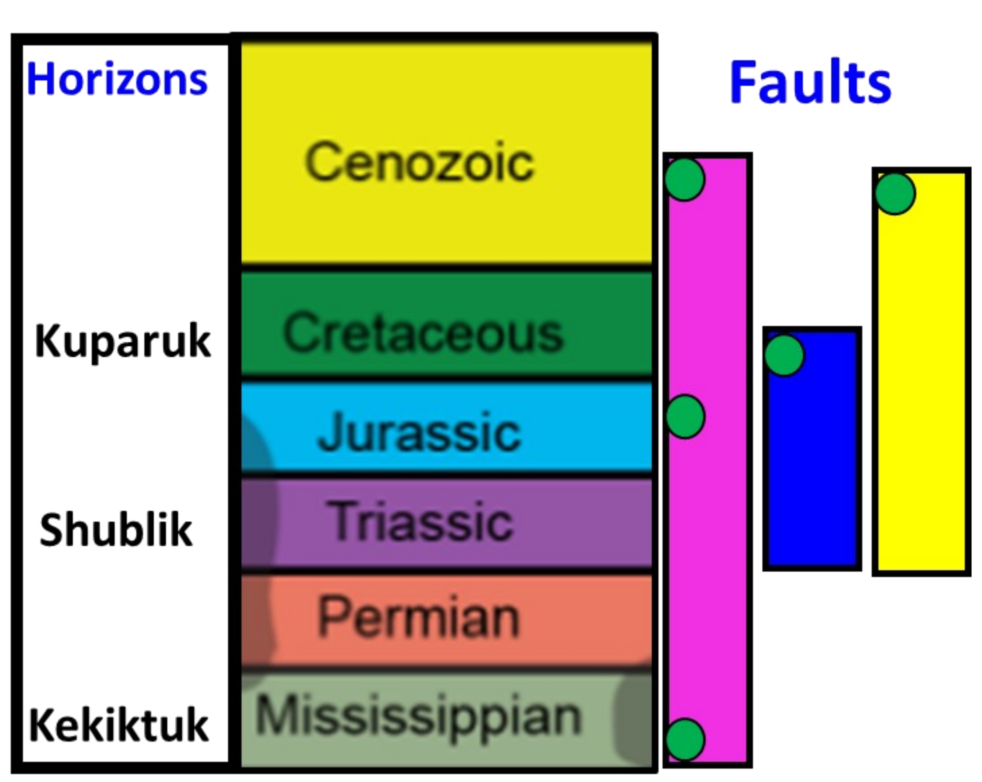


Figure 5: Top– concept of curvature and aberrancy on a curve (modified after Qi and Marfurt, 2018). The red circle indicates peak, and the blue circle indicates trough. Bottom– small offset faults, are seen as a continuous reflector by seismic with a little flexure. So, such faults are not visible on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



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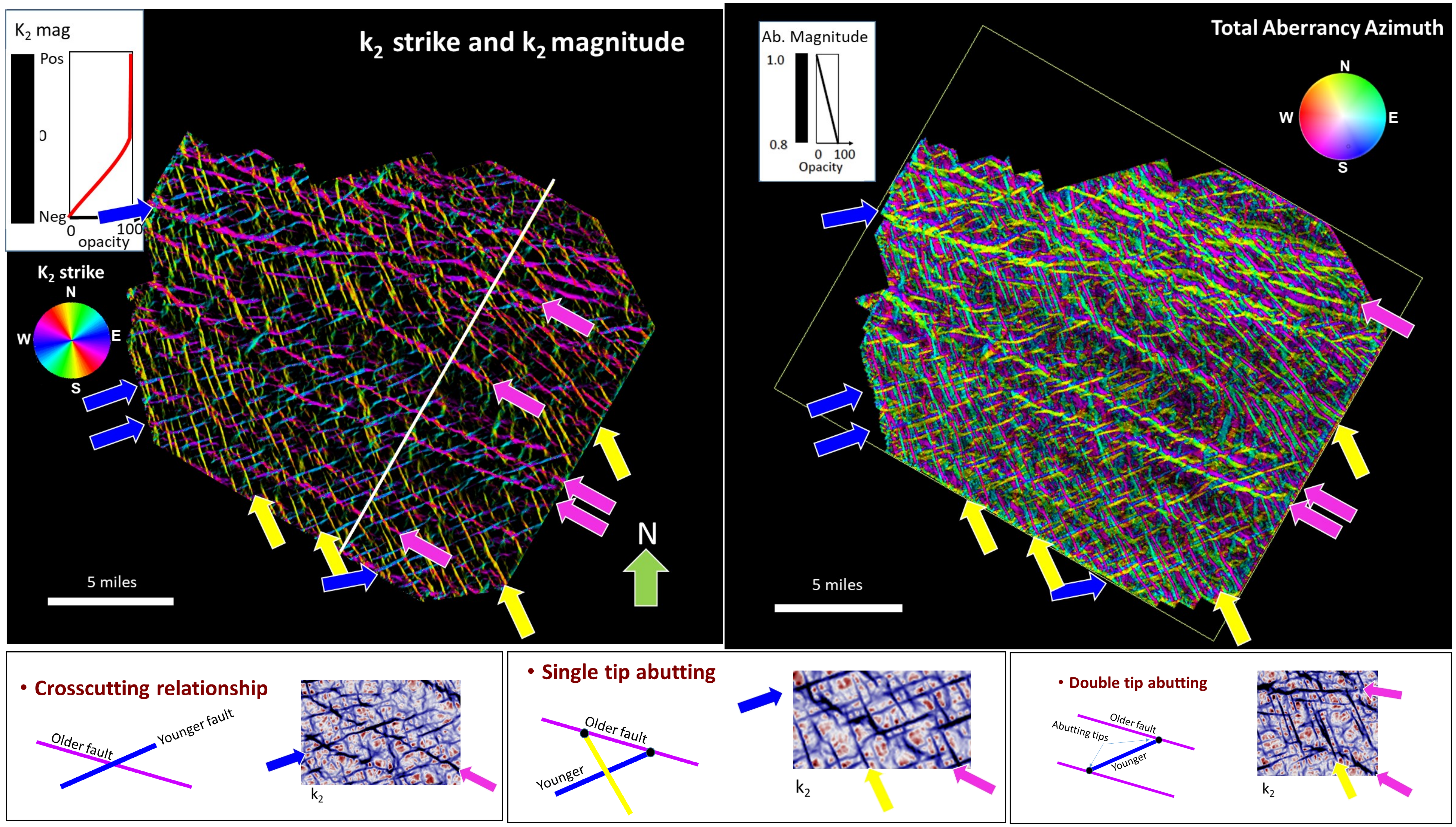

Figure 6: (a) the most-negative curvature (k_2) strike modulated with most negative curvature magnitude slice along the Shublik surface. b) Total aberrancy azimuth modulated with total aberrancy magnitude along the Shublik surface. The bright areas indicate high flexure or aberrancy values. The type 1 and type 2 faults in Figure 3 and 4, have the same orientation (along WNW), and may be genetically related. They are indicated as magenta arrow. Whereas the type 3 faults can be divided in to two sets of lineation (faults?); the NNW-oriented faults are indicated by yellow; the NE-oriented faults are indicated by blue. Based on the cross-cutting, relationships, single-tip abutting and double-tip abutting relation shows, that both yellow and blue structural events (faults?) are younger than magenta fault events. Extension in an oblique direction to the preexisting fault resulted in en-echelon segmented younger faults.

4. CONCLUSIONS

- Big throw- magenta fault: WNW-oriented faults were reactivated several times.
- Insignificant throw- blue fault: NE-oriented faults might have generated due to the oblique reactivation of the deeper WNW faults— that resulted in an en-echelon faults
- Insignificant throw- yellow fault: NNW-oriented faults might have generated due to the oblique reactivation of the deeper WNW faults— that resulted in an en-echelon faults
- Coherence was not useful here for faults with minimal offset.
- Curvature and aberrancy illuminated the complex faults. Curvature provided the strike of faults.
- Together, curvature and aberrancy attributes, help find the approximate relative ages of the faults.

6. ACKNOWLEDGEMENTS

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