[GC]Interpreting Fault and Fracture Lineaments with Euler Curvature*

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General Statement

Geometric attributes such as coherence and curvature are commonly used for mapping faults, joints and large fractures, or fault damage zones. There are several curvature attributes that are available to a seismic interpreter, but the two most popular attributes are the most-positive and most-negative curvature.

They are not only intuitively easy to understand, but they provide more continuous maps of faults and fractures. There is another attribute, called Euler curvature, which has useful applications when calculated for 3-D seismic volumes. We had described this attribute and some of its applications in our Geophysical Corner article Euler Curvature Helps Define Lineaments, Search and Discovery Article #40838. We revisit it in this article and describe how an interpreter can determine the fault or fracture lineaments in different orientations in more detail, by putting them together in a 3-D viewer. Such a display can provide convenient interpretation of the lineaments of interest.

Determining Euler Curvature

Euler curvature is determined from the most-positive and most-negative curvature magnitudes as well as their strikes. Because the reflector dip magnitude and azimuth can vary considerably across a 3-D seismic survey, it is more useful to equally sample azimuths of Euler curvature on a horizontal x-y plane and project the lines onto the local dipping plane of the reflector. In this way, Euler curvature can be calculated in any desired azimuth across a 3-D seismic volume to enhance the definition of specific lineaments. Such enhanced lineaments along specific azimuths can be brought together for interpreting azimuth-dependent structure for convenient interpretation.

We describe here the application of Euler curvature to a 3-D seismic volume from the Montney-Dawson area of northeastern British Columbia, Canada. The data volume displayed is close to 500 square kilometers.

In Figure 1, we show a stratal slice through a coherence volume which shows fault lineaments in the NNW-SSE orientation indicated by red arrows. An east-west oriented fault indicated by green arrows is seen at the bottom of the display. These prominent lineaments can easily be seen on the vertical seismic sections where the reflectors exhibit finite offset across the faults. The challenge for an interpreter is to identify and interpret less obvious, more subtle lineaments that may also exist in the zone of interest.

In Figure 2, we show stratal slices through three long wavelength Euler curvature attribute volumes corresponding to ±90 degrees, -30 degrees and +30 degrees. Notice how the fine lineaments in the three orientations stand out as indicated by the yellow, blue and green sets of arrows.

In shale resource plays, we might know the present day orientation of the maximum horizontal stress (SH), from image logs or azimuthal anisotropy analysis. If the tectonic history is such that natural cracks and fractures are parallel to these lineaments, the lineaments parallel to the SH orientation might be of particular interest, with areas of anomalously higher degree of curvature being potential sweet spots. Alternatively, we may wish to co-render the three chosen orientations together using an RGB color bar.

We start in Figure 3 by plotting each set, setting the larger positive values to be opaque. Then in Figure 4, we co-render these three images by simply adding the R, G and B components of the images in Figure 3. In this way each lineament is assigned a specific color, while areas of crossing lineaments combine to form intermediate colors using the well understood RGB color model.

This image provides a composite of all the lineament orientations and is very useful in terms of the more detail that it provides for interpretation.

Conclusions

The level of detail seen on the composite display is much higher than what is seen on the equivalent coherence stratal display. We find merit in putting Euler curvature lineaments together in a 3-D viewer for their convenient interpretation.

The next step would be to calibrate these seismic attribute based lineaments with lineaments interpreted from image logs. One challenge for doing this is usually the scarcity of the latter data. We do emphasize the importance of image logs in such confirmatory exercises.

Acknowledgement

We appreciate the help extended by Thang Ha and Fangyu Li, students at the University of Oklahoma, in fixing the image shown in Figure 4.

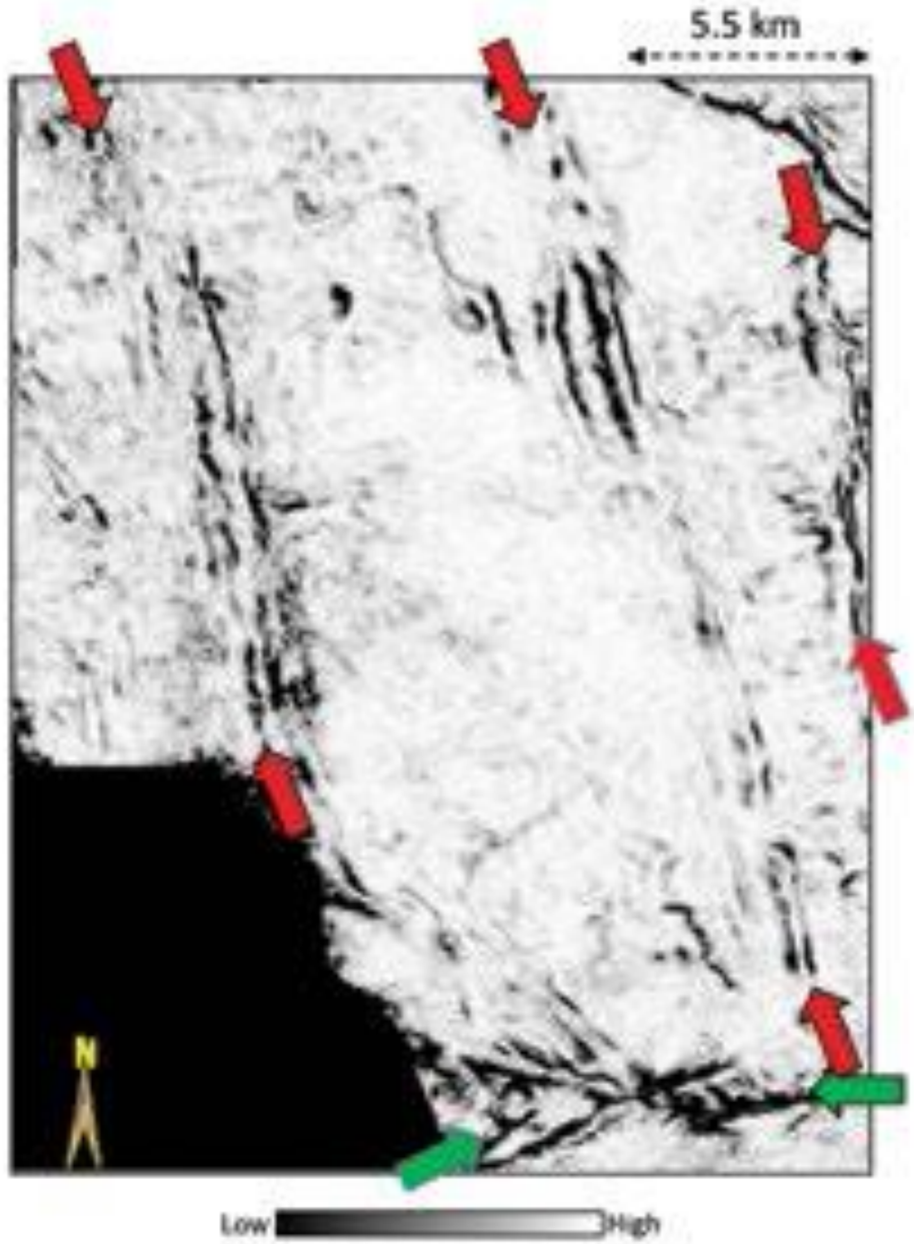

Figure 1. Stratal display through a coherence volume at a level close to t=1600 milliseconds. Fault lineaments striking -30 degrees from north are indicated by red arrows. Another lineament striking approximately east-west is indicated by green arrows.

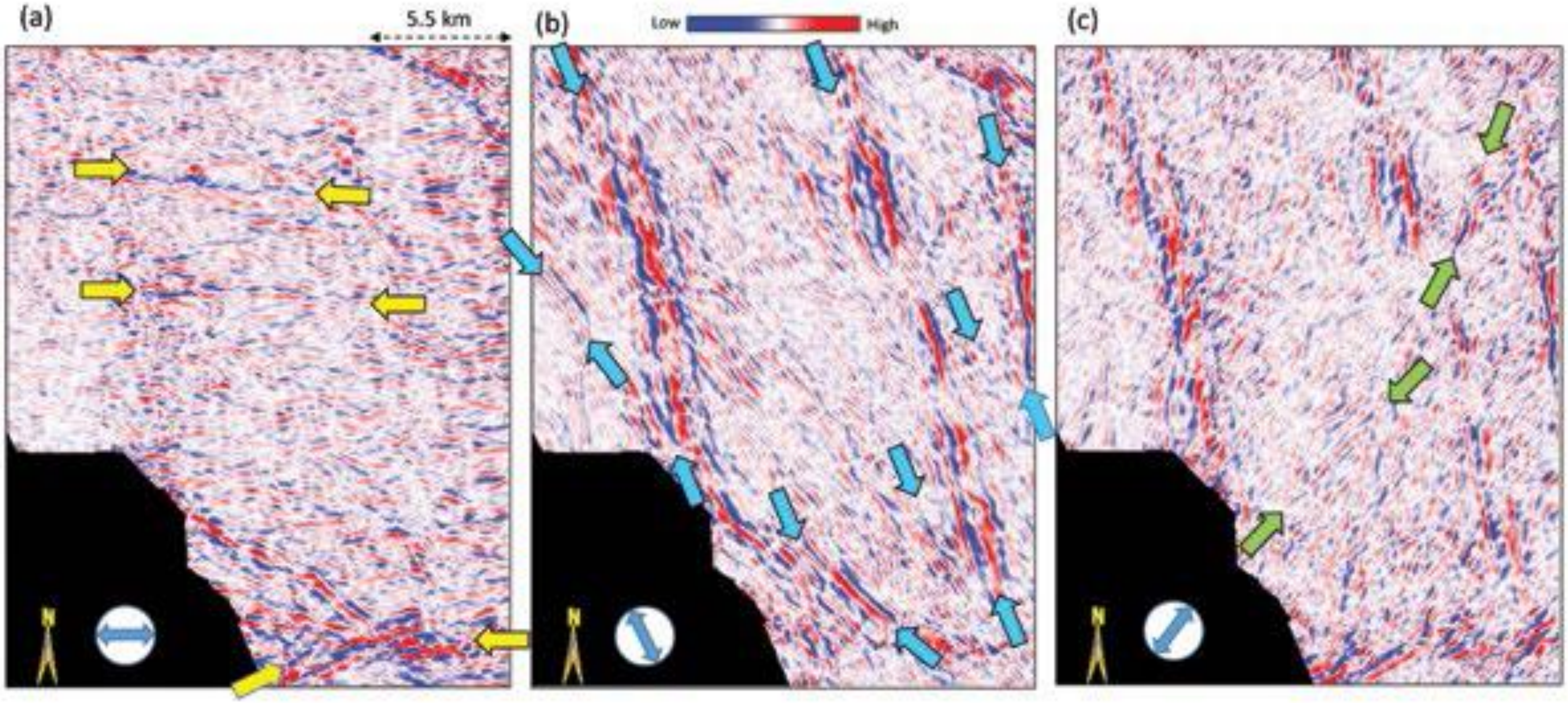

Figure 2. Stratal slices through long-wavelength Euler-curvature attribute volumes with strikes of: (a) ±90 degrees, (b) -30 degrees, and (c) +30 degrees as indicated by the insets. In essence, Euler curvature is an azimuthally filtered version of the most-positive and most-negative principal curvatures, accentuating faults and flexures along any desired strike direction. The subtle lineaments seen in (c) may correspond to splay faults or relay ramps controlled by the major faults shown in (b).

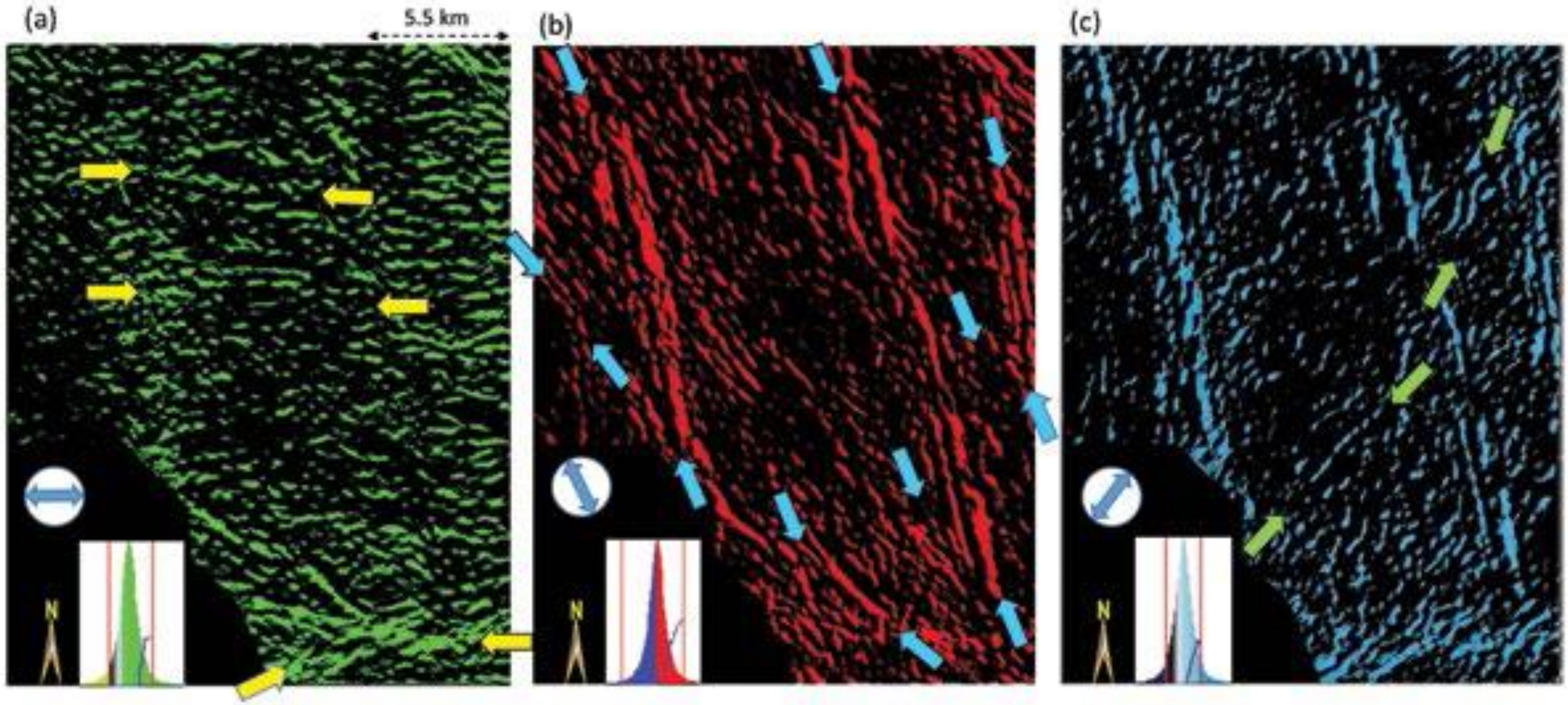

Figure 3. The same stratal slices shown in the previous figure, but now plotted against green, red and blue color bars using opacity to enhance the most positive anticlinal features.

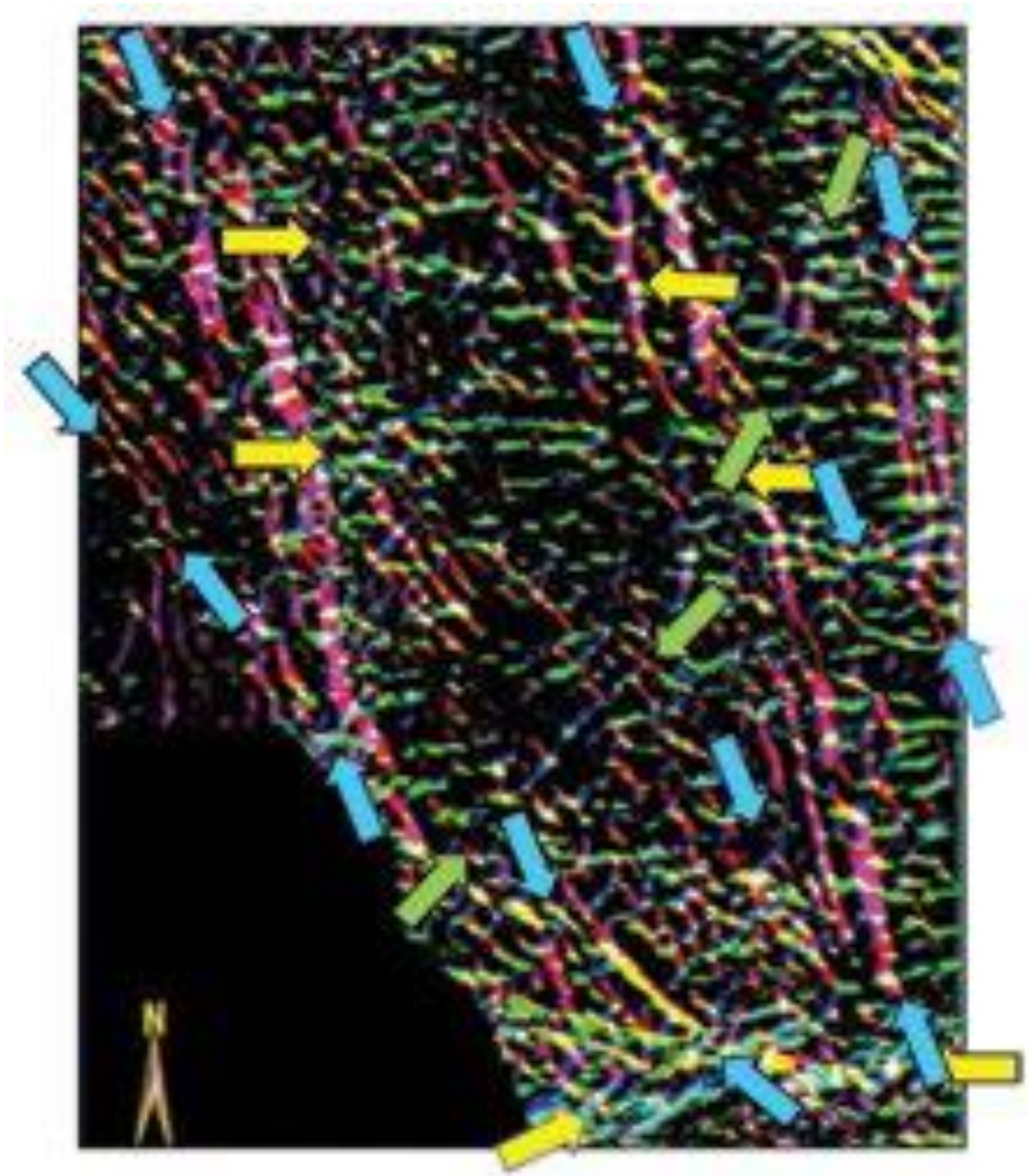

Figure 4. Co-rendering the three images of the anticlinal lineaments in Figure 3 together using a modern 3-D viewer and thus generating a composite display amenable to extracting more detailed interaction between the three hypothesized fault sets.