Interpreting Fault and Fracture Lineaments with Euler Curvature

By SATINDER CHOPRA and KURT J. MARFURT

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 published in the December 2011 issue of the EXPLORER. We revisit it in this issue of the EXPLORER. We describe here the application of Euler curvature to a 3-D seismic volume from the Montney-Dawson area of northeastern British Columbia, Canada. 

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 start in figure 3 by plotting each set of arrows. Such a display can provide convenient interpretation of the lineaments of interest. Figure 1 (left): 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 (right): 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 spaly faults or relay ramps controlled by the major faults shown in (b).

In figure 4 (right): 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.

The level of detail seen on the composite display is much higher than what is seen on the equivalent coherence stratal display.

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.

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.

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The Geophysical Corner is a regular column in the EXPLORER, edited by Satinder Chopra, chief geophysicist for Arcis Seismic Solutions, TGS, Calgary, Canada, and a past AAPG-SEG Joint Distinguished Lecturer.
In the “less is more” department, researchers at the University of Glasgow in Scotland are developing a device that could potentially revolutionize the field of gravity sensing. Borrowing from smart phone technology, they have developed and demonstrated a fingernail-size gravimeter. Richard Middlemiss and several colleagues with the university’s Institute for Gravitational Research published results of their research in the journal Nature. “Gravimeters have been around for decades. The problem with them is they generally cost hundreds of thousands of pounds, or dollars, and they weigh 10 kilograms, 20 kilograms, up to hundreds of kilograms,” he said.

Middlemiss said the device could be produced much more economically than current gravimeters. “What we’ve done is we’ve taken the technology that’s used in a mobile phone – that’s the thing that turns the screen sideways when you tilt it (an accelerometer). ... We’ve made this thing massively more sensitive and massively more stable and we’re now able to use that as a gravimeter,” he added.

**Application in the Field**

Aapg Member Joseph P. Fagan Jr., president of Centennial Geoscience Inc. in Littleton, Colo., agreed that if the device can be fully developed and mass-produced commercially, it could be an important advancement for the field and for energy exploration. “We’re going to have to watch and see how it develops. It has a lot of promise and it really is exciting,” Fagan said. “If it can be effectively mass-produced, it would reduce overall costs. You could place gravimeters in the field for real-time or ongoing monitoring,” he said. “To me, acquiring gravity and magnetic data is the logical first step to help design an exploration program.” Fagan said. He said gravimetry, especially airborne, has been advancing in quality and cost-effectiveness, and a further reduction in cost and improvement in convenience would go a long way. “If it (gravimetry) helps and prevents you from shooting a couple square miles (of seismic) you didn’t need, it has probably already paid for itself,” he said. He said airborne geophysical methods have extra value when land access is a problem. “Since these data are all acquired remotely, there are no feet on the ground,” he said.

**How It Works**

The team’s new device, which they have named “Wee-g,” uses the same cheap, mass-producible micro-electromechanical systems (MEMS) used in smartphones’ internal accelerometers. While the MEMS technology in phones uses relatively stiff and insensitive springs to maintain the orientation of the screen relative to the Earth, Wee-g employs a silicon spring about a tenth of the thickness of a human hair. This allows Wee-g’s 12 millimeter-square sensor to detect very small changes in gravity, according to the university release.

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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 stratigraphic 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 doing this is usually the scarcity of the latter data. We do emphasize the importance of image logs in such confirmatory exercises.

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. [Editor’s note: Kurt Marfurt is an AAPG Member and professor of geophysics at the University of Oklahoma.]