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Chair (9 MB)   Cube Curve Strat3 (43 MB)
Jullienne Most-Neg-Curve (54 MB)   Jullienne (9 MB)
Jullienne TSL (8 MB)

Detecting Stratigraphic Features via Cross-Plotting of Seismic Discontinuity Attributes and Their Volume Visualization*

Satinder Chopra[1] and Kurt J. Marfurt[2]

Search and Discovery Article #40644 (2010)
Posted November 22, 2010

*Adapted from oral presentation at AAPG Convention, New Orleans, Louisiana, April 11-14, 2010. Please see closely related article, Volumetric Curvature Attributes for Mapping Faults, Fractures, Depositional and Diagenetic Features, Search and Discovery article #40341 (2008).

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Abstract

Fold and fault geometries, stratal architecture and large-scale depositional elements (e.g. channels, incised valley-fill and turbidite fan complexes) are often difficult to see clearly on vertical and horizontal slices through the seismic reflection data. Consequently, visualization techniques are used for viewing the data, whether it's the input seismic data or derived data in terms of seismic attributes. Such visualization helps extract meaningful information, allows for greater interpretation accuracy and improves efficiency. 3D volume rendering is one form of visualization that involves opacity control to view the features of interest 'inside' the 3D volume. A judicious choice of opacity applied to edge-sensitive attribute sub-volumes such as curvature or coherence co-rendered with the seismic amplitude volume can both accelerate and lend confidence to the interpretation of complex structure and stratigraphy.

In addition to co-rendering, we evaluate an interpretation workflow that cross-plots pairs of edge-sensitive attributes. By cross-plotting coherence and an appropriate curvature attribute, we can define a polygon that highlights "clusters" that exhibit low coherence (indicating a discontinuity) and high curvature (indicating folding, flexing, fault drag, or differential compaction). Modern volume

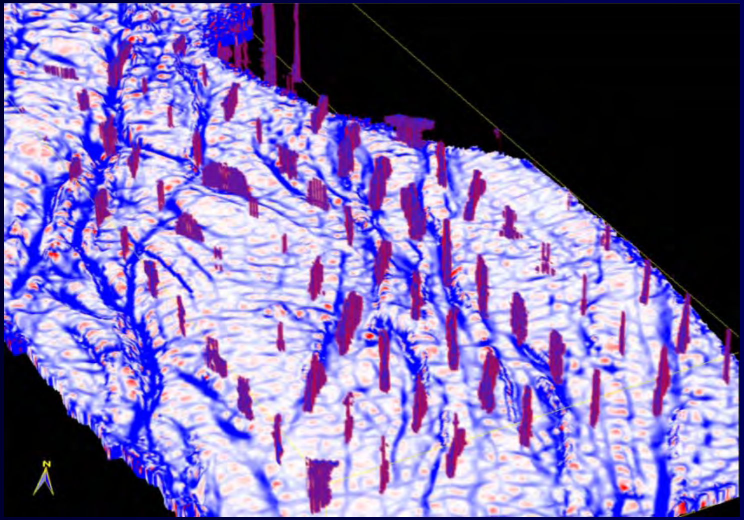
interpretation software allows us to link and display these interpreter-defined clusters in the seismic volume for further examination. Once identified interactively, such visual ‘clustering’ can be used to supervise geobody delineation using neural networks and other classification algorithms. This saves the seismic interpreters considerable time and effort. We illustrate this new workflow through application to several 3D seismic surveys recently acquired in western Canada and demonstrate that multi-attribute volume co-rendering and clustering provides a powerful tool that leads to a better understanding of the spatial relationships between seismic attributes and the geologic objectives being pursued.

References

Ganguly, J., A.M. Freed, and S.K. Saxena, 2009, Density profiles of oceanic slabs and surrounding mantle; integrated thermodynamic and thermal modeling, and implications for the fate of slabs at the 660-km discontinuity: Physics of the Earth and Planetary Interiors, v. 172/3-4, p. 257-267.

Rao, B.H., V. Sridhar, R.R. Rakesh, D.N. Singh, P.K. Narayan, and P.K. Wattal, 2009, Application of in-situ lysimetric studies for determining soil hydraulic conductivity: Geotechnical and Geological Engineering, v. 27/5, p. 595-606.

Detecting Stratigraphic Features Via Cross-plotting Of Seismic Discontinuity Attributes And Their Volume Visualization



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UNIVERSITY OF OKLAHOMA, NORMAN

Seismic Discontinuity Attribute Applications-Benefits

1. Easier recognition of detailed geology within a 3D seismic dataset.
2. Interpretation of higher resolution faults/fractures in any orientation without interpretation bias.
3. Clearer stratigraphic features for more accurate interpretations.
4. Features imaged in a consistent three-dimensional manner.
5. Suitable comparison with log data enables confident interpretation of faults/fractures.
6. Reduce exploration and development risk by providing a more accurate understanding of subsurface geologic features recorded by 3D seismic data.

Seismic Discontinuity Attribute Applications-Benefits

7. Reduces interpretation cycle time and costs by providing a clearer picture of the subsurface.
8. Adds value to existing 3D seismic investment by exploiting the data to its fullest.
9. Represents a small percentage of the total seismic cost.

Lack of adoption of 3D visualization and volume interpretation

(Expert Answers, RECORDER, Nov 2005)

1. Windows based software used by companies don’t have adequate visualization capabilities.
2. 2D image or profile processing is a mature technology.
3. Present generation of visualization software is not yet user friendly, all purpose Leatherman tool that is desired.
4. Not enough motivation to expand their training and technical skills.

Benefits of 3D Volume Visualization

1. 3D volume rendering offers great opportunities for exploring within the 3D seismic data volumes. It involves opacity control to view inside the 3D volume. It is a truer sense of 3D visualization.
2. Allows the interpreter to comprehend large volumes of data rapidly and gain insights into both regional and prospect specific geological features.
3. Complex stratigraphic systems and complex fault systems are much more apparent and so useful for lead identification and prioritization.
4. Visualization systems allow identification and visualization of depositional patterns far more effectively than section-based interpretation.

3D Volume Visualization Features

1. Instead of the full volume, a sub-volume could be used for roaming.
2. Illumination and lighting control from low angles, could prove to be useful.
3. Color manipulation, along with opacity control can enhance certain attributes.
4. Multi-volume rendering can help combine two or more coincident volumes by varying the opacity and control of each.
5. ……

3D Volume Visualization Status

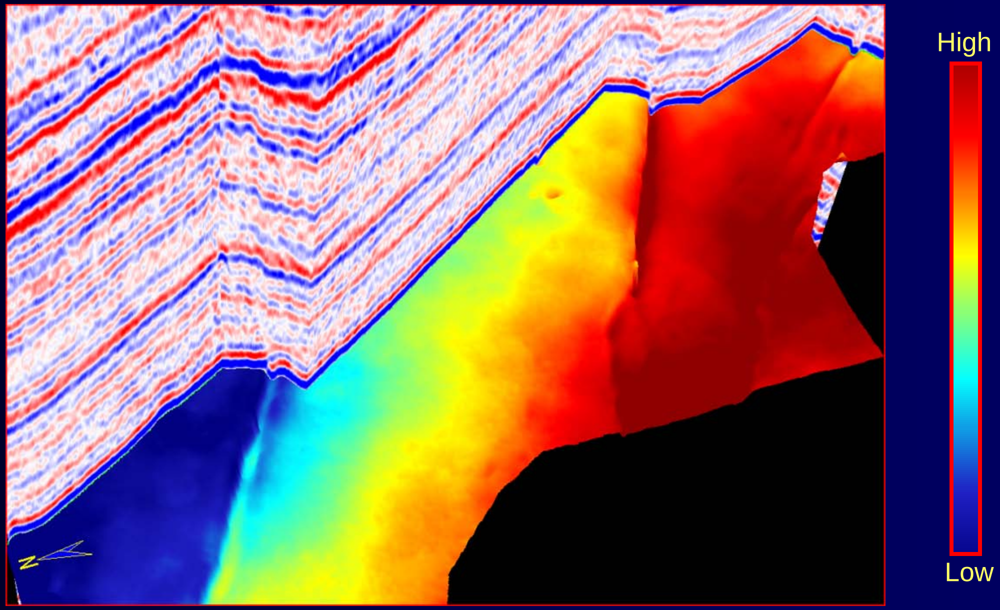
1. 3D visualization is almost there now.

2. Experienced interpreters are aware of the many benefits of 3D visualization.

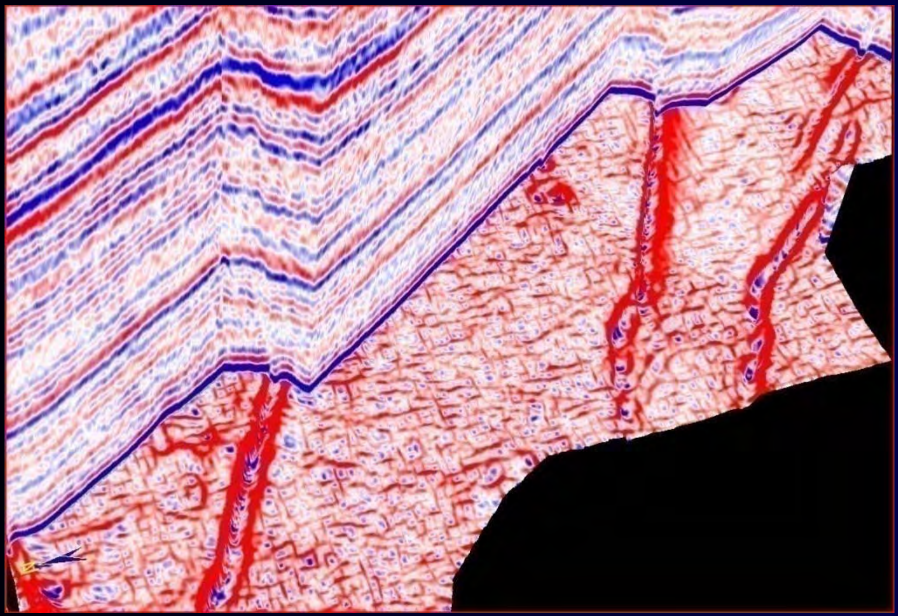
3. Can use 3D visualization to find exploration leads or better delineate known reservoirs.

4. ……

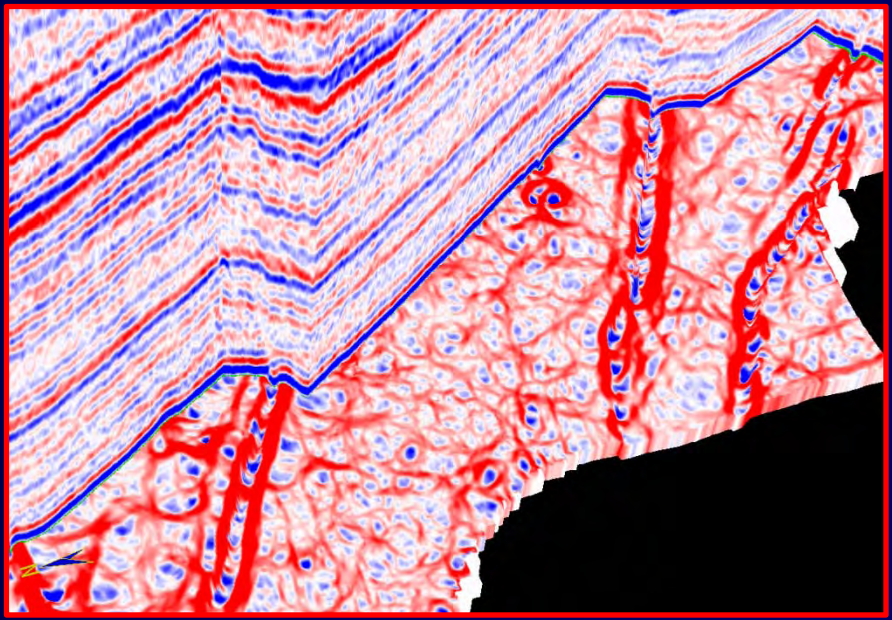
Curvature



Time surface through the seismic volume

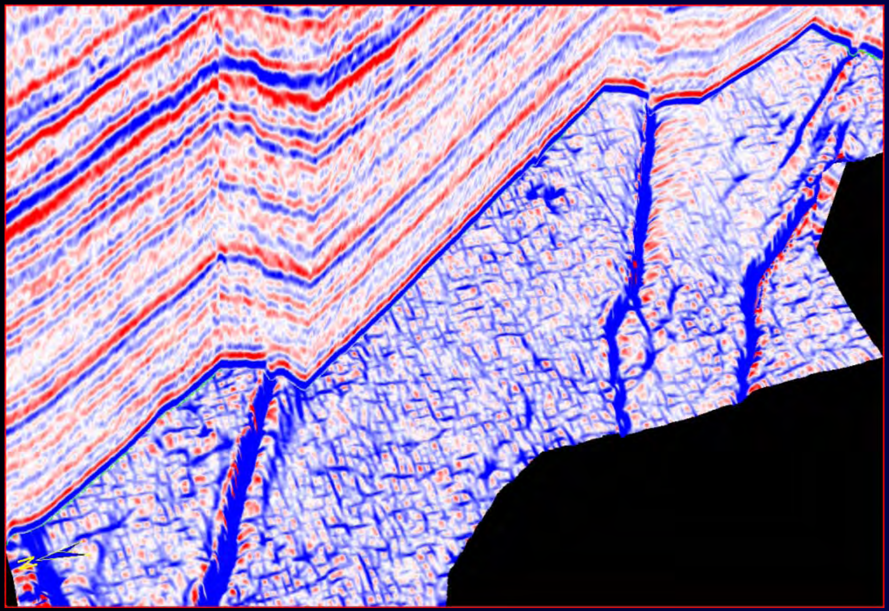


Most-positive curvature computed along the time surface

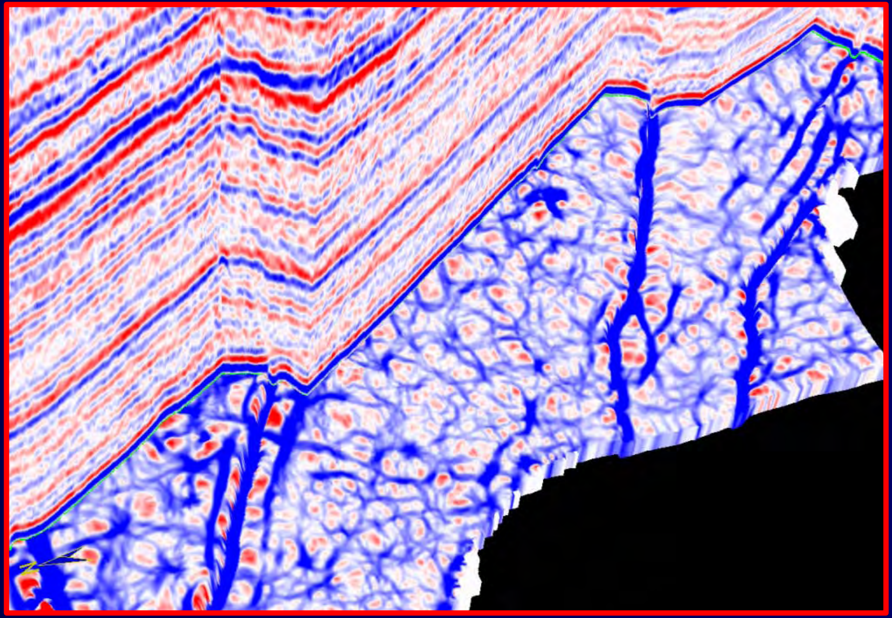


Most-positive curvature extracted along the time surface from the volume

Curvature

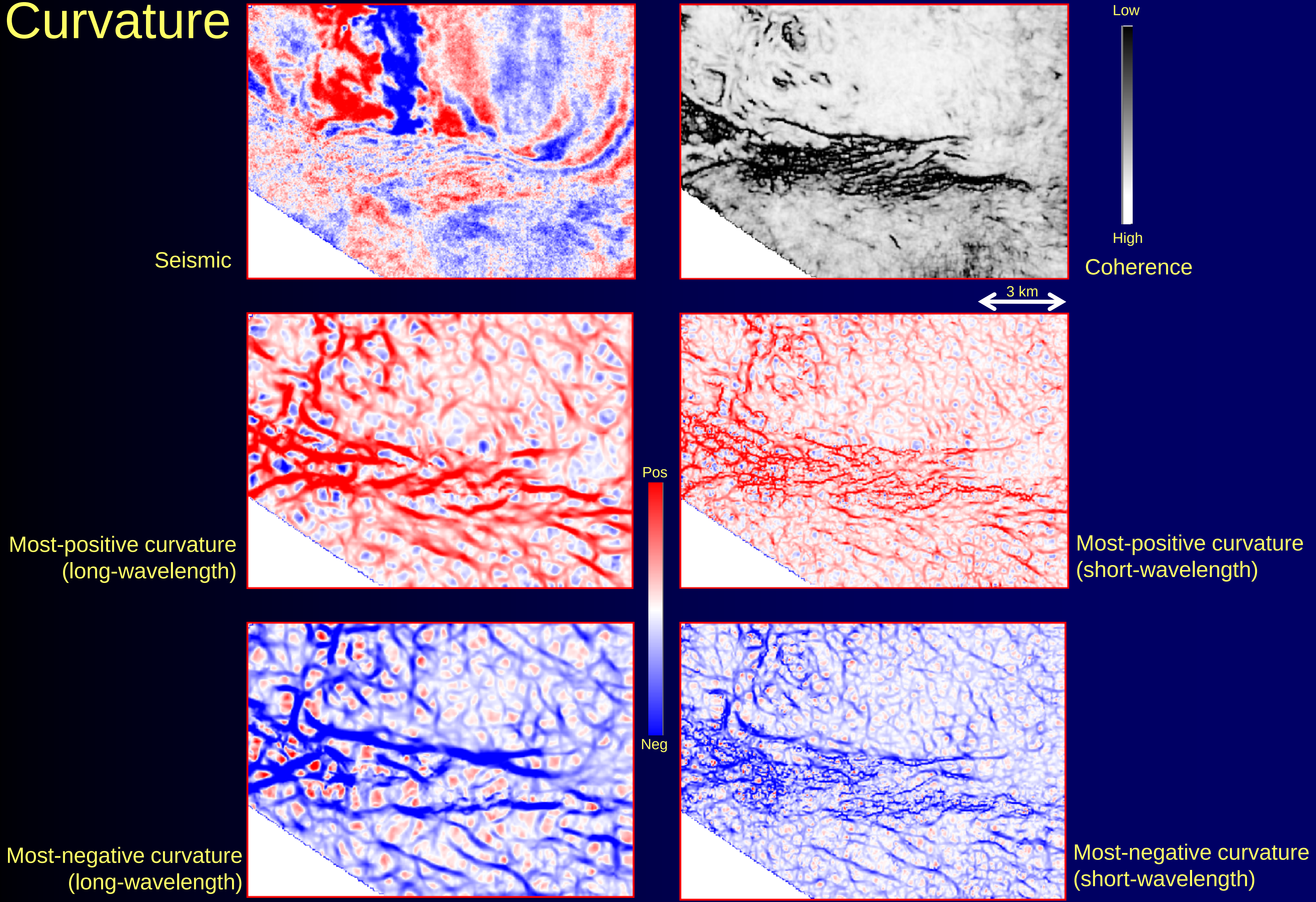


Most-negative curvature computed along the time surface



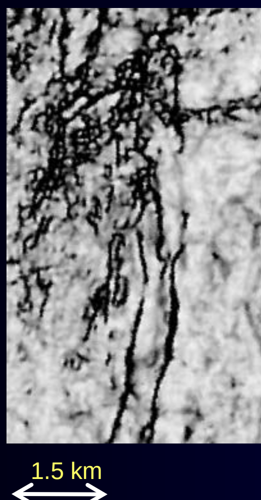
Most-negative curvature extracted along the time surface from the volume

Curvature

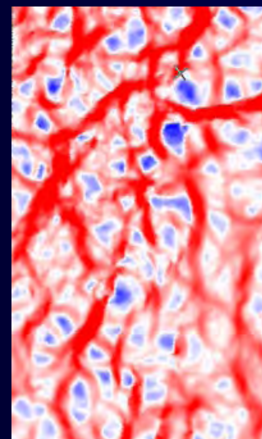


Notice the clear set of faults/fractures generated from coherence and curvature attributes.

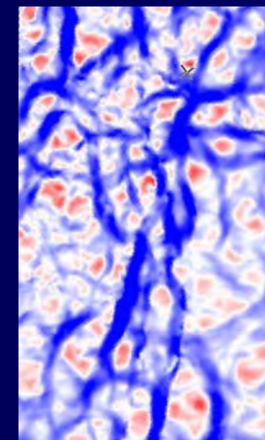
Curvature



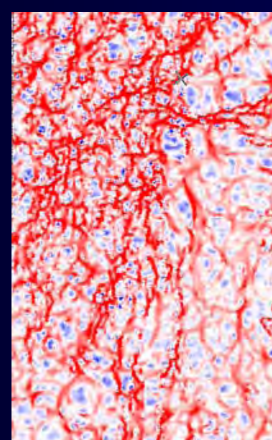
Coherence



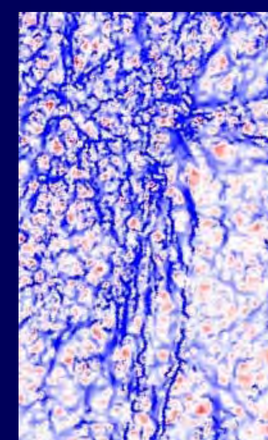
Most-positive curvature (long-wavelength)



Most-negative curvature (long-wavelength)



Most-positive curvature (short-wavelength)

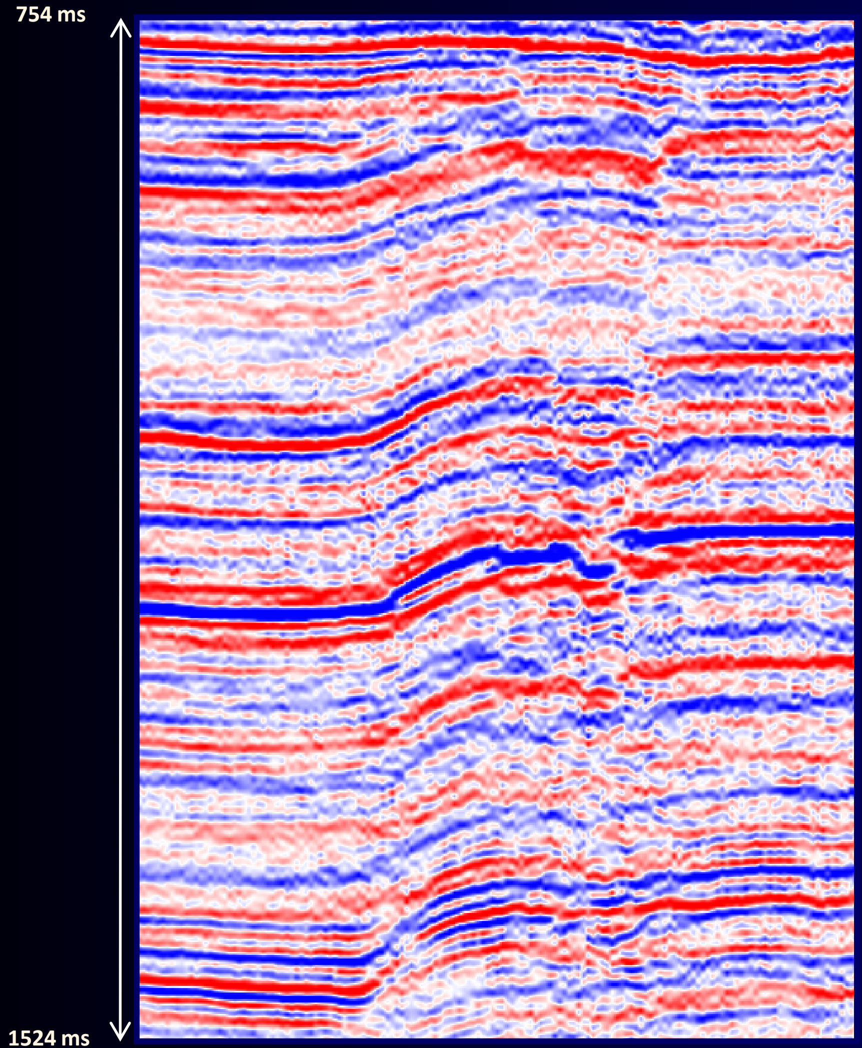


Most-negative curvature (short-wavelength)

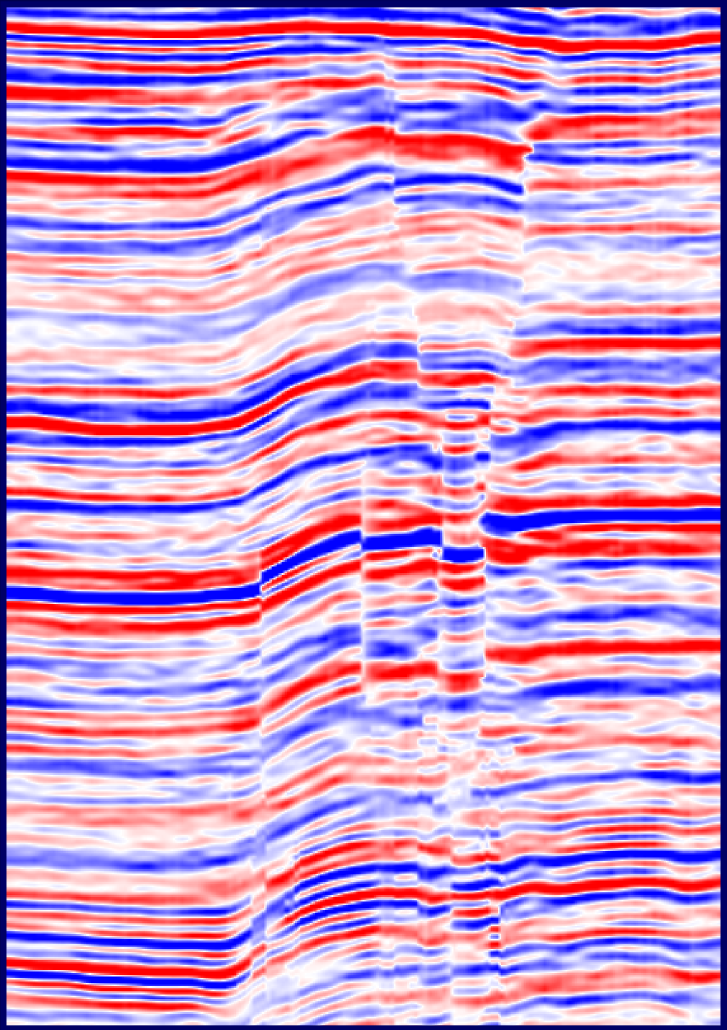
Time slices (1978 ms)

(Images courtesy: POGC & FX Energy)

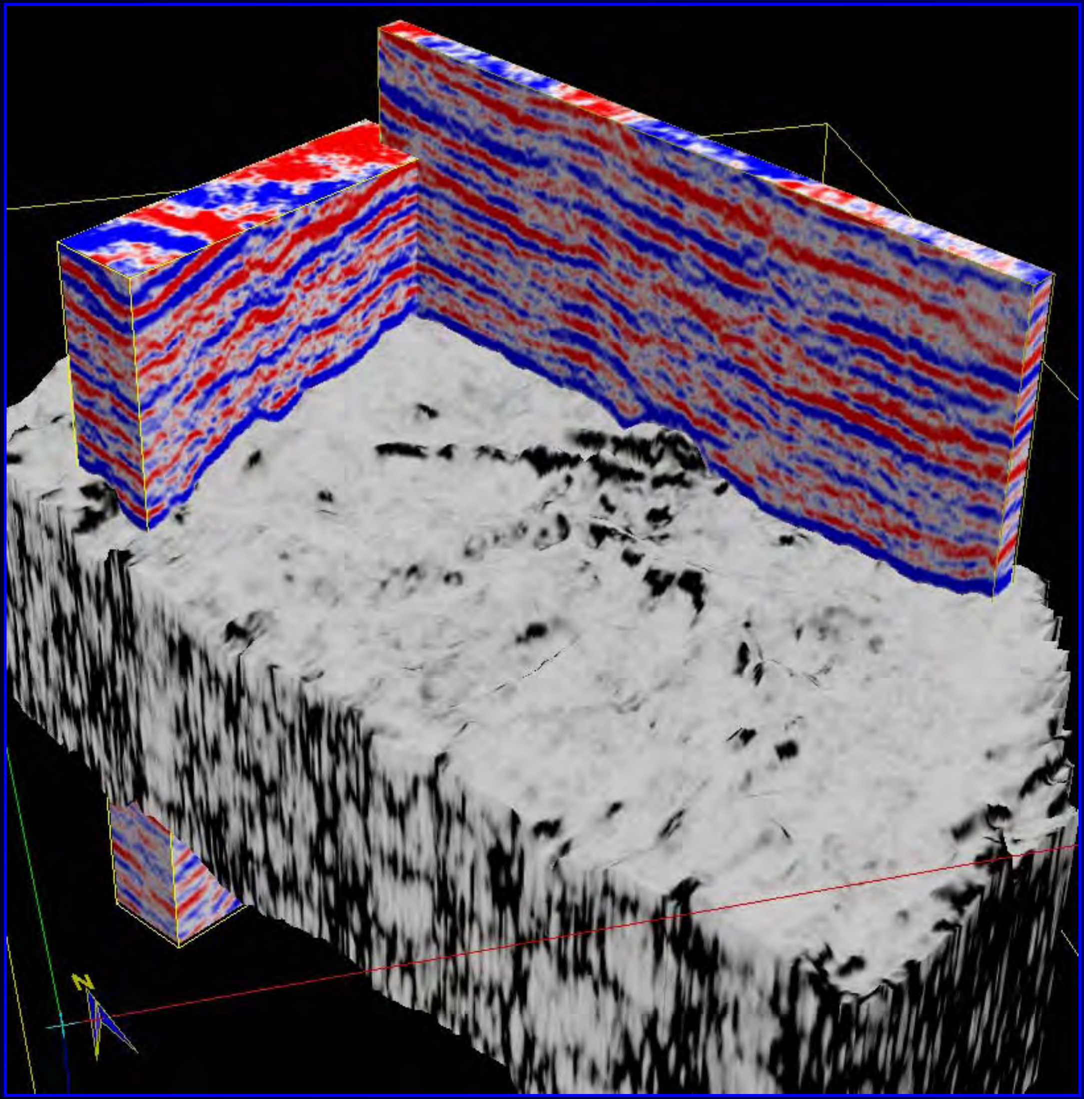
Pre-conditioning of seismic data



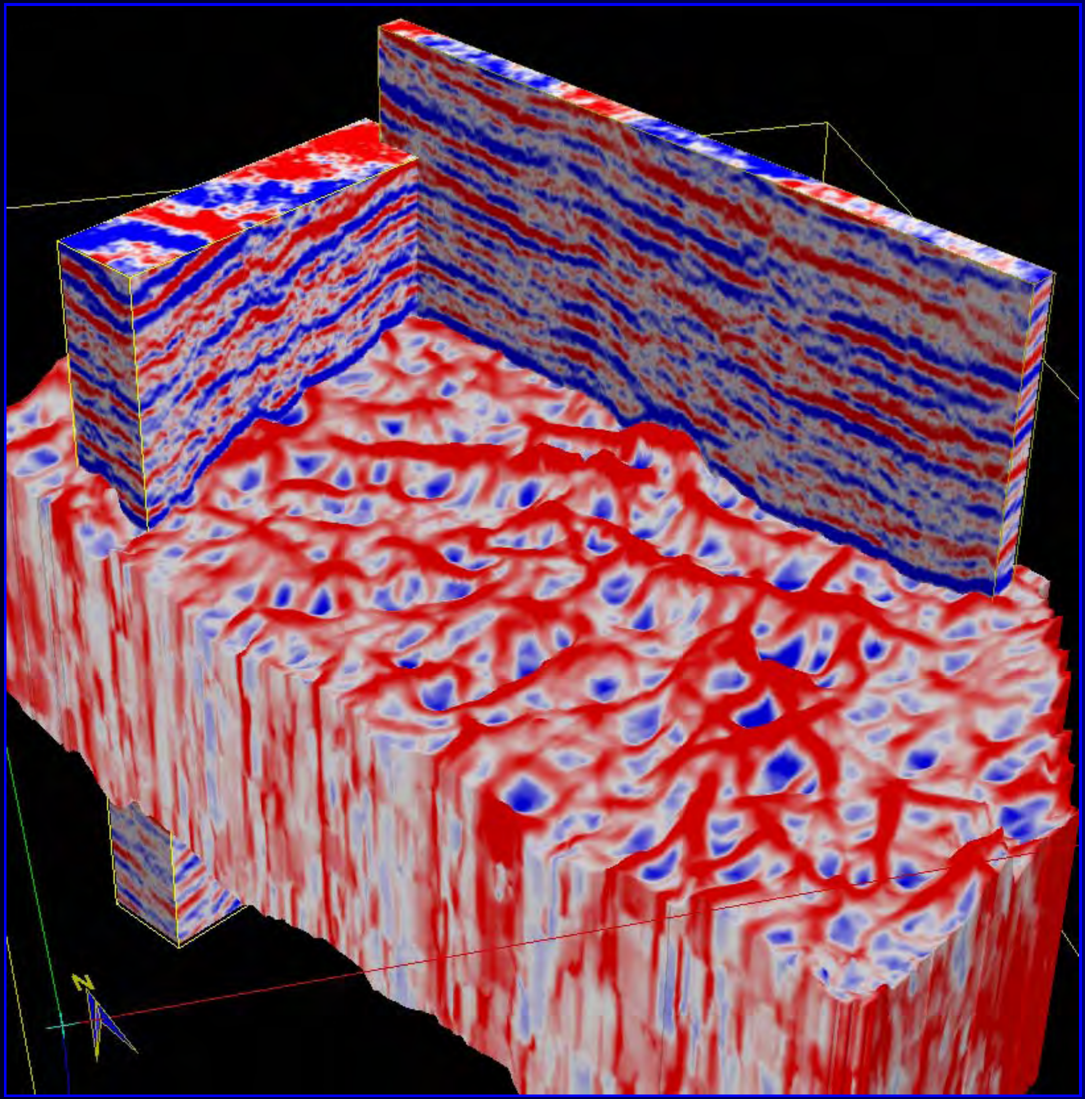
An inline through the input data volume



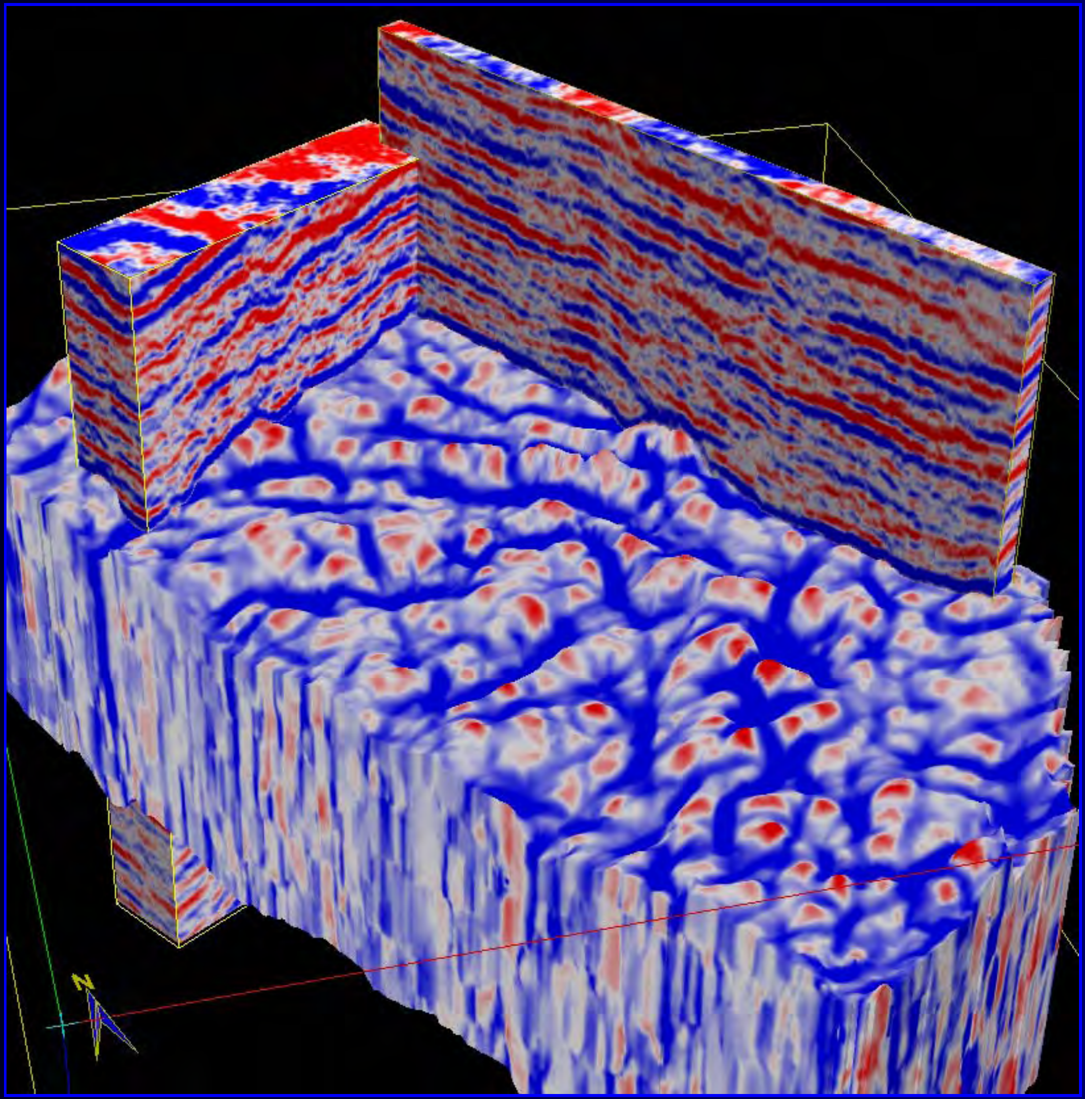
The same inline in (a) but after running pc-filtering on the input data volume



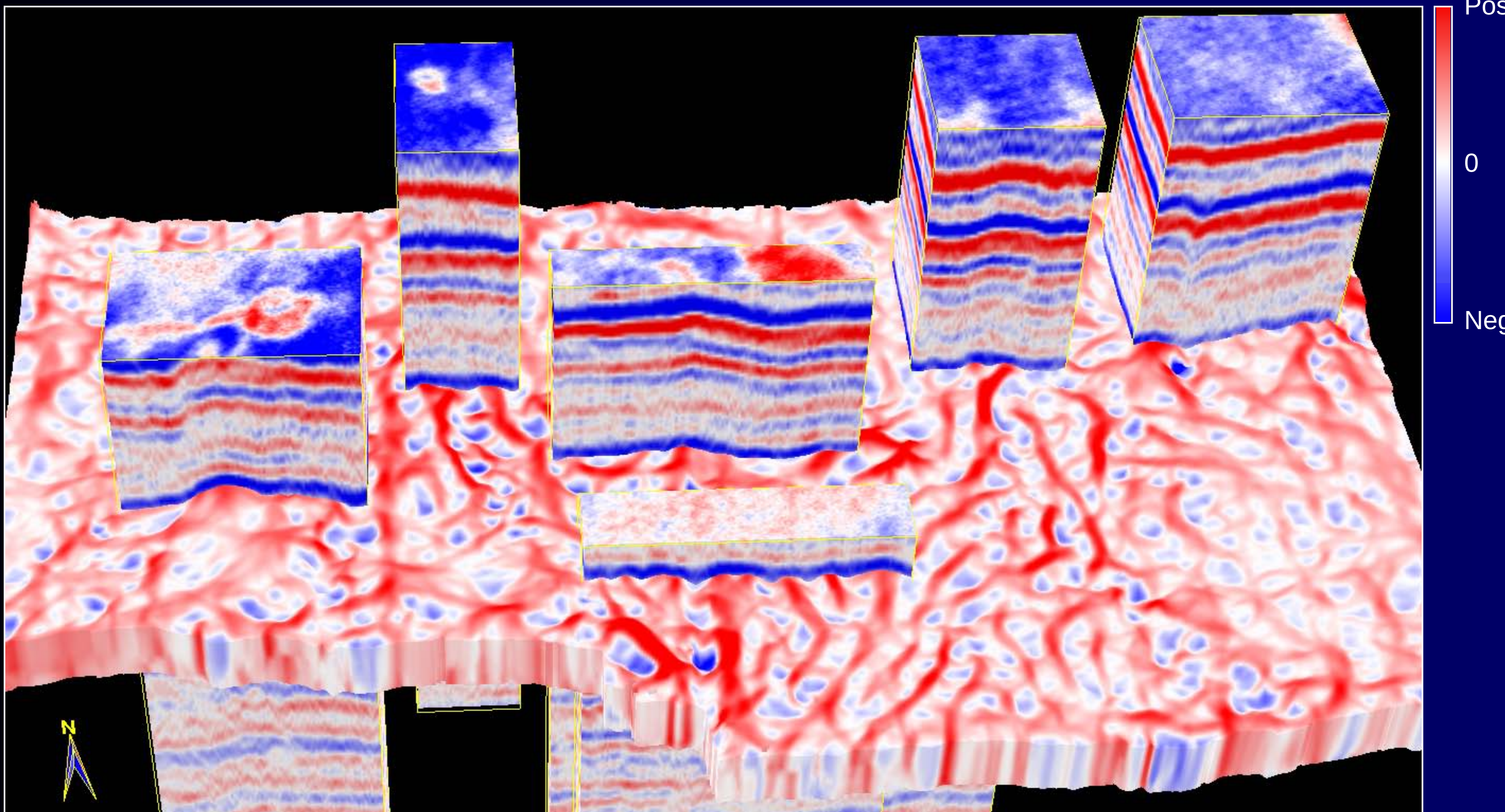
A seismic sub-cube intersecting the coherence strat-cube



A seismic sub-cube intersecting the most-positive curvature strat-cube



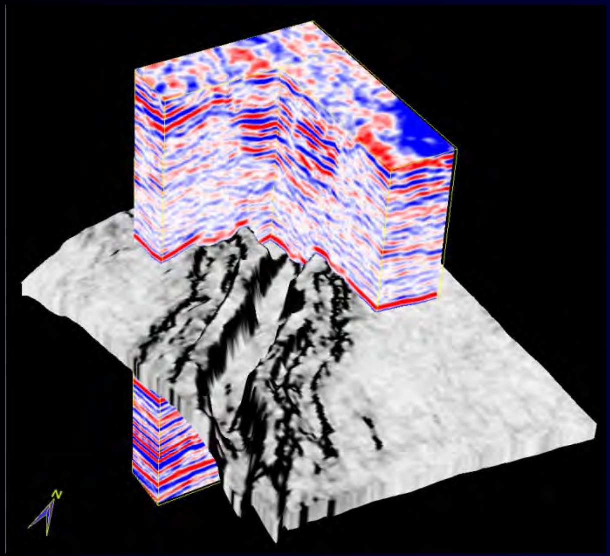
A seismic sub-cube intersecting the most-negative curvature strat-cube



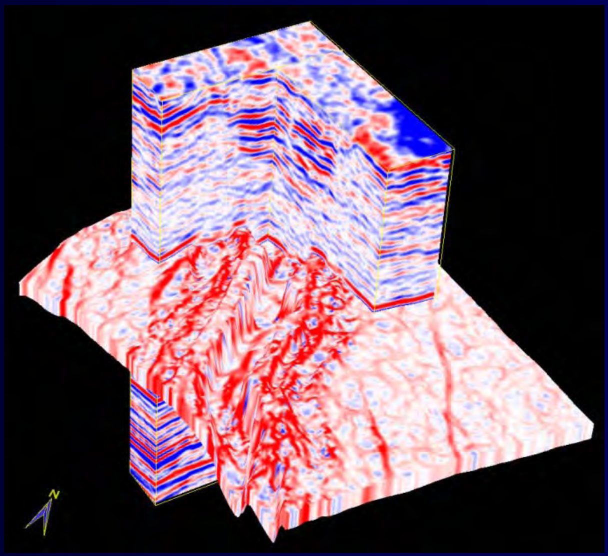
Data courtesy: Arcis Corporation, Calgary

Chair displays

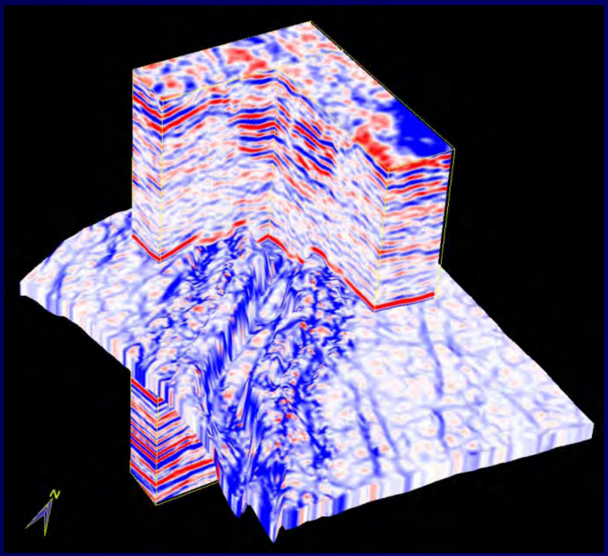
seismic inline and horizon slices from different attributes



Coherence



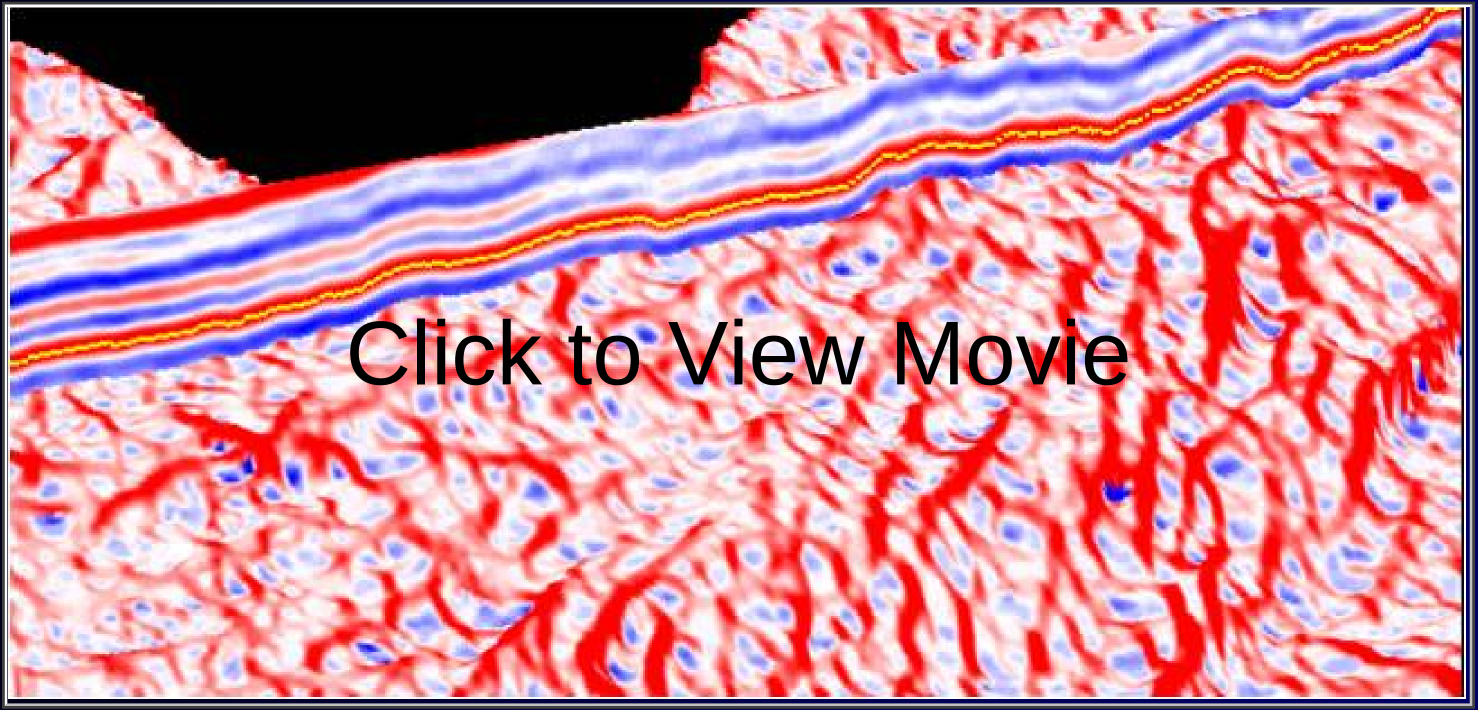
Most-positive curvature (short-wavelength)



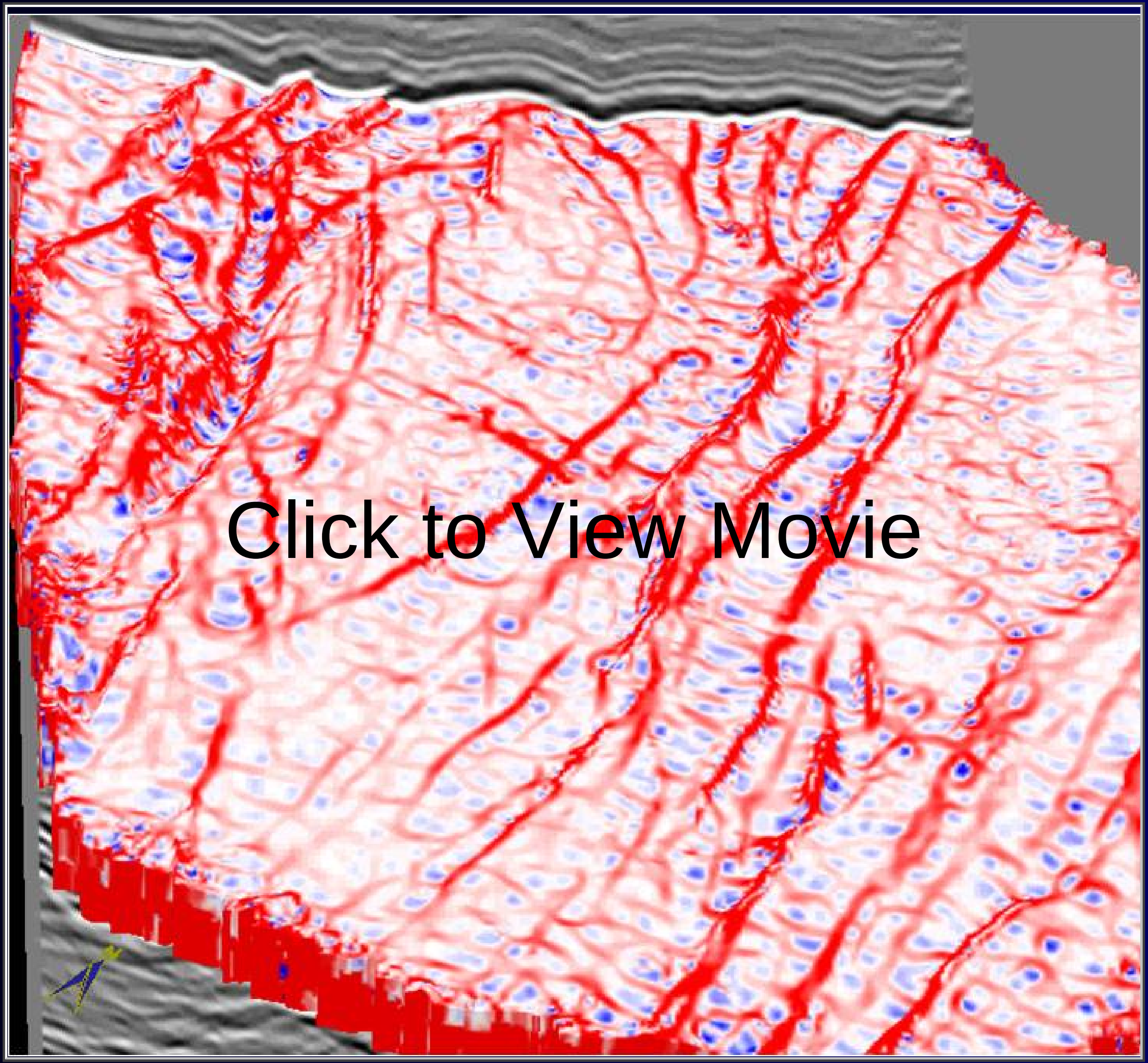
Most-negative curvature (short-wavelength)

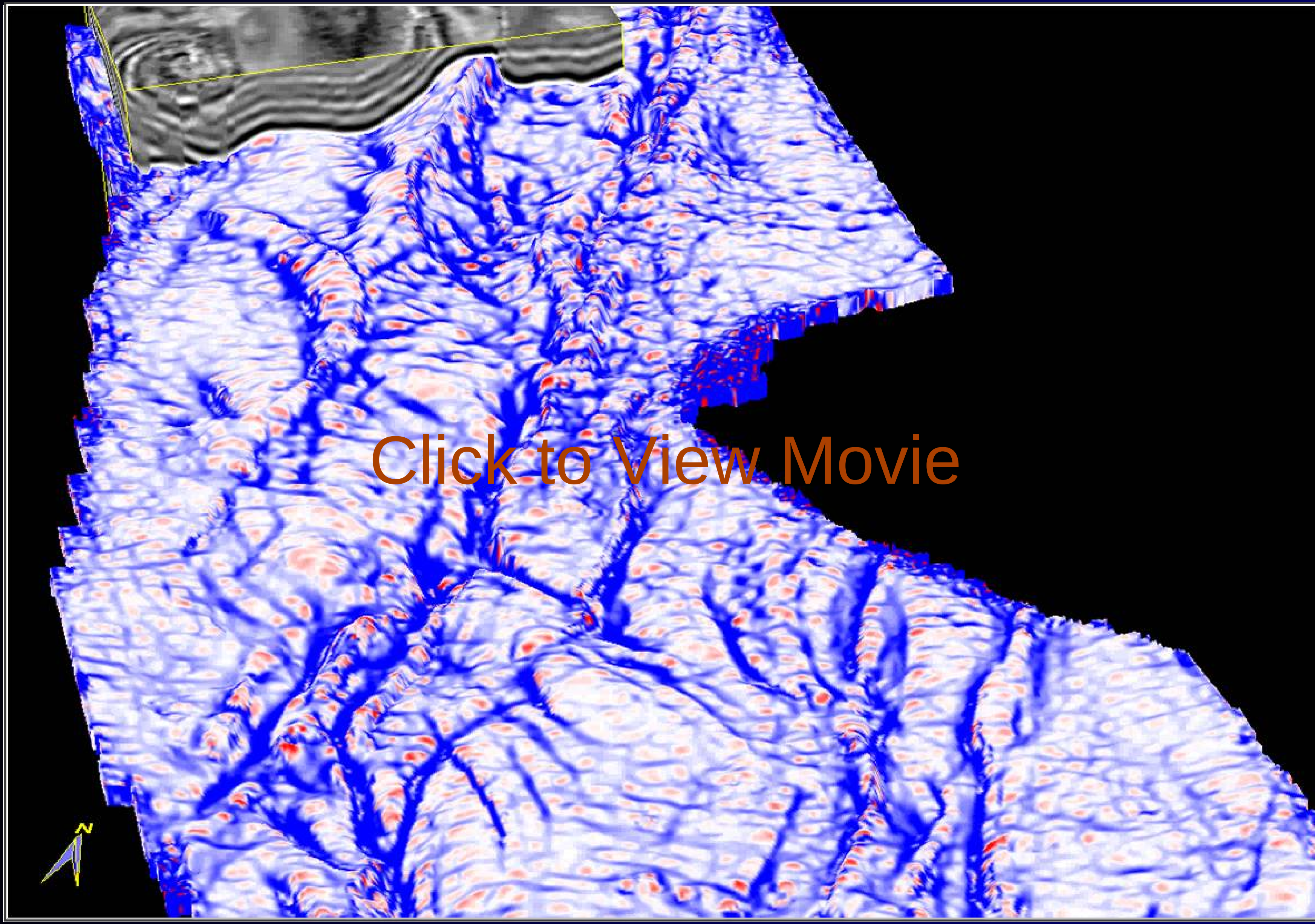
(Images courtesy: POGC & FX Energy)

Correlation of strat-cube from most-positive curvature (low-res) with seismic



Most-positive curvature (high-res) strat-cube correlated with a seismic volume

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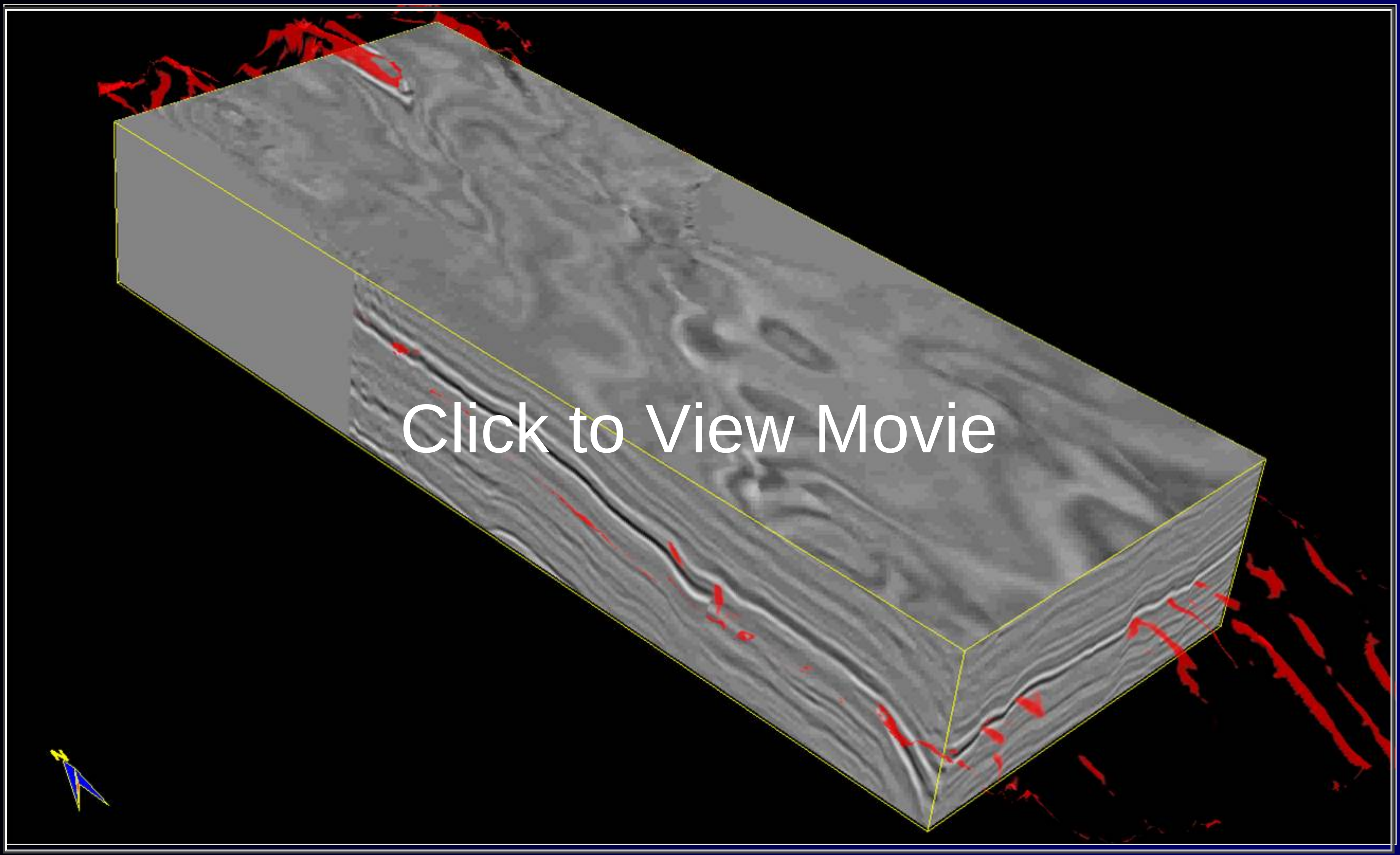
N

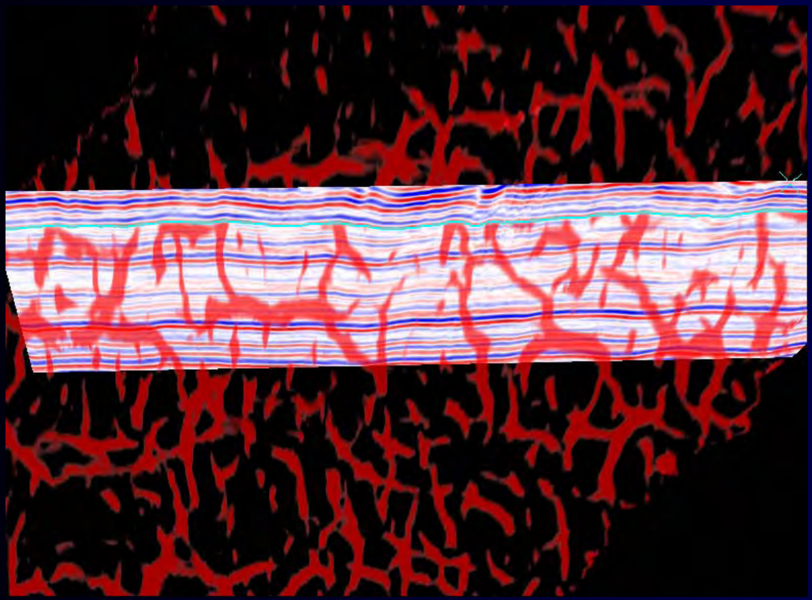
Most-positive curvature strat-cube correlated with a seismic volume

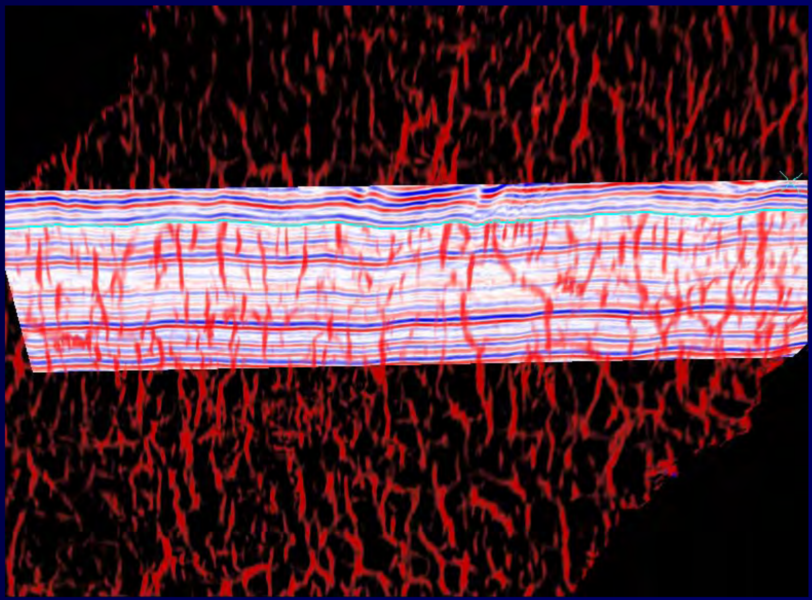
Click to View Movie

Most-positive curvature strat-cube correlated with a seismic volume



Most-positive curvature strat-cube correlated with a seismic volume

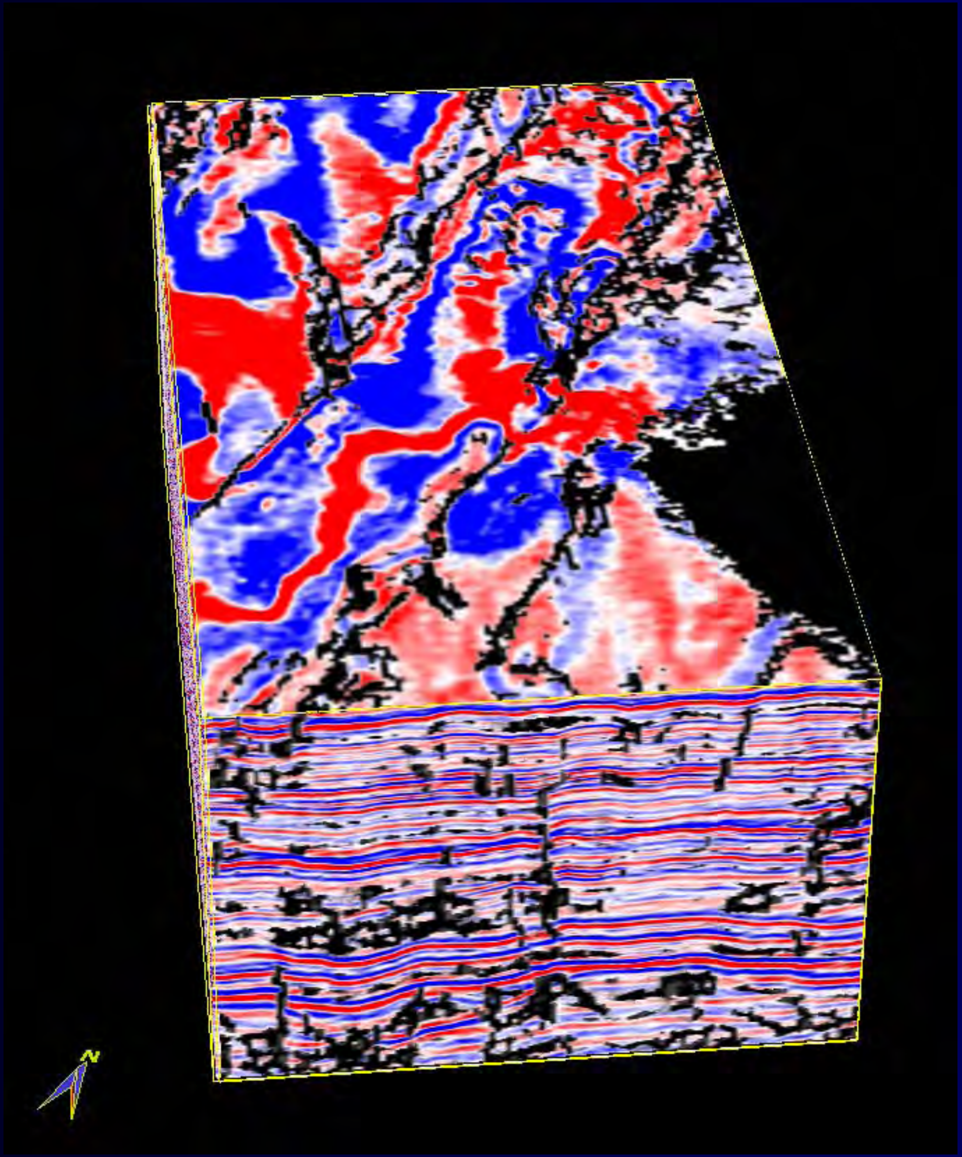




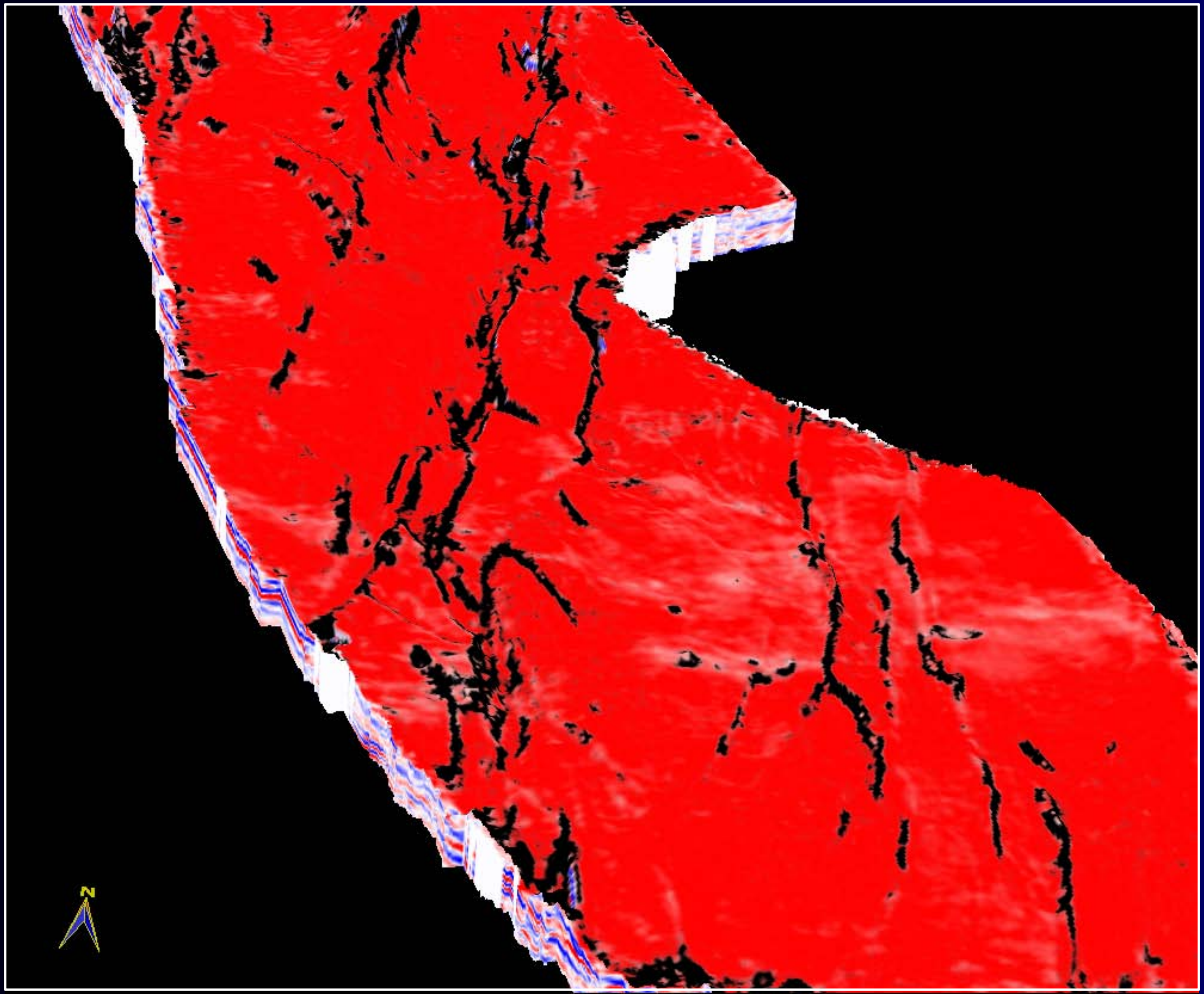
Fracture network as visualized using transparency on the most positive curvature strata-cube, long–wavelength (left) and short-wavelength (right) and also correlated with seismic.

Data courtesy: CGGVeritas Library Canada

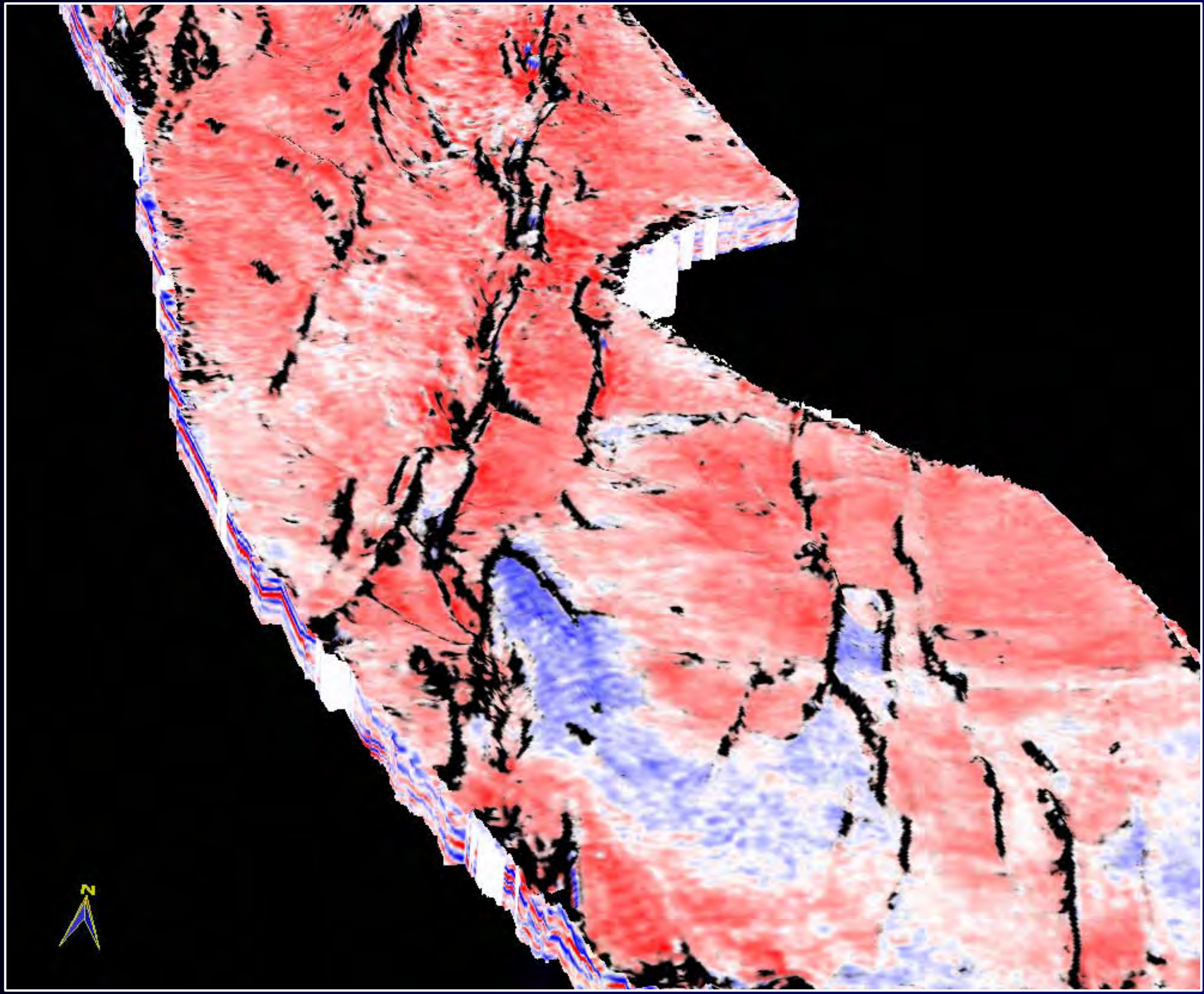
Merging data volumes



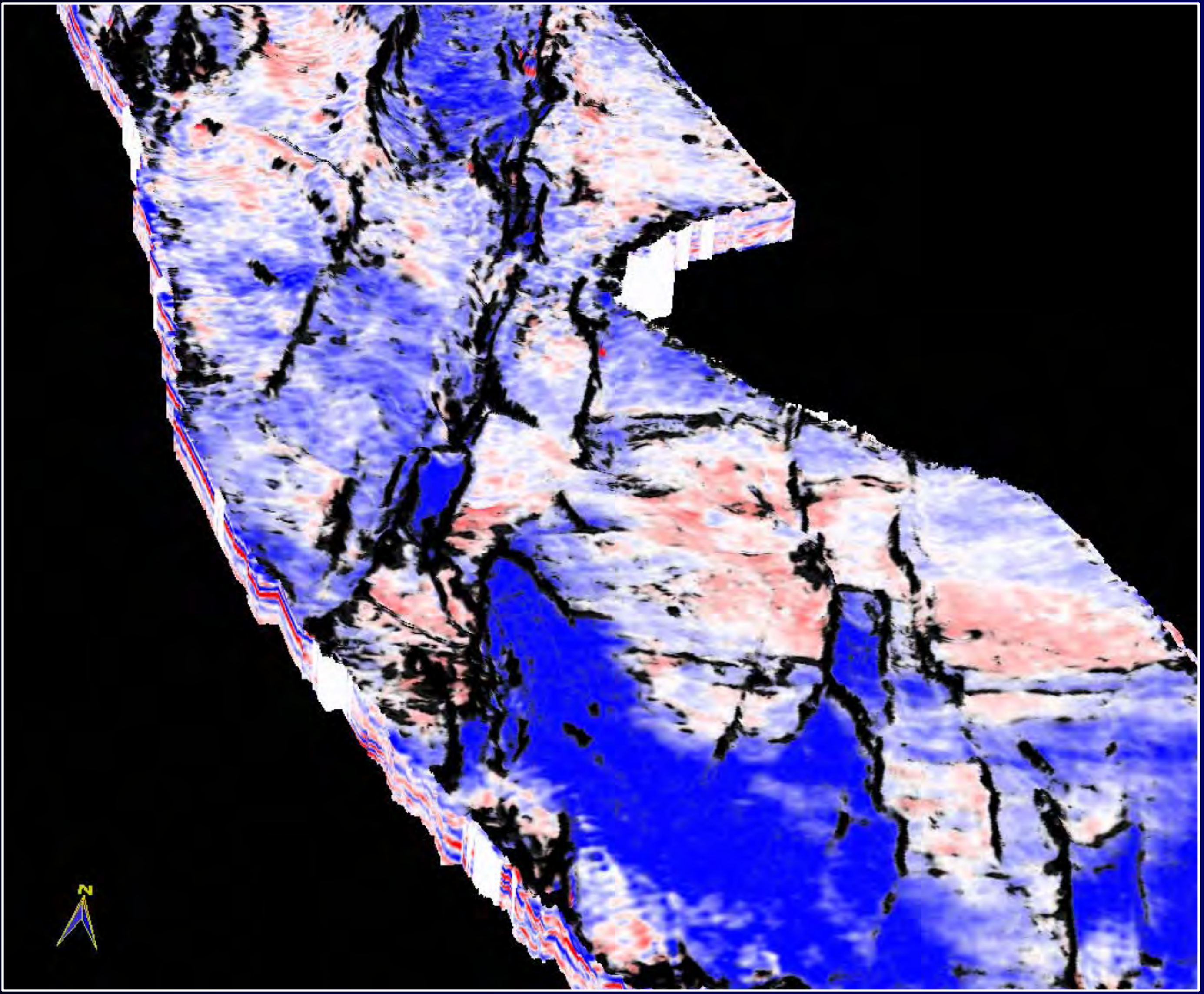
Merging the amplitude and coherence cube allows the interpreter to see the correlation of discontinuities with the corresponding seismic signatures.



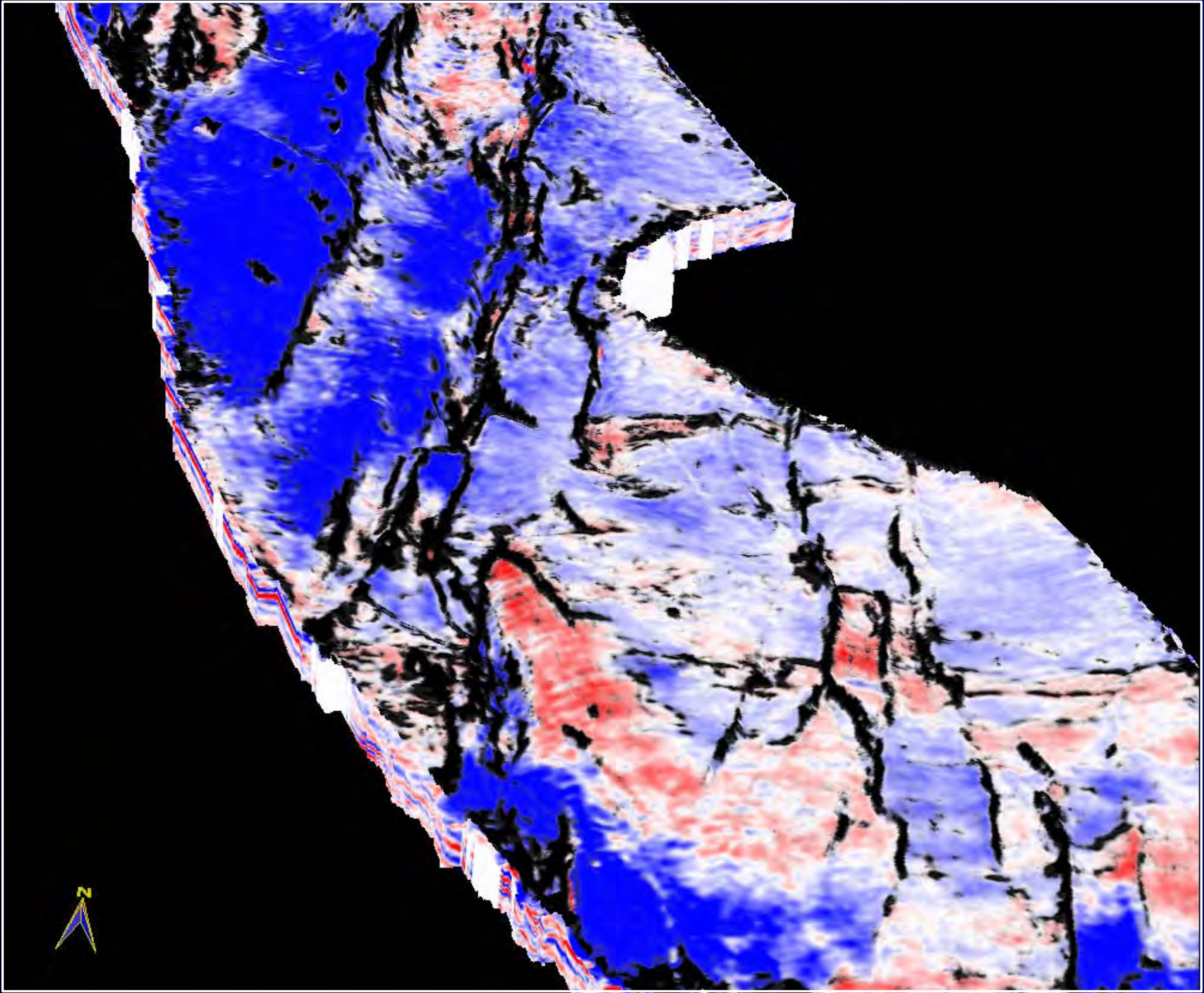
Strata-cube from the merged volume (coherence and seismic amplitude)



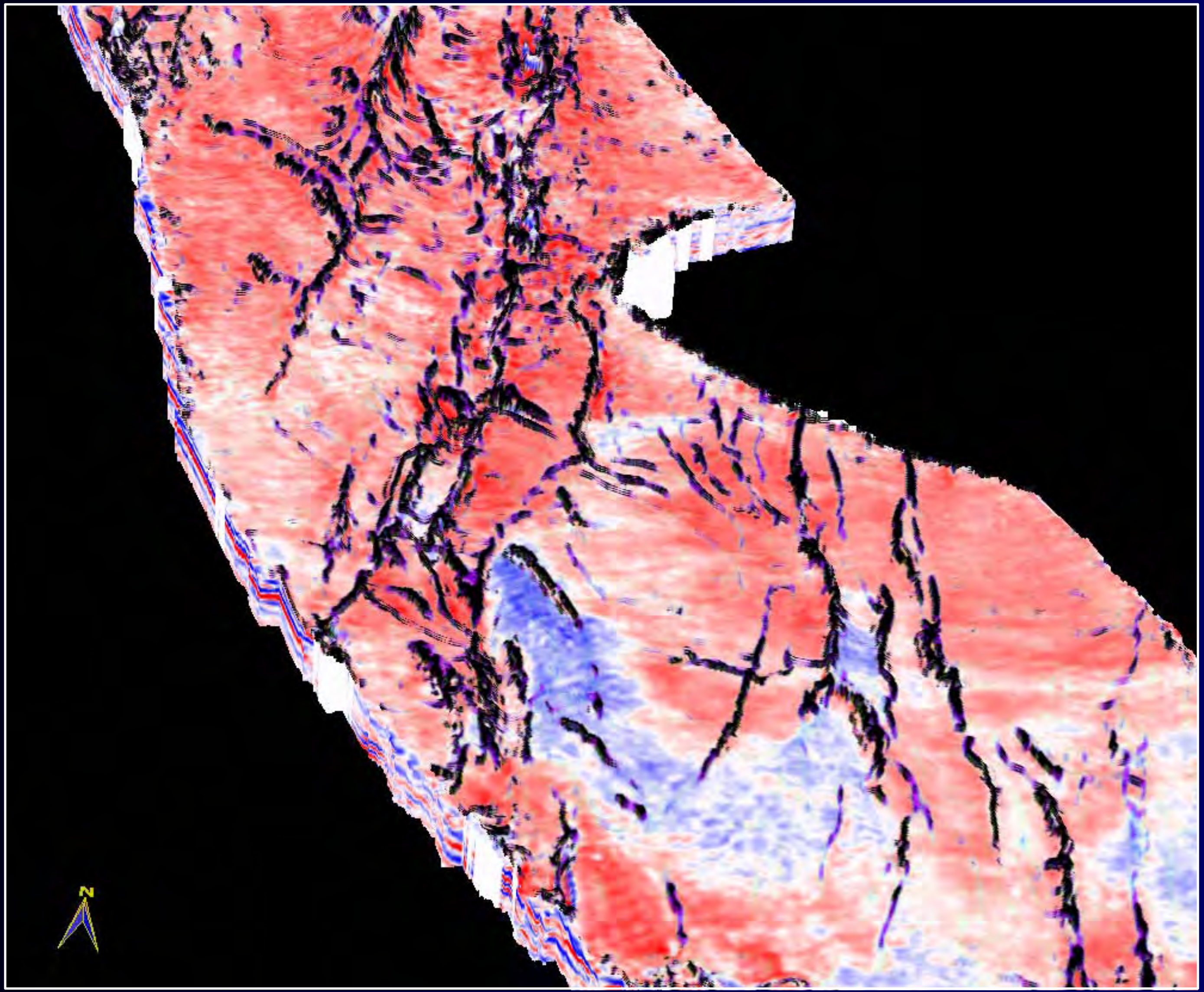
Strata-cube from the merged volume (coherence and seismic amplitude)
(next sample)



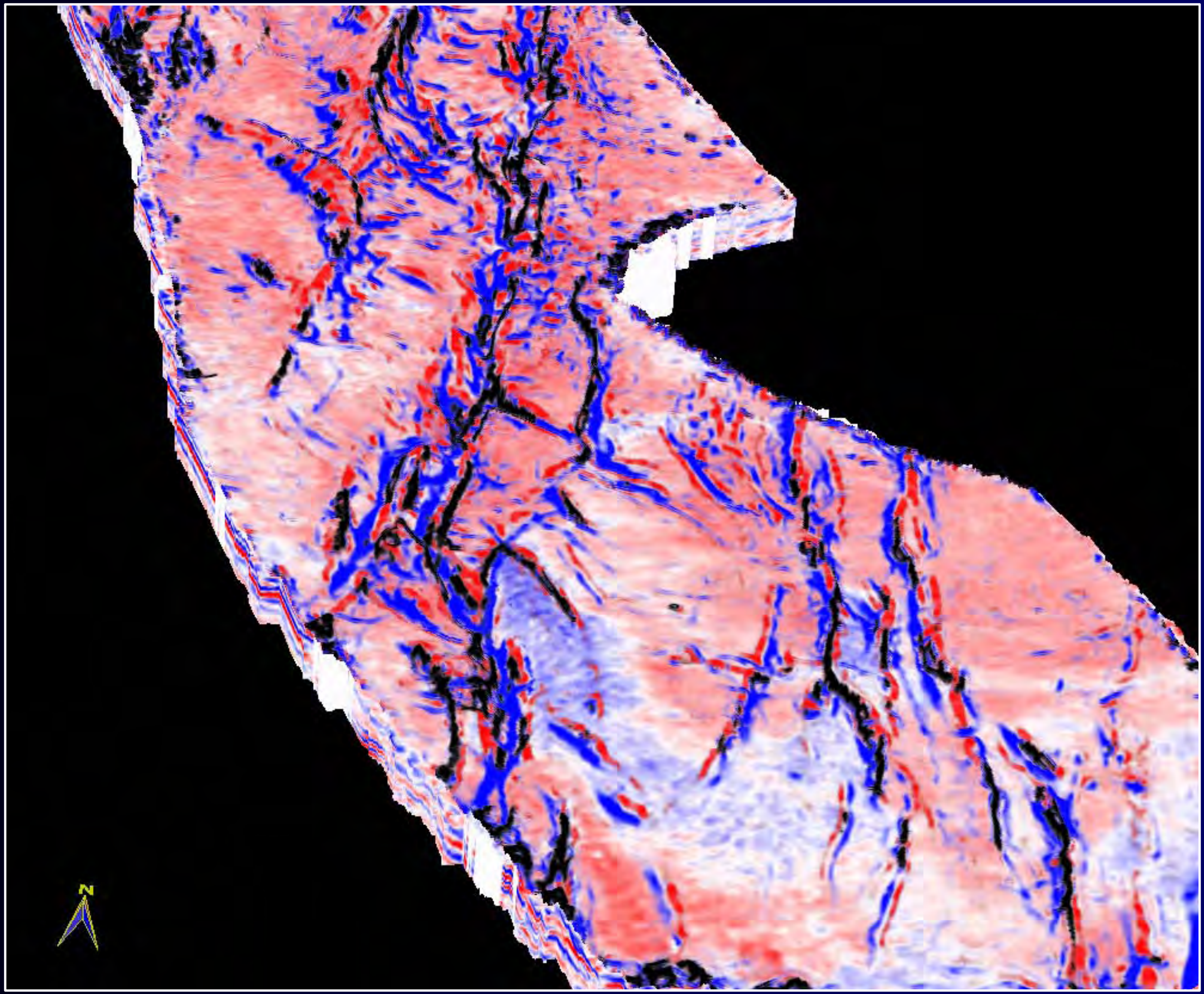
Strata-cube from the merged volume (coherence and seismic amplitude)
(next sample)



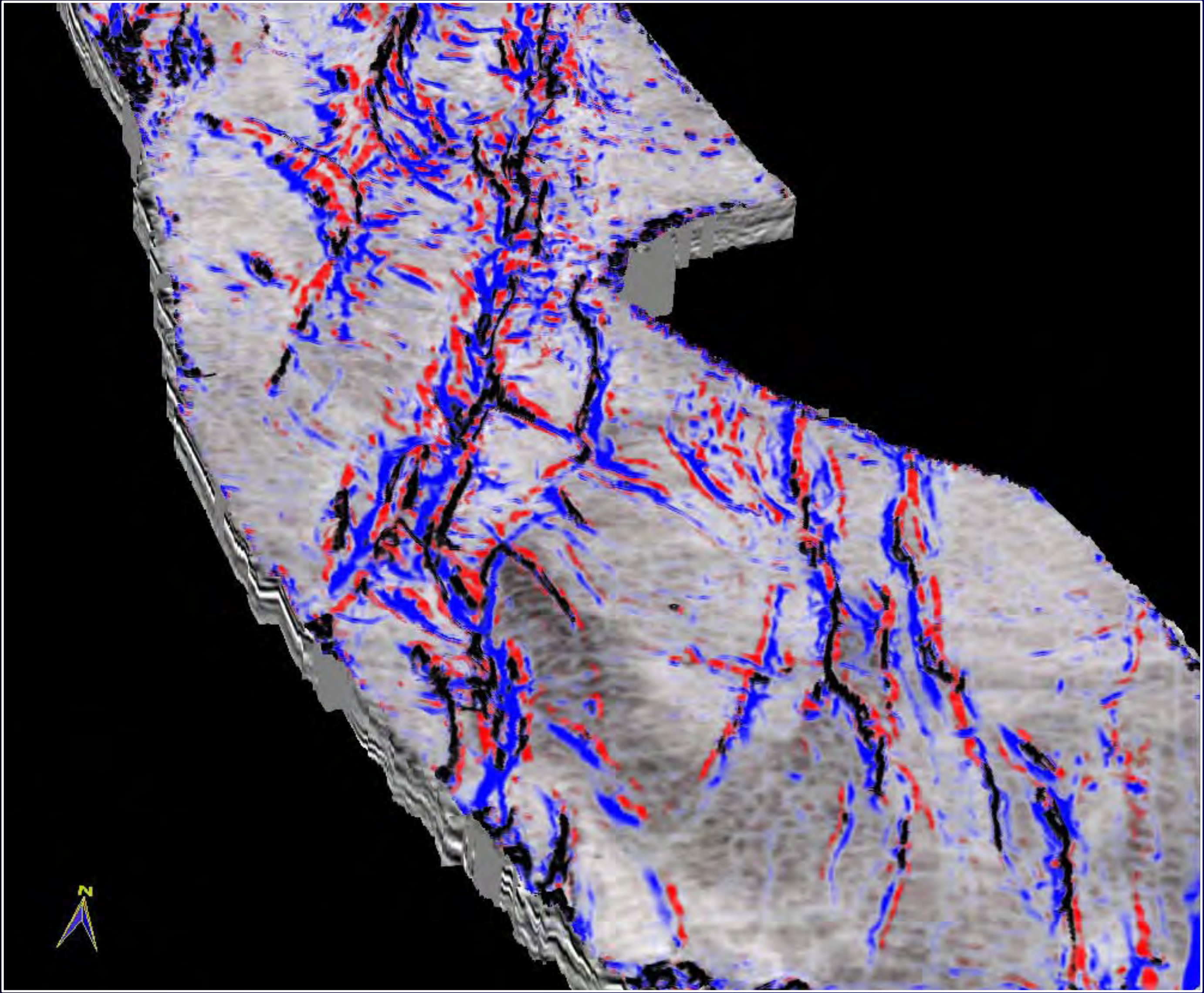
Strata-cube from the merged volume (coherence and seismic amplitude)
(next sample)



Strata-cube from the merged volume (amplitude and most-positive curvature)

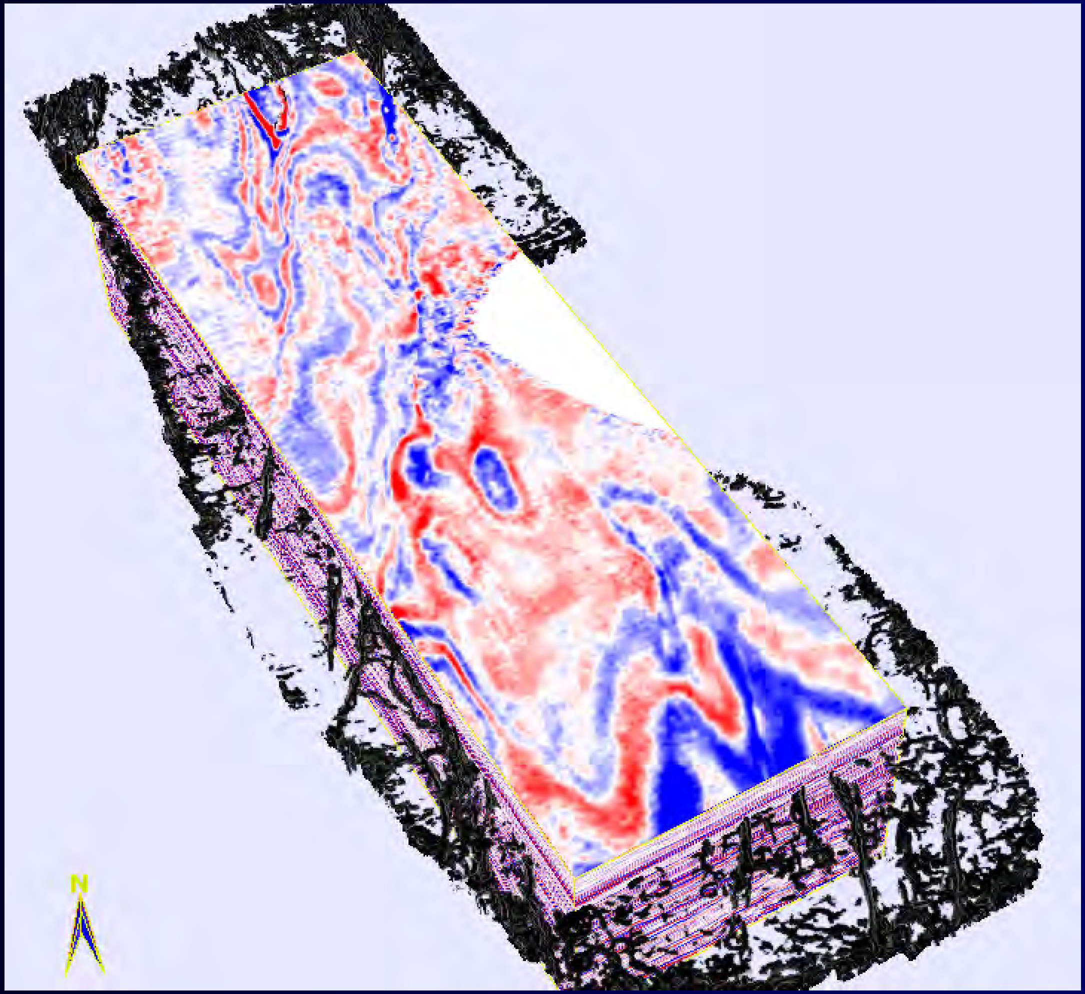


Strata-cube from the merged volume (amplitude, coherence, most-positive and most-negative curvature)

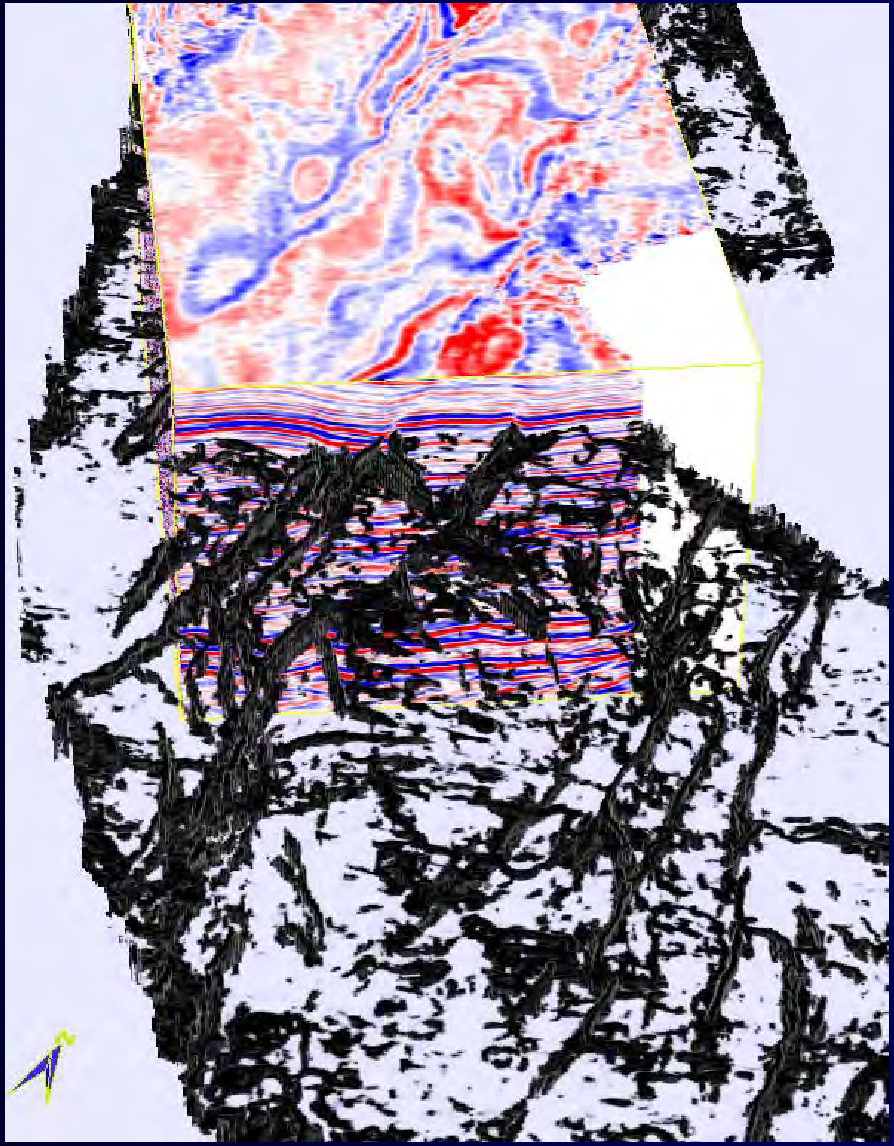


Strata-cube from the merged volume (amplitude, coherence, most-positive and most-negative curvature)

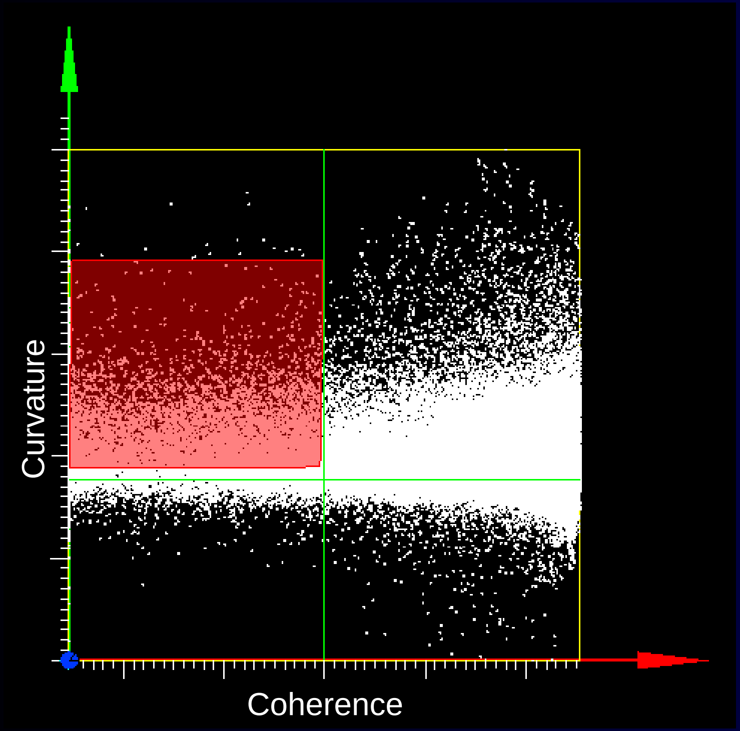
Coherence strat-cube correlated with a seismic volume



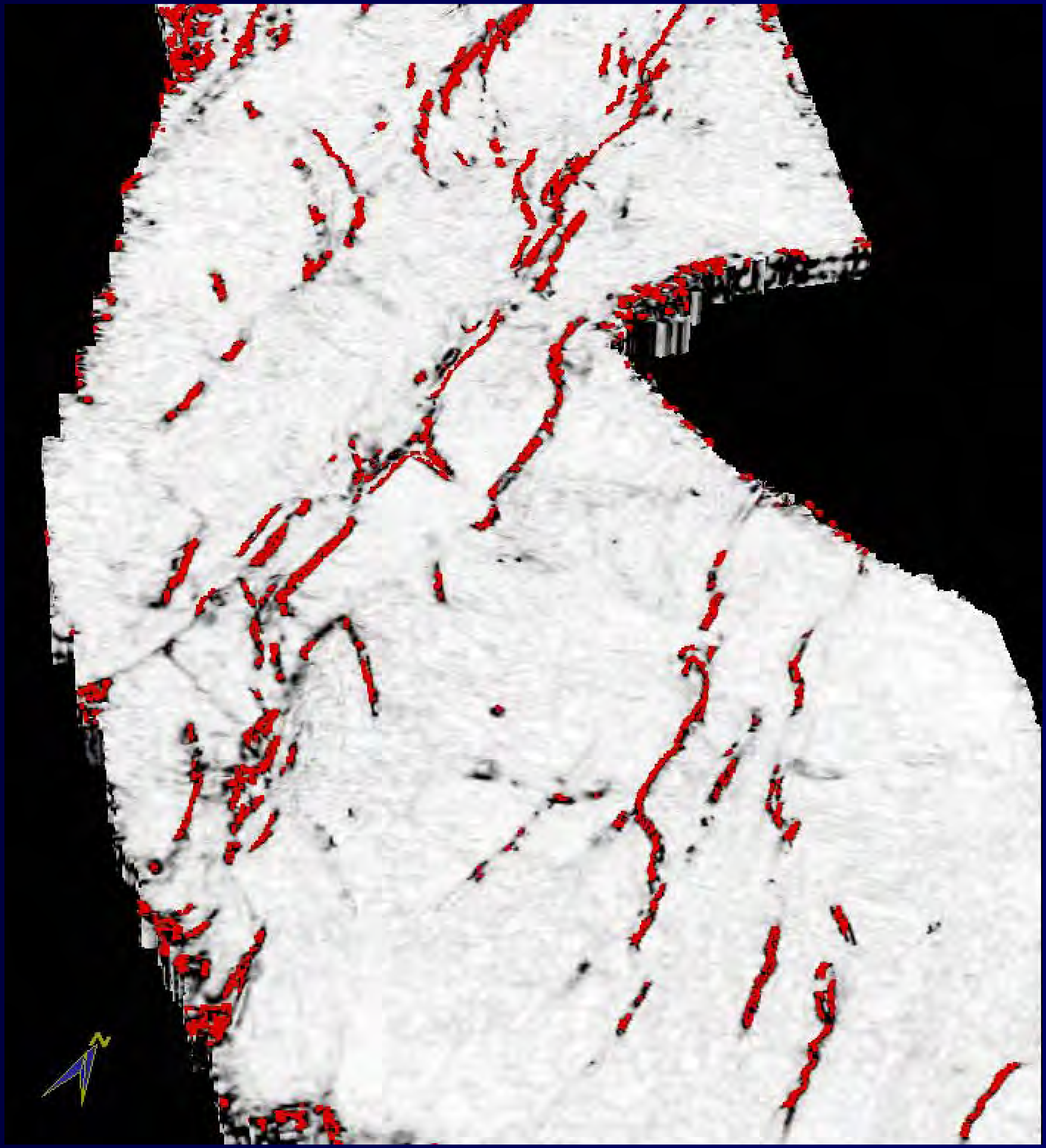
Coherence strat-cube correlated with a seismic volume



Crossplotting discontinuity attributes

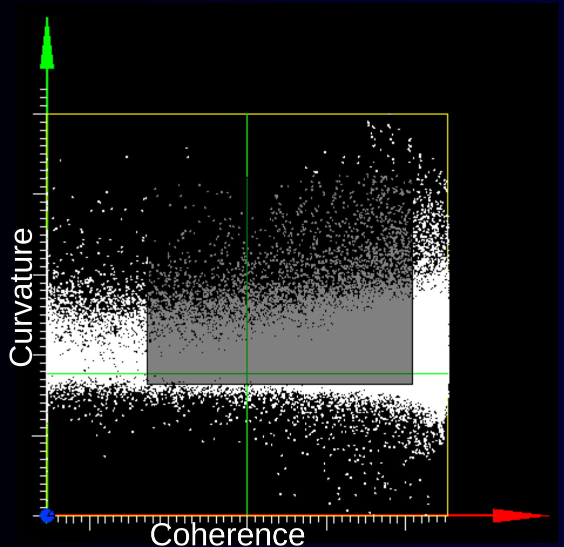


Crossplot of coherence versus most-positive curvature

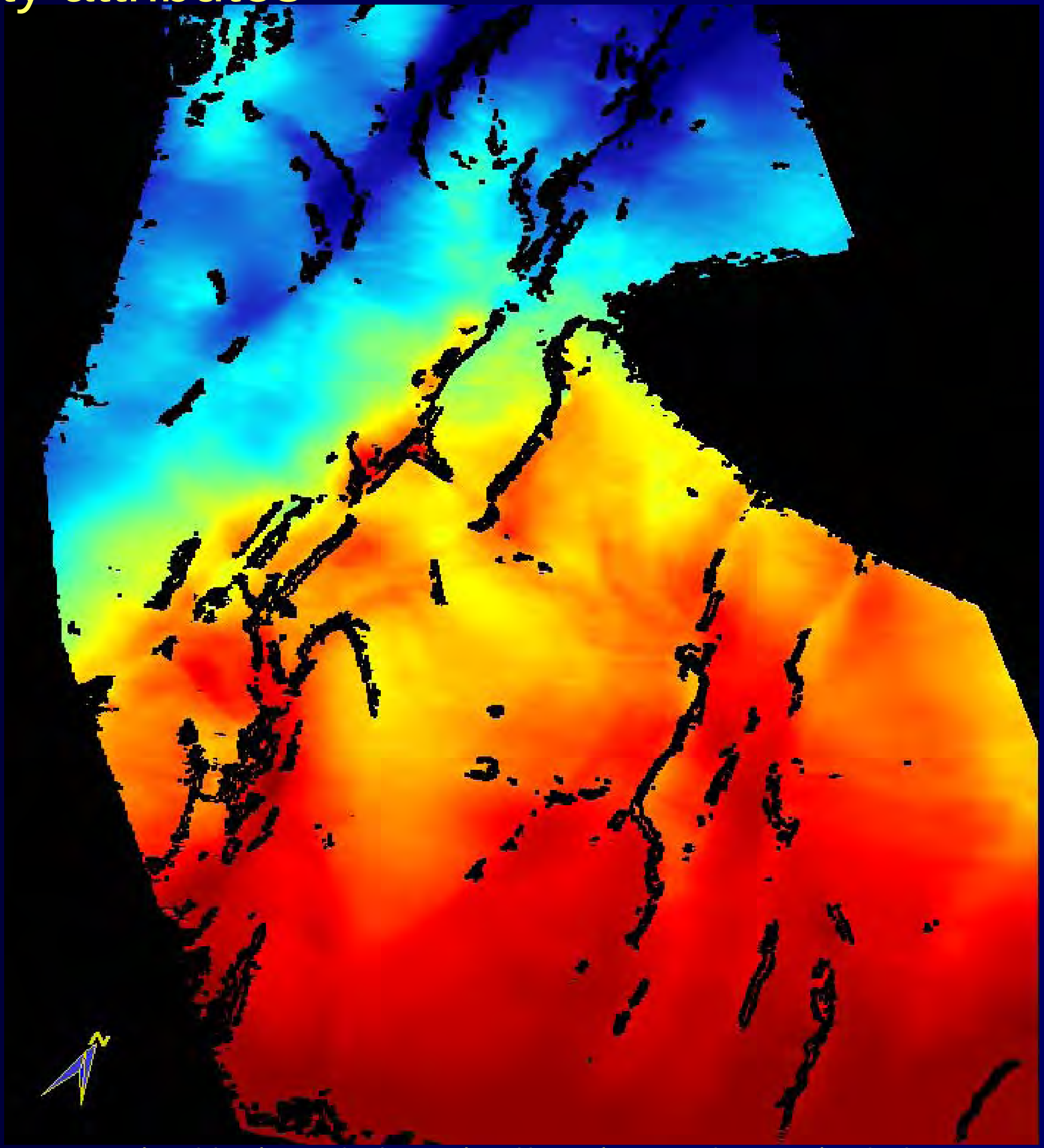


Overlay of the cluster of points enclosed in a polygon on the crossplot of coherence versus most-positive curvature, on the coherence strat-slice. The red lineaments align with the faults that one would interpret on the coherence strat-slice

Crossplotting discontinuity attributes

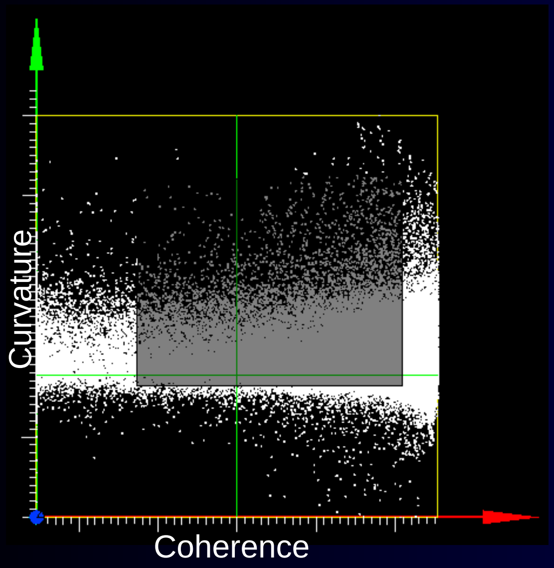


Crossplot of coherence versus most-positive curvature

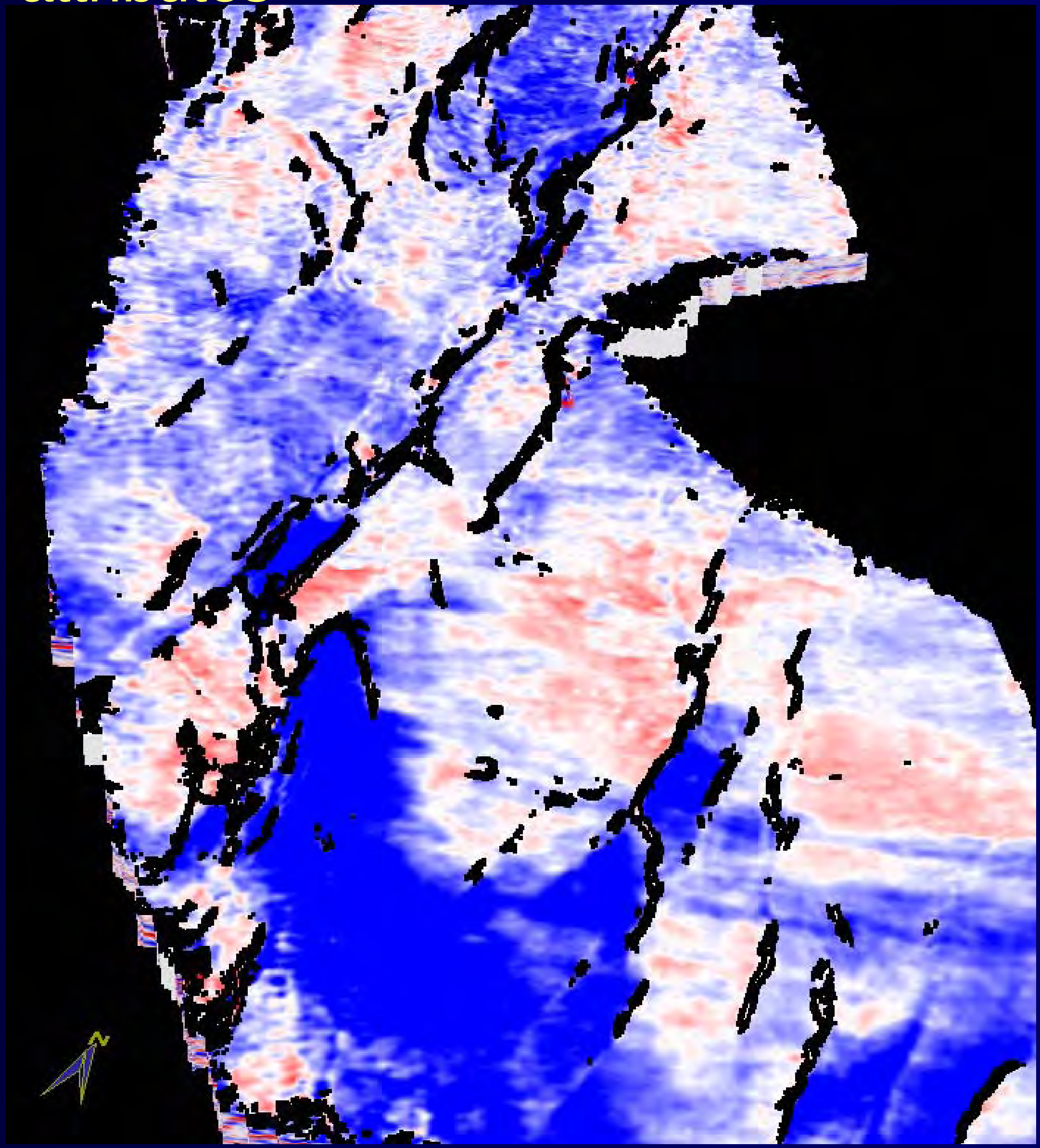


Overlay of the cluster of points enclosed in a polygon on the crossplot of coherence versus most-positive curvature, on an interpreted horizon. The black lineaments align with the impression of faults that are visible on the horizon.

Crossplotting discontinuity attributes

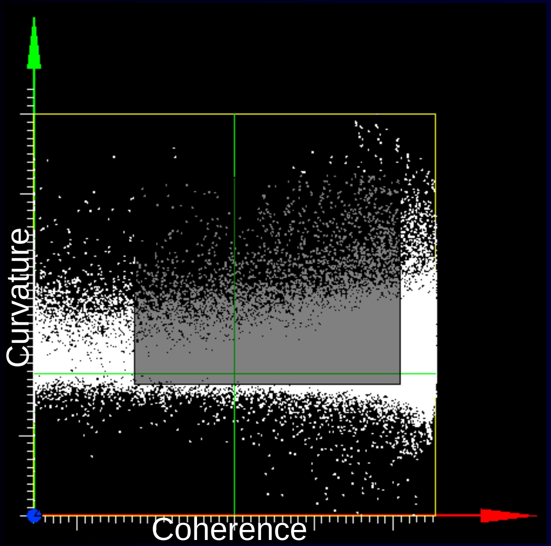


Crossplot of coherence versus most-positive curvature

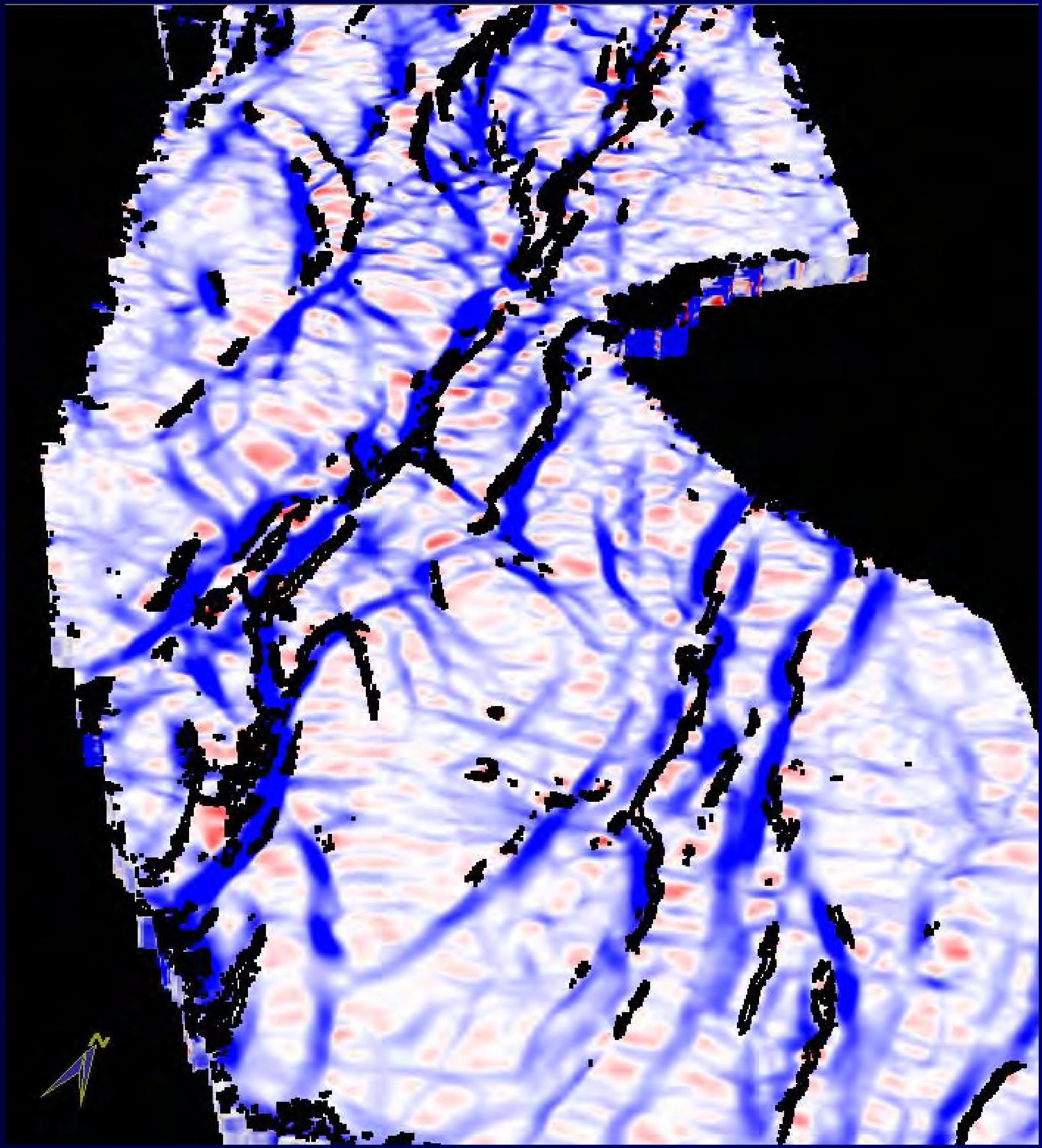


Overlay of the cluster of points enclosed in a polygon on the crossplot of coherence versus most-positive curvature, on the amplitude strat-slice 12 ms below the tracked horizon. The black lineaments align with the faults that one can see on the amplitude strat-slice.

Crossplotting discontinuity attributes

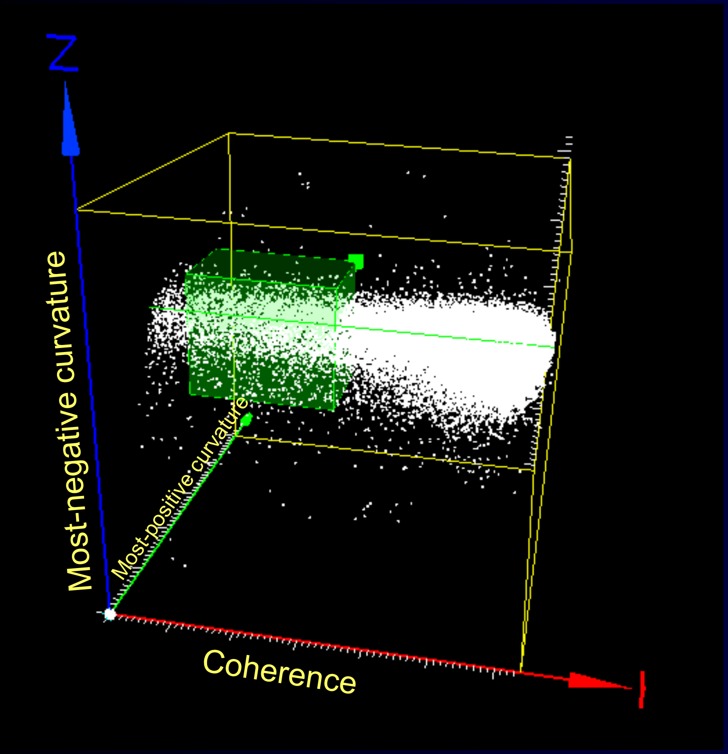


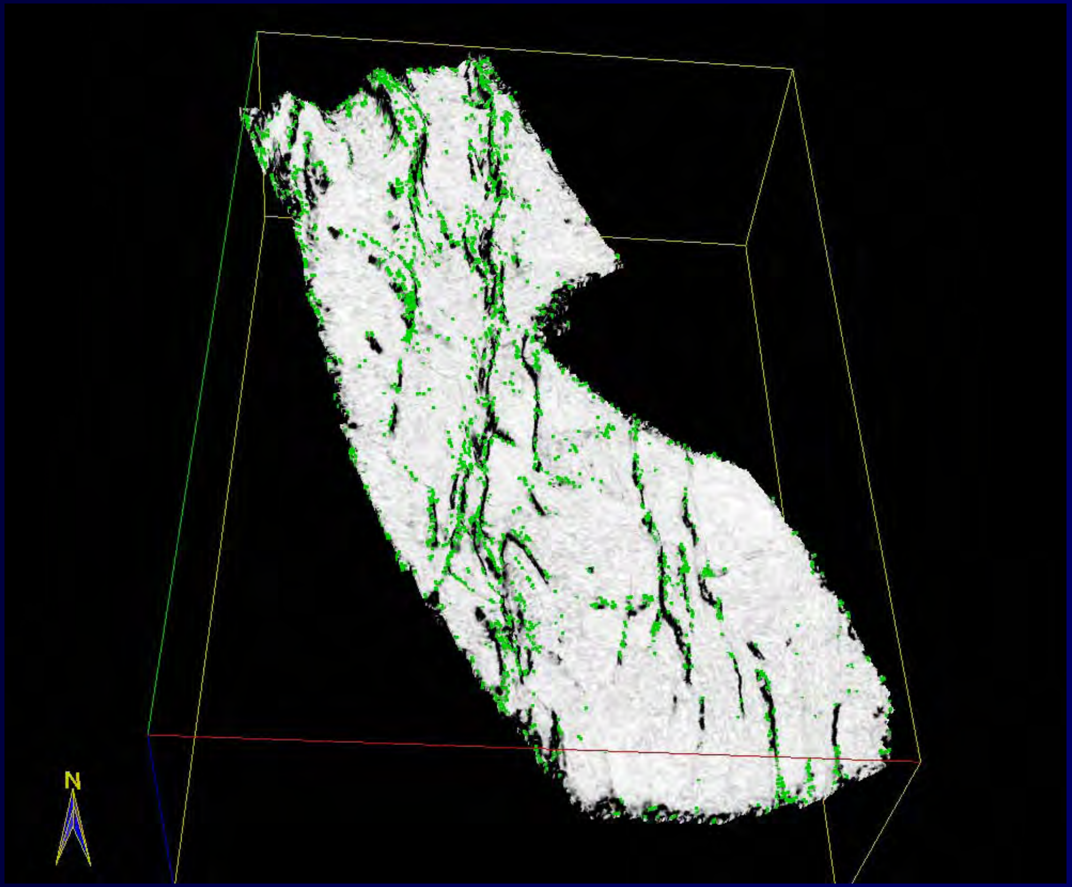
Crossplot of coherence versus most-positive curvature



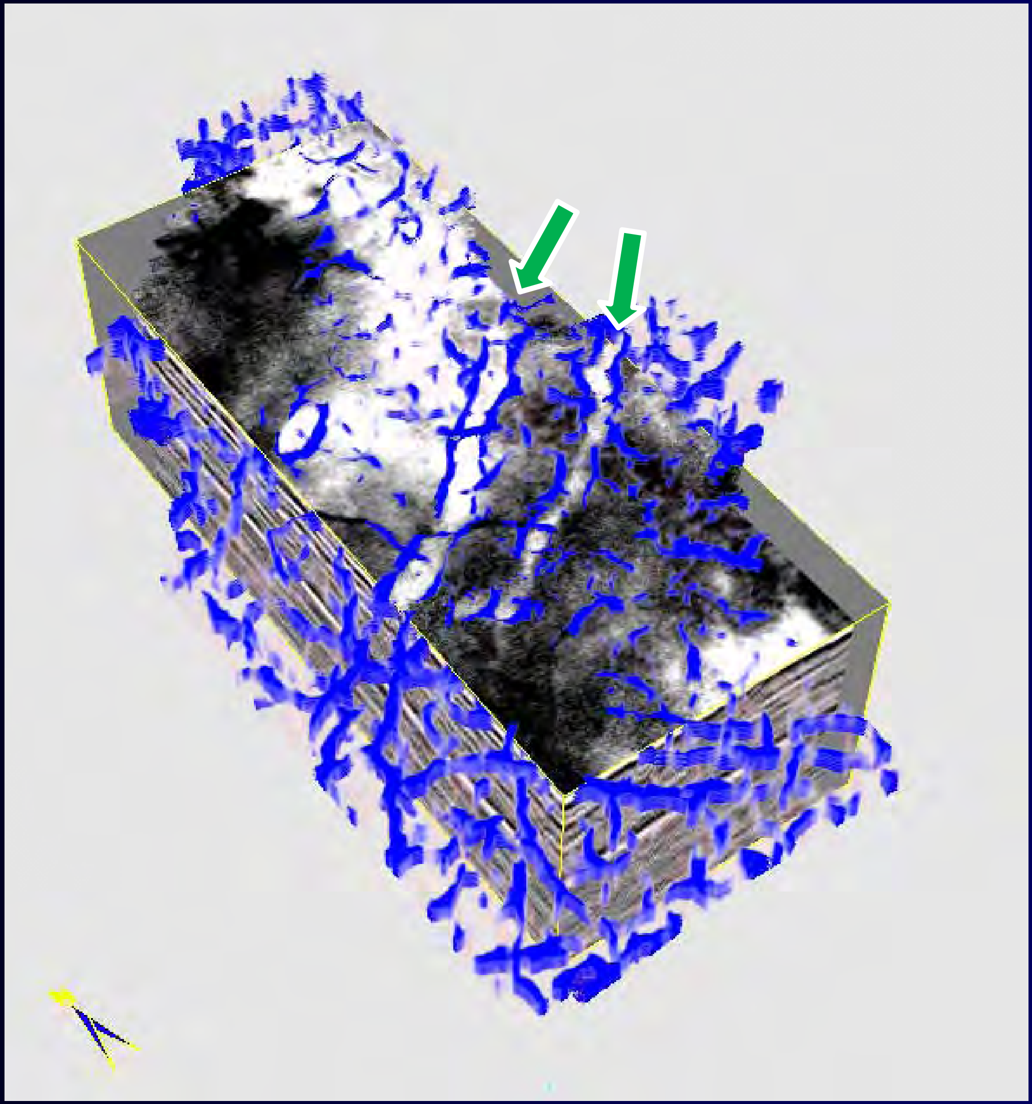
Overlay of the cluster of points enclosed in a polygon on the crossplot of coherence versus most-positive curvature, on the most-negative curvature strat-slice. The black lineaments align with the faults that one would interpret on the most-negative curvature strat-slice

3D Crossplotting of discontinuity attributes

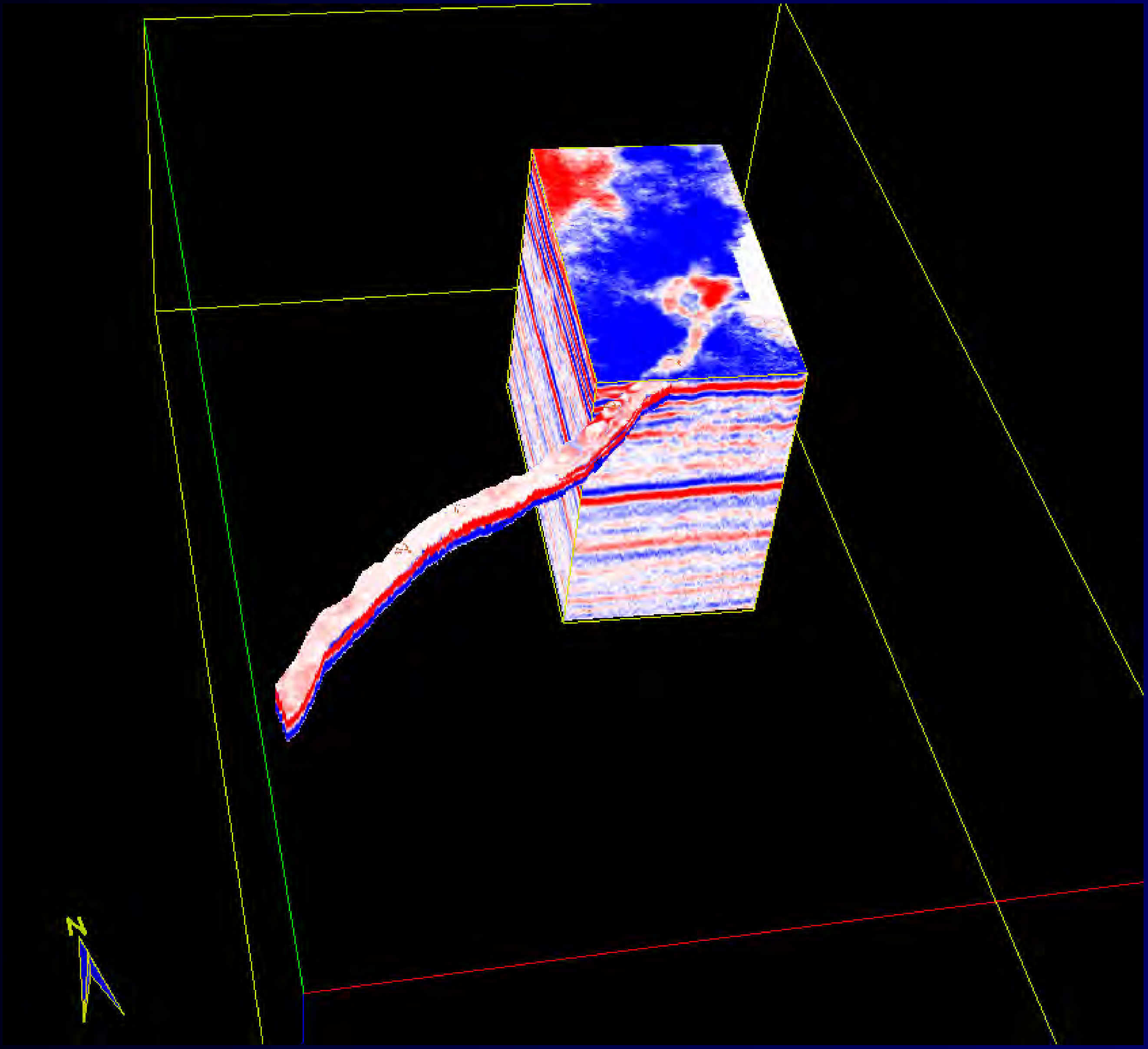




Coherence strata-cube



A fault skeleton from the most-negative curvature attribute being correlated with seismic data, exhibiting channels with differential compaction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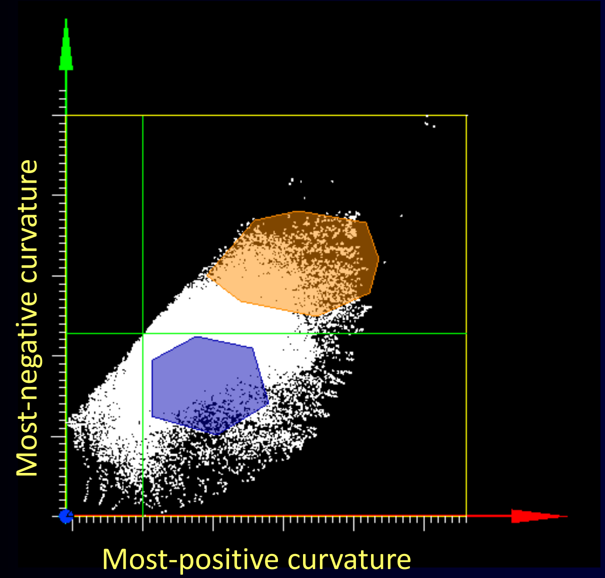


Steps followed:

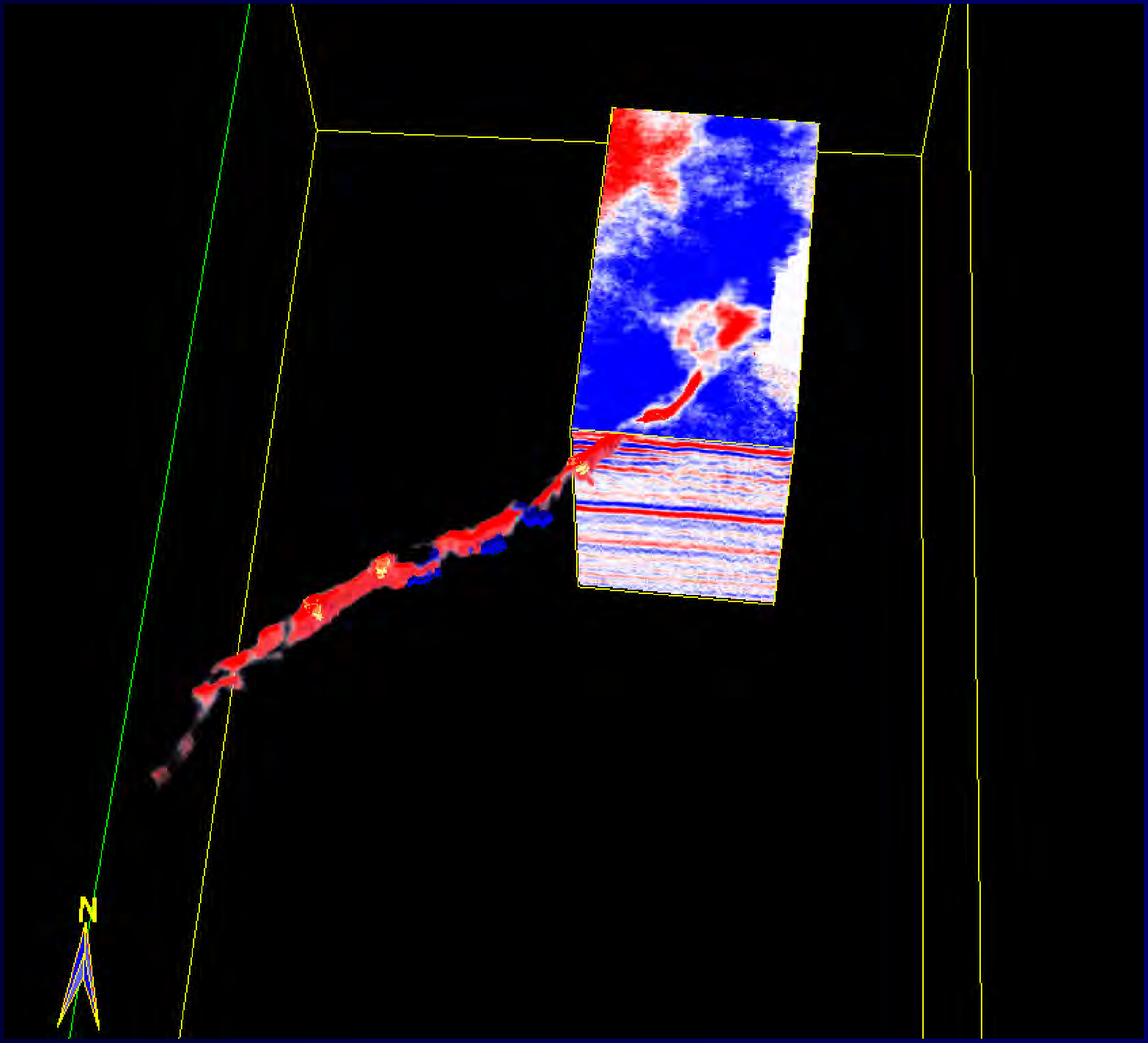
1. Generate strat-grid with the interpreted horizons- top and bottom boundaries of the channel.

2. Create a crossplot within the strat-grid with attributes.

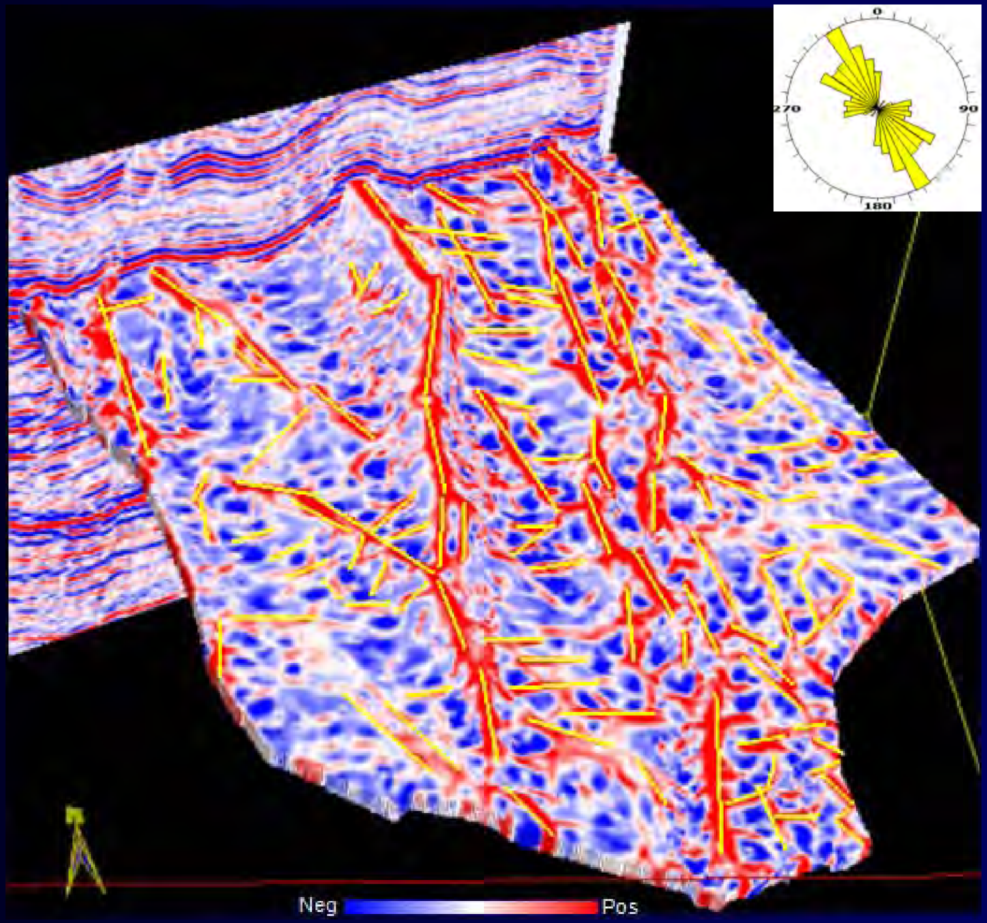
3. Using the polygon areas on the crossplot, generate the classification.

4. Detect geobodies in the classification for the top 5 (shown in yellow) and the bottom 5 strat-slices (shown in blue).

5. Display the strat-grid and the geobodies in the 3D viewer. Part of the grid was made transparent using the opacity curve.

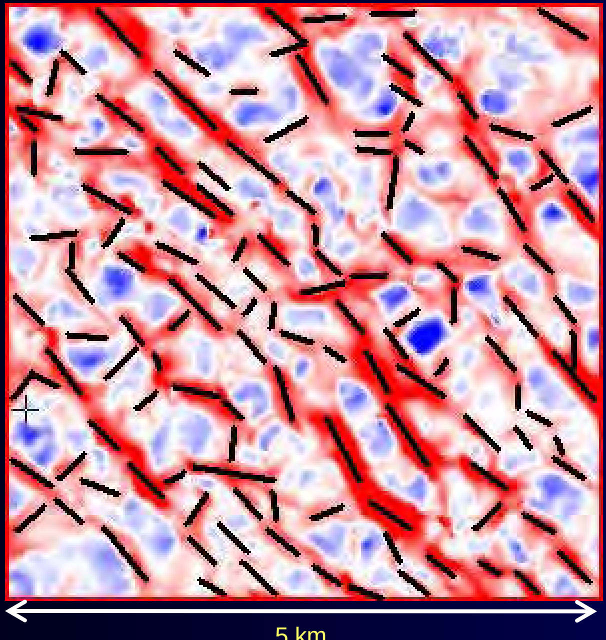


Interpretation of lineaments on curvature displays

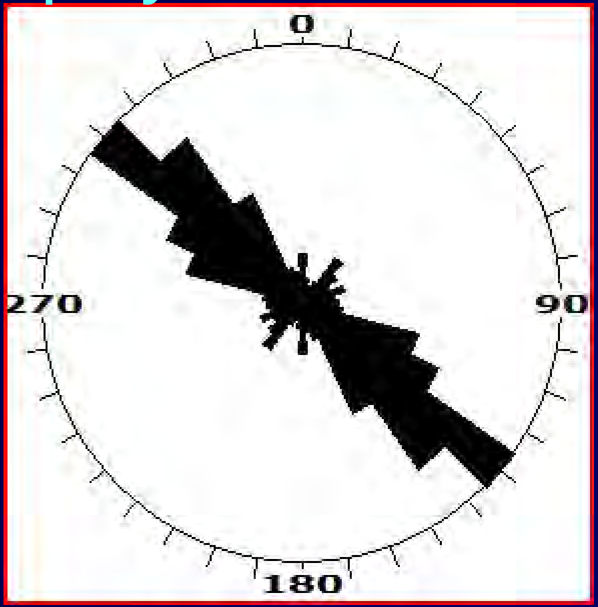


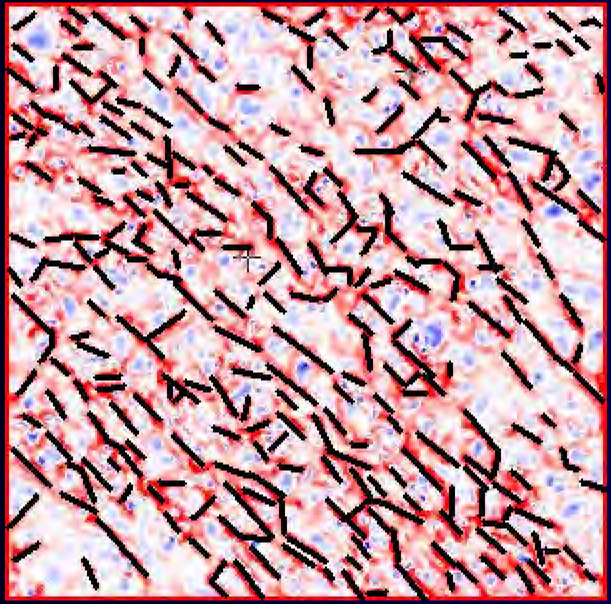
Lineaments on most-positive curvature horizon slice interpreted as yellow line segments and transformed into a rose diagram shown in the inset.

Interpretation on curvature displays

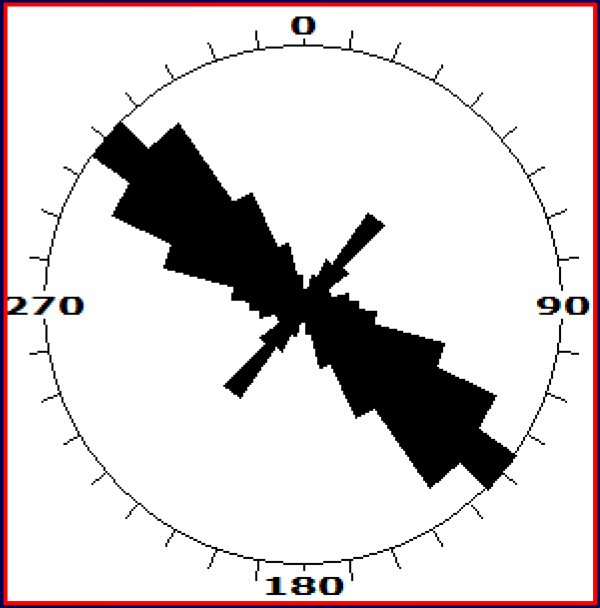


Most-positive curvature (low-res)





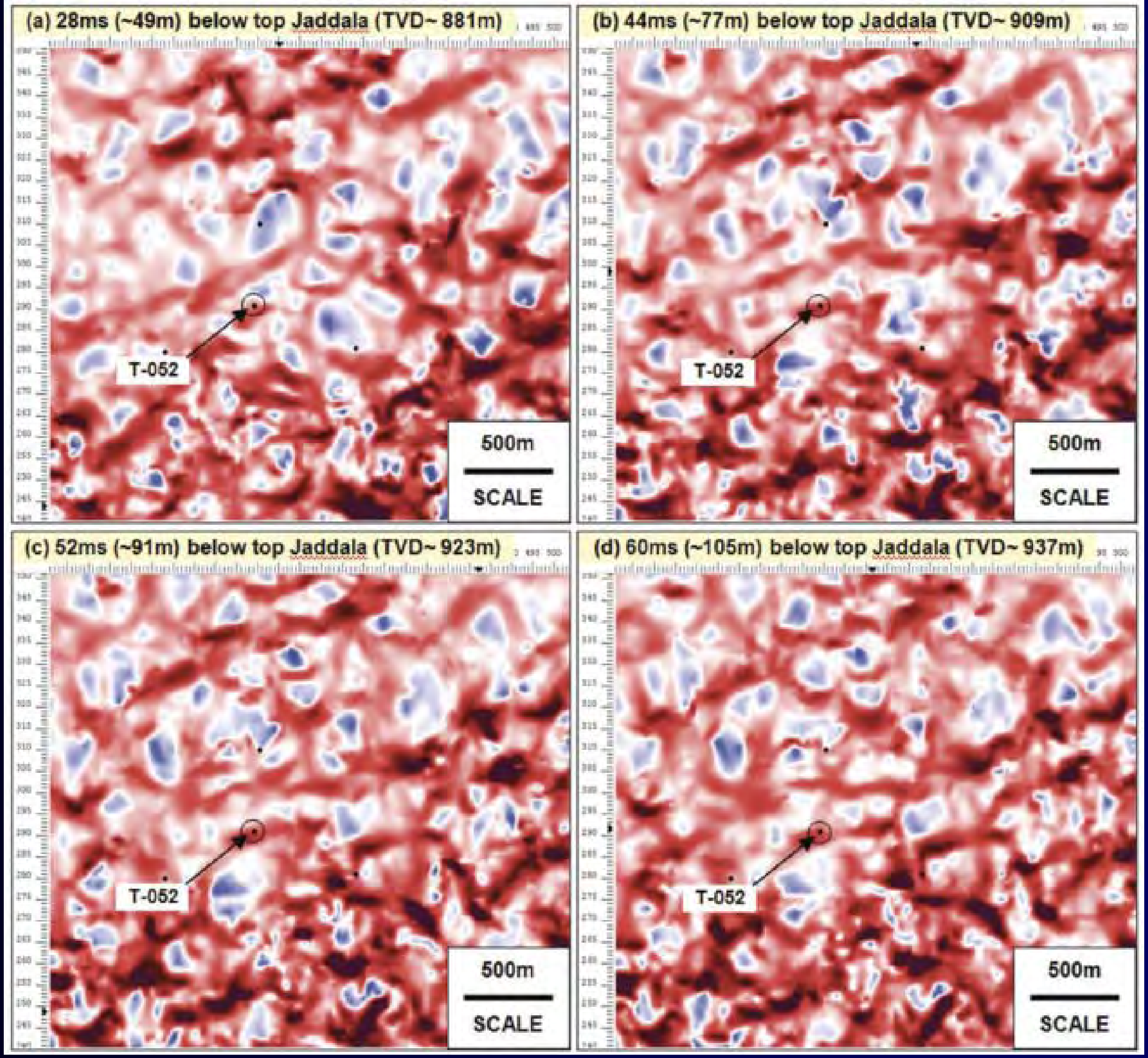
Most-positive curvature (high-res)



Case study - 1

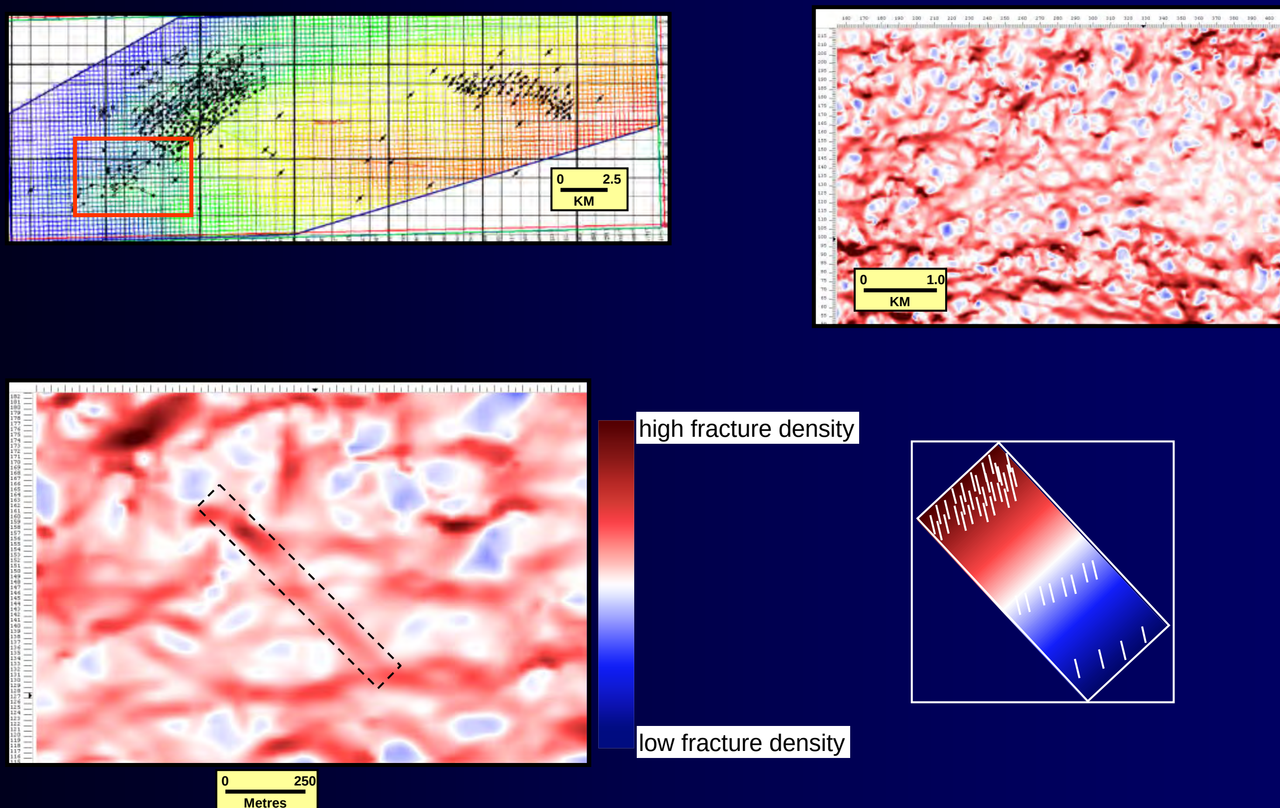
A horizon slice at Chilou-1 level from the most-positive curvature is shown here retaining only the high values of curvature and making all the other values transparent. The cluster of red lineaments represent fractures. (Ganguly et al, 2009)

Case study - 1



Calibration of the curvature attribute with results of well T-052. Horizon slices representing the four producing (perforated) zones are shown. All attribute results indicate good agreement between predicted fracture density and well results. (Ganguly et al, 2009)

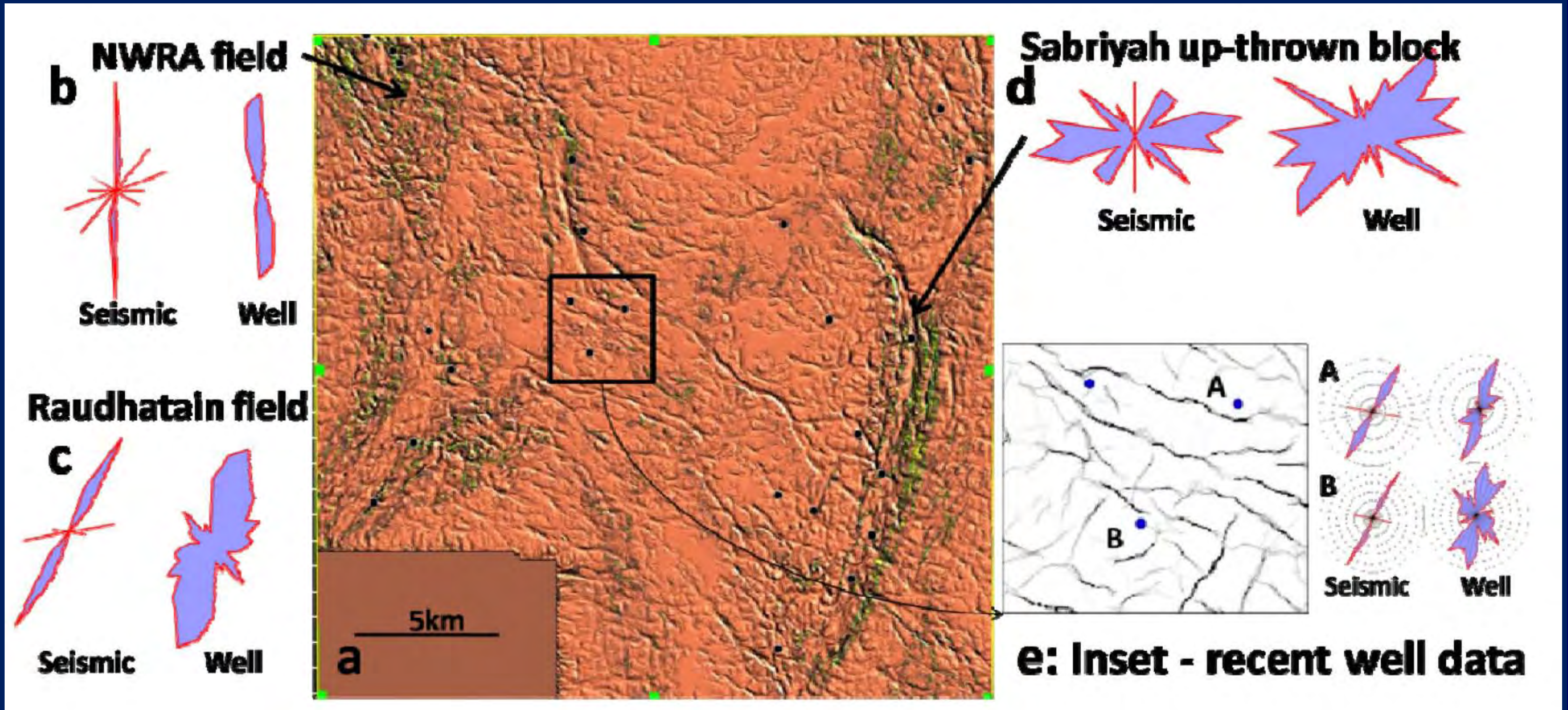
Case study - 1



Fracture model developed using image log data from wells and curvature attribute from 3D seismic. The seismic identifies areas of high fracture density, while the orientation of individual fractures are obtained from image logs.

(Ganguly et al, 2009)

Case study - 2



(a) An example from multi-volume visualization (EDGE and volume curvature) highlighting subtle features; (b), (c), and (d): strike rosettes showing open fracture detection encountered in the respective fields and corresponding rosette generated from seismic faults, lineaments and structure. (e) inset showing the well-wise match of these two sets of rosettes for the recently drilled wells (rose diagrams rotated by 90 degrees for better visual impact). (Rao et al, 2009)

Bottomline

It is possible to interpret fractures from seismic discontinuity attributes.

Demonstrated the qualitative approach

Visualization plays a big role in this exercise.

We can add value to seismic data with attributes and their visualization

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