

AV Delineating Fractures from Seismic Attributes*

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Abstract

Fractures can enhance permeability in reservoirs and hence impact the productivity and recovery efficiency in those areas. 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. Seismic attributes help us in characterizing stratigraphic features that may comprise reservoirs, and they form an integral part of most interpretation projects completed today. Coherence, curvature, and relative acoustic impedance are some important seismic attributes that are used for such analysis. However, for extracting accurate information from seismic attributes, the input seismic data needs to be conditioned optimally. This includes noise removal, using robust dip-steering options and superior algorithms for computation of seismic attributes.

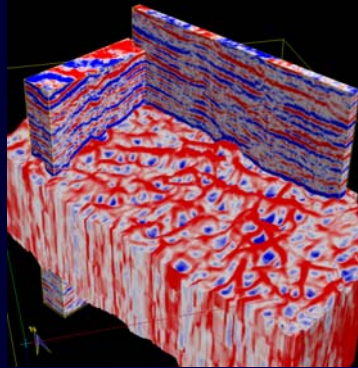
Curvature attributes in particular exhibit detailed patterns for fracture networks that can be correlated with image log and production data to ascertain their authenticity. One way to do this correlation is to manually pick the lineaments seen on the curvature displays for a localized area around the borehole, and then transform these lineaments into rose diagrams to compare with similar rose diagrams obtained from image logs. Favorable comparison of these rose diagrams lends confidence in the interpretation of fractures. Another way is to generate automated 3D rose diagrams from seismic attributes and correlate them with other lineaments seen on the coherence attribute.

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. Volume visualization of stratigraphic features is a great aid in 3D seismic interpretation and can be greatly aided by adopting cross-plotting of seismic discontinuity attributes in the interpretation workflow as we demonstrate in this presentation.

References

- Al-Dossary, S. and K.J. Marfurt, 2006, 3D volumetric multispectral estimates of reflector curvature and rotation: *Geophysics*, v. 71/5, p. P41-P51.
- Chopra, S. and G. Larsen, 2000, Acquisition footprint – it's detection and removal: *CSEG Recorder*, v. 25/8, p. 16-20.
- Gersztenkorn, A. and K.J. Marfurt, 1999, Eigenstructure-based coherence computations as an aid to 3-D structural and stratigraphic mapping: *Geophysics*, v. 64/5, p. 1468-1479.
- Hart, B.S., T. Engler, R. Pearson, and R.L. Robinson, 2002, 3-D seismic horizon-based approaches to fracture-swarm sweet spot: *AAPG 2002 Annual Meeting Expanded Abstracts*, p. 73.
- Lisle, R.J., 1994, Detection of zones of abnormal strains in structures using Gaussian curvature analysis: *AAPG Bulletin*, v. 78/12, p. 1811-1819.

Delineating Fractures from Seismic Attributes



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**UNIVERSITY OF OKLAHOMA,
NORMAN**

Qualitative interpretation of fractures

Fractures enhance permeability in reservoirs and so impact the production and recovery efficiency in those areas.

Consequently, detection and characterization of fractures in reservoirs are of great interest.

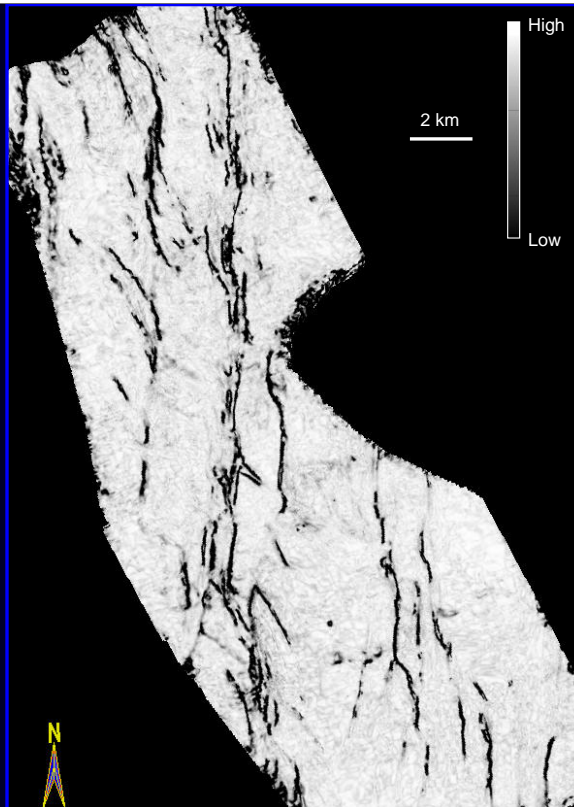
Surface seismic data have been used for detection of faults and large fractures.

Recent developments in seismic attributes have shown promise in identifying closely spaced fractures, or interconnected fracture networks.

How can we interpret fractures from discontinuity attributes?

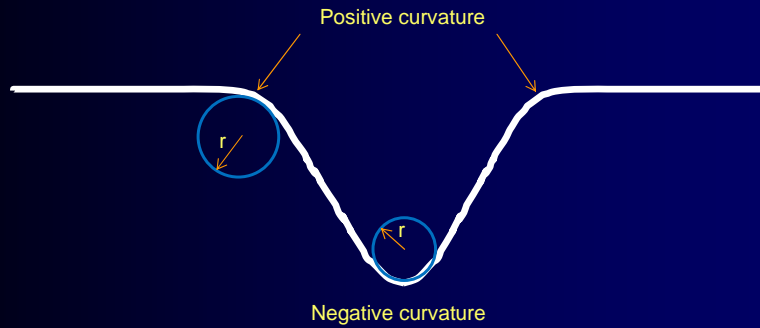
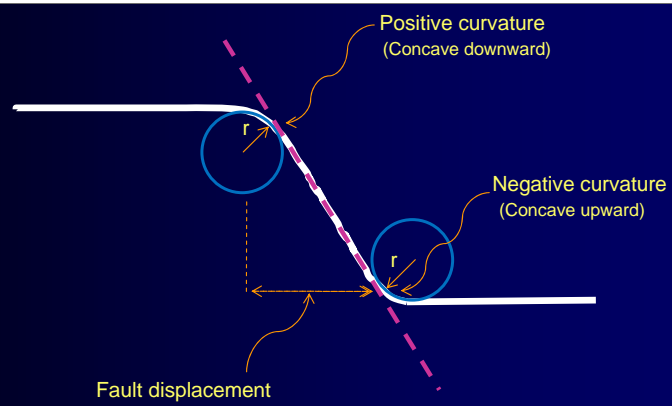
Coherence

Horizon slice through the
coherence volume

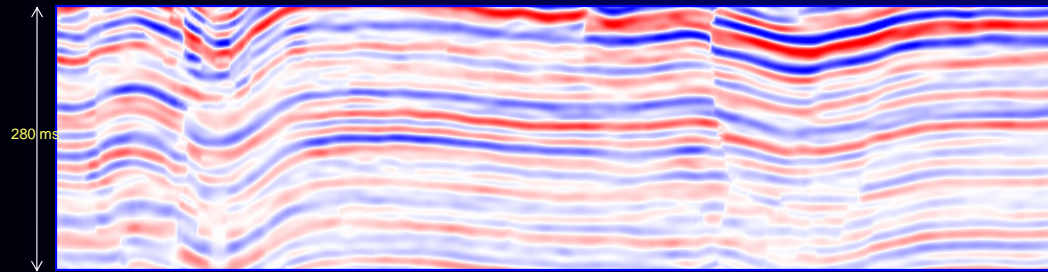


*Data courtesy: Arcis
Corporation, Calgary*

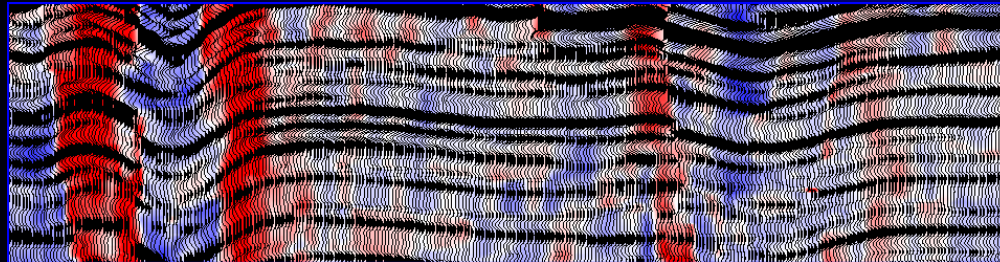
Curvature



Curvature



Segment of a seismic section after structure-oriented filtering



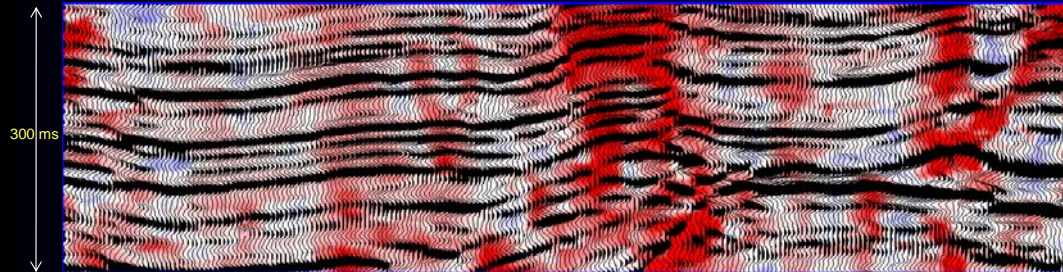
Seismic section with most-positive curvature overlaid on it.

Neg



Pos

Curvature



Seismic section with most-positive curvature (long-wavelength) overlaid on it.



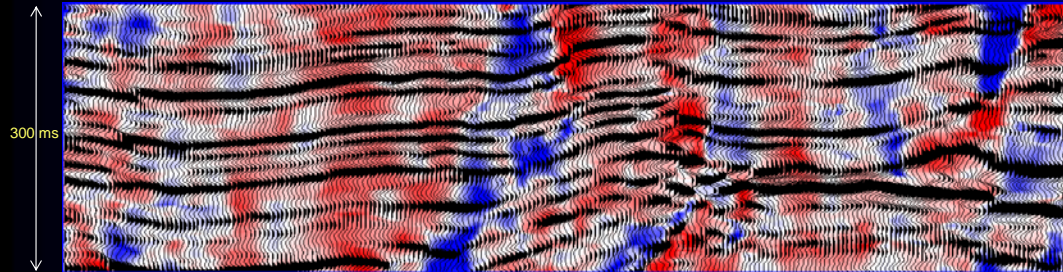
Seismic section with most-positive curvature (short-wavelength) overlaid on it.

Neg

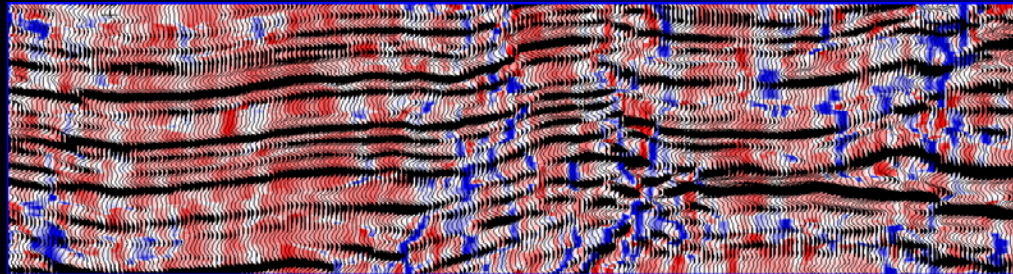


Pos

Curvature



Seismic section with most-negative curvature (long-wavelength) overlaid on it.



Seismic section with most-negative curvature (short-wavelength) overlaid on it.

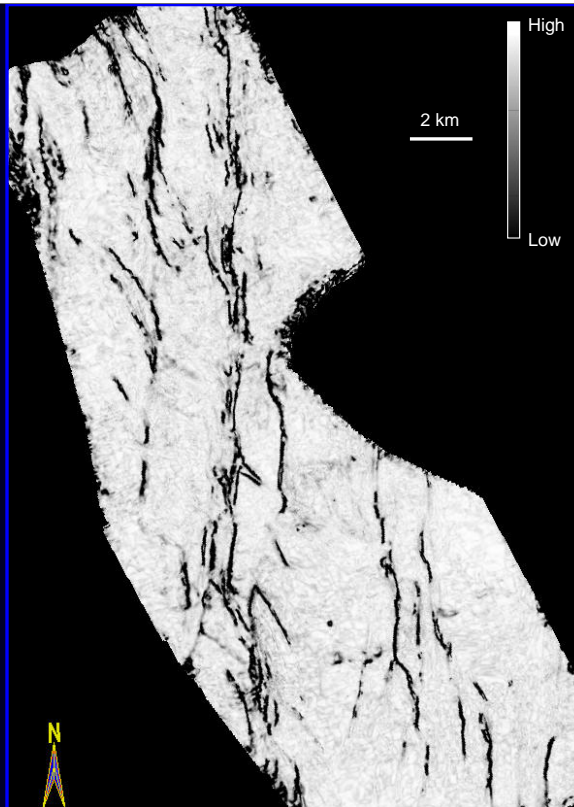
Neg



Pos

Coherence

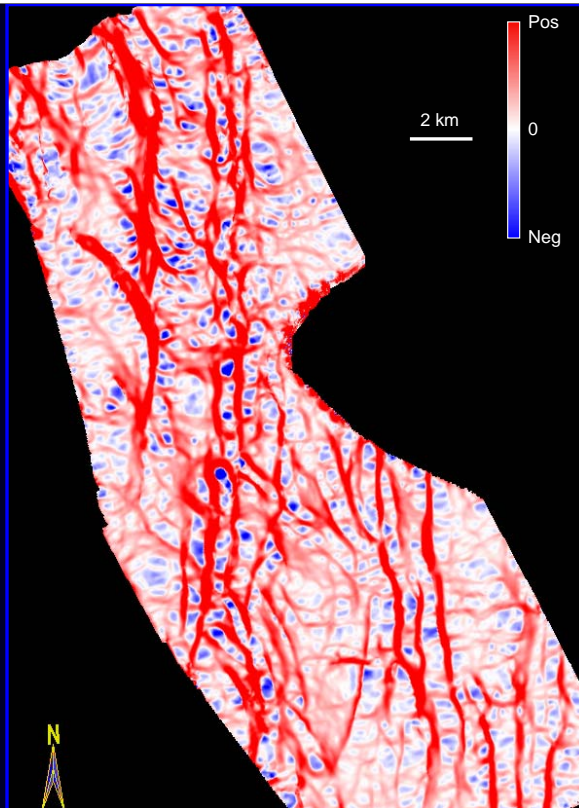
Horizon slice through the
coherence volume



*Data courtesy: Arcis
Corporation, Calgary*

Curvature

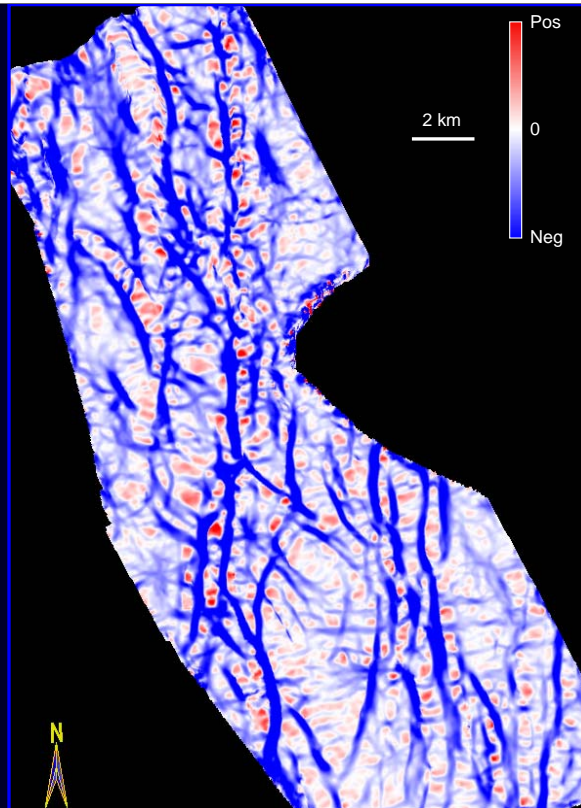
Horizon slice through the
most-positive curvature
volume



*Data courtesy: Arcis
Corporation, Calgary*

Curvature

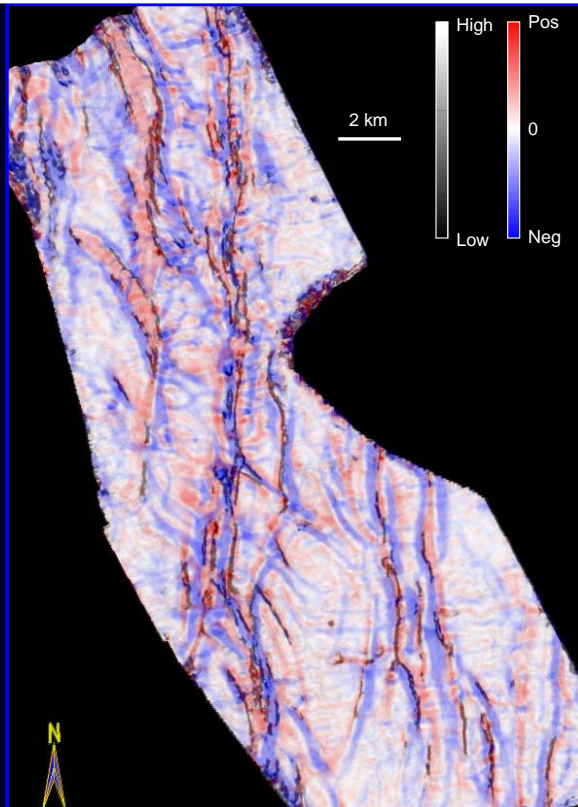
Horizon slice through the
most-negative curvature
volume



*Data courtesy: Arcis
Corporation, Calgary*

Coherence and Curvature

Color stack of coherence,
most-positive curvature, and
most negative curvature

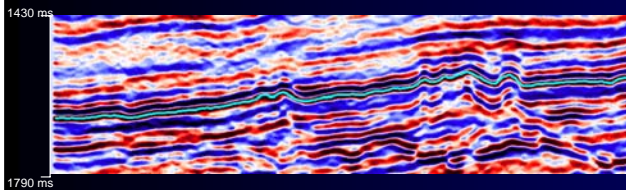
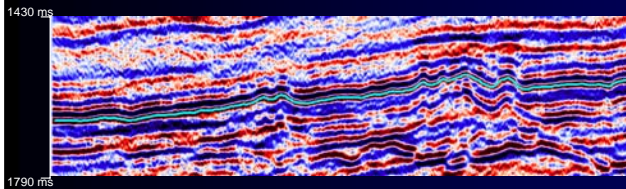


*Data courtesy: Arcis
Corporation, Calgary*

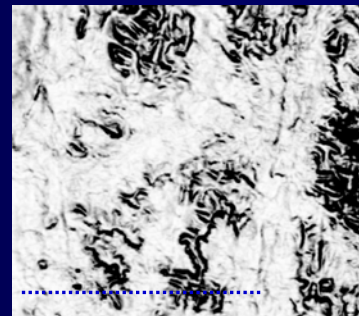
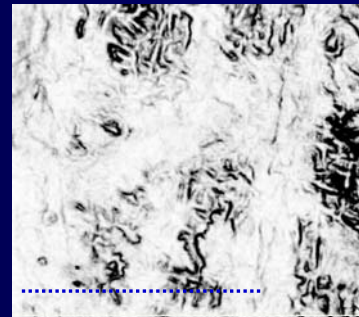
Seismic Attributes for Fault/Fracture Determination

1. Conditioning of data
2. Choice of algorithm
3. Use of dip-steering option

Dip-steered median filtering



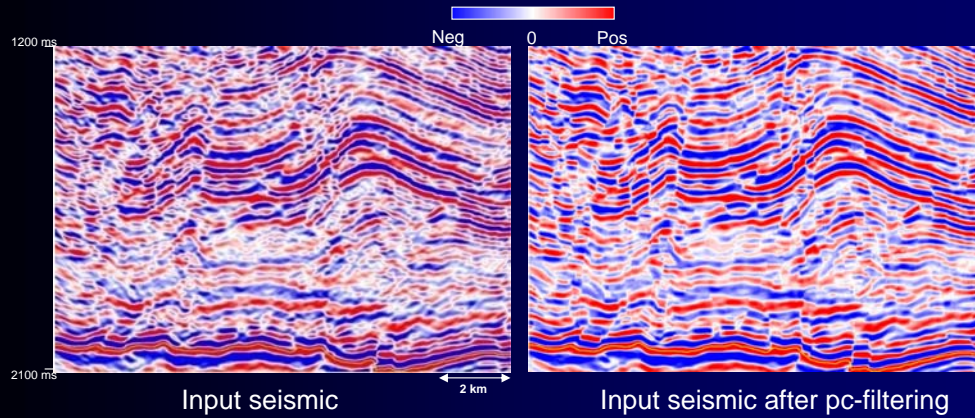
Inline sections through (a) the input seismic volume, and (b) the median filtered seismic volume



3 km

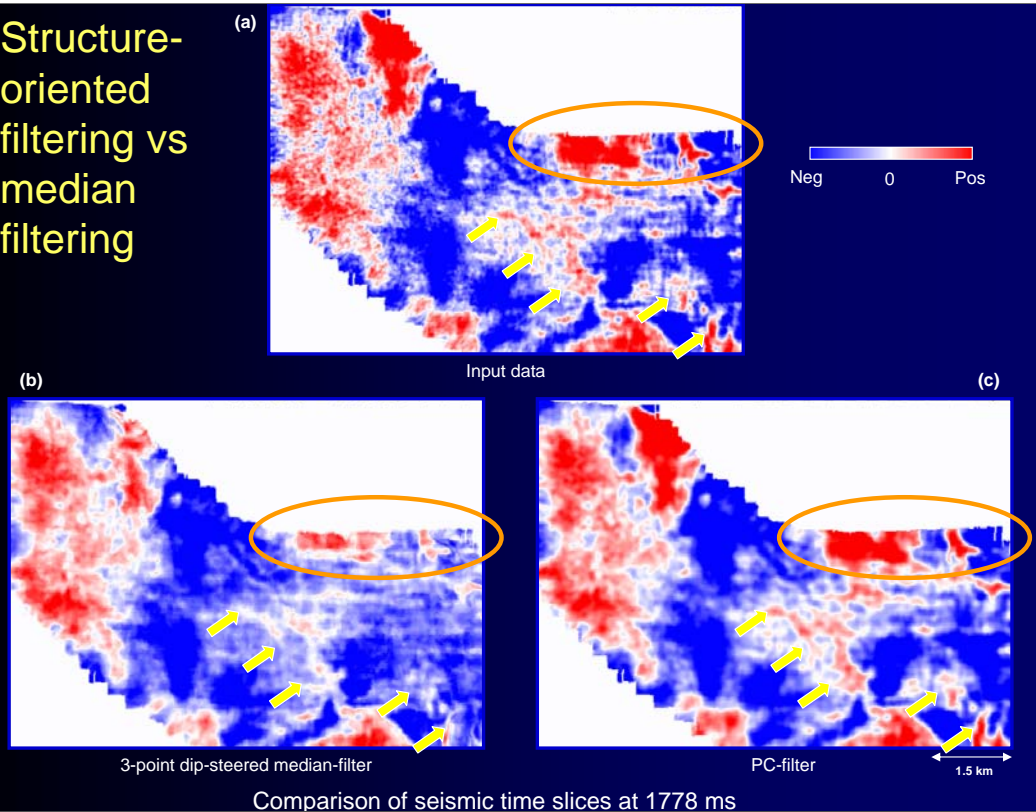
Strat slices through coherence volumes run on (c) the input seismic volume, and (d) the median filtered seismic volume, 76 ms below the horizon shown in (a) and (b)

Structure-oriented filtering

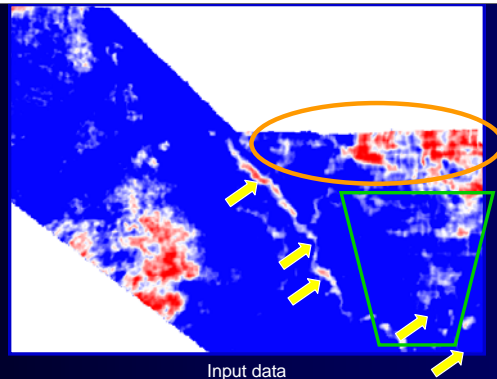


(Data courtesy: Olympic Seismic, Calgary)

Structure-oriented filtering vs median filtering

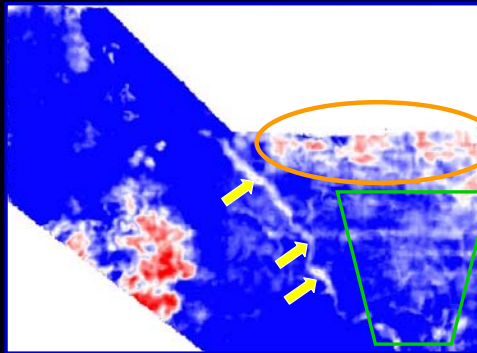


Structure-oriented filtering vs median filtering

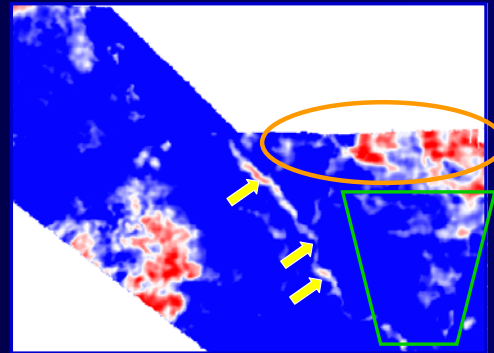


Input data

Comparison of horizon slices, 66 ms above a flattened marker



3-point dip-steered median-filter



PC-filter

1.5 km

Common causes of acquisition footprint

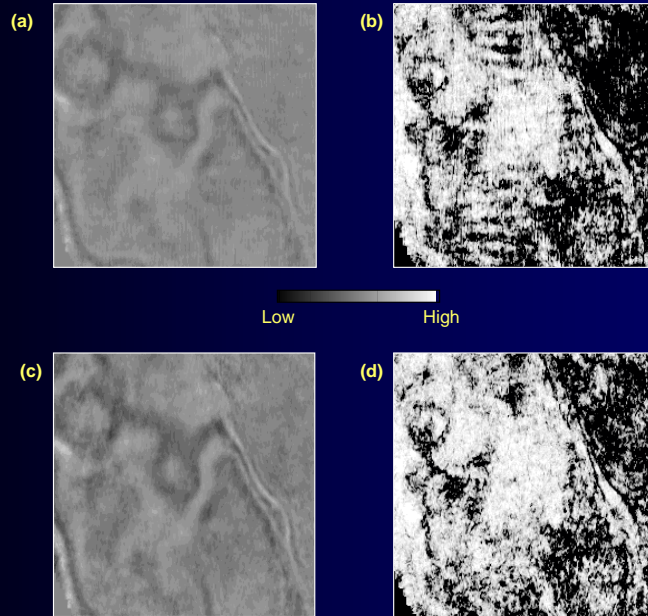
Problems due to acquisition program

- Non-uniform offsets and azimuths in bins
- Non-uniform backscattered noise suppression
- Obstacles such as lakes, villages, or platforms
- Currents and tides

Problems due to processing

- Incorrect velocities
- Migration operator aliasing

Footprint removal

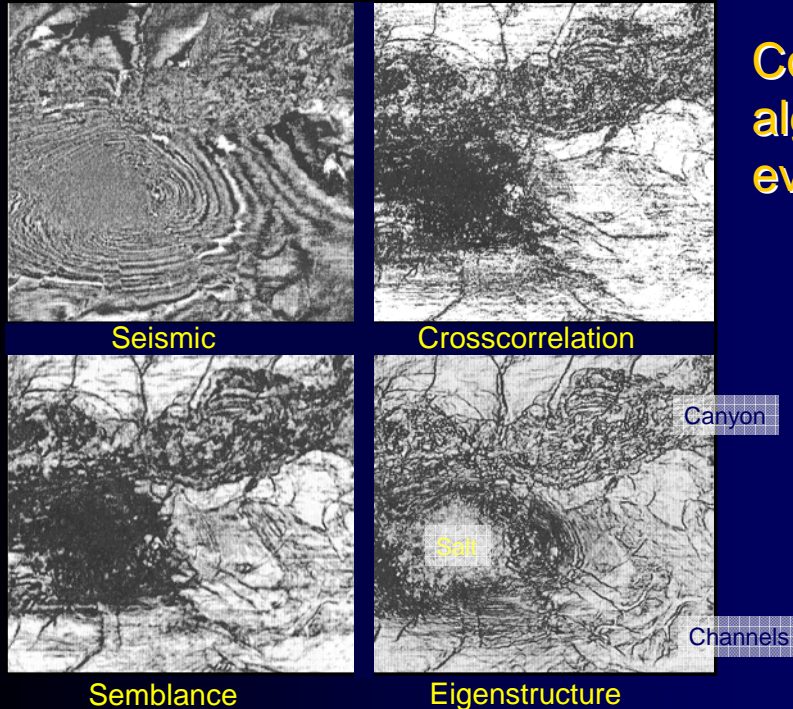


(Chopra and Larsen, 2000)

Seismic Attributes for Fault/Fracture Determination

1. Conditioning of data
2. Choice of algorithm
3. Use of dip-steering option

Coherence algorithm evolution

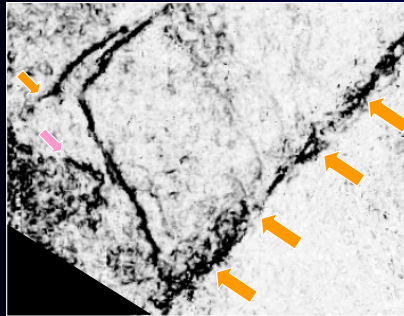


(Gersztenkorn and Marfurt, 1999)

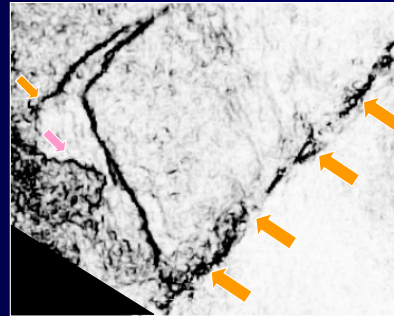
Notes by Presenter:

Comparison of alternative coherence algorithms used on data from South Marsh Island, Gulf of Mexico, USA. The volume shown contains both structural and stratigraphic features associated with deposition over a terrain influenced by salt tectonism. (a) A time slice through the time-migrated seismic data at 1.8 s. “S” denotes a salt dome, and “F” indicates several radial faults. Corresponding slices through coherence cubes were generated using the (b) three-trace crosscorrelation algorithm, (c) a five-trace semblance algorithm, and (d) a five-trace eigenstructure algorithm. All coherence computations used the same 80-ms vertical analysis window. The circular rings seen in (a) correspond to sediments dipping against a salt dome, which are cut by radial faults indicated by “F.” The disorganized feature indicated by “C” in the northeast is interpreted to be a canyon. The salt dome and faults appear to be incoherent (black) in (b) through (d). Note that there is considerably less “speckle” noise in the five-trace semblance algorithm than in the three-trace crosscorrelation algorithm. An even greater improvement in the signal-to-noise ratio and in lateral resolution accompanies the five-trace eigenstructure algorithm. The structural artifacts (leakage) about the salt dome indicated by “L” and the overall grayer level of the image in (d) are the result of a failure, in this early work, to search over structural dip. After Gersztenkorn and Marfurt (1996).

Comparison of algorithm performance



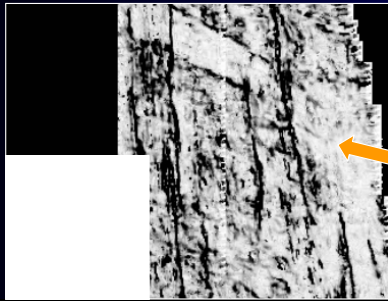
Coherence
(Eigen decomposition)



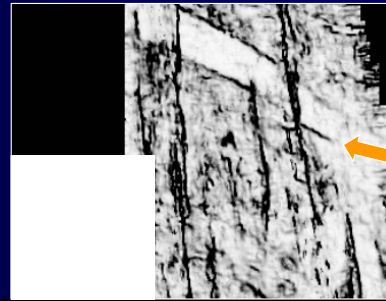
Coherence
(Energy ratio)

Time slices at 1342 ms

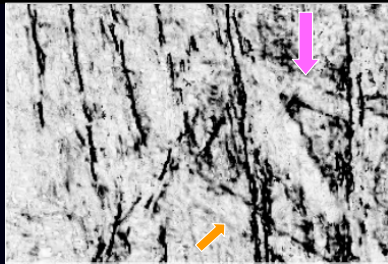
Comparison of algorithm performance



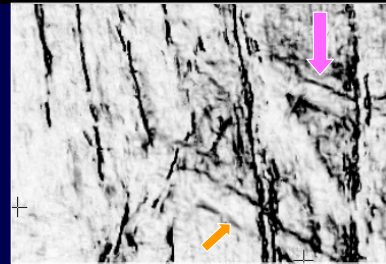
Coherence (Eigen-decomposition)



Coherence (Energy ratio)



Coherence (Eigen-decomposition)



Coherence (Energy ratio)

Time slices

Seismic Attributes for Fault/Fracture Determination

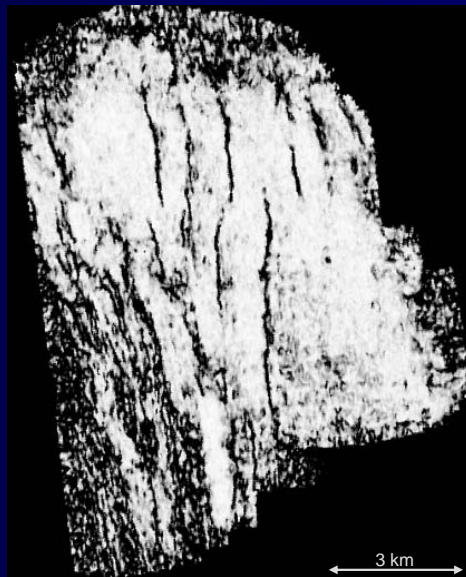
1. Conditioning of data
2. Choice of algorithm
3. Use of dip-steering option

(a)



Coherence using semblance without dip-steering option

(b)

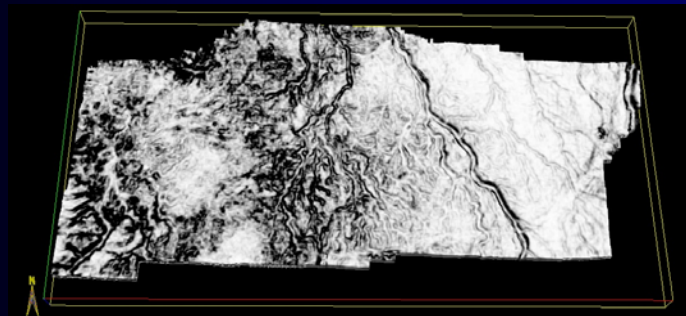


Coherence using Energy ratio



(Data courtesy: Olympic Seismic, Calgary)

(a)

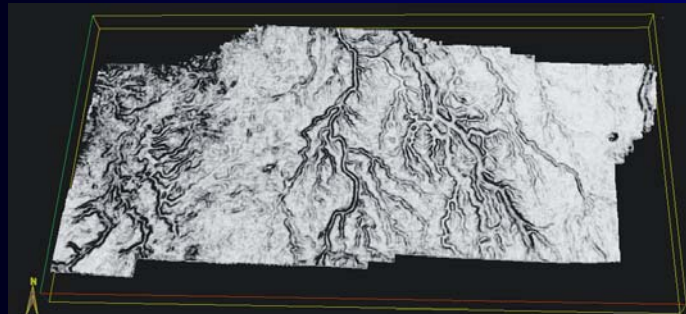


Low

High

Semblance

(b)

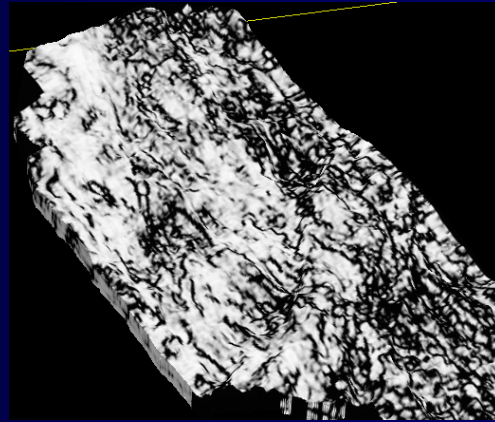
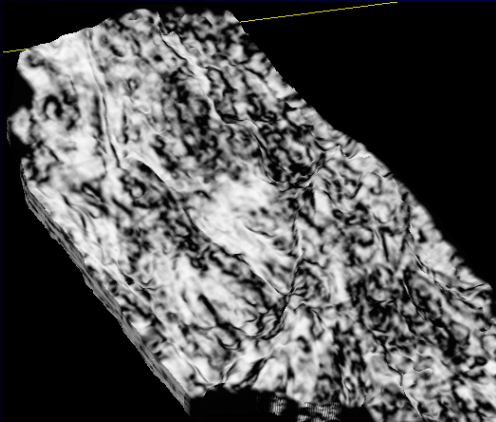


Coherence (Energy ratio) after PC-filtering

(a)

Strat-slices

(b)



Semblance without dip steering

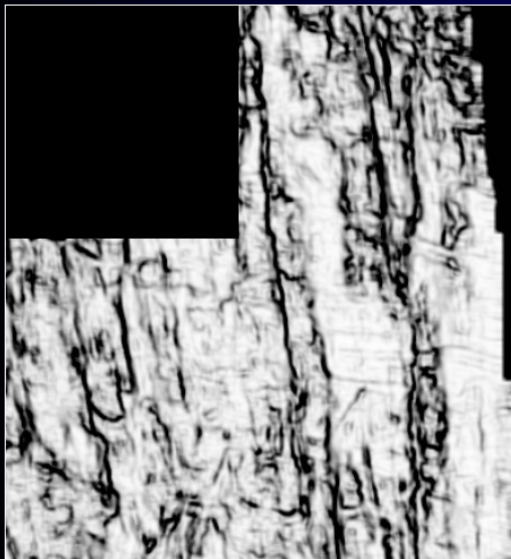
Energy ratio with dip steering



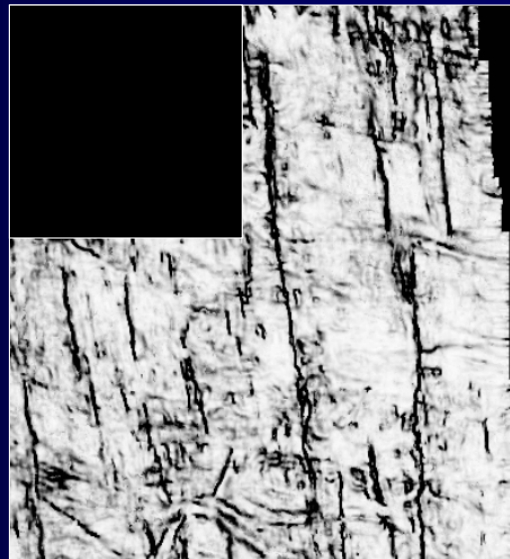
(a)

Time slices (1360 ms)

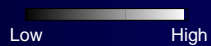
(b)

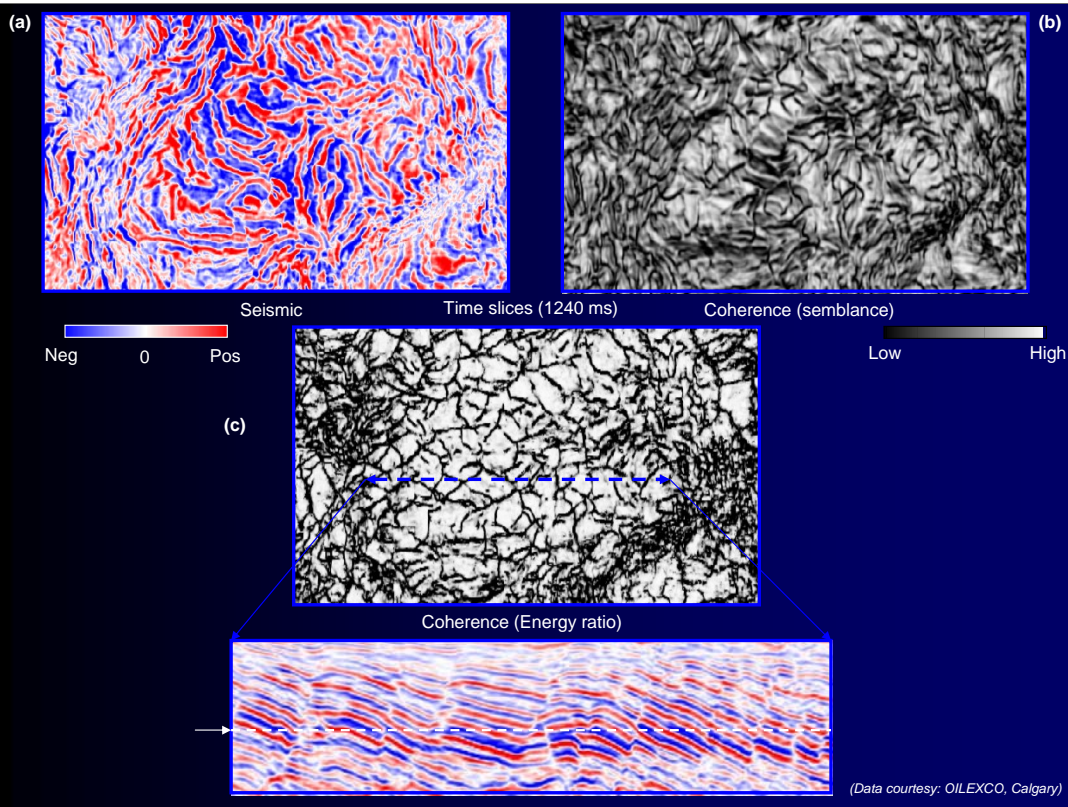


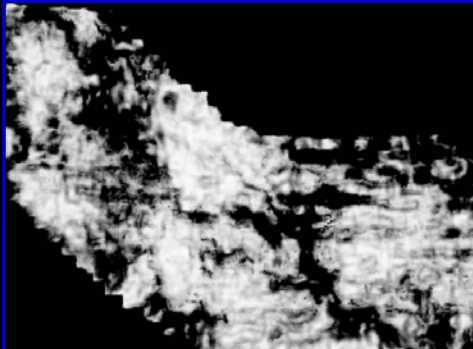
Semblance without dip steering



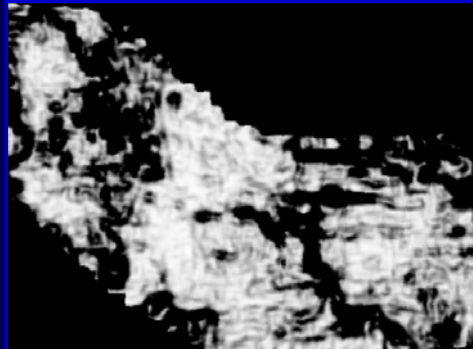
Energy ratio with dip steering



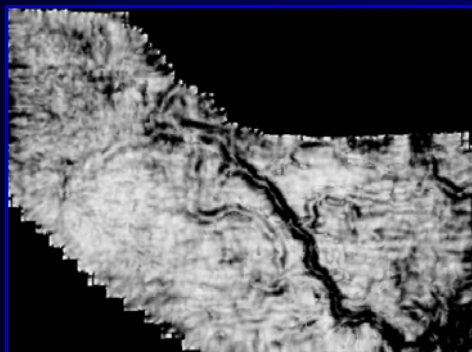




Semblance on input data



Semblance on input data with dip-steered median filter



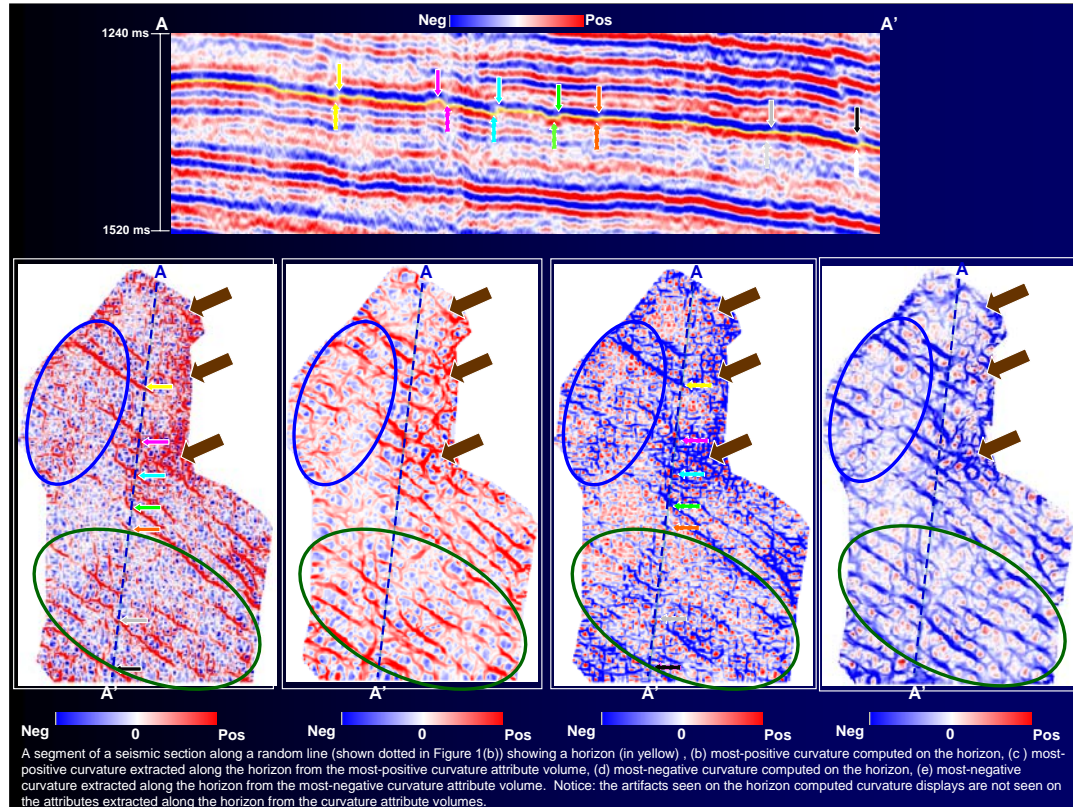
Energy-ratio on PC-filtered data

Seismic Attributes

Volumetric computation of curvature

Horizon-based curvature has been used successfully for prediction of faults and fractures (Lisle(1994), Hart et al. (2002)).

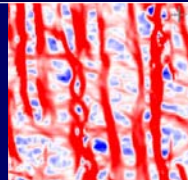
Volumetric curvature dispels the need to pick horizons (Al-Dossary and Marfurt (2006)).



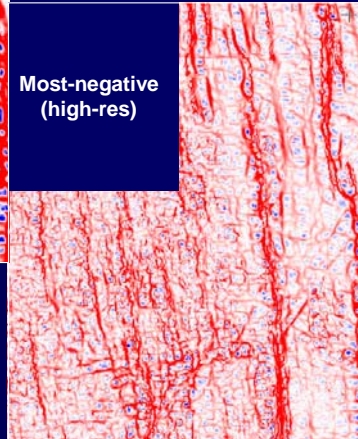
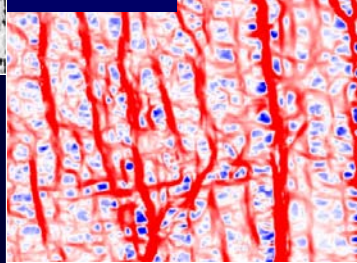
Coherence



Most-positive
(long-wave)

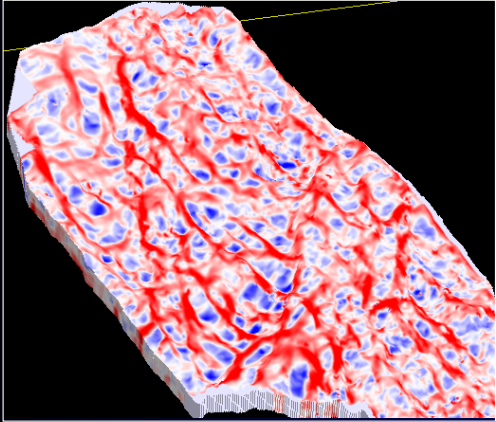


Most-negative
(high-res)

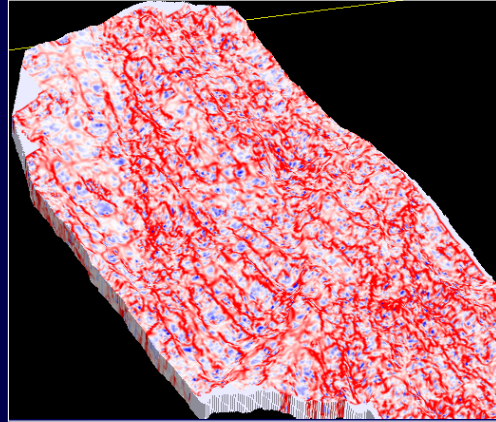


Time slice 1160 ms

Strat-slices



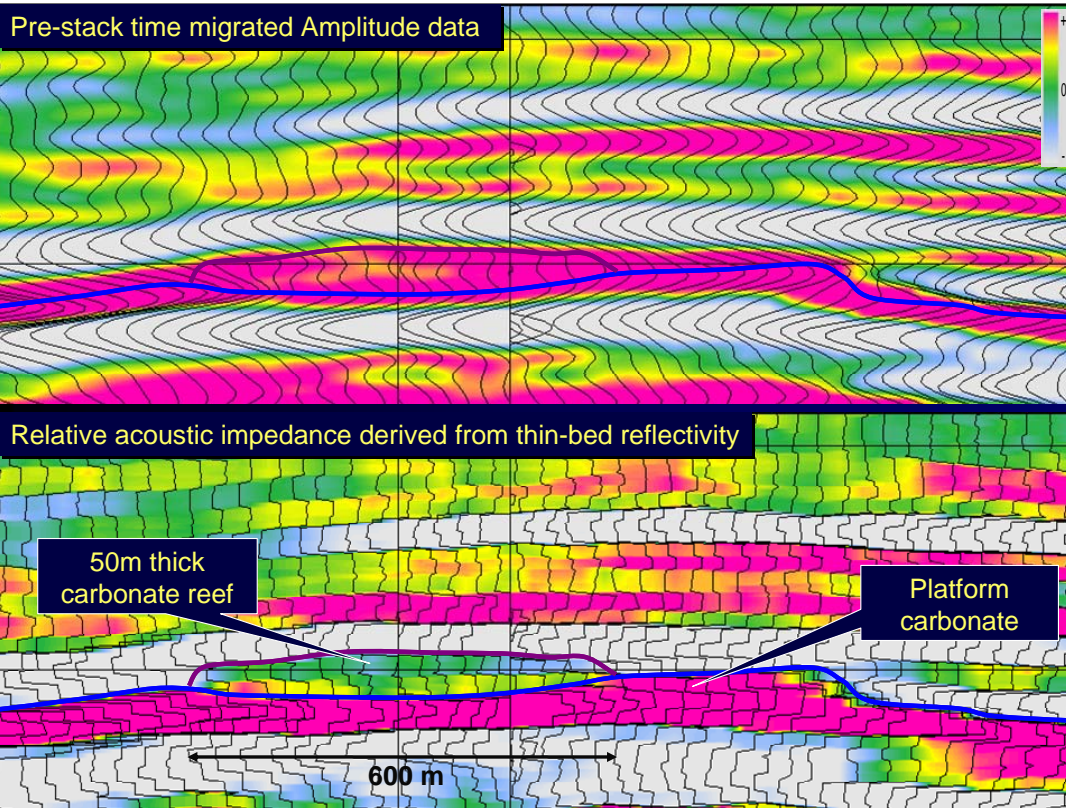
Most-positive curvature
(Long wavelength)

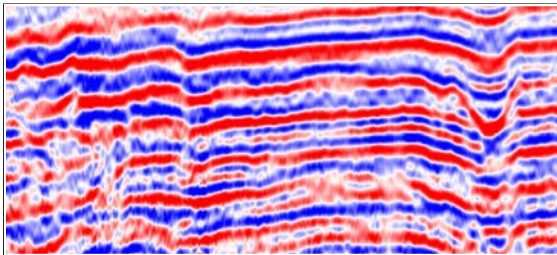


Most-positive curvature
(High resolution)

Seismic Attributes

For delineation of fractures, the frequency content of input seismic data is important



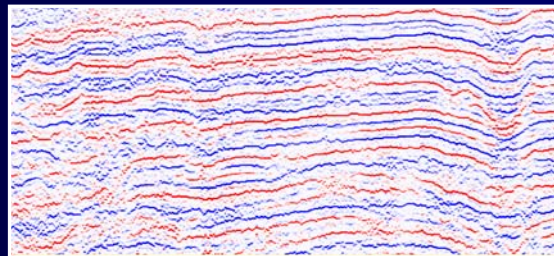


Seismic

(a)

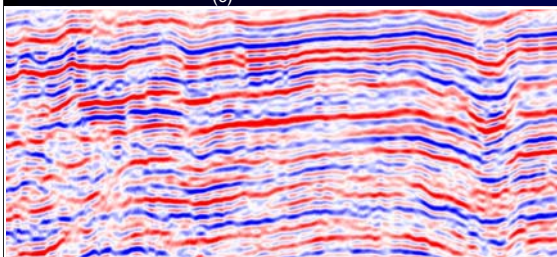
250 ms

(b)



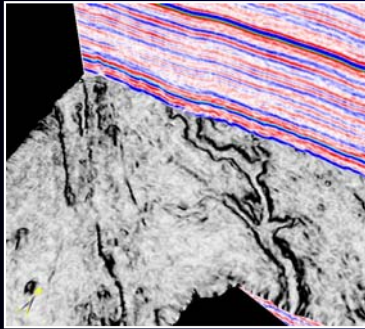
Thin-bed reflectivity

(c)

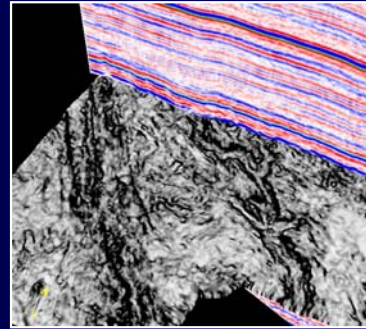


Reflectivity with a bandpass wavelet (high end 120 Hz)

Data courtesy: Arcis Corporation, Calgary



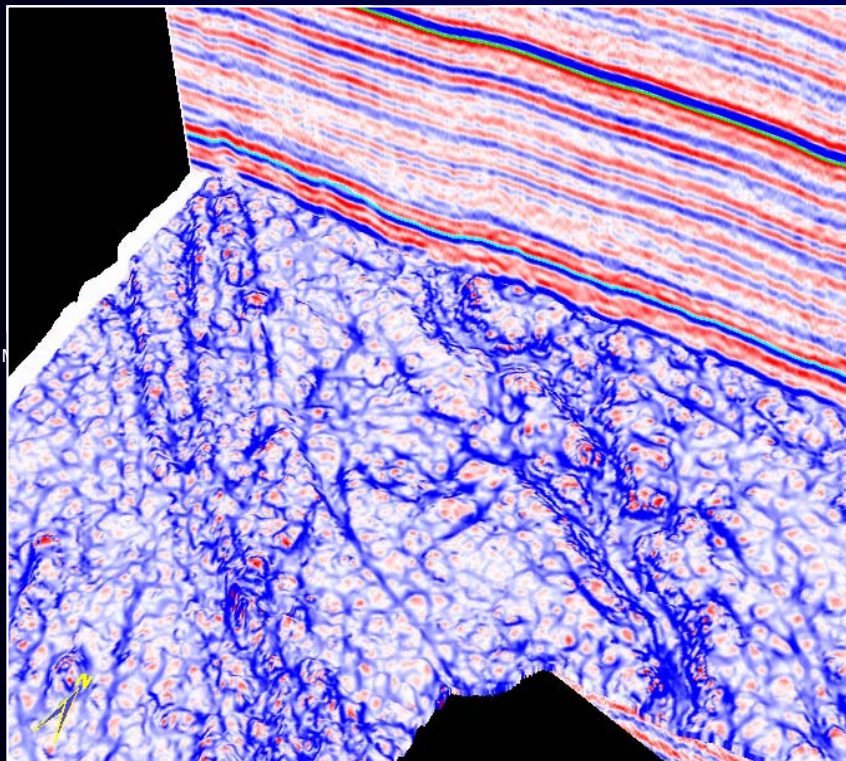
Coherence on the input volume



Coherence on the frequency-enhanced volume



Data courtesy: Arcis Corporation, Calgary



put volume
ed with a

Bottomline

It is possible to glean meaningful information from seismic attributes.

Be aware of how to do it.

Fractures can be delineated by running appropriate seismic attributes on seismic data with optimum frequency bandwidth.

THANK YOU