HampsonRussell
Attributes

Advanced seismic attributes

The **Attributes** package brings together a comprehensive, continually updated collection of the latest industry-standard seismic attributes, revealing subtle geological features — faults, fractures, discontinuities, frequency and phase-dependent behavior, that improve seismic data conditioning, interpretation quality and reduce uncertainty in reservoir characterization.

Benefits of Attributes:

- Extract and display subtle seismic features such as fault discontinuities, structural curvature, and frequency content, for higher-confidence interpretation
- Access a comprehensive collection of multi-trace algorithms in one integrated toolset
- Feed derived attributes directly into **Emerge**, multi-attribute analysis and machine learning product for estimation of reservoir properties.
- Use the computed attributes in geostatistical mapping software **MapPredict** to relate attribute slices to map-based well values such as hydrocarbon production.

Core attributes are anchored by a full spectral decomposition toolset, alongside Curvature, Phase Congruency, Energy ratio, and Amplitude Variation with Frequency (AVF), a frequency-dependent attribute that serves as a direct hydrocarbon indicator.

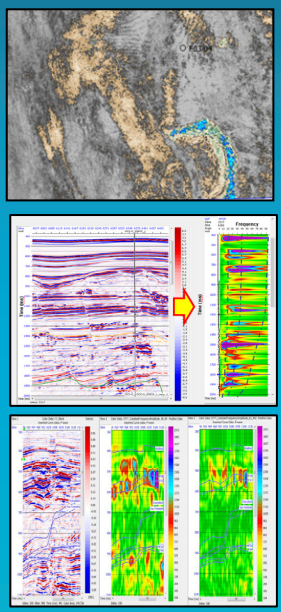
Multi-trace edge-preserving filters, including the Kuwahara and alpha trimmed mean filters, provide optimal pre-conditioning of seismic data.

Basic single-trace volume attributes such as instantaneous envelope, phase and frequency, trace integration and differencing, are also included.

Basic volume attributes:
- Instantaneous attributes
- Derivative and integrated attributes
- Filter slices, etc.

Spectral Decomposition:
- Short-time Fourier Transform
- Wavelet Transform
- S-transform
- Basis Pursuit
- Empirical Mode Decomposition

Amplitude vs Frequency (AVF)

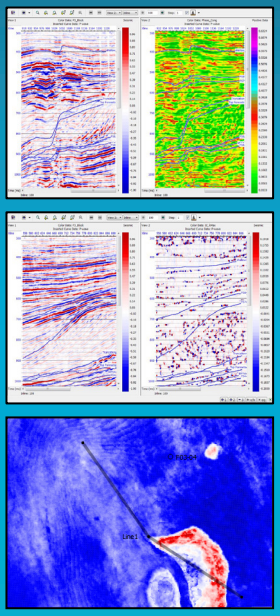


Multi-trace data conditioning:
- Anisotropic Diffusion Filter
- Edge-preserving Filters
- 3D Gaussian Smoothing Filter

Curvature Attributes:
- Instantaneous Curvature
- Volume Curvature

Edge Enhancement Attributes
- Energy Ratio Attributes
- Phase Congruency

Bandwidth Attribute



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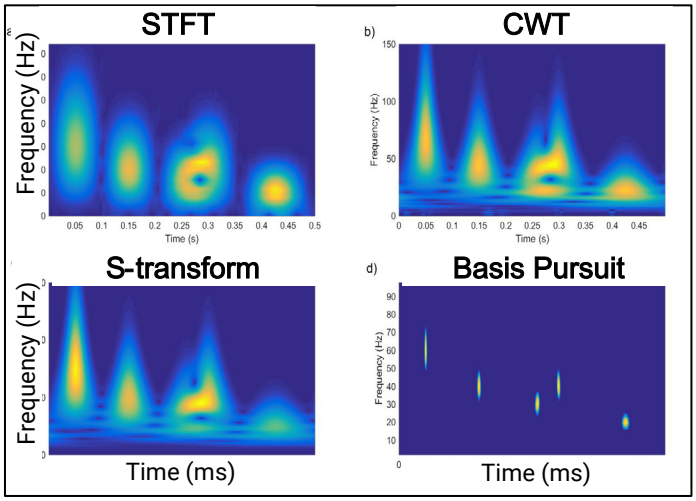
Spectral Decomposition

- Spectral decomposition, also called time frequency analysis or spectral estimation, is a fundamental analysis tool that has a wide range of applications in the geophysical community.
- It aims to reveal signal features of the seismic trace such as any underlying periodicities that are not obvious in the time domain, thus aiding the seismic interpretation.
- Spectral decomposition has been successfully utilized in thin bed analysis, hydrocarbon detection, subsurface geological structure detection, stratigraphic delineation and attenuation estimation.
- It has also found applications in seismic processing, such as random and coherent noise attenuation, regularization and interpolation of seismic data.
- The **Attributes** package provides a variety of frequency attributes for spectral analysis, from standard instantaneous frequency attributes, widely used Short Time Fourier transform (STFT)and Continuous Wavelet Transform (CWT), S-transform and Basis Pursuit to advanced Empirical Mode Decomposition methods.



Comparison of spectral decomposition methods applied to the same seismic dataset (after Han et al., 2017).

Amplitude Variation with Frequency (AVF)

- AVF is a frequency-dependent attribute analyzing amplitude across pre- or post-stack gathers, giving a hydrocarbon indicator that complements AVO.
- The seismic wave loses its high-frequency content due to cumulative attenuation. In the zone with hydrocarbon presence, the amplitude spectrum tends to have lower dominant frequency and lower high-frequency content relative to the background trend.
- This anomaly can be used to delineate the hydrocarbon-bearing reservoir , using the post stack seismic data only, in the case of no gather data is available, or even as addition to the AVO analysis.
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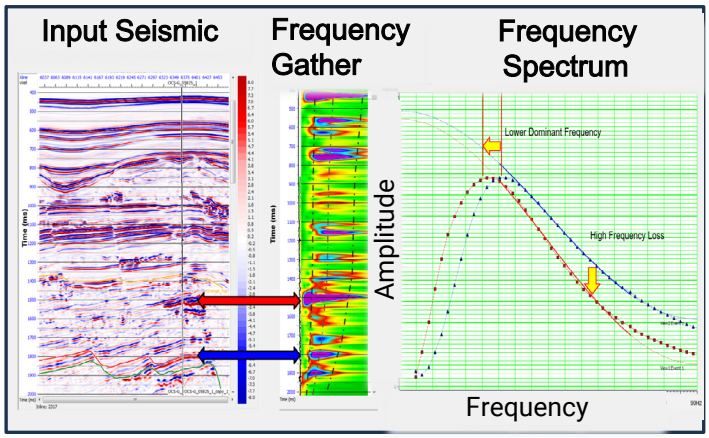
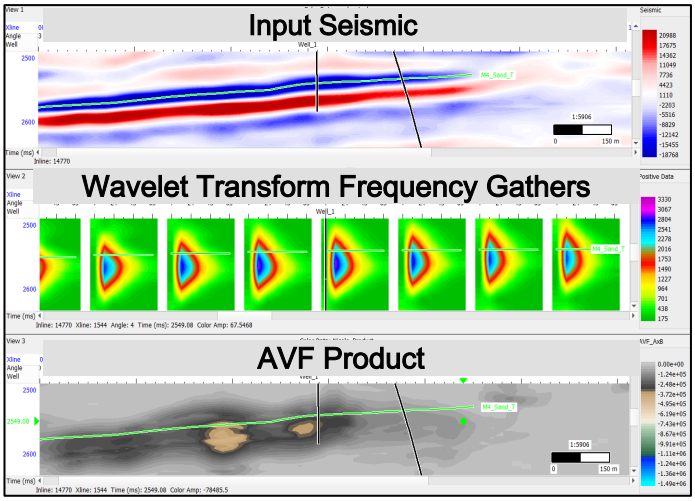
- This is due to the hydrocarbon bearing medium especially in high porosity medium tends to absorb the seismic wave energy.



Interactive Spectral Decomposition Analysis.



From seismic data to frequency gathers to AVF product.

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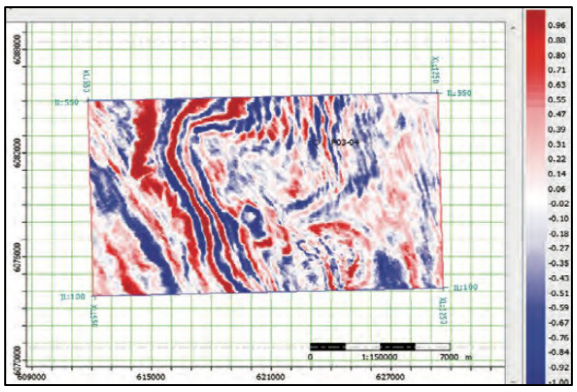
Curvature

Curvature can detect fractures, faults and other discontinuous features in seismic volumes. The instantaneous curvature and volume curvature algorithms are included. Instantaneous curvature calculates spatial frequencies, while volume curvature is based on computing the small time shifts within the volume.

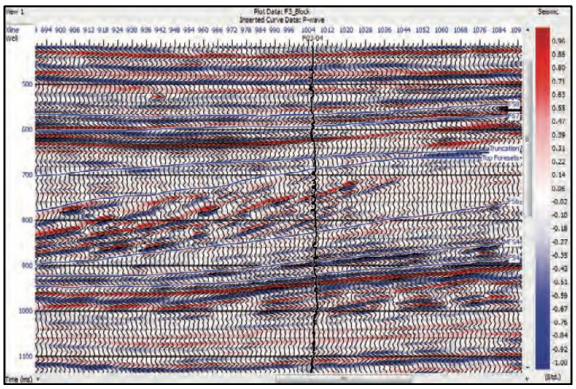
Other curvature attributes include:

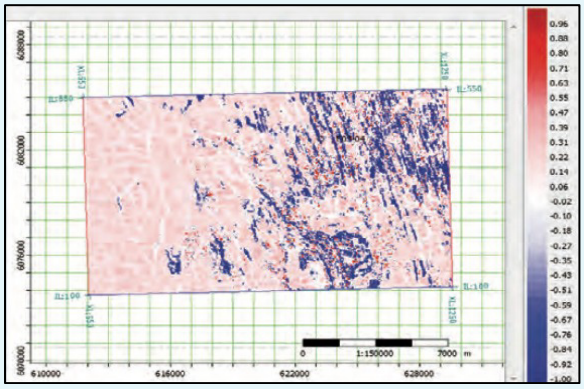
- $K_m = (K_{max} + K_{min})/2$, mean curvature
- $K_g = K_{max}K_{min}$, Gaussian curvature
- $K_{positive}$ and $K_{negative}$ the most positive and negative curvatures
- K_c contour curvature, the curvature of the map contours along the surface
- K_d dip curvature, curvature in dip direction
- K_s strike curvature, curvature in strike direction
- K_n curvedness, the magnitude of the curvature independent of shape

Associated with the dip and strike curvature attributes, the dip and azimuth angles can also be computed.

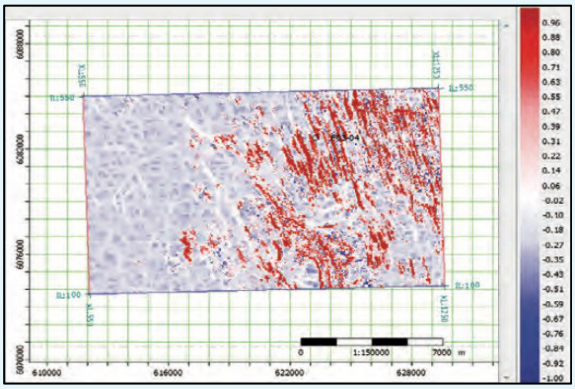


Example dataset showing an amplitude time slice at 1000 ms through the seismic volume (top) and inline 442 from the same volume (bottom).





K_{min} attribute: computed on a 1000 ms time slice.



K_{max} attribute: computed on a 1000 ms time slice.

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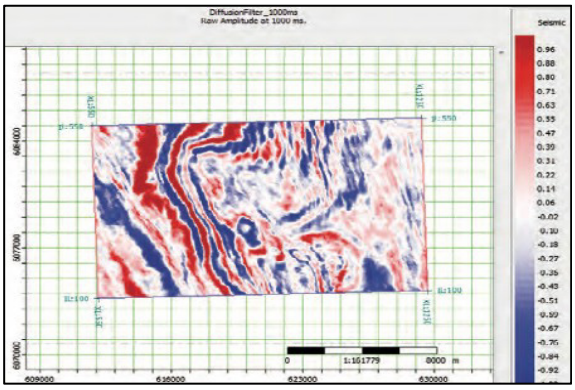
Anisotropic Diffusion Filter (ADF)

ADF is a pre-conditioning filter that enhances seismic data before volume attributes are computed.

Based on the Van Gogh filter technique (Fehmers and Höcker, 2003), ADF uses anisotropic to smooth data parallel to seismic reflections. This reduces random noise and small-scale artifacts while preserving edges, allowing key geological and structural features to remain clearly defined. ADF works by:

- Computing a diffusion tensor from the local seismic structure, aligned with the reflections.
- Deriving structural orientation implicitly from the tensor's eigenvalues and eigenvectors.
- Appling diffusion iteratively, revealing overall structure first, then stepping back through less-filtered iterations for finer detail.
- Preserving fault boundaries via the edge-detecting option.

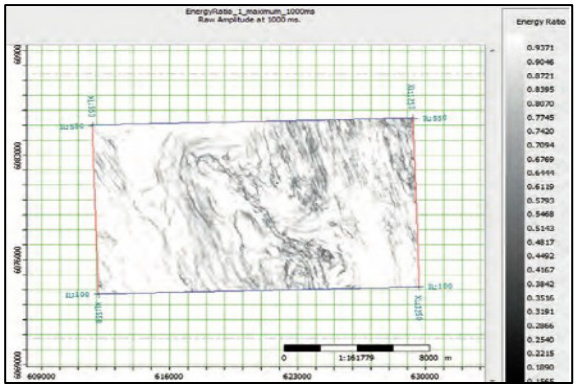
Unlike conventional Structure-Oriented Filtering (SOF), which requires dip and azimuth volumes to guide filtering, ADF derives orientation directly from the seismic data. Its iterative approach allows interpreters to first identify major structural trends and then examine earlier, less-filtered iterations to recover finer geological detail.



Anisotropic diffusion filtering with edge detection applied to the 1000 ms time slice.

Energy Ratio

Energy ratio offers an alternative way to reveal geological discontinuities such as faults, and like phase congruency, it can also expose subtle fractures. It's computed by moving a sub-volume through the seismic volume, filtering out steeply-dipping coherent events, then taking the ratio of filtered to unfiltered energy and assigning that value to the sub-volume's center before moving to the next position.

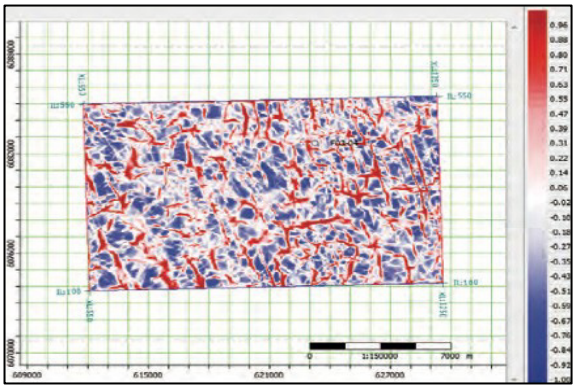


Energy ratio attribute computed for the 1000 ms time slice, clearly delineating the fault network and associated discontinuities..

Phase Congruency

The phase congruency algorithm, developed by Kovesi (1996), was initially used in robot vision to detect edges. The fundamental idea is to find the point where the phase of the various frequency components in a data set are equal, or congruent.

Because it relies on frequency alignment rather than amplitude, phase congruency highlights faults, fractures, and subtle stratigraphic boundaries that amplitude-based attributes can miss, especially in noisy or low-amplitude zones, making it a strong complement to curvature and other structural attributes.



Phase congruency attribute computed for the 1000 ms time slice, highlighting the continuity and delineation of structural discontinuities..