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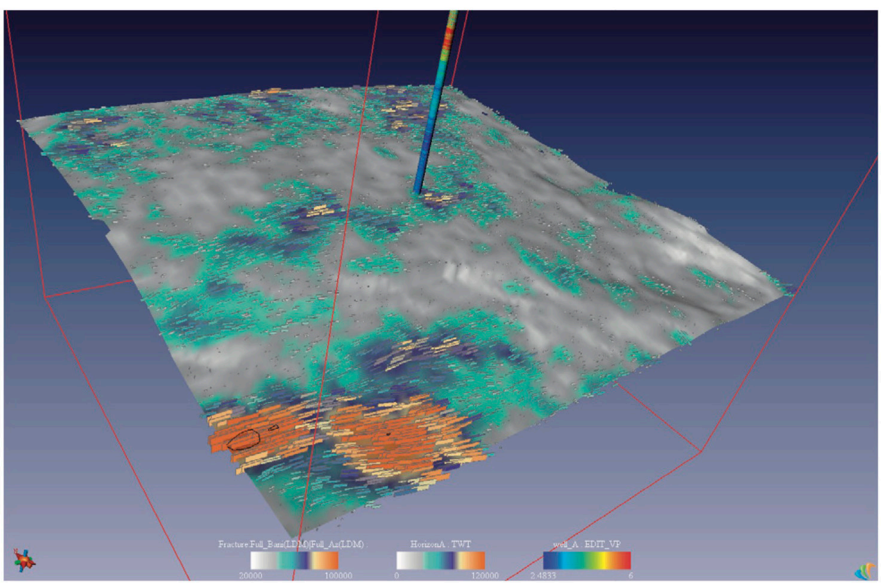
ProAZ

Anisotropy: fracture and stress interpretation

ProAZ maps fractures and predicts stress by observing azimuthal variations in the P-wave seismic data. Prestack azimuthally processed seismic data are analyzed for time and amplitude azimuthal variations attributed to anisotropic effects. **ProAZ** provides a series of tools to enable interpreters to interactively explore azimuthal variations in their datasets and generate azimuthal attributes to summarize the results. These attributes contain both magnitude and orientation information and can be displayed using **HampsonRussell**'s visualization software.

ProAZ Features

- **Azimuthal Modeling**
  - Model the anisotropic response due to fractures and stress
  - Model the amplitude and traveltime response due to anisotropy
- **Azimuthal Traveltime Analysis**
  - Analyze residual azimuthal traveltimes to determine layer based anisotropy
  - Correct for residual azimuthal NMO
- **Azimuthal Processing**
  - Create and view azimuthal gathers
  - Most processes are generalized to include azimuth data, especially Stacking, Parabolic Radon, NMO



- **Azimuthal AVO Attributes and Analysis**
  - HTI Rüger equation (near and far)
  - Azimuthal Fourier Coefficients
  - Nonlinear estimates for the symmetry axis and fracture parameters
- **Graphical Tools**
  - Rose Diagrams
  - 3D visualization to view azimuthal attributes as platelets
  - AVOAz and VVAz interactives

ProAZ includes the following tools to model, display, analyze and interpret azimuthal effects:

Model well log changes due to anisotropy and create a synthetic seismic	Sort, **display** and **process** prestack gathers according to azimuth and offset	Analyse AVO-azimuth **amplitudes** of reflection events	Analyse azimuthal **velocity** changes for geologic intervals	Interpret and **visualize** the magnitude and orientation of azimuthal effects

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Anisotropy has several effects upon CDP gathers, as some source- receiver azimuths have different values than other azimuths. For P-wave data, two of the effects are:

- Delays in the arrival time at the base of an anisotropic interval
- Changes in the amplitude of reflections at both the top and bottom of an anisotropic interval

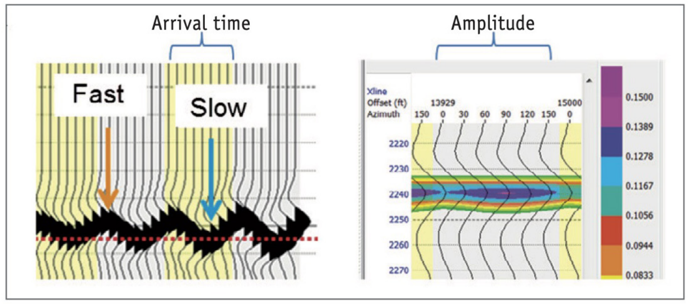
Azimuthal Modeling

ProAz lets you model well log changes for different types of anisotropy (VTI, HTI, Orthorombic media) and create synthetics for these models.

Anisotropic modeling parameters can be input as Thomsen parameters, fracture weakness parameters, fast and slow S-wave logs, plus additional methods.

Modeling can provide answers to questions such as:

- Is it possible to see an AVAz response due to fractures?
- How does the fluid filling the fracture influence the response?
- How is the response modified if the background media is VTI instead of isotropic?
- How does noise affect azimuthal analysis?
- What are the effects of the acquisition geometry (fold, offset and azimuth sampling)?

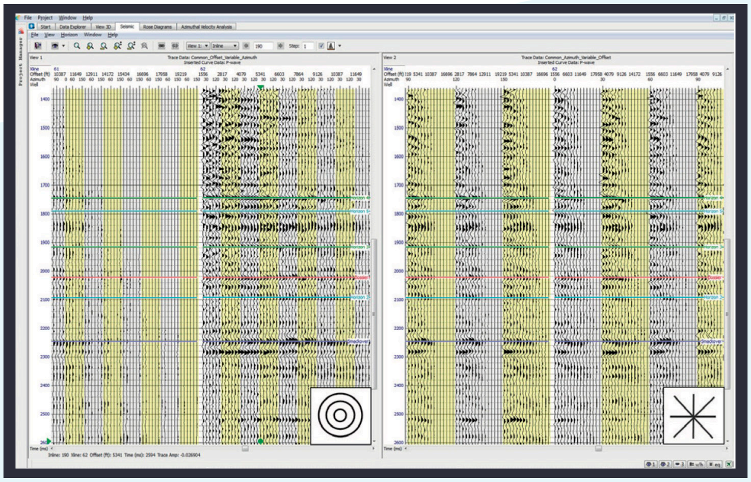


Different azimuths with the same offset

Azimuthal Processing

The conditioning of azimuthal data is as critical for accurate results as the gather conditioning for standard AVO work. Most processes within HRS have been extended to include azimuthal values. For example:

- Is it possible to see an AVAz response due to fractures?
- Stacking
- Trim Statics
- Parabolic Radon Transform
- Starting from offset or angle, you can show the super gathering of azimuthal data in two different ways:
- Common-offset or Common-angle gathers with variable azimuth within each sector: this shows the amplitudes at a fixed offset with varying azimuth, and is useful for determining travel time variation due to anisotropy
- Common-azimuth gathers with variable offset within each sector: this identifies azimuthally varying AVO amplitude anomalies



Common-offset, variable-azimuth gather. *Common-azimuth, variable-offset gather.*

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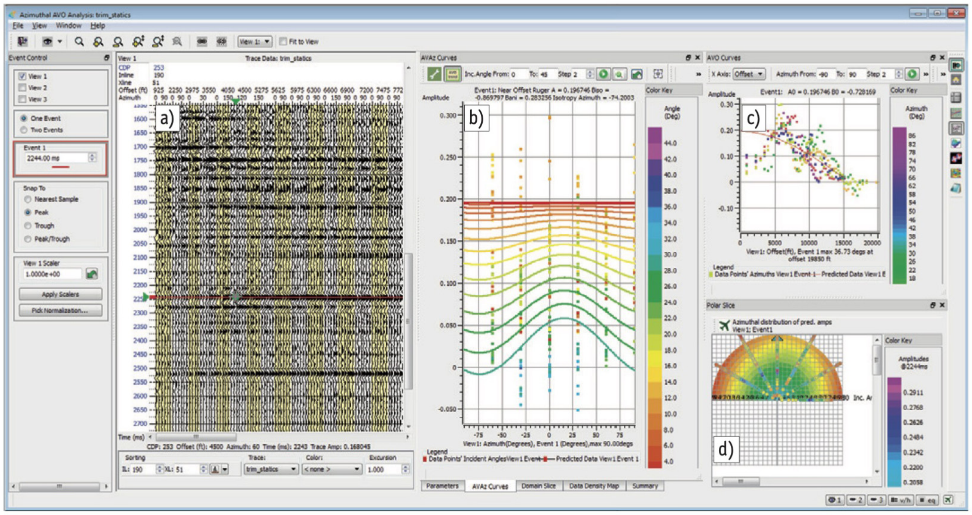
Azimuthal Amplitude Analysis

The Azimuthal Amplitude Analysis tool lets you interactively analyze and observe data as a function of azimuth, offset, or both offset and azimuth on a single gather.

With the azimuthal AVO analysis tool, you can:

- Graph amplitude as a function of azimuth and offset at a particular time or event and then perform AVAz inversion on this event to characterize the degree of azimuthal variation
- You can choose model-based approaches (near-offset or far- offset Rüger equations) or data-driven approaches (Azimuthal Fourier Coefficients)
- Perform direct observation of the distribution of offsets and azimuths at the analysis location
- Study noise effect and scattering of data
- Examine how changes in parameters such as size of the super gather, the maximum offset, the range of incident angles used to fit the AVO trend, and the AVAz analysis type influence the results



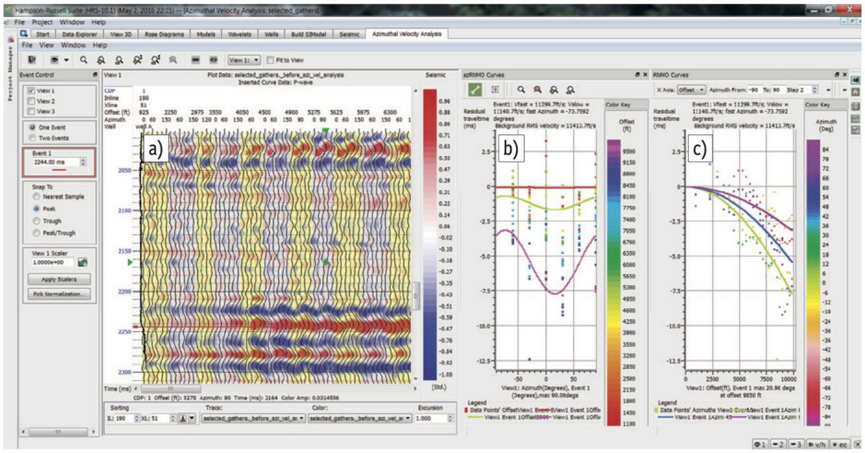
a) Prestack seismic data (left);
b) Amplitude versus azimuth with angle information shown in color (center);
c) Amplitude versus azimuth and offset with amplitude information shown in color (top right);
d) Polar plot with the amplitude displayed in color as a function of azimuth and incident angle (bottom right).

Interactive azimuthal amplitude analysis at a reflection event.

Azimuthal Velocity Analysis

The Azimuthal Velocity Analysis tool can be used for an interactive azimuthal velocity analysis at a specific seismic event.

- The azRNMO display can plot the residual travel time versus azimuth along with the modeled azimuthal RNMO
- It is also possible to observe the offset-dependent residual NMO in the RNMO curves panel



Interactive Azimuthal Velocity Analysis at a reflection event.

a) The calculated residual traveltimes are displayed in color along with the seismic gather (left)
b) The azRNMO display shows the residual travel time versus azimuth along with the modeled azimuthal RNMO (center)
c) The RNMO panel shows the offset dependent residual NMO (right)

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Benefits of ProAZ:

- A single module to condition, analyze, and interpret azimuthal data
- Easy QCs showing the distribution of azimuths and offsets at a particular location
- Quick displays of azimuthally processed data and generation of common offset/ common azimuth gathers
- Interactive tools to explore for azimuthal amplitude and velocity variations
- Multiple methods to generate azimuthal attributes
- Azimuthal attributes displayed as platelets and azimuthal uncertainty in 3D visualization software

Azimuthal AVO Attributes

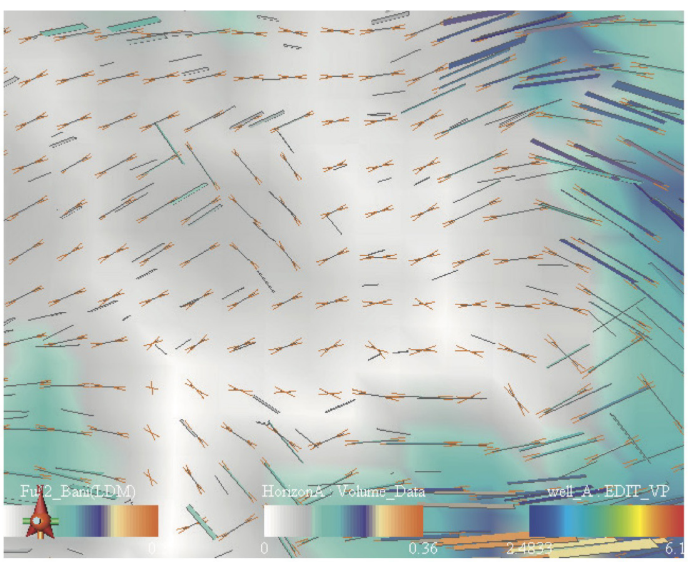
When the azimuthal gathers are properly conditioned and the amplitudes are robust, **ProAZ** can create and extract different azimuthal AVO attributes to detect and visualize anisotropy.

Several different approaches to compute azimuthal AVO attributes are available:

- Near-Offset and Far-Offset Rüger equations
- Azimuthal Fourier Coefficients

The Azimuthal Fourier Coefficient (FC) approach is data driven. It describes the azimuthal amplitude variations at a particular angle of incidence in terms of sinusoids with different magnitudes and phase. The 2nd FC is similar to ellipse fitting and can be related to fracture parameters through rock physics models. The Near- Offset Rüger equation uses all the data to fit an AVAz model parameterized in terms of:

- A: Standard intercept
- B_{iso}: Isotropic gradient
- B_{ani}: Anisotropic Gradient – a measure of fracture density
- Φ_{iso}: Direction of isotropy plane – should be parallel to fracture strikes



The uncertainty display.

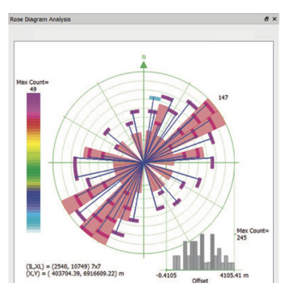
Azimuthal Uncertainty

The anisotropic gradient and azimuth are used to define the magnitude and orientation of the glyphs. The glyphs have length and height, both of which are related to the B_{ani} magnitude.

The azimuth controls the orientation of the glyph. The uncertainty controls the “whiskers” on either side of the glyph. The greater standard deviation of the angle estimate the wider the whiskers are plotted as shown to the right.

Interpretation and Visualization

Both approaches produce magnitude and azimuth attributes. The magnitude attributes contain information about fracture intensity while the azimuth attributes contain information about the fracture strike. The B_{ani} and Φ_{iso} can be combined in the visualization tool (A**dvanced 3D Viewer**) for a display of fracture intensity and primary direction of fracturing.



Rose diagram analysis.

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