

Rock Solid Images is a leader in applying rock physics principles to map fractured reservoir physical properties from seismic data.

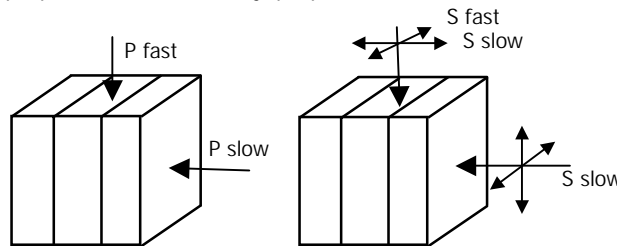
The sensitivity of seismic wave propagation to cracks and fractures is one of the fundamental observations of Rock Physics. Cracks and fractures:

- Decrease P- and S-wave velocity,
- Increase velocity dispersion and wave attenuation,
- Increase pressure-dependence of velocity,
- Increase velocity and attenuation anisotropy,
- Increased potential for stress-induced anisotropy

Rock Solid Images' strategy for fracture detection is to exploit these many different seismic signatures of fractures.

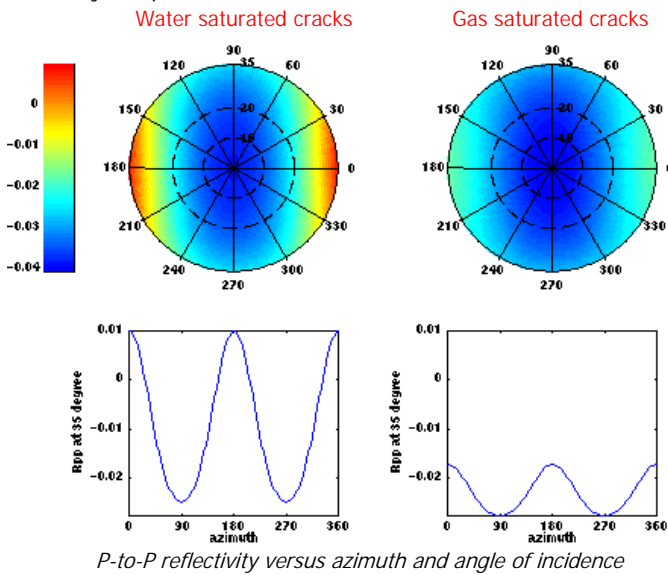
Seismic P- and S-waves tend to "see" fractures when:

- their direction of propagation or
- their direction of polarization is perpendicular (or nearly perpendicular) to the fracture faces. Hence, anisotropy is often a key indicator of fractures.



### Fracture Related Azimuthal Variation of AVO

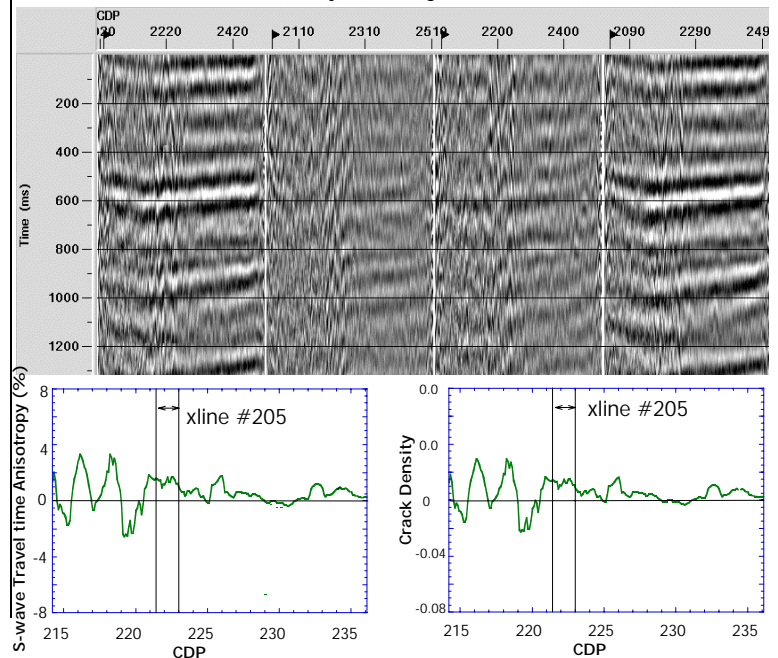
There is no question that P-waves "see" fractures. Vertically propagating P-waves will generally not be very sensitive to vertical fractures. However, as offsets increase a natural fracture-induced velocity anisotropy can exist. Source-receiver azimuths parallel to the fracture strike will tend not to see the fractures, while source-receiver azimuths perpendicular to the fractures will be slowed. Since fractures affect both P- and S-waves, azimuthal variations in AVO can be a powerful tool to not only detect fractures, but also to identify the pore fluid.

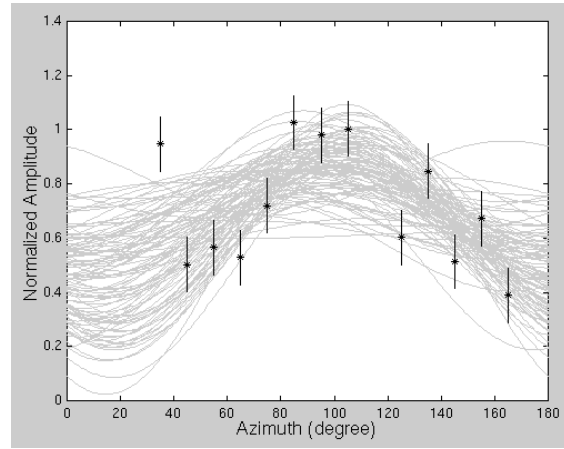
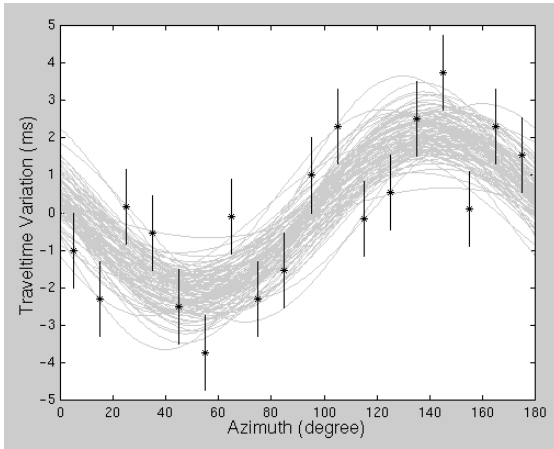


### Shear Wave Splitting

Common field targets are sites with approximately vertical, subparallel fractures. Vertically propagating shear waves that are polarized parallel to the fracture planes will travel faster than shear waves polarized perpendicular to the fracture planes. Any vertically propagating shear wave incident on the medium at arbitrary polarization will immediately split into the two modes, called the fast shear wave and the slow shear wave. This is shear wave splitting or birefringence.

The example below shows shear wave data of different polarizations. The travel time difference between fast and slow shear arrivals (lower left) can be an indicator of fracture density (lower right).





P-wave travel-time picks versus azimuth (left) and azimuthal variation of far-offset reflectivity (right), indicating fracture-related anisotropy. Multiple curve fits are from a bootstrap method, used to explore the range of plausible models that are consistent with the data. (From Teng and Mavko, 1998)

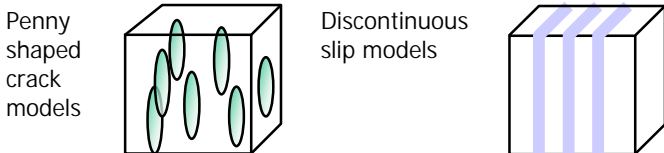
### Emphasis on the Rock Physics Fundamentals

A common strategy is to infer the most likely fracture orientation from the seismic symmetry directions, and the regions of highest fracture density from the highest anisotropy. However, quantifying the underlying fracture density, shape, aperture, connectivity, and pore fluid in geologically reasonable terms is difficult.

As with many geophysical problems, the most reasonable and realistic fracture interpretation requires a careful rock physics analysis, coupled with solid geologic input.

#### Rock Physics Fracture Models

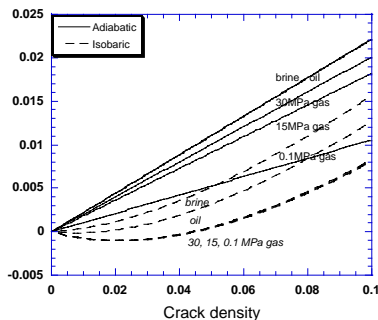
PCI incorporates the two accepted approaches for quantifying the elastic signatures of fracture orientation and density, recognizing that both are only idealized analogs of real reservoir fractures:



Using proper rock and fluid properties is critical (more so than the mathematics) to getting realistic results.

#### Fluid Effects

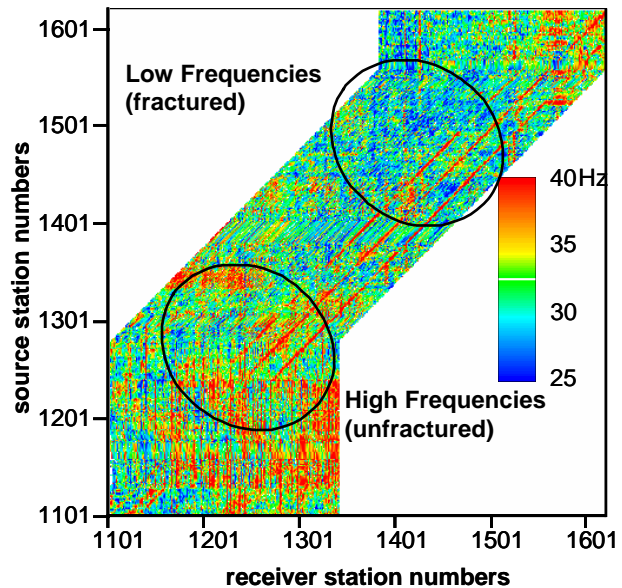
We use state-of-the-art analyses of fluid effects on seismic fracture signatures. Adiabatic estimates of gas, oil, and brine compressibilities and densities are combined with frequency-dependent fracture-fluid models for seismic interpretation and modelling.



AVOZ anisotropy increases with crack density, crack-filling fluid bulk moduli, and seismic frequency

### Fracture Related P-Wave Attenuation Seen as Loss of Frequency

Chen (1995), using simple spectral analysis of stacked traces, found a rough correlation of lower average frequency and fracture occurrence on 2D P-wave lines. Rock physics mechanisms for attenuation include wave-induced pore fluid movements and scattering.



Rock Solid Images is a seismic reservoir characterization company specializing in the integration of rock physics and seismic attributes. The services we provide are the work of a talented and experienced inter-disciplinary team who partner closely with our clients. Our final deliverable is a calibrated reservoir volume(s), used to expedite prospect evaluation and improve decision-making processes of our clients.

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