

Rock Solid is Unconventional

sweet spot identification, placement & landing of laterals, fracking parameters, and productivity prediction



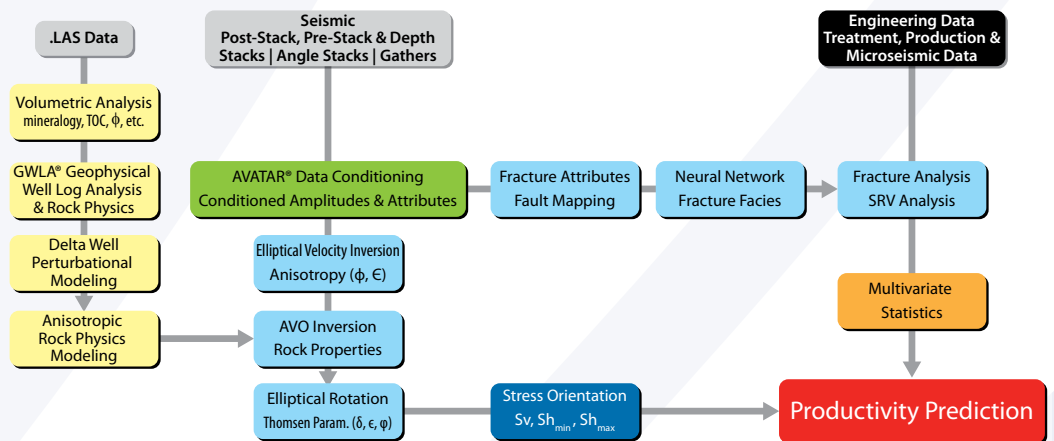
Context



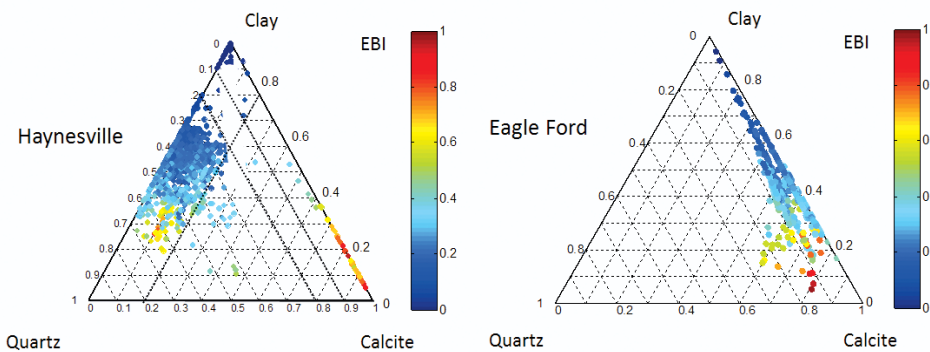
Unconventional shale reservoirs present unique engineering challenges with respect to wellbore stability and completion design. Effectively placed and executed hydraulic fracturing is crucial to establishing and maintaining economic production levels. As a consequence, it is critical that the geoscience community provide the required information to this end. The proper integration and use of log, core, and 3D seismic data generates the requisite parameters for use in well operations.

RSI Workflow for Characterization of Unconventional Reservoirs

From rock physics to seismic inversion, from fracture attributes to integration of production data, RSI's unified approach to shale characterization makes use of all available data convolving it into productivity prediction when possible and information to guide drilling



Analyses

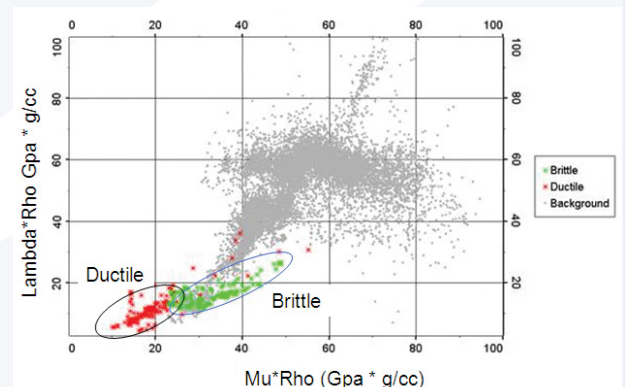


Empirical Brittleness Index (EBI)

Assessing the brittle/ductile nature of reservoir rock is a key consideration for the selection of completion intervals. RSI's EBI examines the effects that mineralogy and rigidity have on brittle/ductile behavior, and the impact they have on seismic signature.

Perturbational Rock Properties Modeling

RSI routinely models pore fluids, thickness, porosity, mineralogy (brittle/ductile), TOC, and cracks. The example to the right shows that it is possible to discriminate layers of more ductile or more brittle character in Lambda-Rho versus Mu-Rho space.



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Variables Affecting Elastic Properties in Shales

Arrows show sense and magnitude of change

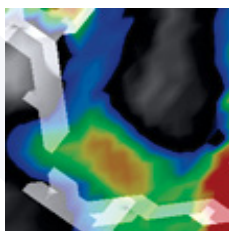
GAS OIL BRINE

Increasing Reservoir Property	λ	μ	ρ	Vp	Vs	E	Anisotropy
Fractures	↓ (GAS), ↓ (OIL), ↓ (BRINE)	↓ (GAS), ↓ (OIL), ↓ (BRINE)	no change	↓ (GAS), ↓ (OIL), ↓ (BRINE)	↓ (GAS), ↓ (OIL), ↓ (BRINE)	↓ (GAS), ↓ (OIL), ↓ (BRINE)	↑ (GAS), ↑ (OIL), ↑ (BRINE)
TOC	↓	↓	↓	↓	↓	↓	variable
Fluid Density ↑ (BRINE) ↓ (GAS)	↑	no change	↑	↑	↓	↑	no change
Stress	↑ (GAS), ↑ (OIL), ↑ (BRINE)	↑ (GAS), ↑ (OIL), ↑ (BRINE)	↑	↑ (GAS), ↑ (OIL), ↑ (BRINE)	↑ (GAS), ↑ (OIL), ↑ (BRINE)	↑ (GAS), ↑ (OIL), ↑ (BRINE)	↑
Pore Pressure	↓	↓	↓	↓	↓	↓	↓

This table shows the relative response of elastic properties as a function of increasing reservoir property for oil, gas, and brine conditions. Other variables including mineralogy, salinity, porosity, texture, pore connectivity, and the orientation of grains and pore shapes need to be considered, because they will change the rock's elastic properties and elastic behavior significantly, as well.

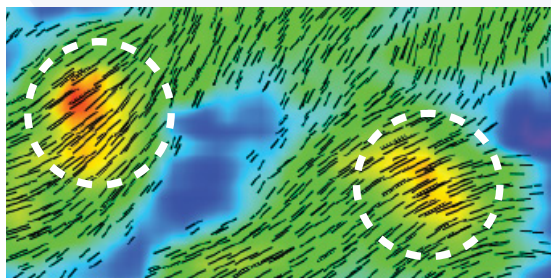
Fracture Intensity and Orientation

The results of an elliptical velocity inversion for anisotropy are a proxy for elevated levels of natural fracturing. Intensity of anisotropy is shown in color density and the anisotropy azimuth (SH-max) is shown as sticks. Note that the SH-max azimuth is significantly different in different anisotropic areas, shown by two circles.



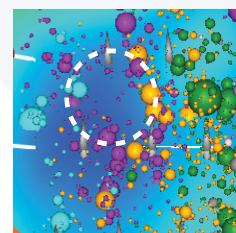
Attribute analysis

Attributes sensitive to the presence of subseismic faults and fractures are included in our analysis. Here, high values of curvature (color gradient) are collocated with areas of low coherence.



Microseismic and Geomechanical Data

Microseismic events recorded during fracking can be an important component of the analysis. Here, microseismic events (spheres are scaled to magnitude) are co-rendered with static Young's Modulus. Circle shows moderately ductile area lacking events. Microseismic is also used to calculate Stimulated Rock Volume (SRV).



Productivity Prediction

Multivariate statistics are used to explore relationships between the derived variables and production data. The variables that prove to be the best predictors of production are used in combination to generate critical information for engineering, to guide well placement and completion design.

