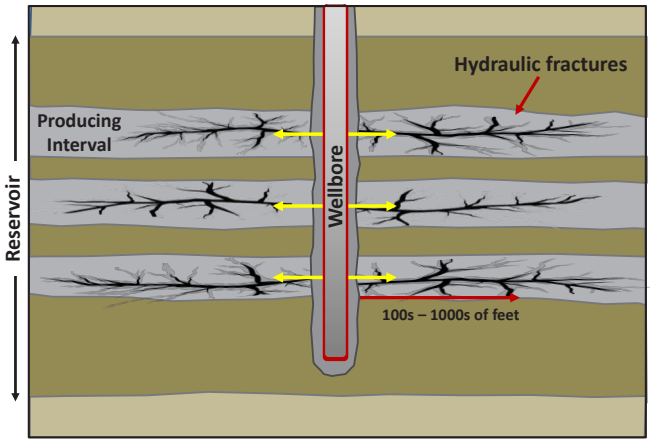
RSI

A Comprehensive Rock Physics Study & Atlas of Seismic Expression for Major North American Shale Plays

Context

Unconventional shale reservoirs present unique engineering challenges with respect to wellbore stability and completion design. Effectively placed and executed hydraulic fracturing (right) is crucial to establishing and maintaining economic gas production levels. Thus, 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.



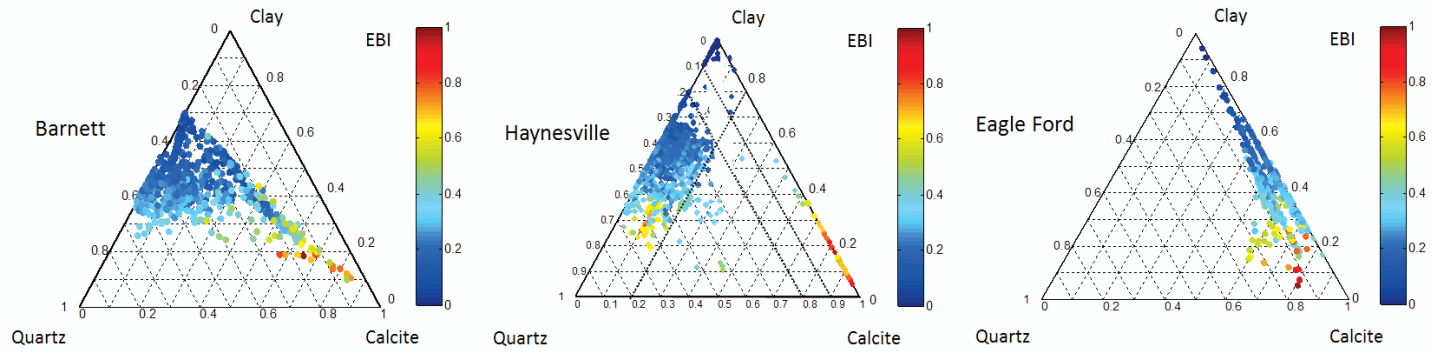
Rock physics plays a central and crucial role as the link between reservoir properties and seismic expression. RSI is undertaking a study to develop a comprehensive rock physics and seismic geomechanics database, and an atlas of seismic signatures of the major shale plays in North America. This JIP project will span a minimum of 20 key shale plays in North America (shown below), and will facilitate authoritative comparison of rock properties and seismic expression between many unconventional shale plays, both domestic and international.

Barnett	*Fayetteville*	*Haynesville*	*Marcellus*	*Eagle Ford*
Woodford	*Niobrara*	*Bakken*	*Wolfberry*	*Utica*
Granite Wash	*Collingwood*	*Bone Spring*	*Monterey*	*Antrim*
Avalon	*Lewis*	*Colorado Group*	*Montney*	*Horn River*

Key Workflow Components

Geophysical Well Log Analysis (GWLA®)

Well log measurements are influenced by borehole rugosity, mud filtrate invasion, dipping beds, thin-beds, mud weight, pressure, temperature, dispersion, etc. By addressing such issues in an iterative manner for each well, we will ensure the generation of a consistent, high quality data set that is appropriately conditioned for rock physics modeling.

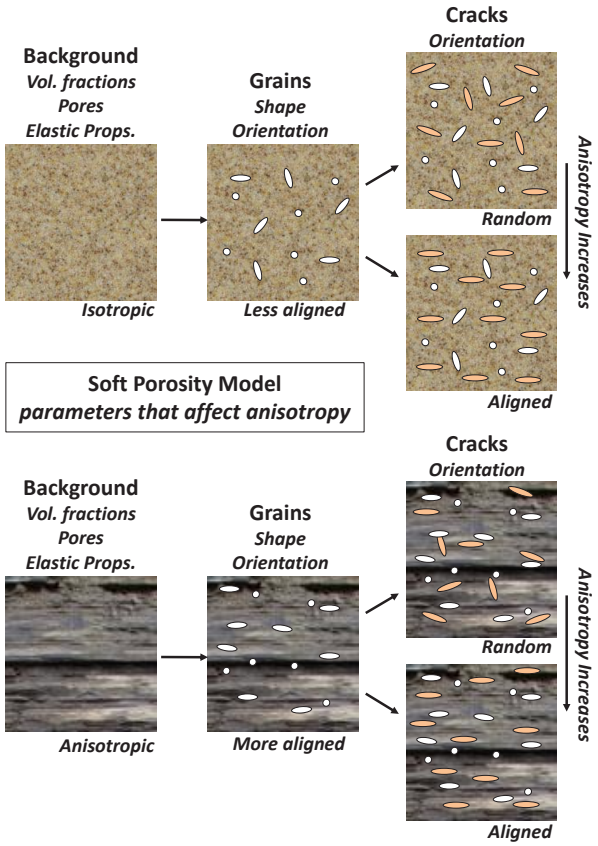


Empirical Brittleness Index (EBI)

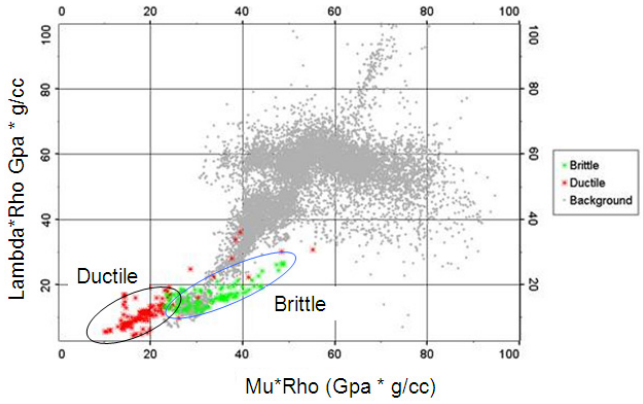
Assessment of the brittle/ductile nature of reservoir rock is key to the selection of completion intervals. It is commonly understood that there is significant mineralogical variability not only within the same shale unit, but across the spectrum of shale plays. For comparative purposes, we have developed a method of unitizing brittleness (EBI) as a function of "hard" versus "soft" minerals, static Young's Modulus and Dynamic Poisson's Ratio. One key deliverable will be a normalized suite of analyses that examine the effects that mineralogy has on brittle/ductile behavior, and the impact it has on seismic signature (above).

Rock Physics Diagnostics (RPD)

RPD is the process that enables us to understand and predict the behavior of reservoir and non-reservoir zones, and correct for some of the problems encountered in well log data. A rock physics model is established that is consistent with available well and core data. This allows for quantification of various sedimentologic & diagenetic features in terms of their elastic properties. In shale plays we use a proprietary implementation of the Soft Porosity Model, right.



Perturbational Rock Properties Modeling



In this study the following properties will be modeled: thickness, porosity, mineralogy (brittle/ductile), TOC, fluids, and cracks. The example (above left) shows that it is generally possible to discriminate layers of more ductile or more brittle character in Lambda-Rho versus Mu-Rho space.

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	↓	↓	no change	↓	↓	↓	↑
TOC	↓	↓	↓	↓	↓	↓	variable
Fluid Density (BRINE ↑ GAS)	↑	no change	↑	↑	↓	↑	no change
Stress	↑	↑	↑	↑	↑	↑	variable
Pore Pressure	↓	↓	↓	↓	↓	↓	↓

Table showing 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.

Reservoir Property Matrix

The goal of this modeling study is to provide, for each play, a matrix of reservoir properties versus elastic properties. The diagram to the left shows the relative response of shale elastic properties as a function of increasing reservoir property for oil, gas, and brine conditions.

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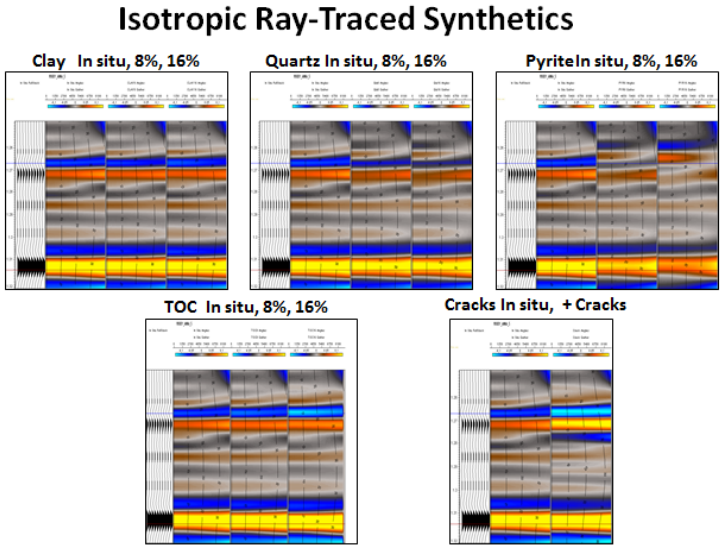
Numerically Modeled Synthetic Seismograms

We will also be delivering an atlas of seismic expression that captures the variability in prestack and poststack seismic response to reservoir property heterogeneity. It is anticipated that this catalog of seismic characteristics will serve as an excellent reference for understanding how best to interpret seismic amplitude-derived attributes such as AVO, AVAZ, impedances, etc., for establishing the resource potential of similar shale plays, both domestic and international.



Required Data

Early participant sponsors will be required to provide well data for a minimum of four wells that penetrate the plays included in the study (other shale plays may be considered). These data will be made available to other sponsors of the study and, ultimately, to companies that purchase the study. Early participant wells will be worked on in the order in which they are received.

Deliverables

- Conditioned log data, all models, and synthetics
- Catalog of seismic responses to changes in key shale reservoir properties, e.g., fluid, TOC, thickness, porosity, mineralogy, fluids, and cracks
- Catalog of seismic responses to changes in geomechanical rock properties, e.g. anisotropy and rock strength parameters (Young's Moduli and Poisson's Ratios)
- Standard rock physics crossplots
- P-P, P-S, isotropic and anisotropic ray trace synthetics developed for in- situ well conditions and pseudo-well conditions
- Technical report
- Processed/generated log curves will be delivered in LAS format and synthetic seismic data will be delivered in 32-bit SEG-Y format – both on a USB drive

This study and the resultant atlas will enable energy companies to determine how best to extract and calibrate engineering-related information from seismic data that relates directly to well placement and completion (hydraulic fracturing) operations. It is anticipated that the study will become an indispensable reference for assessing the similarity of rock properties encountered in shale plays elsewhere in the world with those found in North America.

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