Shale Reservoir Characterisation

CGGVeritas has developed an integrated geophysical approach to characterising shale gas reservoirs, based on pre-stack azimuthal seismic data analysis calibrated with well log and core measurements to identify sweet spots.

Relative production estimates across the reservoir may be derived by combining seismic estimates of lithological, geomechanical and stress properties, correlated to existing well measurements to predict porosity, volume of shale, carbonate content and water saturation. This technique has been applied to the CGGVeritas Tri-Parish multi-client survey in the Haynesville Shale with positive results. However, all shale plays are different, so the selection of geomechanical and lithological parameters that provide the best correlation with production will vary from one play to another and must be derived for each survey.

A quantitative understanding of a host of rock properties such as acoustic impedance, Poisson's ratio, and Young's modulus can be obtained from prestack seismic. These properties are in turn related to quantitative reservoir properties such as porosity, Total Organic Content (TOC) and mineral content.

CGGVeritas combines the elastic rock properties, derived from seismic inversion, with azimuthal velocity and AVO analysis of conventional 3D seismic data to estimate principal stresses. The Differential Horizontal Stress Ratio (DHSR) is an important parameter for prediction of hydraulic fractures and can be estimated from seismic data alone. These estimated stresses are then calibrated to the stress state of the reservoir, derived from drilling and completion data, microseismic analysis and regional information. Zones with relatively high brittleness (derived from isotropic Young's Modulus, Lambda-Mu-Rho, etc.) and low DHSR (no preferential stress orientation) are more prone to fracturing and tend to produce fracture swarms when completed, potentially increasing production.

CGGVeritas has applied this workflow to its Tri-Parish data. This is a high-pressure, high-temperature (HPHT) field with no large structural features and so has a relatively homogeneous stress field. Although there is an east-west regional orientation of the maximum horizontal stress field over the Haynesville area, there are lateral variations in the local stresses. The understanding of this variability is crucial for optimal completions. Potentially brittle zones have been identified and their associated DHSR, fracture initiation pressure and closure stress have been estimated. Calibration and validation are critical. These seismically derived predictions were calibrated with existing production and well core and test measurements to determine optimal zones for drilling and completion.

The azimuthal signature needs to be adequately recorded, processed and measured In order to estimate the stress field distribution. After gather conditioning a dataset should have maximized signal-to-noise ratios, flattened reflector events and preserved amplitude variations.

The key steps in compliant amplitude-versus-offset and amplitude-versus-azimuth seismic data conditioning are random noise attenuation, angle muting to remove spurious energy beyond a threshold angle of incidence, high-resolution de-aliased radon transform de-multiple and high-density velocity analyses for both anisotropic and azimuthal velocity derivation. Ray bending for offset angle gather conversion and reservoir-oriented gather conditioning for prestack inversion are also critical.
Multi-attribute analysis of the Tri-Parish data suggests that better development locations are found here in areas that have a combination of certain key rock properties, for example, better porosity development, high siliceous mineralogical content, and high values of TOC. Detailed rock property analyses showed that properties such as Poisson's ratio and Lambda-Rho (incompressibility) are useful for identifying these areas in this field. Low Poisson's ratio areas indicate the more siliceous, low-carbonate content, normally associated with better porosity development. Bulk volume of gas can be estimated by combining these properties via multi-attribute analysis.

In general, the researchers found that no single attribute provided enough information to correlate seismic data to production, but multiple elastic- and stress-related attributes can be correlated to average production and horizontal well length at well locations with 95% correlation. The predicted production shows several undrilled areas with potentially high productivity.

For validation, the predicted local stress fields were compared to tri-axial measurements from core samples at two locations. The full strain tensor and the principal stress directions were measured from these core samples, which then served as baseline values for correlating seismic predictions. We found that the direction of maximum horizontal stress, predicted from seismic observations, matched the corresponding core stress measurements to within 5%.

Although a statistical method of exploitation, where several wells are drilled near a productive well and areas around failed wells are abandoned, has proved successful so far in the relatively homogeneous Haynesville Shale, there are opportunities to increase production by targeting predicted sweet spots. This is what CGGVeritas can provide through the analysis and calibration of the stress and related attribute volumes derived from this seismic shale gas workflow. This analysis and workflow have the potential to predict fracture behavior and reservoir drainage geometry, enabling optimal well placement and completion designs including stage zoning in hydraulic fracture stimulation. Significantly, this will also mitigate the risks associated with drilling hazards and hydraulic stimulation.

Image: Mapping of the predicted first six months of production (calibrated to horizontal well length), based on correlation of calibrated geomechanical and lithological attributes with actual production rates. High-productivity areas are shown in red.