North American Case Study Demonstrates the Ability of 3-D/3-C Seismic Data in Predicting the Petrophysical Properties of Shale

Harris, Ron *1; Tinnin, John 2 (1) Anadarko Petroleum, The Woodlands, TX. (2) ION Geophysical / GX Technology, Houston, TX.

The Devonian age Marcellus is a major shale play in North America that has drawn international attention. It covers approximately 250,000 square kilometers, trending northeastward from West Virginia into New York. The Marcellus is believed to have the potential to become the second largest gas field in the world, with original gas-in-place estimated at nearly 1500 tcf. Commerciality was established in 2004 and the basin now has over 100 rigs actively drilling. The majority of these wells are drilled as horizontal wells with laterals 1 to 2 kilometers in length. Hydraulic fracturing is required to stimulate a sufficient volume of shale that will produce commercial quantities of natural gas. Within the study area, the Marcellus is approximately 60 meters thick and buried at a depth of 2.6 kilometers.

The challenges of this play include:

1) identifying shale 'sweet spots' which represent areas of higher productivity and are driven by several petrophysical properties including porosity, permeability, brittleness and total organic content (TOC);

2) optimizing well designs and geo-steering through detailed, seismically derived structure maps that also identify subsurface features such as faulting and karsting;

3) optimizing the stimulation program by understanding the variances in rock properties within the shale zone and the areal distribution of Young's Modulus, Poisson's Ratio, and local stress regimes.

To address these challenges, a 67 square-kilometer, wide-azimuth, multi-component (3-C), 3-D seismic survey was recorded in central Pennsylvania. Its purpose was to determine the effectiveness of modern 3-D/ 3-C seismic data in extracting certain rock properties from the Marcellus Shale to identify 'sweet spots' and optimize both the drilling and stimulation programs.

In parallel, a rock physics study was conducted on well logs penetrating the Marcellus Shale within the survey area to model the predicted seismic attribute response. Analysis of the modeled attributes provided valuable insight into shale porosity, brittleness, kerogen content, VP/VS and density. Seismic attribute volumes that reflect elastic properties were generated from the seismic data along with geometric attributes of curvature and coherency. Multiple inversion techniques were also investigated, including a P-wave simultaneous inversion and a joint PP/PS inversion to document the value derived from the 3-D/3-C seismic data. All elastic and geometric seismic attribute volumes were calibrated to the existing subsurface data including wireline data, core data, microseismic events and production information for use in 'sweetspot' prediction.

Upon completion of the project, our team concluded that 3-D/3-C seismic data allowed us to predict a set of rock properties from composite inversions and attribute volumes within the Marcellus shale that were validated by well data. By utilizing these multiple attribute volumes and inversion products, ‘sweet spots’ can be identified to optimize drilling locations and stimulation programs.