3-D Seismic Lithology Analysis Utilizing Extended AVO: A Case Study

by James DiSiena, Geophysical Development Corporation

In this Gulf of Mexico case study, extended Amplitude Versus Offset (AVO) analysis enables the generation of sand and gas reservoir maps not obtainable from conventional 3-D data. This seismic lithology interpretation is the result of calibrating the 3-D/AVO response to lithology and pore fluid variations.

1. Analysis of well data provides lithology, velocity, and density control necessary to estimate Poisson's ratio, as well as rock property variations from wet to gas-filled conditions.
2. AVO modeling based on these variations yields the anticipated seismic lithologic response, thereby linking the log properties to the 3-D seismic interpretation.
3. Processing to recover the "extended" AVO response from data with source-to-receiver offsets out to two times the target depth enables lithologic mapping when supported by the above calibration.

The reservoir sands range from 6,000 to 13,000 feet in depth, lying above and below geopressure. Conventional seismic analysis associates the amplitude of the reflections to the contrast in acoustic impedance, the product of velocity and density. On the log data, the target sands appear to have little contrast in acoustic impedance with their encasing shales. Because of this low contrast, the amplitudes on the seismic stack sections show little to no discrimination between sand-shale lithologic variations or pore fluid variations.

A two-term model for the seismic amplitude provides the basis for unraveling the complex AVO responses of lithologic variations and gas sands. The first term, the Normal Incidence reflectivity (NI) responds to changes in acoustic impedance. The second term, defined as the Poisson reflectivity (PR), relates to changes in Poisson's ratio. Crossplots show that even when the sands have the same acoustic impedance as the encasing shales, Poisson's ratio discriminates between them. To obtain a robust estimate of PR (called model-based PR or MBPR), the AVO processing incorporates corrections for anisotropy, which extends the AVO analysis out to very far offset traces. Finally, a view of the lithostratigraphic properties develops by displaying the NI and MBPR estimates from the 3-D seismic data with a novel color crossplotting method. Unlike the stack amplitude, distinct reservoir features appear in the seismic crossplot volume. After calibration, these 3-D crossplot sections provide maps of reservoir quality sands and potential pay intervals, as well as the stratigraphic setting.

Biographical Sketch

James P. DiSiena is Director of Interpretation Services for Geophysical Development Corporation (GDC), providing client support for integration of geological and reservoir properties into GDC's 3-D AVO analysis. He holds an M.S. in exploration geophysics from Stanford University and a B.S. in physics from John Carroll University. Jim joined EDC after 15 years with ARCO.

Prior to 1989, he was Director of Applied Seismology with ARCO in Plano. He moved to Houston with ARCO to provide interpretation and geophysical support on a wide range of exploration projects. He received the Atlantic Richfield Corporation, Outstanding Technical Achievement Award for his work on applications of Vertical Seismic Profiling. He is past president of the Dallas Geophysical Society, SEG Vice President, and SEG Continuing Education Lecturer. Jim received the Best Presentation Award from the SEG in 1983 for a paper on VSP and the Matson Award at the 1996 AAPG Annual Convention for his paper on seismic lithology. ■