Novel Use of P-wave and S-wave Seismic Attenuation for Deep Natural Gas Exploration and Development

DE-FC26-04NT42243

Goal:
To develop and test a new methodology for using seismic attenuation attributes, from multi-component P-wave and S-wave seismic data, for assessing the presence of high oil or natural gas saturations, and estimating reservoir properties (in particular, gas saturation, lithology, porosity, etc).

Background:
Deeply buried gas reservoirs along the Gulf of Mexico shelf are an important future energy resource for the U.S. One of the greatest problems encountered by operators in this area is identifying commercially viable targets for drilling. Because of their great depth (over 15,000 feet), the most common 3D seismic methods for direct hydrocarbon indication, such as amplitude versus offset (AVO) have proven unreliable in the past.

The approach of this study combines three elements: (1) a synthesis of the latest rock physics understanding of how rock P-wave and S-wave inelasticity is related to rock type, pore fluid types, and pore microstructure, (2) synthetic seismic modeling that will help identify the relative contributions of scattering and intrinsic inelasticity to apparent Q attributes, and (3) robust algorithms that extract relative P- and S- wave attenuation attributes from seismic data. Recognizing the pitfalls of measuring attenuation in-situ, RSI will implement procedures that emphasize relative attenuation anomalies that are calibrated to well log information, and that incorporate empirical and theoretical constraints from rock physics.

After developing the necessary methodologies for computing Q from downhole measurements and reflection seismic data, RSI will employ Artificial Neural Network and other methods to link the well-derived reservoir properties to the seismic attenuation attributes. This will provide a quantitative means to interpret Qp and Qs in terms of oil and gas saturation, lithology, porosity, and perhaps even permeability. This will be the ultimate accomplishment of this project. The developed methods will be tested using actual field data to be supplied by U.S.-based oil and gas companies. The data will be analyzed for indications of hydrocarbon accumulation and those results will be compared to data from “blind” wells that will be withheld from the original analysis.

Performer:
Rock Solid Images (RDSPI, LP)

Location:
Houston, Texas 77063

Potential Impact:
RSI plans to develop and test a new methodology for extracting seismic attenuation attributes from multi-component P-wave and S-wave seismic data, and relating these to the presence of natural gas occurrences in deeply buried reservoirs (over 15,000 feet). The methodology will make use of existing seismic data already in the libraries of U.S. operators. Therefore, it will be much more economically viable than methods requiring special and additional seismic data acquisition. The results will make drilling for deep gas much less risky and will encourage more rapid development of deep, higher risk, domestic, natural gas resources.

Accomplishments:
Phase 1 of this project is complete. The project team developed new P- and S- wave attenuation models, studied the synthetic seismic effects of attenuation on AVO, and performed an initial evaluation of the multi-component seismic survey from the Gulf of Mexico that will be used in the validation portion of this study.

Rock physics modeling is key to realistically assessing P- and S- wave attenuation. The new rock physics model, developed as part of this study, links attenuation and velocity dispersion that occurs in partially saturated reservoirs as well as in non-reservoir rock. This new model estimates Qp (P-wave attenuation) and Qs (S-wave attenuation) from basic elastic variables such as, porosity, lithology, fluid, and pressure. Thus far, the results of this modeling effort have been consistent with experimentally-measured values.

A large potential of this model is that it allows for consistent forward modeling of attenuation depending on the properties and conditions in the subsurface to supplement and extend the existing real data. Such rock-physics-based "what-if" forward modeling is a powerful tool of seismic interpretation and has been extensively used with the elastic properties. This new theoretical development will help extend this approach into the inelastic domain.

Attenuation can be used in exploration and development only if it can be extracted from real seismic data. To test whether such extraction is viable researchers, as part of this study, created synthetic seismic traces for P-to-P and P-to-S amplitude using their rock physics predictions. In this synthetic modeling they used a new raytracer tool designed specifically for this task. The results prove that the amplitude is indeed affected by attenuation and, by inference, that the seismic P- and S-wave attenuation can be measured in the field and eventually used for the purpose of rock diagnostics.

Current Status and Remaining Tasks:
Results thus far indicate that while the P-wave attenuation is noticeably affected by the presence of hydrocarbons, but the S-wave attenuation is not. The model predicts that the ratio of these attenuation values can be used as a hydrocarbon indicator. Currently the project team is working with real seismic and well log data, from a survey in the deep Gulf of Mexico, to further calibrate and validate the proposed methods of reservoir characterization as well as to chart the areas of their applicability.

Project Start Date: September 29, 2004
Project End Date: September 30, 2007

DOE Contribution: $776,321
Performer Contribution: $332,709

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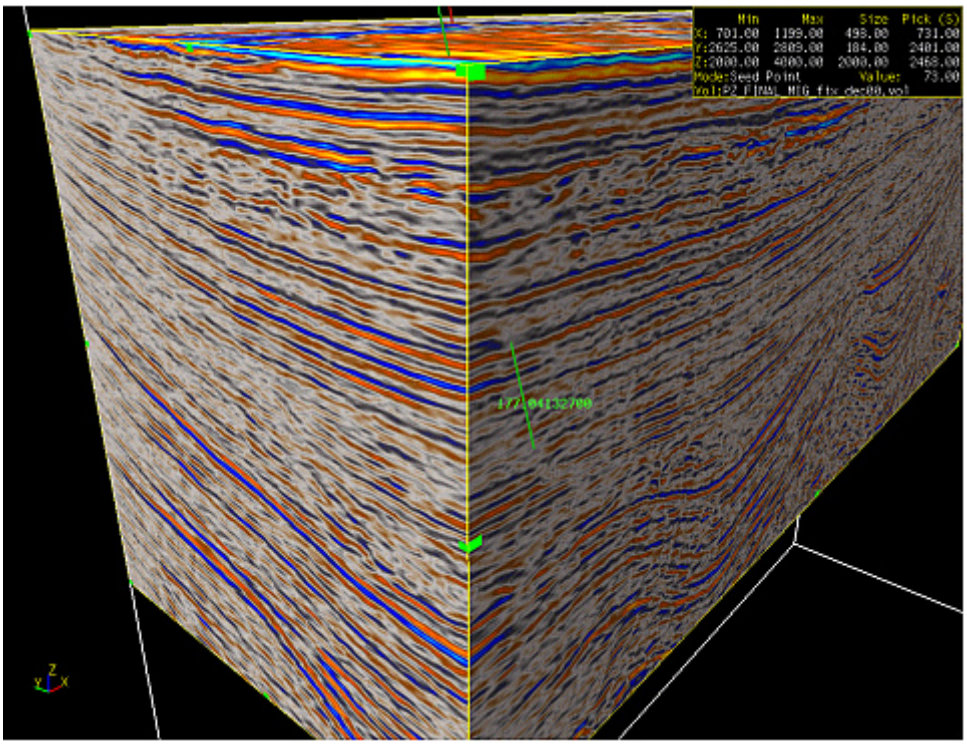
Additional Information:
The following papers were presented at the 2005, Society of Exploration Geophysics meeting:

A Rock Physics and Attenuation Analysis of a Well from the Gulf of Mexico [PDF-190KB]
Gary Mavko, Stanford University, Jack Dvorkin*, Stanford University and Rock Solid Images, Joel Walls, Rock Solid Images

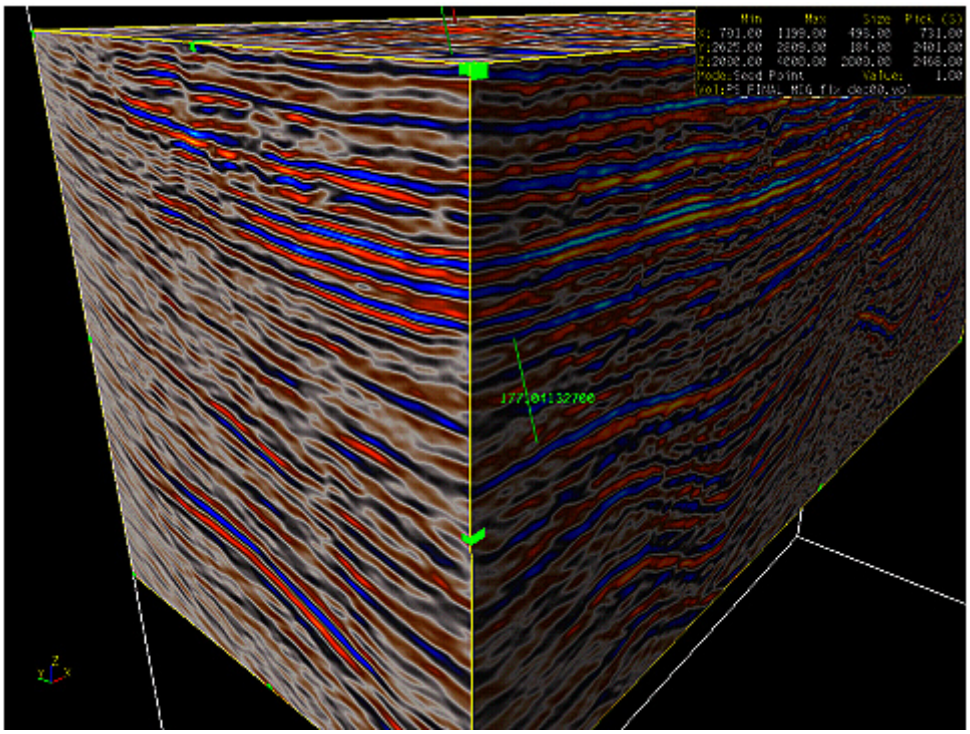
A Theoretical Estimate of S-Wave Attenuation in Sediment [PDF-70KB]
Gary. Mavko*, Stanford University, Jack Dvorkin, Stanford University and Rock Solid Images, Joel Walls, Rock Solid Images

Evaluation of an Inelastic (Q) Synthetic Seismic Generator [PDF-275KB]
Scott Singleton*, Rock Solid Images, and Jack Dvorkin, Stanford University and Rock Solid Images

Effects of pore fluid properties at high pressure and temperature on seismic response [PDF-238KB]
Joel Walls*, Rock Solid Images and Jack Dvorkin, Rock Solid Images and Stanford University



Well 2700 and PP seismic volume from Seitel



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