Imaging Reservoir Quality Seismic Signatures of Geologic Processes

DE-FC26-04NT15506

Program

This project was selected in response to DOE's Oil Exploration and Production solicitation DE-PS26-04NT15450; program ID 2A. Subsurface imaging.

Project Goal

The project goal is to develop an interpretational model for clastic reservoirs, quantifying the links between the products of sedimentary and diagenetic processes, rock properties, and seismic signatures.

Performer

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Project Results

We have documented the similarity in the rock physics patterns of sand-rich deep water deposits from offshore Gulf of Mexico and other similar depositional environments. Lithofacies successions from diverse depositional environments show distinctive patterns in various rock-physics planes (seismic velocity-porosity, velocity-density and porosity-clay volume). Four clear examples of decameter-scale lithofacies sequences have been observed: (1) fluvial deposits from the Miocene of Colombia show an inverted-V pattern indicative of mm- to cm-scale dispersed fabric in the mixed lithofacies, (2) a fining-upward lithofacies sequence of mud-rich deep water deposits from offshore West Africa shows a linear trend associated with mm- to cm-scale horizontally laminated sand-clay mixtures, (3) sand-rich deep water deposits from offshore Gulf of Mexico present a pattern resulting from the scarcity of mixed lithofacies, and (4) a coarsening-upward lithofacies sequence of shallow marine deposits from Colombia presents evidence of both dispersed and horizontally laminated mixed lithofacies, with predominating dispersed mixtures generated by bioturbation..

Benefits

Approximately two-thirds of all the oil discovered in the United States remains in the ground, largely due to uncertainties and complexities in the nature of oil reservoirs. This project will help to mitigate some of these difficulties through improved reservoir characterization, reduced risk by more effectively quantifying geologic constraints and their seismic signatures, and quantifying the uncertainties associated with the interpretations for better decision making and risk analysis. The final product of this will be improved recovery, increased national petroleum reserves, and lower environmental risk through more informed drilling and production planning.

Background

Seismic stratigraphy, seismic sedimentology, and 3D-seismic geomorphology are the state-of-the-art techniques for interpretation and prediction of depositional lithofacies using seismic data. In classic seismic stratigraphy, geologists use qualitative analysis of reflection events (amplitude, apparent frequency, continuity and geometry) to separate seismic facies. The connection to the actual lithofacies is established using sequence stratigraphic models and local calibration with well logs. Uncertainties in these methods arise from their inability to resolve features at scales lower than the dimensions of the seismic-facies groups, normally about 100 m, and also from the assumption of oversimplified relationships between seismic impedance and general lithologies

A critical factor for seismic reservoir characterization is that seismic velocities in the subsurface are related to key rock parameters such as porosity, mineralogy, microtexture, pore fluid saturation, and effective pressure. Relating sediment and rock properties to observed seismic signatures is the aim of applied rock physics in this project.

Project Summary

This project consists of the following four tasks.

Task 1: Geologic Controls on Rock Microstructure. The objectives here are (1) to identify how essential rock properties, which link reservoir properties to seismic response, evolve geologically -- how they vary within stratigraphic sequences associated with different depositional settings, and during the various diagenetic stages; (2) to better understand the variation of composition, fabric and elastic properties of different types of shale, and mixed lithofacies, according to their depositional environments; (3) to evaluate and develop empirical and theoretical models of porosity-depth trends for sands, shale, and mixed lithofacies.

Task 2: Quantify Elastic (Seismic) Signatures The objective here is to quantify the elastic signatures of lithology, multi-scale stratigraphic cycles, textural maturity, pore pressure, and the diagenetic processes of compaction and cementation.

Task 3: Site Selection In this task we will identify an optimum data set for the field study. Criteria for site selection will include: a geologically and economically interesting setting, relatively simple structure, and excellent core, log, and seismic data quality. The focus will be on clastic targets. We will evaluate data sets already in house, as well as data sets from our industrial affiliates.

Task 4: Validation, by Integrating and Interpreting Reservoir Field Data. The objective here is To demonstrate, validate, and refine the methodology for quantitative reservoir characterization on a real field dataset.

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More recently, we have been developing a workflow that uses rock physics principles to more effectively link seismic stratigraphy with seismic amplitude analysis. The objective is to improve reservoir characterization via quantitative estimation of mineral composition, textural maturity, clay content, net-to-gross, porosity, and reservoir quality. At the heart of this problem is the question: what sediment properties control reflection amplitudes along chronostratigraphic surfaces? We envision that this workflow will consist of three parts:

(1) Perform conventional stratigraphic analysis of the 3D seismic data, identifying multiple likely interpretations and estimates of their likelihood or uncertainty.
(2) From the interpretations of step (1), predict likely general trends of sedimentological parameters such as grain size, sorting, textural and sedimentological maturity, and net-to-gross.
(3) Use rock physics models to convert the sedimentologic parameters to rock elastic properties, compute associated seismic amplitude attributes, and compare with field seismic to validate or improve the initial geologic interpretations.

To date, we have done a preliminary demonstration of the workflow on an available deep-water dataset, but we are attempting to identify a more comprehensive site with logs, cores, thin sections and seismic to more thoroughly develop the methodology.

Current Status

At the end of 18 months, the project is on schedule. Preliminary field data have been obtained and analyzed. Initial rock physics models have been proposed and tested in four different depositional environments. The effort now is to develop a more formal practical worklflow that will use rock physics to link principles of seismic stratigraphy with seismic amplitude attributes.

Publication

T Dutta, T Mukerji, G Mavko,: 2005, Modeling Elastic Properties of Unconsolidated Sands, Proceedings, American Geophysical Union, Session no: MR33A-0144.

Contract Information:

Project Start: 01/01/2005 (original was for 10/01/04)
Project End: 12/31/2007.
Anticipated DOE Contribution: $ 631,918
Performer Contribution: Stanford @ 20% cost sharing of 156.5K.

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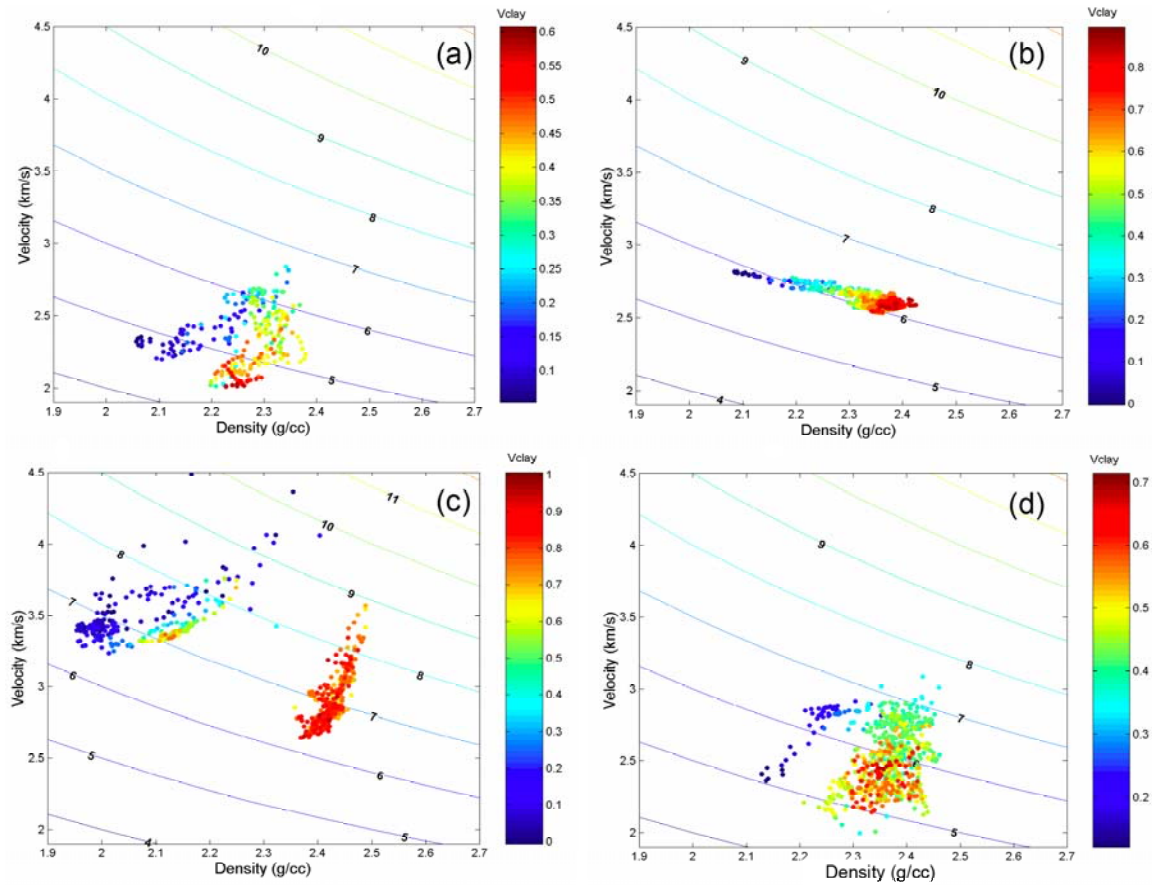
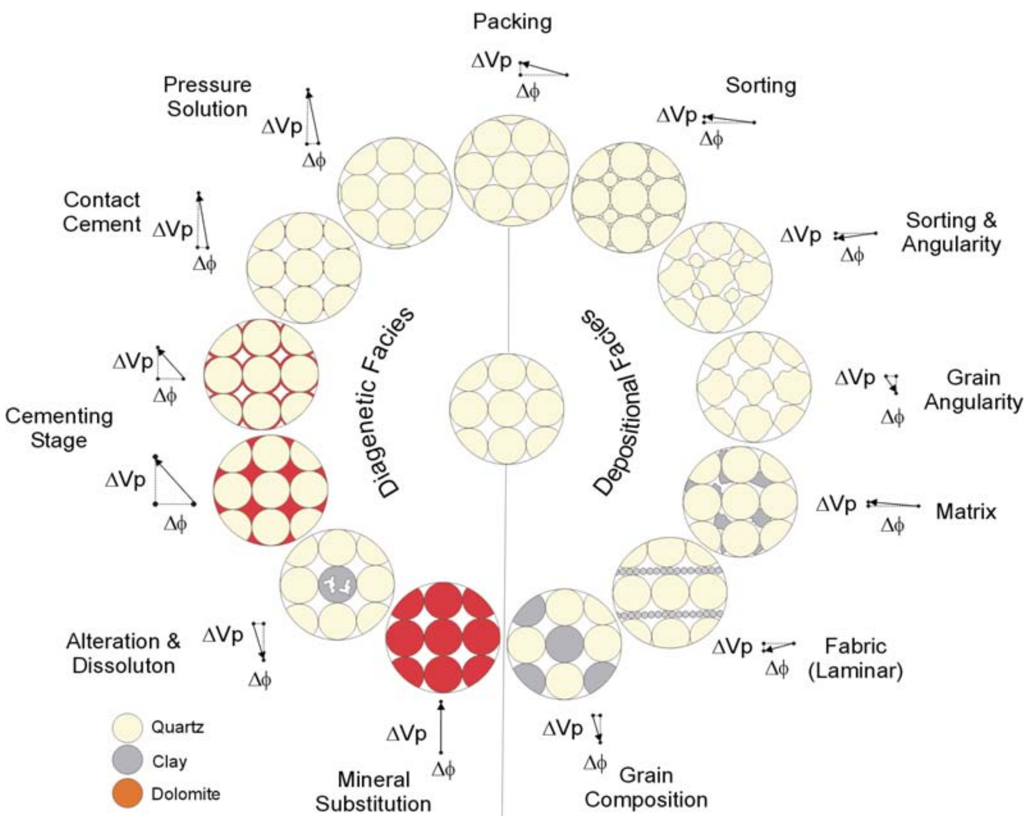
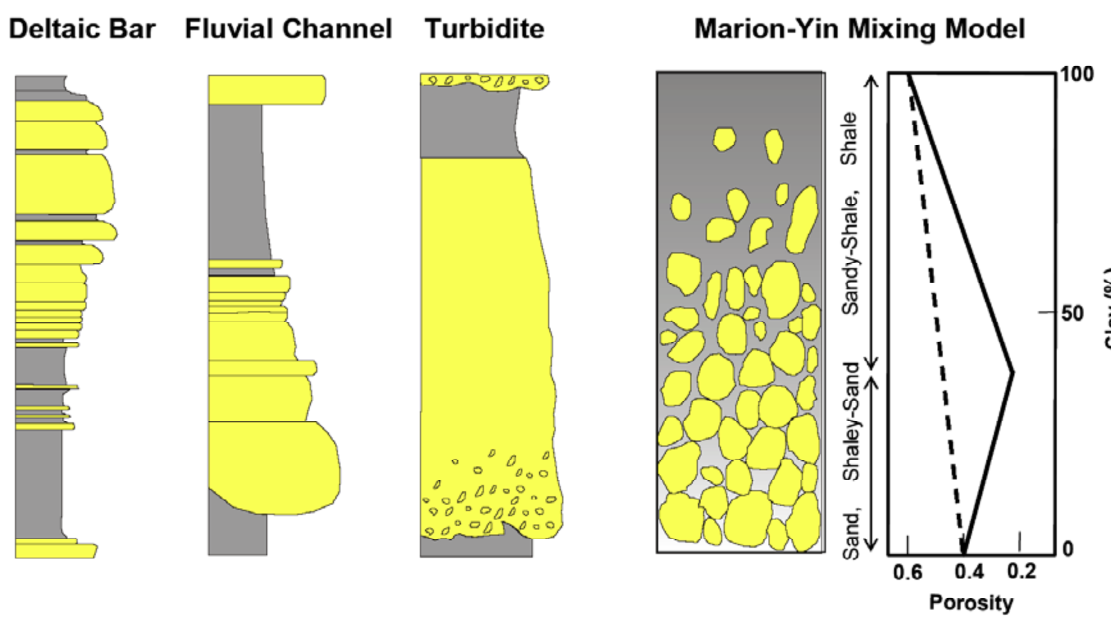
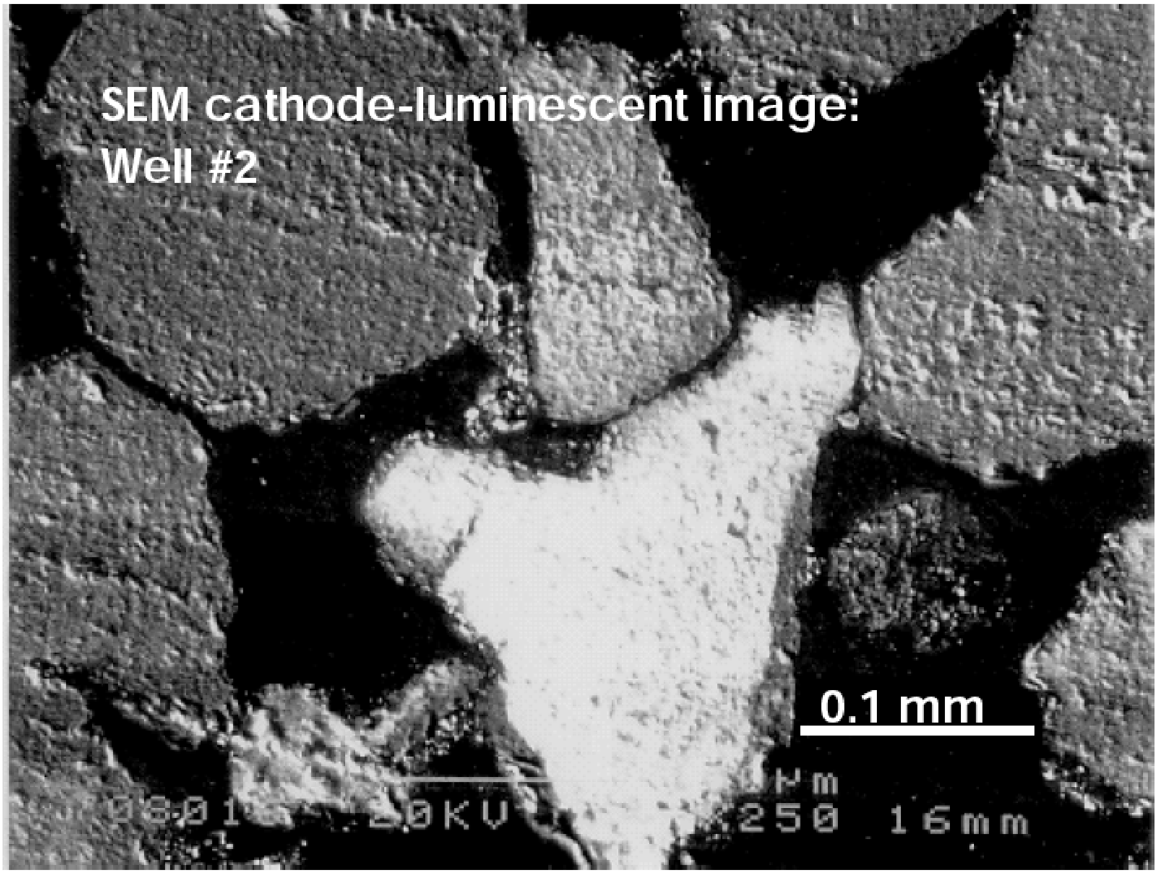


Graphics



Conceptual model illustrating that depositional parameters such as sorting, packing, grain angularity, fabric and diagenesis have predictable relations with porosity and elastic properties.

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