FREQUENCY-DEPENDENT SEISMIC ATTRIBUTES OF POORLY CONSOLIDATED SANDS

Kurt T. Nihei, Zhuping Liu, Seiji Nakagawa, Larry R. Myer, Liviu Tomutsa, and James W. Rector
Contact: Kurt T. Nihei, 510/486-5349, ktnihei@lbl.gov

RESEARCH OBJECTIVES

The objectives of this work are to: (1) provide a theoretical basis for frequency-dependent amplitude attributes associated with multiple fluid (and gas) phases in poorly consolidated sands, for a range of consolidation conditions; (2) explore the possibility of new seismic attributes; (3) use numerical modeling to examine optimum 3D seismic-acquisition geometries and processing schemes for illuminating these attributes in poorly consolidated sand reservoirs; and (4) apply the results of these analyses to 4D seismic imaging.

APPROACH

This research combines laboratory acoustic measurements, theoretical development, and 3D visco-elastic wave simulations. The focus of the acoustic measurements and theoretical development is to obtain a frequency- dependent theory for wave propagation in poorly consolidated sands, a theory that can be used to predict the effects of fluid substitution and reservoir compaction on elastic waves. The focus of the wave-simulation effort is to embed this rock physics model into a numerical simulator to predict the changes in and effects of fluid distributions on acoustic properties in the presence of different reservoir structures. After all this work, we will analyze synthetic data for robust seismic attributes that can be used for 4D monitoring of changes in reservoir fluid/gas migration and reservoir consolidation.

ACCOMPLISHMENTS

The second year of the project has focused on three efforts: (1) analysis of the measured extensional wave velocities and attenuation (1–9 kHz) using existing rock physics models, (2) addition of torsional-wave sonic-frequency-measurement capabilities to our extensional wave apparatus, (3) completion of our lab velocity and attenuation measurements on medium-grain clean sands under a range of gas saturations and confining pressures, (4) design of a seismic- frequency (1–100 Hz) stress-strain apparatus, and (5) 3D dynamic poroelastic modeling of wave propagation in media with heterogeneous gas distributions.

Here, we describe some results for Effort 1. (Efforts 2–5 are presently ongoing.) Figure 1 displays the extensional wave velocities obtained from a 3 kHz pulse transmission test on a 0.8 m long packing of a coarse grain Monterey sand. Three different styles of gas saturation were introduced into the sample and imaged using an x-ray computerized-tomography scanner: (1) CO_2 degassing, yielding near-homogeneous gas phase; (2) injection of water into a dry horizontal sample, yielding patchy saturation consisting of horizontal stratification; and (3) injection of water into a dry vertical sample, yielding patchy saturation consisting of vertical segregation.

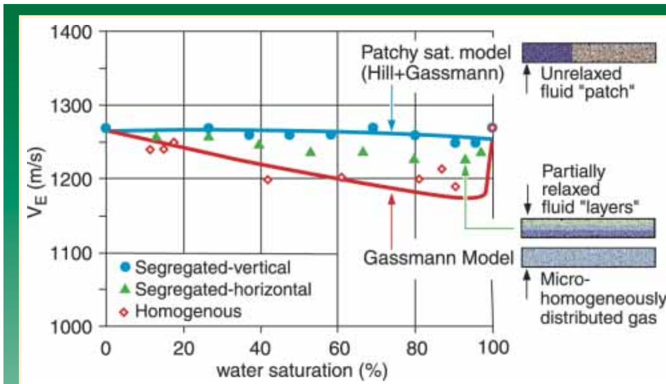

Figure 1. Comparison of measured extensional wave velocities with Gassmann theory (homogenous saturation) and Hill and Gassmann theory (patchy-vertical saturation)

Figure 1 shows that several static-effective-medium theories (Gassmann for the homogeneous case and Hill for the patchy-vertical case) show good agreement with the measured extensional wave velocities. These results demonstrate that sonic-frequency velocities for a coarse-grain sand are not unique functions of the water saturation. That is, the details of the distribution of the fluid and gas phases have an effect on the velocities. Note that measurements to date suggest that the attenuation (not shown) may provide additional information that can be used to deduce the style of saturation (i.e., homogeneous versus heterogeneous).

SIGNIFICANCE OF FINDINGS

Seismic characterization of fluids in poorly consolidated sands is a problem of growing importance, especially on the Gulf Coast. A basic understanding of sand acoustic properties under moderate stresses and in the presence of multiple fluids and gases is required to relate seismic attributes to fluid distributions. The laboratory and modeling efforts described here will provide clearer relations between heterogeneous and homogeneous partial-gas saturations in poorly consolidated sands, with sonic-frequency velocities and attenuation.

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