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Inversion of multicomponent seismic data and rock physics interpretation for evaluating lithology, fracture and fluid distribution in heterogeneous anisotropic reservoirs.

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Objectives: Conduct theoretical investigations into the effects of fluids and fractures on anisotropic elastic constants, and consequent constraints on lithology that may be obtained from seismic parameters.

Project Description: Seismic anisotropy, now widely recognized as a common feature of most subsurface formations, may lead to significant distortions in conventional seismic processing, such as errors in velocity analysis, mispositioning of reflectors, and misinterpretation of the amplitude variation with offset (AVO) response. Seismi anisotropy can arise from aligned fractures, stress-induced anisotropy, and intrinsic rock fabric anisotropy. Furthermore, geophysical characterization of fractured reservoirs via their elastic anisotropy is an extremely important economical problem, in particular for the continental United States. In tight formation, which can include sandstones, shales, carbonates, and coal, often the only practical means to extract fluids is by exploiting the increased drainage provided by fractures. The practical difficulties that must be overcome before effectively using these fractures include: Locating the fracture zones, determining the position, orientation, spatial density, and connectivity of fractures, and characterizing the spatial relationships of fractures to other reservoir heterogeneities which might enhance or inhibit the fluid flow. It is also important to understand the similarities and differences between fracture anisotropy ad stress-induced anisotropy. Stress-induced anisotropy is specially important for less consolidated sediments. In this project, we are developing theoretical models to describe anisotropy in sediments and rocks. Fluids play an important role in the anisotropy. The presence of fluids is a key interpretation problem for the oil and gas industry, in amplitude-*versus*-offset analysis and in fluid substitution modeling using Gassmann's equations.

Results from last year: A major portion of our activity this year was focused on laboratory measurements of the signatures of stress-induced velocity anisotropy. Details of the work are given in the attached paper. We give a brief summary of the results here.
Acoustic properties of rocks and soft sediments are commonly measured under hydrostatic pressure in the laboratory. However, the stress fields in the Earth are generally anisotropic. Moreover, the mechanical properties of sands are sensitive to the stress field and can drastically affect the borehole stability, and lead to shallow water flows, compaction, and subsidence. Despite these facts, there is a void in the literature about how to extrapolate acoustic measurements in sands under hydrostatic pressure to more realistic borehole and field stress conditions

As most of the acoustic measurements in rocks are measured in hydrostatic conditions and there is non-studied equivalence of hydrostatic pressure and polyaxial stress experiments, one goal of our project is to compare compressional velocities in sand using hydrostatic and polyaxial apparatus. In order to find the equivalence between these apparatus, we simulate hydrostatic conditions in the polyaxial apparatus. For instance, we designed and implemented a quasi-hydrostatic stress test that consists in placing a sample under three orthogonal stresses of same magnitude.
We measured Vp under hydrostatic and quasi-hydrostatic stress conditions. We found that our sand samples had depositional fabric anisotropy that is evidenced in the velocities of a quasi-hydrostatic stress test. We attribute this effect to layering perpendicular to the direction of raining grains (sedimentation). In addition, we compare the results with a previous uniaxial strain test in the same sand. This comparison corroborates that the acoustic anisotropy (just mentioned) is not due entirely to stress. Moreover, we compare our measurements with hydrostatic data made in same sand at lower frequency, and also with other data made in finer sand at lower frequency. Our results indicate that velocities measured under hydrostatic pressure are faster than the velocities measured under polyaxial stress. Nevertheless, further study is needed.

Plans for next year: During the next year we will continue our laboratory work on the sources of anisotropy in soft sediments, with a series of experiments on uniaxial compaction under a variety of conditions. We will also use the results to theoretically explore the implications of fabric and stress-induced anisotropy on interpretation of seismic data. Most analysis at present is done assuming isotropic rock and sediment models. Preliminary results suggest that ignoring anisotropy can introduce systematic errors into interpretation of the seismic signatures of pore fluid and stress changes.
We will also continue with work on the rock physics signatures of fractured rock, and fluids, attempting to develop procedures for exploring the realistic range of conditions that might be encountered in a given field site.