Statistical Rock Physics for Estimating Uncertainty in Seismic Reservoir Characterization

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Description: Stanford Rock Physics Lab continues its pioneering research in applied statistical rock physics for reservoir characterization. The goal is to quantify and reduce uncertainties in reservoir exploration and management by integrating fundamental concepts and models of rock physics, statistical pattern recognition, and information theory, with seismic inversions and geostatistics. Rock physics allows us to establish the links between seismic response and reservoir properties, and to extend the training data by Monte Carlo simulations. Prior geologic information can help to constrain the various possible interpretation models and help reduce the uncertainty. Seismic imaging brings an indirect, but nevertheless spatially exhaustive, information about reservoir properties that are not available from pinpoint well data alone. Classification and estimation methods based on computational statistical techniques such as non-parametric Bayesian classification, bootstrap, and neural networks help to quantitatively measure the interpretation uncertainty and the mis-classification risk. Geostatistical stochastic simulations incorporate spatial correlation and small-scale variability. Figure 1 shows a North Sea example of Bayesian classification guided by rock physics modeling. Combining deterministic physical models with statistical techniques helps us to develop new methods for interpretation and estimation of reservoir rock properties from seismic data. These formulations identify not only the most likely interpretation but also the uncertainty of the interpretation, and serve as a guide for quantitative decision analysis. Subsurface property estimation from remote geophysical measurements is always subject to uncertainty because of many inevitable difficulties and ambiguities in data acquisition, processing, and interpretation. Even with perfect data, interpretation is uncertain because of intrinsic natural variability. It is therefore necessary to express quantitatively the information content, and uncertainty in rock property estimation from seismic data.

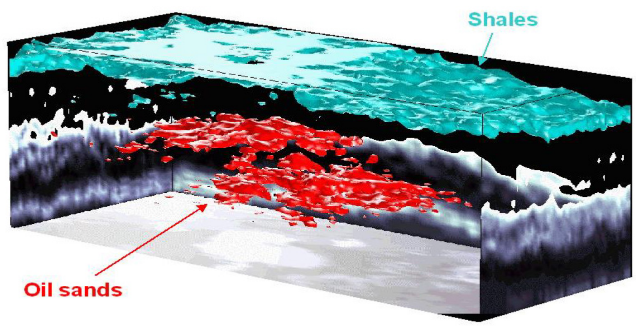

Figure 1: An example of seismic reservoir characterization. Isoprobability surfaces resulting from a statistical rock physics analysis of near and far-offset seismic impedances. The surfaces indicate zones of high probability of oil sands and shales.

Geologic information can provide very useful constraints to reduce the uncertainty of interpretation. One of the focus areas of our research has been to reconcile and integrate qualitative geologic descriptions with mathematical rock physics models. An example of this is shown in Figure 2 from a fractured reservoir characterization study. Outcrop and well log studies showed that the limestone reservoir had three different depositional facies: sub-tidal, shoal margin, and shoal, with different probabilities of occurrence as shown in Figure 2. The shoal environment had a fracture occurrence of only about 16%. Well logs indicated that the shoal facies had distinctly lower velocities and impedances. This combined to give a robust prior constraint on fracture occurrence. This simple prior probability helps to constrain more complicated interpretations based on P-wave seismic anisotropy. Diana Sava at the Stanford Rock Physics Project has developed innovative Bayesian methods for fracture prediction from seismic data by combining geologic information with rock physics models of fractured porous media. One of our projects involves applying these methods to characterize basement fractures in offshore India.

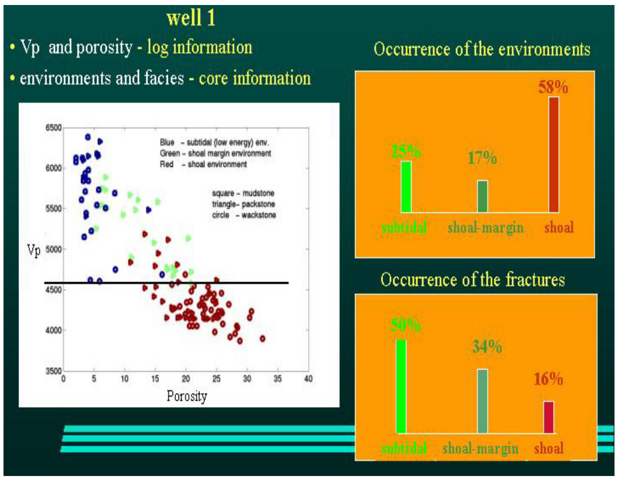

Figure 2: Depositional environments and fracture distribution.

We are also working on applying the methods of statistical rock physics to analyze converted wave (P-to-S) seismic attributes. Ezequiel Gonzalez is developing practical methods for exploiting P-to-S AVO behavior. By combining near and far offsets it may be possible to distinguish fizz water from commercial gas concentrations. Statistical rock physics analyses shows the promise of P-to-S impedances to increase dramatically the probabilities of seismically discriminating high and low gas saturations.

Status: The work continues sponsored by Stanford Rock Physics Project. Some of the emerging research areas in applied statistical rock physics include: strategies to better understand, quantify, and integrate qualitative, 'fuzzy' geologic information in terms of probabilities for seismic interpretation of reservoir properties and a better understanding of the physics behind attributes based on mode conversions and wave attenuation.

Publications

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