Lithology and Fluid Detection in Hydrocarbon Reservoirs

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Sponsors: The Stanford Rock Physics Consortium.

Description: Our long-term objective has been to help the domestic petroleum industry to discover and safely produce hydrocarbons to mitigate our national dependence on foreign oil. Our principal approach is to use the rock physics to relate the in-situ lithology and hydrocarbon saturation to seismic observables, such as the acoustic and elastic impedance, and seismic wave attenuation.

One example where systematic physics-based approach is needed is in the discrimination of sand with commercial gas quantities from sand with residual gas during seismic prospecting. Such discrimination is obviously very important, especially in the deep water where well costs are enormous. However, such discrimination may be difficult because only small amounts of free gas are required to be present in brine to lower the P-wave impedance and Poisson's ratio of the rock. As a result, seismic reflections may be only weakly dependent on gas quantity.

To solve this problem, we recognize that in real rock lithology, porosity, saturation, and their elastic signatures are interrelated. For example, in a fining-upwards depositional cycle, the mean grain size is small which means that the irreducible water saturation is large. Large irreducible water saturation translates into small non-commercial gas saturation. In other words, large quantities of gas simply cannot enter sand where the irreducible water saturation is large and the capillary forces that keep the original brine in place are strong. Once such basic logic is established, we may start looking for seismic attributes that can help map the shape of the reservoir to uncover its fining-upwards character. Such attributes could be pseudo-impedance and pseudo-Poisson's ratio (Figure 1) obtained from seismic traces within a certain frequency window.

We also pursue a pseudo-well generation approach where the properties of shale and reservoir sand are perturbed at a prototype well to imitate depth-related compaction, diagenesis, or variations in a depositional setting. After a pseudo-well is generated, synthetic seismic traces are calculated at this pseudo-well and compared with real seismic data with a supposition that if the seismic responses match, the conditions of the subsurface are also similar. In line with this effort, we work on creating lithological templates from which an earth model could be assembled and then synthetic seismic traces generated. We also explore how to use modern recording techniques which employ multicomponent seismic reflections to better map hydrocarbon quantity in-situ.

Status: This work continues, sponsored by the Stanford Rock Physics Project.

Publications:

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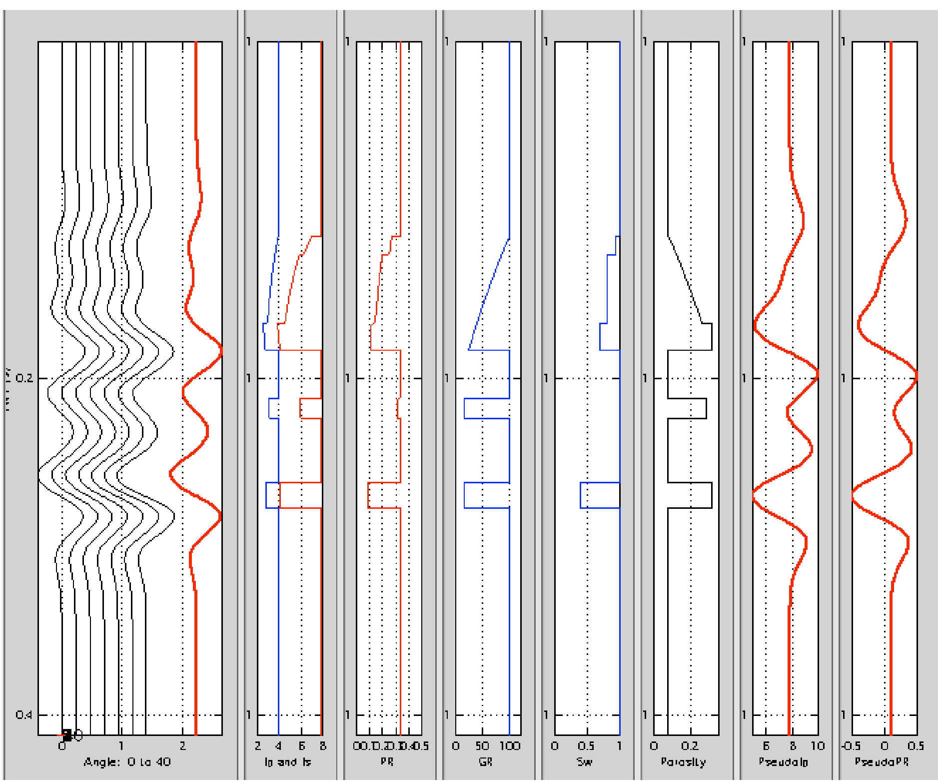

Figure 1. Synthetic seismic traces and attributes for the pseudo-well at low frequency. From left to right: Gather (black) and stack (red); P- and S-wave impedance; Poisson's ratio; GR; water saturation; total porosity; pseudo-impedance; and pseudo-Poisson's ratio. The sand with small gas saturation (large water saturation) has a fining-upwards shape.