Abstract

Primary and secondary recovery processes in many hydrocarbon reservoirs generally cause two main changes in reservoir rock acoustic (or seismic) properties:

(a) Saturation changes from the replacement of produced hydrocarbon by, say, injected or aquifer brine and/or solution gas, and
(b) Changes in pore pressure, which may increase (at/near injectors) or decrease (depletion). The associated stress changes may be enough to cause reservoir compaction, surface subsidence and/or induced seismicity.

While the former may be adequately modeled via (for example) the Gassmann equation, the latter effect is more difficult to predict without some prior measurement on a core sample of the reservoir rock in question. This is because changes in the static and dynamic properties of rocks due to stress result from a combination of different mechanisms. These include: grain sliding and rotation leading to an increased number of grain contacts; closure (or opening) of thin cracks/pore spaces; elastic deformation of grains; inelastic deformation of weak minerals (e.g. clays); and cracking of grains and grain contacts. However, some workers have reported difficulties in matching the results of laboratory measurements with seismic observations.

In this paper we describe the results of ultrasonic velocity measurements on core samples from a number of sandstone reservoirs. Tests were conducted on a variety of stress paths (i.e. the relative change in vertical and horizontal stresses) and span a range of porosity and sandstone compositions. The stress paths investigated represent realistic compaction scenarios for these reservoirs. A subset of (twin) samples was tested “dry” and brine saturated to assess the effects of velocity dispersion.

The results of experiments are compared with the predictions of a number of popular empirical and theoretical models to determine which models may be most applicable to cases where core material is not available.

The Effect of Stress on Ultrasonic Velocities: Implications for 4D Seismic Response

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