How Pore Filling Shale Affects Elastic Wave Velocities in Fully and Partially Saturated Sandstone: Characterization, Measurement, and Modelling

The elastic bulk modulus of a sandstone is affected by the fluid saturation as compression induces a pressure in the fluid thus increasing the bulk modulus of the sandstone as a whole. Assuming a uniform induced pressure and no interaction between the saturating fluid and the solid rock the fluid contribution to the elastic bulk modulus is quantified by Gassmann's equations. Experimental measurements of the fluid contribution to the elastic moduli are, however often much larger than predicted within the assumptions of Gassmann. Clay-rich low-mobility sandstones are especially prone to having elastic moduli highly sensitive to the fluid saturation. The presence of clay in a sandstone can affect two of the underlying assumptions to Gassmann's equations: decreased fluid mobility can cause pressure gradients and fluid-clay interactions are common. The elastic and petrophysical properties of clay are not well defined and the consequent parameter fitting makes both effects viable when modelling elastic moduli measured on fully saturated sandstones. To address this question, we conduct a thorough characterization of a suite of sandstones and measure their elastic moduli at different saturations. We supplement the data with low field NMR spectra at each saturation step to determine if any anomalous effects are associated with the fluid mobility and distribution in the pore-space. We find anomalous fluid contributions to the elastic moduli in sandstones with high clay contents. We also find that the anomalous fluid contributions are closely linked to the fluid distribution in the pore-space, meaning that pressure gradients associated with the presence of clay is more significant than fluid-clay interactions.