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Quantitative measurements of partial saturations in Brine-CO₂ saturated Rocks at pore scale

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Understanding the relation between CO₂ saturation/distribution and velocity/attenuation of acoustic wave propagation is fundamental for an accurate and reliable quantitative interpretation of (seismic) CO₂ monitoring data.

Quantitative interpretation of geophysical data requires understanding of the relationship between the physical properties of the rock, the microstructure of the rock, and the spatial distribution of the fluids saturating the pore space. A large number of laboratory acoustic measurements on rocks has been carried out in the past 10 years, with indirect assessments of how the saturation distribution is formed under in-situ conditions from ultrasonic range (Mavko et al., 1994) to seismic frequency scale (Tisato et al., 2014). However, there are almost no efforts towards quantitative measurements of how saturation distributions affect the acoustic measurements. In particular, no direct experimental link has been demonstrated between the quantitative distributions of saturations at pore scale and the acoustic properties of the saturated rock.

The relationship between elastic wave velocities and fluid saturations (brine/CO₂ and brine/oil/CO₂ mixtures) is strongly dependent on the spatial saturation distribution, i.e., whether distribution is heterogeneous (patchy) or homogenous (uniform). The saturation distribution in turn has a strong signature on attenuation and dispersion of propagating waves, even at seismic frequencies, in the porous media due to wave-induced fluid flow mechanisms (Müller et al., 2004 and 2010). Hence, predicting saturation effects on the seismic response requires a fundamental understanding of how attenuation and velocities are affected by fluid distributions. Seismic quantitative interpretation of CO₂ monitoring data can be largely flawed if such mesoscopic phenomena are not taken into account, both for amplitude-based methods (due to attenuation) and waveform-based methods (due to attenuation and dispersion) (Dupuy et al., 2017). The correct quantification of saturation and pore pressure levels require understanding the fluid distribution and physical properties (Rubino et al., 2011).

The relationships mentioned above are difficult to predict and highly case-dependent. We present preliminary results on a technique for establishing the relationships by core studies based on acoustic measurements in the ultrasound scale on CO₂-brine saturated rocks. The experimental setup is simultaneously imaged in X-ray CT-scanner where the rock, its microstructure, and the fluid distribution at pore scale are visualized. This is a first step in the effort to study in laboratory the time resolved (4D) and spatial relationships between microstructures, physical properties and saturation distribution of reservoir rocks exposed to CO₂-bearing fluids.

References

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