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Geophysical signatures of carbonate rocks flooded with CO_2-rich water: effect of the presence of oil in the pore space

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Monitoring of CO_2 sequestration projects, both for quantification and storage security purposes, requires new methods to take into account the impact of eventual fluid-rock geochemical interactions within the subsurface on geophysical parameters. In that context, laboratory injections of CO_2-rich water (pH= 3.2) have been performed under a confining pressure of 1 MPa in various calcite carbonate rocks. Samples range from either clean or oil-bearing micritic mudstones to wackestones and packstones. The reactive fluid was continuously injected in 1" core plugs under a flow rate of about 10mL/min, with regular stops to measure P- and S-wave velocities and sample lengths, under both fully saturated conditions and dry conditions. The fluid was also regularly sampled at the outlet to measure its calcium content, which, combined with volume changes of the sample under the effect of pressure, allowed to monitor the change in sample porosity, due to both dissolution and compaction. Although creation of secondary porosity and changes in rock stiffness (which translates in a decrease in both P- and S-wave velocities) were observed for all studied samples, the magnitude of these changes varied among the samples, with the clean mudstones experiencing the biggest changes. Since experimental conditions were kept the same for all samples, it was hypothesized that different reactive surface areas, themselves due to different initial microstructure or the presence of coatings such as organic matter, oil, hydroxides..., may be responsible for this observation. To investigate the effect of the presence of oil only, we compared two micritic mudstone samples initially free of oil and having a similar initial microstructure, composed of (1) a microporous matrix (micrite), (2) a spar cement and (3) macropores. One sample remained oil-free whereas the other one was saturated and aged with crude oil to make the pore surfaces oil-wet. This later was then flushed with tap-water, which left about 45% of oil in the pore space, as deduced from mass balances. After injection of the reactive fluid, P-wave velocities showed larger relative decreases in the clean sample, compared with the oil-bearing sample. To better understand the reason of such a difference, sample microstructure was observed under VP-SEM and confocal microscopy. Images revealed that oil was trapped in the micritic matrix, preventing its dissolution. Dissolution can thus only occur through the macropores and the spar cement. On the other hand, all the microstructure of the clean sample was affected by dissolution. Since micrite has been reported as a stiff component of the rock, inhibiting its leaching will lead to a lower relative decrease in P-wave velocity compared to the case where micrite can be leached.