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Effect of water content on the flow of non-hydrous fluids through tight rocks

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Clay-rich sandstones and shales are important constituents of many tight reservoirs, as well as caprocks. Therefore, the permeability, and fluid flow behaviour of these rocks, under realistic in-situ conditions, is of great importance for a variety of subsurface processes and operations. We have performed permeability measurements on natural shale samples, as well as on analogue samples composed of quartz, smectite and kaolinite, under in-situ conditions, to explore the effects of effective confining pressure, clay content and type, and water content on non-hydrous fluid (CO_2) permeability.
Our results show that water content has a major impact on CO_2-permeability and fluid flow behaviour of both natural and analogue samples. Injecting water into natural or clay-bearing analogue samples resulted in a decrease in CO_2-permeability by several orders of magnitude. In the analogue samples, such decreases in permeability were observed regardless of clay-type or content. Furthermore, the observed effects of water content were completely reversible, as demonstrated by the return of permeability after subsequent drying of the samples. In addition, during constant flow measurements on samples that contained water, rapid increases in permeability, i.e. breakthroughs, were observed. After such constant flow tests, enhanced permeabilities were still observed over several days.
Our results show that the water content of tight rocks is a key factor controlling their permeability to other fluids. The most likely mechanism by which water controls tight rock permeability to other (non-wetting) fluids is by inhibiting flow through narrow pathways, such as fractures and pore throats. A breakthrough occurs when such fluid is displaced, and the pathway is made accessible to flow of the non-wetting fluid.