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The effect of long-term fluid-rock interactions on the mechanical properties of reservoir rock - a case study of the Werkendam natural CO_2 analogue field

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Geological storage of CO_2 is one of the most promising technologies to rapidly reduce anthropogenic emissions of carbon dioxide. During long-term geological storage of CO_2, fluid-rock interactions, induced by the formation of carbonic acid, may affect the mineralogical composition of the reservoir rock. Commonly expected reactions include the dissolution of carbonate and/or sulphate cements, as well as the reaction of primary minerals (feldspars, clays, micas) to form new, secondary phases. In order to ensure storage integrity, it is important to understand the effect of such fluid-rock interactions on the mechanical behaviour of a CO_2 storage complex. However, most of these reactions are very slow, which limits the ability to study coupled chemical-mechanical processes in the lab. A possible way to circumvent long reaction times is to investigate natural CO_2 analogue fields, which experienced CO_2-exposure for thousands of years.

In this study, we looked at the Dutch Werkendam natural CO_2 field and its unreacted counterpart (Röt Fringe Sandstone, Werkendam, the Netherlands). We focussed on CO_2-induced mineralogical and porosity-permeability changes, and their effect on mechanical behaviour of intact rock. Overall, CO_2-exposure did not lead to drastic mineralogical changes, though markedly different porosity-permeability relationships were found for the unreacted and exposed material. The limited extent of reaction was in part the result of bitumen coatings protecting specific mineral phases from reaction. In local, mm-sized zones displaying significant anhydrite dissolution, enhanced porosity was observed. For most of the reservoir the long-term mechanical behaviour after CO_2-exposure could be described by the behaviour of the unreacted sandstone, while these more 'porous' zones were significantly weaker. Simple stress path calculations predict that reservoir failure due to depletion and injection is unlikely.