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Impact of Impurities in Salt Rock for Underground Gas Storage in Salt Caverns

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Salt rock has demonstrated to be an effective seal trapping hydrocarbon reservoirs in geological structures for millions of years. It has favourable properties to act as an underground leakproof storage container thanks to its low permeability, plastic behaviour (creep), self-healing (damage recovery) properties, and high thermal conductivity. Natural Gas and hydrogen can be stored in underground salt caverns and be extracted to supply power generation in certain moments of the day or during specific periods of the year to meet peak demand in the electricity grid. Linked to gas injection and withdrawal periods, salt caverns are subjected to cyclic temperature and pressure fluctuations related with the type of storage gas or cavern usage. Salt rock, which mainly consists of halite, can contain solid solution impurities and second phase content, such as anhydrite, gypsum, clay and other minerals. Previous studies have shown that this salt rock composition affects its rheological behaviour and physical properties. The presence of these different minerals in the salt rock formation can result in a rock that is more prone to crack and microcrack development. The effect of second phase content in salt rock under cyclic temperature and pressure conditions still needs to be better constrained.
A total of ten samples of natural salt rock with varying second phase content from Boulby Mine have been geochemically analysed and tested under a set of cyclic thermo- mechanical conditions for 48h. Three different cyclic thermo-mechanical scenarios were tested simulating the depth of the main salt caverns in the UK. The samples were tested under cyclic thermo-mechanical triaxial conditions with axial compression cycles between 4.5 and 7.5 MPa, at a rate of 0.5 MPa/s for a total of 48h, and adapting the confining pressure and test temperature to the three depth scenarios. For the scenario of shallow salt cavern (depth of 200- 500 m), two tests were performed at same confining pressure of 12 MPa and two different temperatures, one at 25ºC and then 55ºC. The other two scenarios were middle depth (800- 1200 m), tested at 25 MPa and 25ºC and 55ºC, and deep depth (1500- 2000 m), tested at 45 MPa confining pressure and 55ºC and 75ºC. After the mechanical tests, a microstructural analysis is performed in order to study the different rheological behaviour of the rock components and the resulting microstructures.
The chemical analysis from the natural samples indicated a main composition of halite (between 85-90%, depending on the sample) with some anhydrite (around 5- 10%) and a low content of kieserite and carnallite (around 3- 5% maximum in total depending on the sample) only in some samples as impurities. During the cyclic thermo-mechanical tests, major deformation is observed in the initial stages of the test and a more uniform deformation after completion of the first cycles. Different initial stiffness is observed to be related to second phase content in the salt rock. Microstructural analysis of the samples after the deformation test allowed identifying the main deformation boundary structures between minerals with different rheology.