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Inelastic deformation of porous sandstones and its influence on rock properties under cyclic triaxial loading conditions

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In underground hydrogen storage, pore pressure cycling due to annual or more frequent gas production (depletion) and injection leads to changes in the stresses acting on the reservoir rock, which in turn lead to rock deformation. Although inelastic deformation has an important effect on the physical properties of the rock, its effect on rock mechanical and transport properties is not well understood. To investigate the effect of inelastic strain, triaxial cyclic axial compression experiments were carried out on Castlegate and St Bees sandstone samples with 26% and 20% porosity, respectively. This was done using the Harpers THMC Flow Bench at Heriot-Watt University at 4.5 MPa, 10.5 MPa, and 19.5 MPa confining pressure. Permeability tests were carried out at key differential stress points throughout the compression tests. 3D images of the whole specimens before and after the cyclic loading experiments were obtained by performing X-ray micro-computed tomography scans, and digital core models were established to quantitatively characterize the geometric topological features of the two sandstones. The results show that the total axial strains of the two sandstones after cyclic loading ranges from 0.98–1.42% and 0.82–1.17%, respectively. The more porous Castlegate sandstone shows greater inelastic strain than the St Bees sandstone (0.47 to 0.85%, compared to 0.23–0.62%, respectively). However, upon stress changes, the Castlegate permeability shows lower permeability loss (19-46%) compared to St Bees Sandstone (~70%). In both sandstone samples, the first cyclic loading event produced the most significant inelastic strain and therefore permeability loss. Microstructural evidence based on CT analysis indicates that inelastic compaction in the Castlegate sandstone is controlled by a combination of intergranular cracking and intergranular slip, with the former dominating. Some of the large pores were compacted to form smaller pores due to intergranular slip, causing a decrease in the permeability of this sandstone, and the inelastic compaction became more pronounced as the confining pressure increased. In contrast, for the St Bees sandstone, inelastic compaction is mainly controlled by intergranular and intra/transgranular cracking. In addition, broken grains in the pores and throats were responsible for the decrease in permeability.

Participation

In-Person

References

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