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Storing CO_2 in Geothermal Reservoir Rocks: A Laboratory Study on Acoustic and Mechanical Properties

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This work is conducted within the framework of SUCCEED, a research consortium with the aim to validate the utilization of produced CO_2, from the Hellisheiði geothermal plant in Iceland, for re-injection into the field for: i) pressure maintenance, and thus promoting geothermal production, and ii) permanent storage in basaltic formations through CO_2 mineralisation. The objective of work carried out at Hellisheiði in SUCCEED is to provide a state-of-the-art, cost-effective, and low-environmental impact coupled geothermal-CO_2 storage monitoring technique. In this work, a detailed seismic-velocity and mechanical behaviour-characterisation study was carried out on various rock formations present at the outcrops near the Hellisheiði geothermal site.

Laboratory experiments include well-controlled active-source acoustic-assisted unconfined (UCS) and confined (CCS) compressive strength tests. Where the former, i.e., UCS, allow for investigating the mechanical behaviour, or static elastic properties, of the assessed rock formations, the latter, i.e., CCS, shed light on the seismic velocities at field-representative stress conditions (up to 70 MPa). The abovementioned experiments were conducted at ambient temperature and at dry pore-space conditions. For studying pore-scale phenomena (e.g., number of connected pores, mineralogy, etc.), several thin sections were prepared and micro computed tomography (micro-CT) scans were taken.

The studied rock formations included basalts with varying porosities (ranging from 22 to 51 %), i.e., the main reservoir formation, hyaloclastites, and dykes. Micro-CT scan analyses, conducted on the basaltic reservoir formation in Hellisheiði, revealed that its pore structure is highly heterogeneous. Active-source acoustic-assisted UCS tests showed similar velocity – stress trends: a rapid increase in velocity at low stress levels, related to closure of potential microcracks (and thus compaction), followed by a more modest increase at higher levels of axial stress. The pyroclastic hyaloclastite appeared to be the weakest material assessed, revealing relatively low seismic velocities, a static Young modulus of 2.54±0.09 GPa, and an ultimate strength of around 4.3 MPa. On the contrary, the igneous intrusion, i.e., dyke, is by far the stiffest material studied, yielding a Young modulus of 34.85±0.39 GPa and an ultimate strength of more than 200 MPa. The investigated basalt samples indicated a porosity-dependent Young modulus and compressional-wave velocity, where both the modulus and velocity decrease significantly with increasing (connected) porosity following a power-law function.