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EXPLORING AIR MIGRATION IN ARGILLACEOUS FORMATIONS: EXPERIMENTAL RESULTS AND NUMERICAL MODELLING

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Summary. Gas migration process on shales and plastic clay formations is becoming an important issue in current energy-related geomechanical investigations, such as CO_2 sequestration, extraction of gas shale and nuclear waste geological storage. Within this last context, three different potential argillaceous formations for the geological disposal of radioactive waste in Switzerland and Belgium have been investigated on the basis of laboratory work and its modelling. Priority in the experimental programme has been given to study the volume change response of these initially water saturated materials along relatively fast volume rate air injections (air pulse tests) followed by a dissipation stage. These high rates intend to give priority to single-phase air flow mechanisms associated with the opening of stress-dependent discontinuities, rather than on slower two-phase flow and air diffusion mechanisms through the matrix. Particular attention has been focused on the changes in the pore network to detect opening of discontinuities after air injection tests using mercury intrusion porosimetry and micro-CT scans.

1 AIR INJECTION / DISSIPATION TESTS

Controlled-volume rate air injection experiments (0.04, 2 and 100 mL/min), followed by shut-in and dissipation stages at two different orientations of bedding planes (flow parallel and orthogonal to bedding planes) have been performed [1, 2]. Figure 1 on the left shows deep claystone 'Brauner Dogger' samples (depths 777 and 782 m bg in the Molasse Basin of North-eastern Switzerland) that have been tested at three different air injection rates at constant isotropic stress (p=15 MPa). Samples tested at 2 and 100 mL/min undergo an important part of the expansion after shut-in when the air pressure front propagates into the sample inducing the pore pressure to increase. In contrast, the sample tested at 0.04 mL/min experiences most of the expansion along the injection stage. Some elapsed time after shut-in, the air injection pressure starts to decrease along the dissipation stage, which induces sample compression. A new family of large pores, which has not been detected on intact samples, has been systematically observed after these air injection tests. These new pores at entrance sizes larger than 2 µm (dominant pore modes around 10 µm and representing around 10% of the total pore volume) have been associated with fissure opening that act as preferential air pathways.

2. NUMERICAL SIMULATIONS

The experimental results have been simulated using a coupled hydro-mechanical finite element code, which incorporates elements with an embedded fracture permeability model to account for the simulation of the dominant single-phase (air) flow along preferential pathways [3]. Rock intrinsic permeability and its retention curve have been made dependent on fracture aperture changes based on experimental data (Figure 1 on the right). Small-scale heterogeneity has been considered to enhance the initiation of air flow pathways. Results of the simulation are in agreement not only with recorded upstream / downstream pressures and outflow volumes, but also in the volume change response of the material. The experimental results, combined with the numerical simulations, provide good insight into the role of the volumetric response and the hydraulic changes on the air transport properties of the samples, confirming that fracture aperture occurs during air injection affecting further injection and pressure release process.

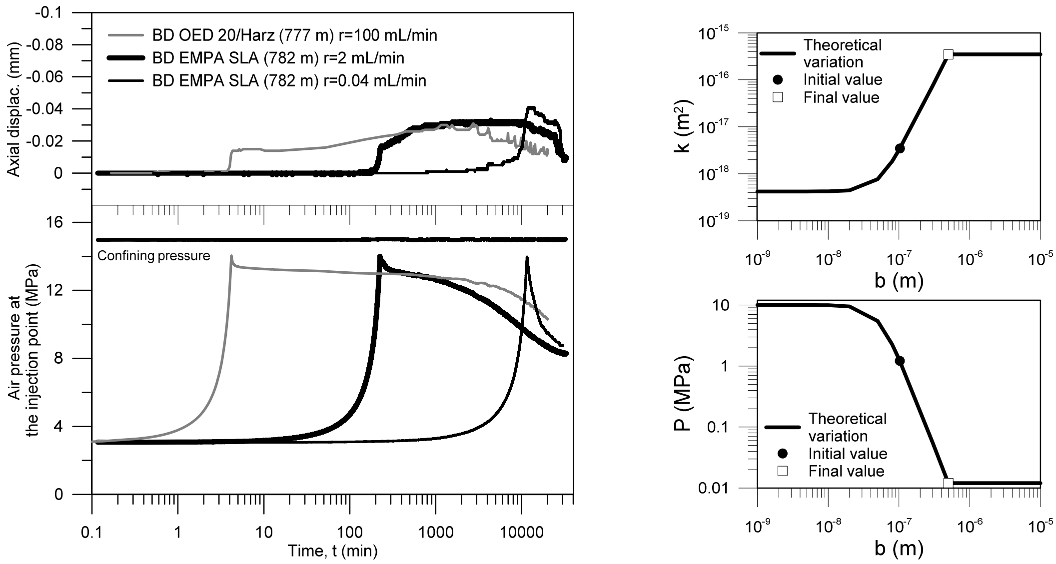

Figure 1. (Left) Time evolution of pressures at injection point and axial displacement at *p*=15 MPa (deep 'Brauner Dogger' claystone samples). (Right) Intrinsic permeability *k* and air entry pressure *P* changes with fracture aperture *b*.

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