Time-dependent THMC properties and microstructural evolution of damage rocks in excavation damage zone

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ABSTRACT:

Modeling coupled THMC processes in geomaterials near nuclear waste repositories at various time scales is an extremely challenging task and requires collaborative research effort from the field of geomechanics, hydrology and geochemistry. The proposed project focuses on the geomechanical aspect, addressing the time-dependent evolution of rock microstructure and its coupling with the THC processes that are of first-order importance to the stability and the isolation performance of the repository. This study is motivated by observing the lack of data and models linking the creep behavior of salt and argillite with microstructural changes under combined mechanical and environmental loadings. Although the use of relatively simple and time-independent material models is justified in short-term predictions, at a time scale of 1 million years, the nonlinearities of host rocks including creep, relaxation, stress corrosion and healing are expected to play a significant role in the near-field hydrology.

This project delineates an integrated experimental, theoretical and numerical strategy in assessing the evolution EDZ over time and its implication on the long-term migration of hazardous species. Rock salt and argillite will be the focus of this study. Firstly, the stress-temperature-moisture path experienced by rocks within the EDZ is analyzed with respect to the construction, operation and post-closure stages of the gallery. This motivates the design of several laboratory test programs that examine the stress-strain-creep behavior of salt and shales that are most relevant to the near-field conditions. Selected samples will be instrumented with in-situ ultrasonic wave measurements to quantify the degree of damage along horizontal direction (**Task 1**). Specimens will be retrieved from the elemental tests and subjected to be microscopic observations to identify evidences of subcritical crack growth and healing. In-situ tests with microscopic observation will be also conducted in a ESEM environment (**Task 2**). The impact of microcracks on the transport properties of rock matrices will be quantified via a series of ponding tests under different hydraulic heads and temperatures (**Task 3**). Theoretical analysis will mainly rely on a generic microcrack damage model that allows for customized THMC coupling components and meanwhile complies to the second law of thermodynamics. The novelty is to directly utilize the information from microscope observations (i.e. the crack density distribution) as the input of the continuum model, to retrieve anisotropic elastic and conduction properties (**Task 4**). Finally, a hypothetical nuclear waste storage site will be studied using the proposed model implemented in ABAQUS, as well as a general plasticity model available in Sierra Mechanics (**Task 5**). All the three stages will be simulated, aiming at reproducing the formation of EDZ and the evolution of EDZ under combined THMC loadings. These results will enhance the confidence of the predicted long-term performance of the repository, thus helping move forwards to the ultimate goal of 1-million-year isolation of high-level nuclear wastes.