Project Title: Effect of high temperature on chemo-mechanical degradation of compacted clays intended for the isolation of high-level nuclear waste and spent nuclear fuel

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ABSTRACT:

Geological Disposal Facilities (GDFs) for high-level nuclear waste (HLW) and spent nuclear fuel (SNF) are based on the multibarrier concept, consisting of a metallic canister (encapsulating the HLW/SNF), an engineered clay barrier (that serves as a buffer around the canister), and the host rock, which serves as a natural barrier. Unsaturated compacted bentonite is the material generally selected to build the engineered barrier systems (EBS). The EBS will be subjected to complex thermo-hydro-mechanical and chemical (THMC) processes triggered by the heat released by the HLW/SNF, the hydration of the clay (from the surrounding rock), increments in stresses induced by progressive wetting and swelling of the compacted bentonite under highly confined conditions, and chemical interactions.

Current understanding of how temperature (*T*) affects the hydromechanical and chemical behavior of the clay buffer is primarily based on studies involving *T* up to 100°C. However, authorities from different countries around the world tasked with developing and delivering GDFs recognize that enabling safe functioning at *T* much higher than 100°C (e.g., 200°C) would allow better optimization of the design, emplacement strategies, interim storage and GDF costs. It has been observed that the swelling pressure (SP) of a Ca- bentonite (i.e., saturated with divalent cations) will tend to decrease with increasing *T*, but the SP of a Na- bentonite (i.e., saturated with monovalent cations) will tend to increase with increasing *T*. The physicochemical phenomena behind this dissimilar behavior have yet to be investigated in detail. This is a critical research component considering both, Na- and Ca-bentonites are envisaged as potential barrier materials for the isolation of HLW/SNF. Achieving a target SP is a key to providing the mechanical protection discussed above, and accurate prediction of this property will be essential when selecting suitable bentonites for a GDF.

The main goal of this project is to gain a better understanding of the behavior of Na- and Ca-bentonites intended for the isolation of HLW/SNF, particularly when involving very high *T* (up to 200°C). The following are the four main objectives of this project: 1) produce high-quality experimental data (involving both macrostructural and microstructural investigations) and accompanying molecular simulations related to the swelling behavior and other THMC properties of compacted bentonites intended for the design of EBS for the isolation of HLW/SPF; 2) upgrade THMC constitutive and numerical models to be used for designing geological repositories for HLW/SNF; 3) develop artificial intelligence (AI) and machine learning (ML) approaches to assist with the identification of bentonite THMC model parameters and expand the information to be gathered from laboratory and traditional numerical techniques; and 4) develop training opportunities for graduate and undergraduate students.

This project will combine researchers from US and UK working at universities (TAMU and ICL) and national laboratories (SNL and BGS) to conduct fundamental, experimental, and numerical investigations to advance the current understanding of the behavior of Na- and Ca-bentonites intended for EBS, when subjected to very high *T*, up to ~200 °C.