Illitization within bentonite engineered barrier system in clay repositories for nuclear waste and its effect on the swelling stress: a coupled THMC modeling study

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Geological repositories for disposal of high-level nuclear waste generally rely on a multi-barrier system to isolate radioactive waste from the biosphere. An engineered barrier system (EBS), which comprises in many design concepts a bentonite backfill, is widely used. Clay formations have been considered as a host rock throughout the world. Illitizaton, the transformation of smectite to illite, could compromise some beneficiary features of EBS bentonite and clay host rock such as sorption and swelling capapcity. It is the major determining factor to estabish the maximum design temperature of the repositories because it is believed that illitizaton could be greatly enhanced at temperatures higher than 100 ºC. However, existing experimental and modeling studies on the occurrence of illitization and related performance impacts are not conclusive, in part because the relevant couplings between the thermal, hydrogeological, chemical, and mechanical (THMC) processes have not been fully represented in the models. Here we present a fully coupled THMC simulation study of a nuclear waste repository in a clay formation with a bentonite-backfilled EBS. Two scenarios were simulated for comparison: a case in which the temperature in the bentonite near the waste canister can reach about 200ºC and a case in which the temperature in the bentonite near the waste canister peaks at about 100ºC. The model simulations demonstrate that illitization is in general more significant under higher temeperature. However, the quantity of illitization is affected by many chemical factors and therefore varies a great deal. The most important chemical factors are the concentration of K in the pore water as well as the abundance and dissolution rate of K-feldspar. For the particular case and bentonite properties studied, the reduction in swelling stress as a result of chemical changes vary from 14% up to 60% depending on chemical and temperature conditions. The modeling work is illustrative in light of the relative importance of different processes occurring in EBS bentonite and clay host rock at higher than 100 ºC conditions, and could be of greater use when site specific data are available.