Coupled thermo-hydro-chemical models of swelling bentonites

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The disposal of radioactive waste in deep geological repositories is based on the multibarrier concept of retention of the waste by a combination of engineered and geological barriers. The engineered barrier system (EBS) includes the solid conditioned waste-form, the waste container, the buffer made of materials such as clay, grout or crushed rock that separate the waste package from the host rock and the tunnel linings and supports. The geological barrier supports the engineered system and provides stability over the long term during which time radioactive decay reduces the levels of radioactivity. The strong interplays among thermal (T), hydrodynamic (H), mechanical (M) and chemical (C) processes during the hydration, thermal and solute transport stages of the engineered barrier system (EBS) of a radioactive waste repository call for coupled THMC models for the metallic overpack, the unsaturated compacted bentonite and the concrete liner. Conceptual and numerical coupled THMC models of the EBS have been developed, which have been implemented in INVERSE-FADES-CORE. Chemical reactions are coupled to the hydrodynamic processes through chemical osmosis (C–H coupling) while bentonite swelling affects solute transport via changes in bentonite porosity changes (M–H coupling). Here we present THMC models of heating and hydration laboratory experiments performed by CIEMAT (Madrid, Spain) on compacted FEBEX bentonite and numerical models for the long-term evolution of the EBS for 1 Ma. The changes in porosity caused by swelling are more important than those produced by the chemical reactions during the early evolution of the EBS (t < 100 years). For longer times, however, the changes in porosity induced by the dissolution/precipitation reactions are more relevant due to: 1) The effect of iron mineral phases (corrosion products) released by the corrosion of the carbon steel canister; and 2) The hyper alkaline plume produced by the concrete liner. Numerical results show that the pH in the bentonite pore water in the presence of a concrete liner can vary from neutral to up to 13 over a time scale of 1 Ma although dissolution of silica minerals and precipitation of secondary calcium silicate hydrate (CSH) minerals in the bentonite alleviate the effect of the hyper alkaline plume. Mineral precipitation reduces the porosity of the bentonite near the bentonite-concrete interface due to the precipitation of CSH minerals. The changes in porosity caused by the precipitation of corrosion products can lead to the clogging of the bentonite pores. The issue of pore clogging due to chemical reactions deserves further experimental and numerical research.