Thermal pressurization in a deep geological repository as a possible mechanism for fault reactivation

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A safe geological disposal site of radioactive waste requires identification of a rock formation that guarantees isolation to prevent unacceptable concentrations of radionuclides from migrating to the accessible environment. A common design for spent nuclear fuel disposal is the emplacement of specifically engineered canisters containing vitrified high-level radioactive waste (HLW) in a clay formation. The increase of temperature of a low permeability, fluid-saturated, media may trigger significant thermal pressurization, where the expansion of pore fluid cannot be accommodated by the thermal expansion of the pore space. With the aid of a coupled thermo-hydro-mechanical numerical simulator, we investigate the possible impact of thermal pressurization during the life of a deep geological repository on the stability of a nearby plane of weakness, assuming that the clay formation mantains its sealing properties. In our model, we represent the fault as a planar structure embedded in a thermo-poro-elastic material and shear activation evaluated by a strain-softening Mohr-Coulomb failure criterion. The results show that stress changes caused by temperature and thermal pressurization of a rock mass volume around the emplacement tunnels may trigger a slip event on a fault plane in proximity of the disposal site, with rupture nucleating at depth, hundreds of meter below the repository itself. We found that stress transfer plays an important role, while a direct hydraulic connection between the repository and the nucleation zone is not necessary in order to reach failure conditions. With a critical stress state (low horizontal to vertical stress ratio) the occurrence of slip may happen for a fault at a distance of up to 600m from the outermost tunnel. Intrinsic properties of the fault dictates the occurrence of seismic or aseismic slip, which may vary with depth. These results stress the need of investigating hydromechanical properties and local stress conditions to guarantee safe operations and predictable behavior of the HLW disposal site.

Keywords: Fault reactivation, thermal pressurization, stress transfer, deep geological repository high level storage, Rupture nucleation, Geomechanics