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Stress-induced permeability alterations in a heterogeneous rock

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The processes of fluid transport in geologic media have important bearings on problems related to environmental geomechanics and the geosciences. The permeability characteristics of geologic media in particular ultimately govern the efficiency of natural geologic media in providing a barrier for the retardation of the migration of hazardous substances such as radionuclides associated with deep ground repositories for the storage of nuclear fuel waste. The construction of deep geologic repositories invariably involve the excavation of openings in stressed geologic formations. The stress relief created by the excavations can lead to varying levels of excavation-induced damage zones within the geologic medium. The level of damage can vary from Excavation Damaged Zones(EDZ) and Excavation disturbed Zones (EdZ) to the undisturbed zone, where the permeability characteristics of the geological formation can exhibit consistent changes. In order to examine the influences of the excavation damage zones on the alteration of permeability, it is necessary to develop the necessary relationships that link permeability of geomaterials to the stress state. While theoretical concepts based on damage mechanics can assist in this objective, it is more reliable to generate experimentally a state space evolution of the permeability through its relationship to the stress change as identified by the invariants of the stress tensor. This research presents the results of experimental investigations of stress induced permeability evolution in a highly heterogeneous argillaceous limestone, which consists of calcite, dolomite, quartz and a clay fraction. The paper presents the results of a series of hydraulic pulse tests and steady-state tests that were conducted to determine the permeability alterations in zones that can experience levels of damage that can be present in vicinity of an excavated underground opening. A "state-space" relationship is developed to describe permeability evolution with the triaxial stress in the pre-failure regime. The permeability evolution in extensively damaged post-failure states of the rock is also investigated. It is shown that permeability alterations were four orders of magnitude higher as a result of significant damage to the material, which is an important consideration in establishing the efficiency of the host rock formation as a barrier for the long-term containment of radionuclide migration.