Evaluating Evolution of Crustal Fluids in Crystalline Basement Systems

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The safety case for a generic deep borehole disposal (DBD) concept for radioactive wastes is being developed by Sandia National Laboratories [1]. The reference concept design [2, 3] is a borehole to a depth of 5,000 m (with at least the lower 3,000 m in crystalline basement (CB) rock) with a 43 cm bottom-hole diameter. Waste packages would be emplaced in the lowest 2,000 m and overlain by a 1,000 m zone of alternating seals of bentonite, cement plugs, and sand/crushed rock backfill.

The DBH safety case relies primarily on the natural barriers such as the great depth of burial, the low permeability CB rock, and the isolated (stagnant) nature of the CB fluids. Reliance on the engineered barriers is secondary, with borehole seals preventing advection for the thermal period (≤300 yrs). Our work evaluates if the CB isolation may be driven primarily by fluid-rock reaction that fixes H_2O into alteration minerals, raises Ca/Na ratios in resulting brines, and decreases permeability via alteration. Reaction-path and reactive transport methods are used to analyse alteration reactions at depth (100-150°C, ~50 MPa) for a varitey of initial mineralogy and starting fluid compositions. Early results for seawater reacting with granite showed fluid evolution consistent with observations of major element chemsitry of CB brines in the literature. Sensitivity studies evaluate dilute groundwater, gabbro mineralogy, and varying anorthite and pargasite components in granite mineralogy. In each case, similar fluid evolution is observed, suggesting that the isolation of CB fluids is an intrinsic result of the low-temperature alteration of CB rocks in these systems. *Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-3574 A.*

[1] Freeze et al. (2019) SAND2019-1915. [2] Brady et al. (2009) SAND2009-4401. [3] Arnold et al. (2011) SAND2011-6749.