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PALEOCLIMATE ANALYSES OF DENSITY-DEPENDENT GROUNDWATER FLOW WITH PSEUDO-PERMAFROST IN DISCRETELY FRACTURED CRYSTALLINE ROCK SETTINGS

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Summary. A high resolution sub-regional scale ($104\,\mathrm{km}^2$) density-dependent, groundwater flow model with fracture zone networks, hydromechanical coupling and pseudo-permafrost, was developed from a larger $5734\,\mathrm{km}^2$ regional scale groundwater flow model of a Canadian Shield setting in fractured crystalline rock. The objective of the work is to examine the impact of glaciation and deglaciation on aspects of regional and sub-regional groundwater flow that are relevant to the long-term performance of a hypothetical nuclear fuel repository. The discrete fracture dual continuum numerical model FRAC3DVS-OPG was used for all simulations. A discrete fracture zone network model delineated from surface features was superimposed onto an 789 887 element flow domain mesh. Orthogonal fracture faces (between adjacent finite element grid blocks) were used to best represent the irregular discrete fracture zone network. The crystalline rock between these structural discontinuities was assigned hydraulic and mechanical properties characteristic of those reported for the Canadian Shield at the Underground Research Laboratory at Pinawa, Manitoba.

The multiple 121 000 year North American continental scale paleoclimate simulations are provided by W.R. Peltier using the University of Toronto Glacial Systems Model, whereby values of ice sheet normal stress, and proglacial lake depth are applied to the sub-regional model as surface boundary conditions. Thermal conditions resulting in permafrost formation are applied as a permeability reduction to both three-dimensional grid blocks and fractures that lie within the time varying permafrost zone. Density-dependent flow is required due to the presence of pore fluids deep in the Canadian Shield with densities of up to $1200\,\mathrm{kg/m^3}$ and total dissolved solids concentrations in excess of $300\,\mathrm{g/L}$. Hydromechanical coupling between the rock matrix and the pore fluid, due to the ice sheet normal stress, is included in the simulations. The flow model includes vertical strain and assumes that areal loads are homogeneous. The importance of hydromechanical coupling is shown using the sub-regional model to investigate the effect on the depth of glacial meltwater migration into the subsurface.