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Improving Canadian Shield crystalline rock characterization in hydrogeological models

Andrew P. Snowdon, Stefano D. Normani, and Jonathan F. Sykes
Department of Civil & Environmental Engineering, University of Waterloo

Summary

An important step in the development of conceptual models of groundwater systems is the assignment of material properties. In the case of the Canadian Shield settings, limited published field data is available to characterize these models. As such, assumptions are often made which may result in increased uncertainty in model performance and predictions. In an effort to address this limitation, additional data, typically from field studies, needs to be acquired and integrated to create a better representation of the groundwater system. Fortunately, a vast quantity of data does exist in paper reports which until recently, had not been utilized.

Background

Atomic Energy of Canada Limited (AECL) spent multiple decades (1970s through 1990s) conducting research on Canadian Shield plutons to develop methods for characterizing the Shield by drilling boreholes at multiple sites and conducting extensive testing and measurement. This research was conducted at seven research areas on the Canadian Shield in Ontario and Manitoba (see Figure 1). Much of this research has never been published in journals and the reports that contain the research are scattered in libraries across Canada.

Prior research by Snowdon et al. (2021) involved creating an extensive database of Canadian Shield pluton permeability values for equivalent porous media (EPM) rock mass and fracture zones, and developed depth-dependent relationships using a novel logistic function. The authors have expanded this database to incorporate data on porosity, tortuosity, and total dissolved solids (TDS) concentrations.

The TDS data is of particular importance because the Canadian Shield has high solute concentrations (Frape et al., 1984, 1985; Frape and Fritz, 1987; Gascoyne et al., 1987; Bottomley et al., 1994; Douglas et al. 2000; Gascoyne, 2000; Bottomley et al., 2003; Gascoyne, 2004; Stotler et al., 2009). While groundwater near the surface is generally considered fresh, with increasing depth, TDS concentrations increase and exceed seawater salinity in many places (Frape and Fritz, 1987). TDS plays an important role in developing conceptual models of Shield environments as pore fluid density is directly related to the TDS concentration. To properly assess hydraulic gradients in variable salinity Canadian Shield environments using pressure data from boreholes, density-dependent flow must be accounted for in simulations.

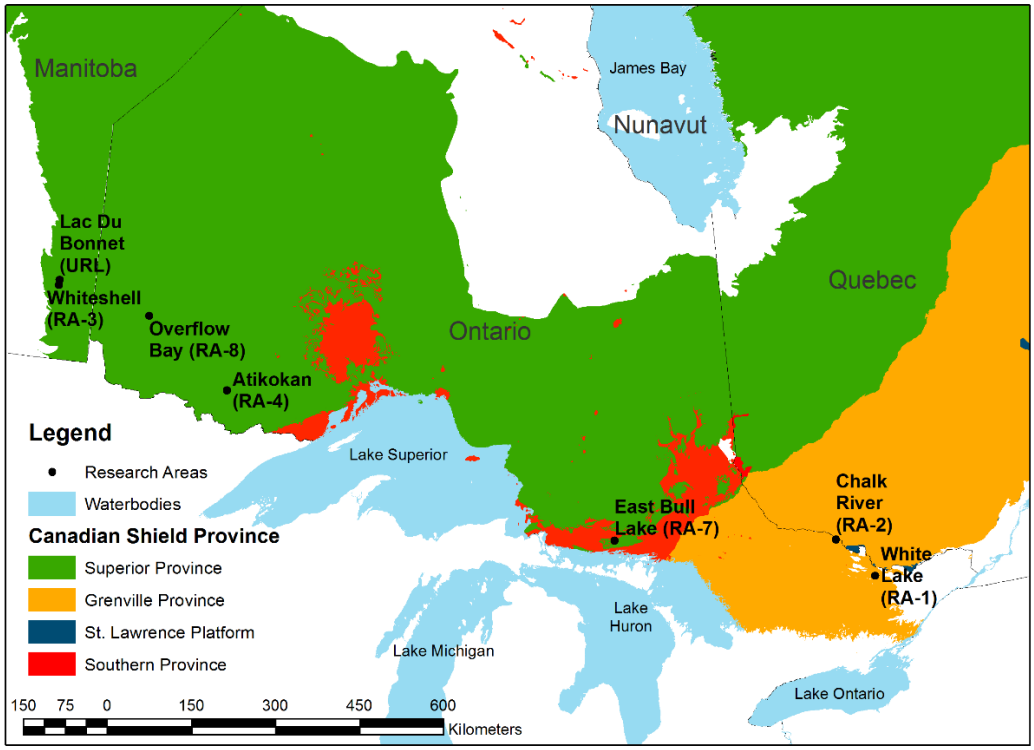

Figure 1 - Map of AECL research areas

Observations

TDS data for the Canadian Shield was collected at the AECL research areas and at mines (Yellowknife, NWT; Sudbury, ON; Thompson, MB). The collection of the mine data was not performed by AECL and will be referred to as non-AECL data henceforth. The data from both of these populations were compiled and analyzed using a logistic function to determine trends versus depth. It was found that TDS concentrations for the AECL and non-AECL locations both followed similar trends with some differences between them at both shallow depths and at depths greater than 1 km. Fitting functions using moving averages and the entire data set reveals depth-dependent trends. The AECL and non-AECL trends with respect to depth appear to be relatively similar at intermediate depth ranges but varied by upwards of an order of magnitude at the tails of the data. This is significant as the choice of TDS profile could impact the interpretation of field measurements.

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