Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

Effects of Glaciation on the Rock Formations Around a Proposed Nuclear Waste Repository

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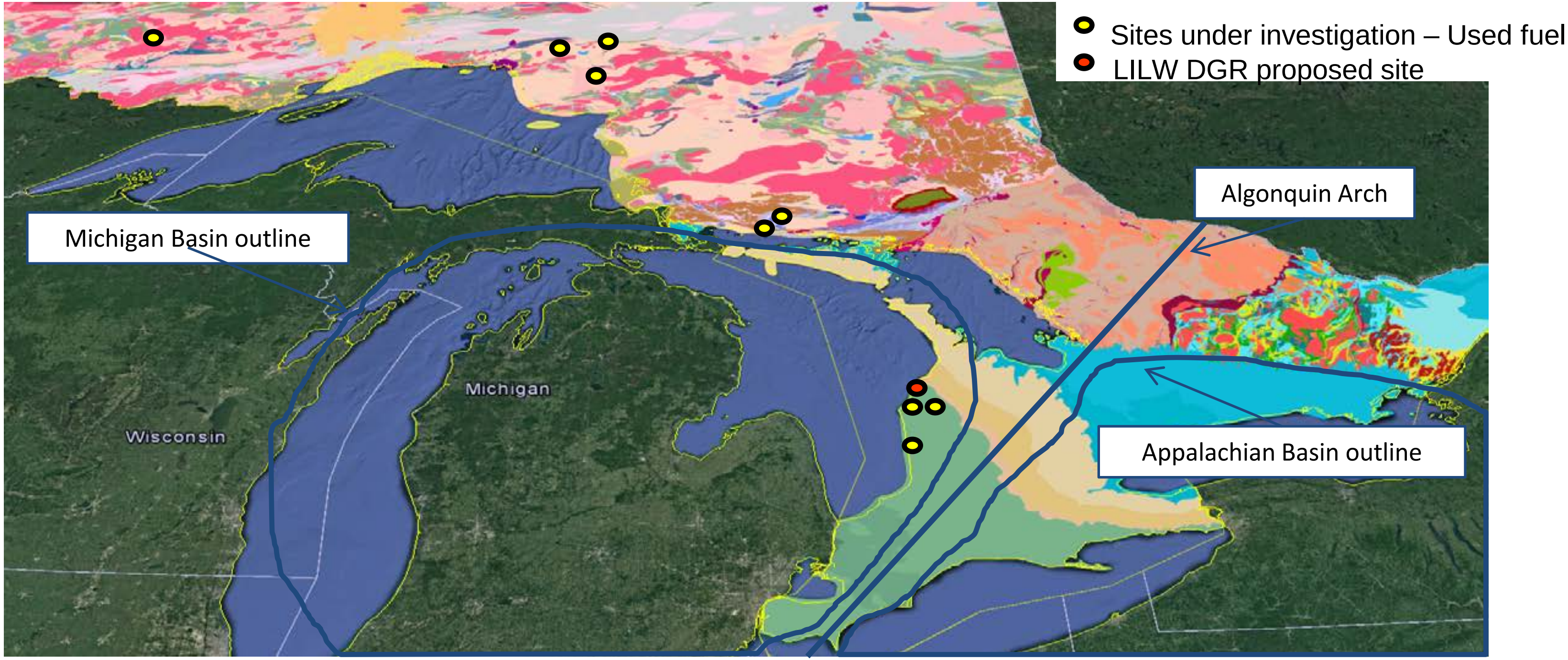
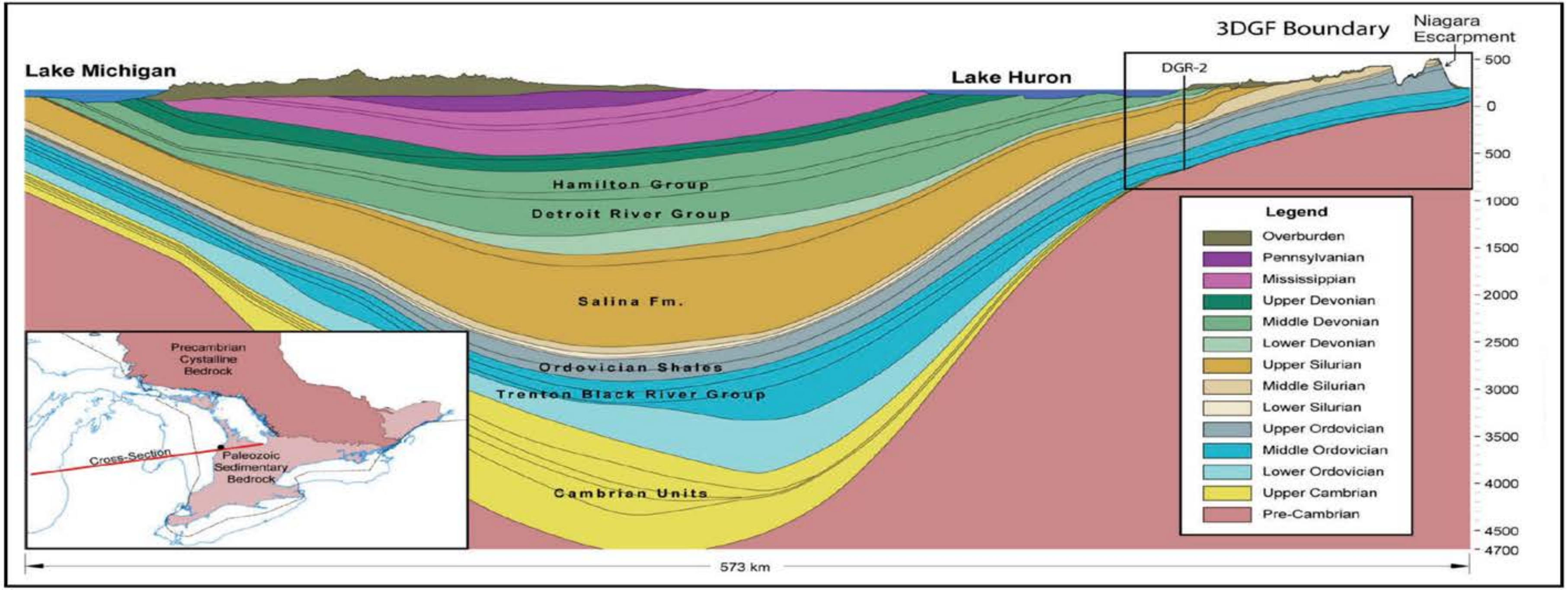
Overview

- Current candidate sites in Canada for deep geological disposal
- The Michigan Basin and the Great Lakes
- Conceptual and mathematical models of glaciation
- Modelling results for past glaciation
- Modelling results for effects of future glaciation on a deep geological repository (DGR) for low- and intermediate-level waste (LILW)
- Conclusions

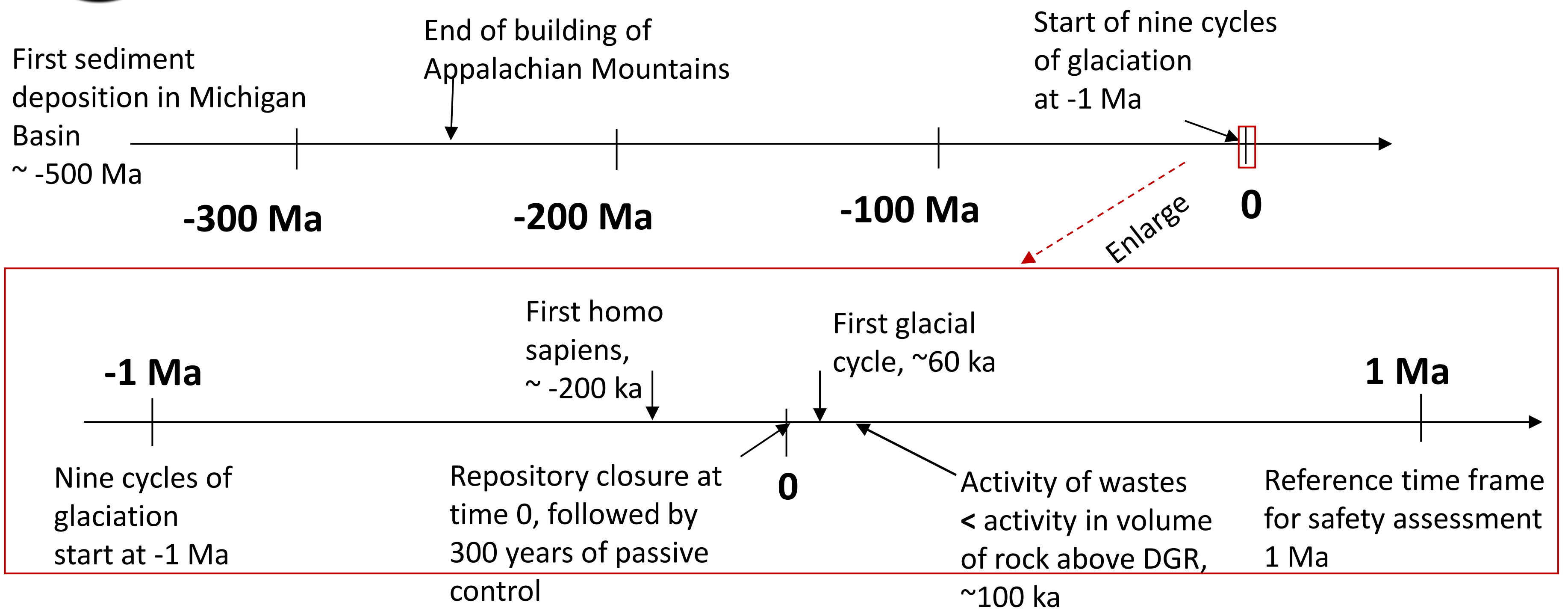
Current Sites Being Considered for Deep Geological Disposal in Canada



Geology of the Michigan Basin

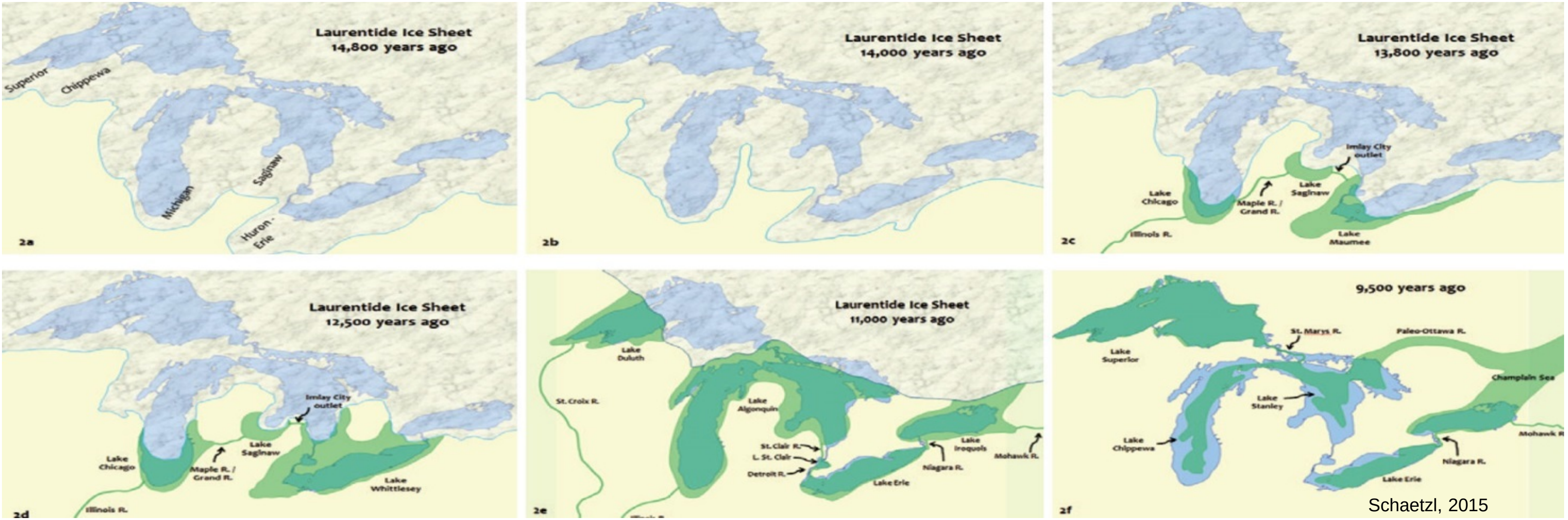


Geological and Repository Time Scales



Formation of the Great Lakes

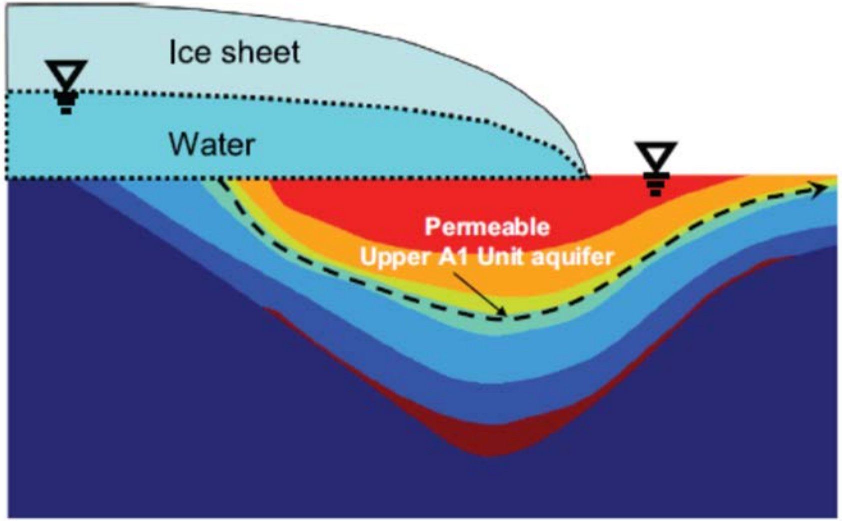
The Great Lakes are near-surface features resulting from quaternary glaciation-deglaciation cycles



Schaetzl, 2015

Conceptualization of Hydro-Chemical-Mechanical Processes Due to Glaciation

- Rock mass conceptualized as a poro-elastic medium
- In the last 1M years, nine glacial cycles have imposed a maximum surface load of 30–40 MPa, leading to:
  - substantial increase in hydraulic gradients
  - redistribution of natural tracers by advection, dispersion and diffusion



Mathematical and Numerical Models

$$\nabla\left[\rho_f \frac{\kappa}{\mu}\left(\nabla p + \rho_f g \nabla D\right)\right] = n\gamma \frac{\partial C}{\partial t} + \rho_f \alpha' \frac{de_{ff}}{dt} + \rho_f S \frac{dp}{dt}$$

$$n\frac{\partial C}{\partial t} + \nabla(-nD_a \nabla C + \mathbf{u}C) = S_c$$

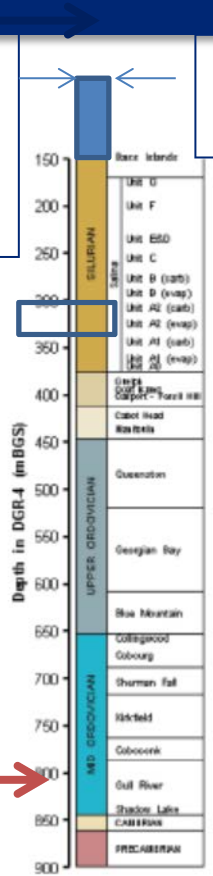
$$G\frac{\partial^2 u_i}{\partial x_j \partial y_j} + (G+\lambda)\frac{\partial^2 u_j}{\partial x_i \partial y_j} - \alpha\frac{\partial p}{\partial x_i} + F_i = 0$$

$$\rho_f = \rho_{f0} + \gamma C$$

Nine glacial cycles simulated as boundary load

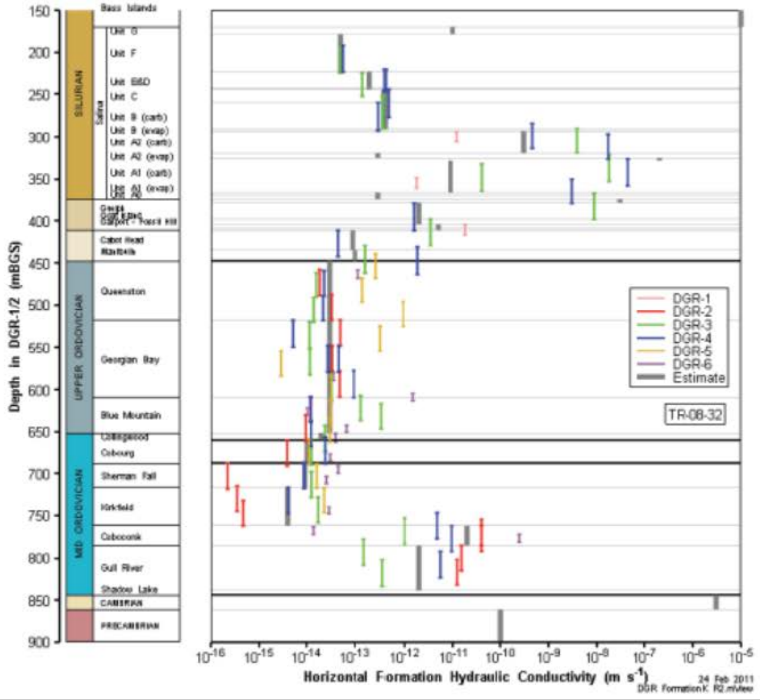
Free-draining C=0

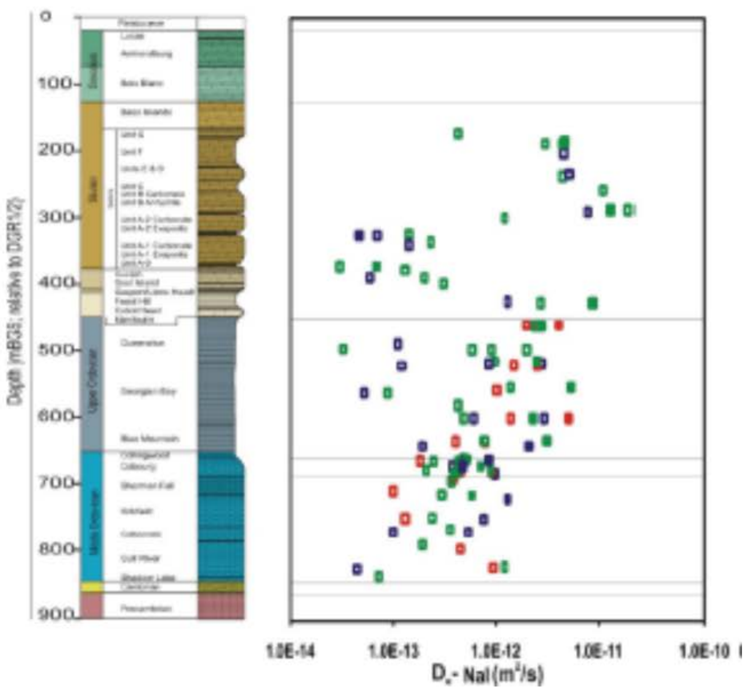
Hydraulically open laterally to ground surface



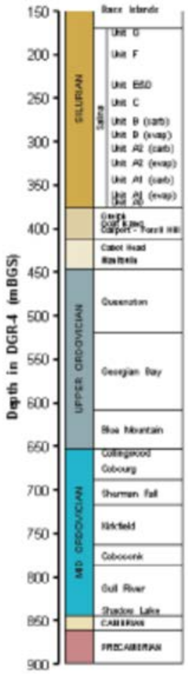
Input Hydraulic and Transport Properties

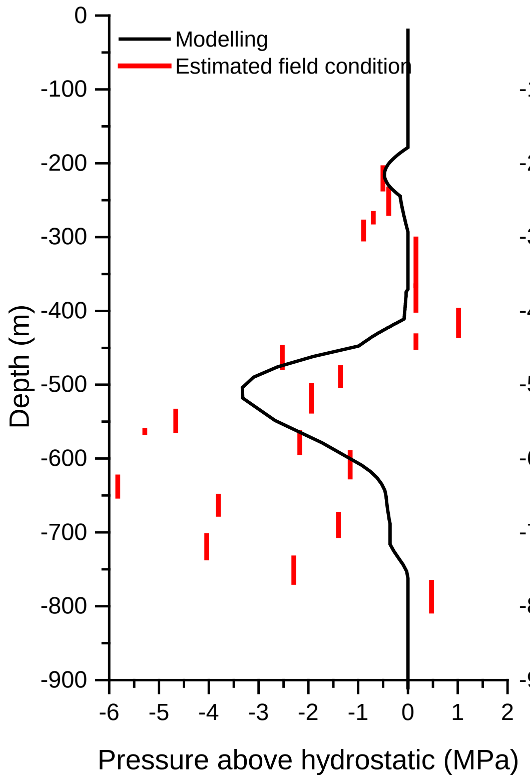
Very low permeability and diffusion coefficients

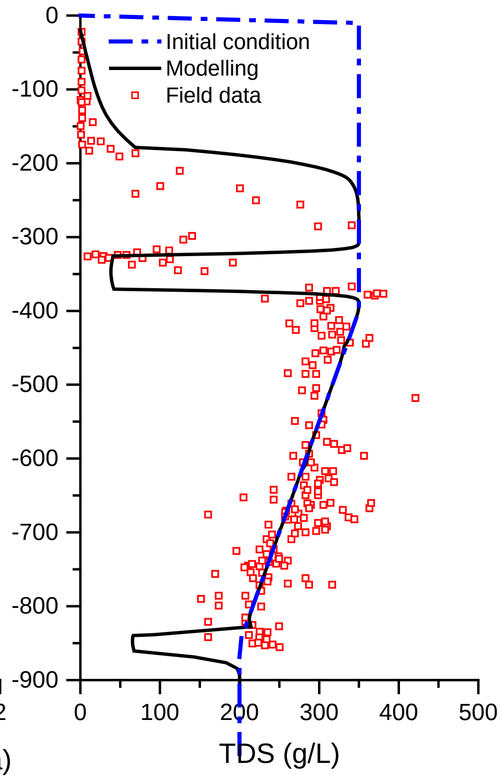




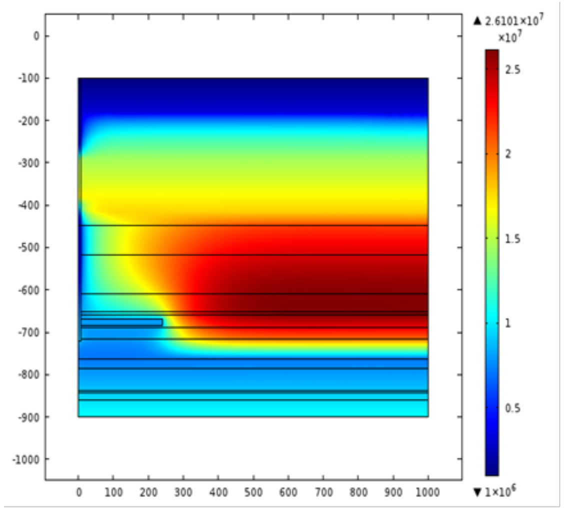
Modelling Results for Present-Day Pressure and Total Dissolved Solids (TDS) Profiles



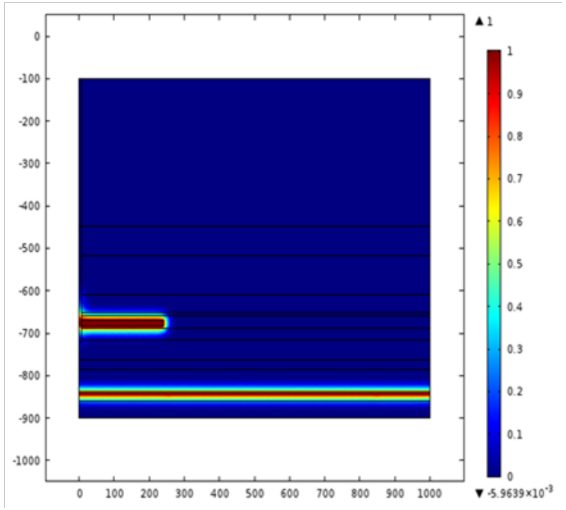




Effects of Future Glaciation on a DGR for LILW



a) Pressure contours



b) Tracer movement

CNSC hydro-chemical-mechanical model predicts that host and cap rock will remain a robust barrier during future glacial cycles

Conclusions

- Mathematical modelling and field data from the site for a proposed DGR for LILW provide multiple lines of evidence that:
  - the deep groundwater system in the host and cap rock formations at the site is hundreds of millions of years old and virtually stagnant – transport of solutes is diffusion-dominated
  - these rock formations and their groundwater have been unaffected by nine cycles of glaciation during the last million years
  - the Great Lakes are features resulting from quaternary glaciation cycles – surface water bodies such as the Great Lakes have remained isolated from the deep groundwater

Conclusions (cont'd)

- Mathematical modelling of future glaciation suggests that for the proposed LILW DGR at the site:
  - the deep rock formations would remain mechanically and hydraulically unaffected
  - any radionuclide release would be contained in the deep rock formations and would not reach shallow groundwater or surface water bodies such as the Great Lakes
- The above geosphere attributes support the safety case for the proposed DGR

Questions?

Thank You!

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