Thermal Analysis of a Nuclear Waste Repository in Argillite Host Rock

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ABSTRACT: **Disposal of high-level nuclear waste in a geological repository requires analysis of heat distribution caused by decay heat. Such an analysis supports design of repository layout to define repository footprint as well as provide information of importance to overall design. The analysis is also used in the study of potential migration of radionuclides to the accessible environment. In this study, thermal analysis for high-level waste in a generic repository in argillite host rock is presented.**

1) NUMERICAL SIMULATION OF THERMAL HYDROLOGY:

Numerical simulations of thermal hydrology in a generic geologic repository at 500 m depth were conducted. For the simulations a repository layout with disposal in horizontal boreholes was assumed (Fig. 1). The 3-D modeling domain covers a limited portion of the repository footprint to enable a detailed thermal analysis. A highly refined unstructured mesh was used with increased discretization near heat sources and at intersections of different materials (Figs. 2 to 4). The CUBIT software was used for mesh generation. The PFLOTRAN code was used to simulate flow and heat transport. Temperature results in the near-field at different simulation times are presented (Figs. 5 and 6).

2) MODEL INPUT:

- **Modeled volume = 1000 m x 1120 m x 1000 m**
- **Mesh size = 33,147,324 grid blocks**
- **Initial and Boundary Conditions: Hydrostatic pressure and geothermal gradient of 25 ° C/km. Top at 10 ° C and 1 atm.**
- **Decay heat source with 468 Watt at time zero**

Material	Permeability (m^2)	Porosity (-)	Thermal K (W/m/K)	Heat Capacity (J/kg/K)
Argillite Rock	1×10^{-19}	0.2	1.7	830.
Disturbed Rock Zone	1×10^{-16}	0.2	1.7	830.
Buffer	1×10^{-19}	0.35	0.6/0.85	830.
Waste Package	1×10^{-20}	0.47	46.0	493.

3) REPOSITORY LAYOUT

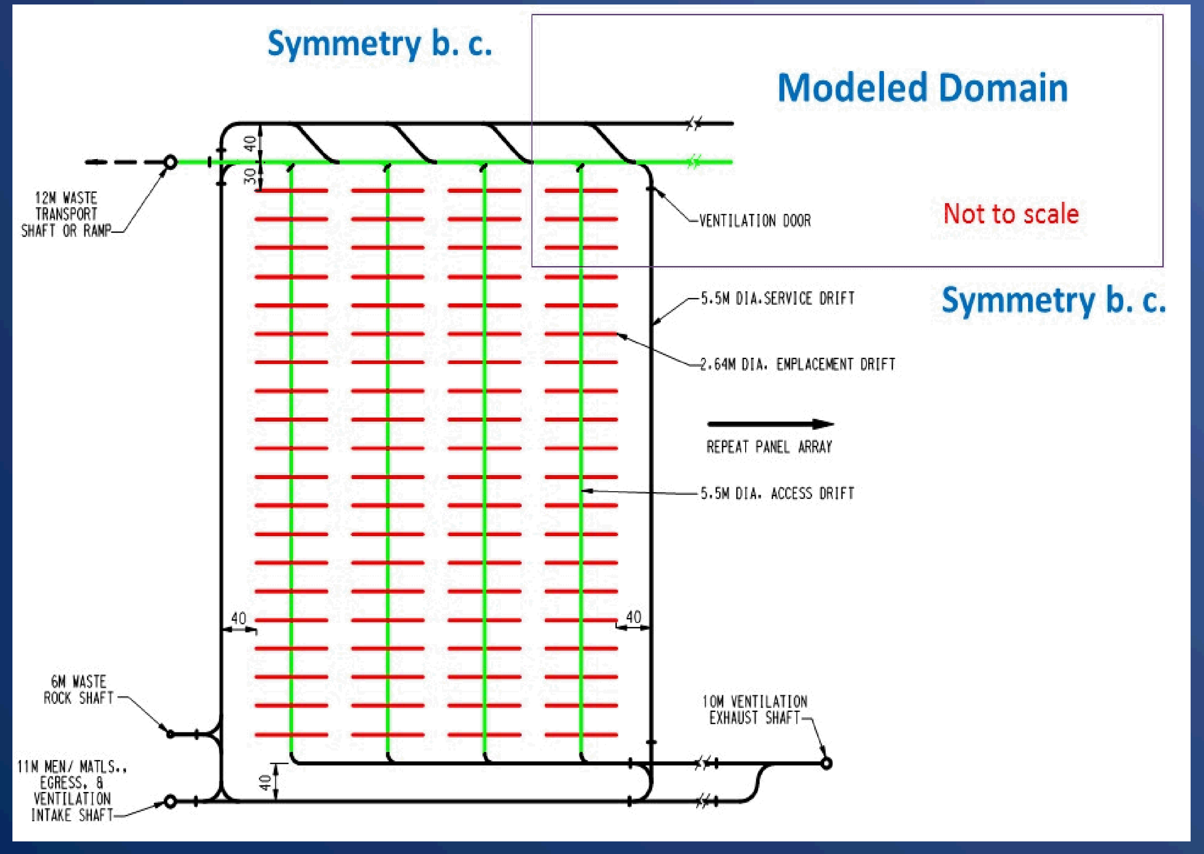

Fig. 1. Subsurface Layout of Disposal (Hardin et al. 2012)

4) MODELED GEOMETRY AND MESH GENERATION:

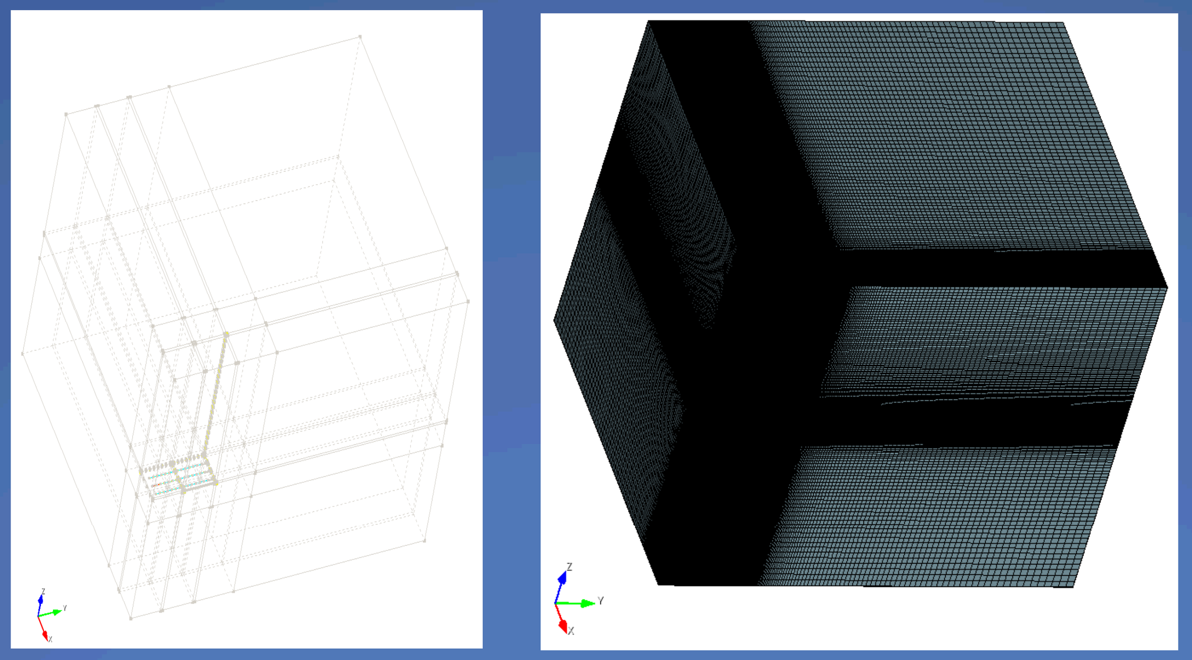

Fig. 2. Model Domain used in the Simulations

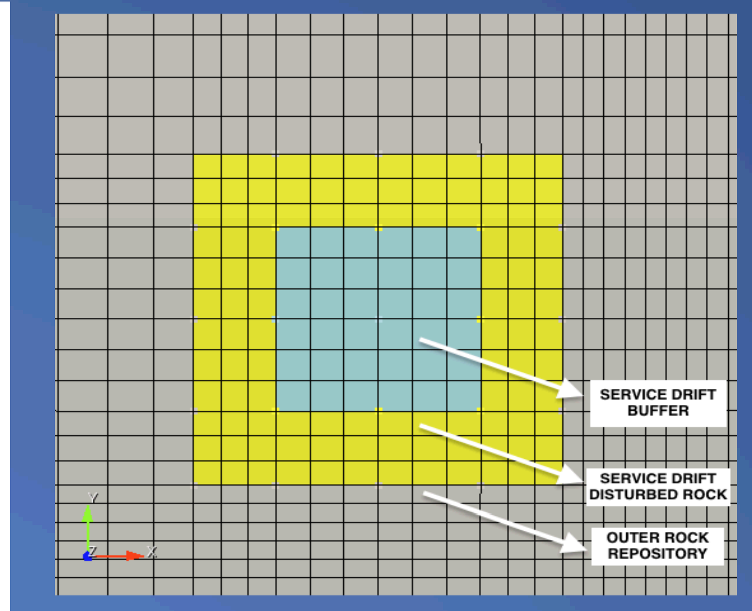

Fig. 3. Access Drift Isometric View

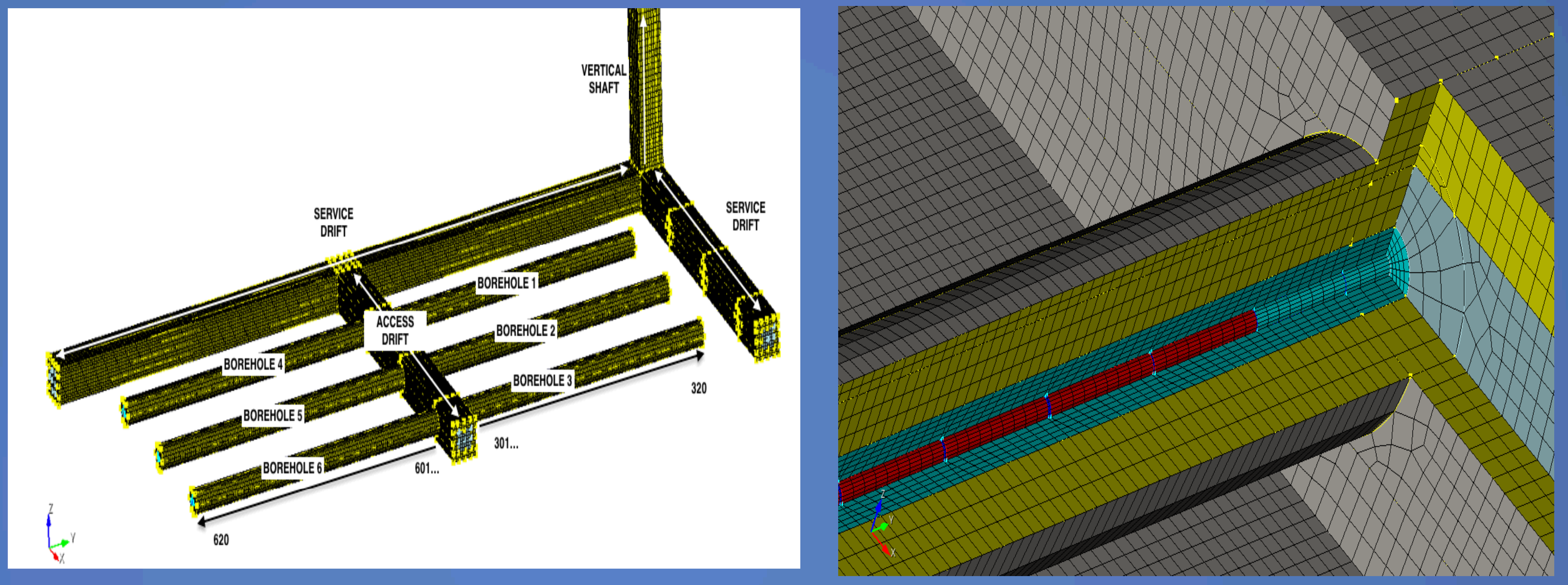

Fig. 4 . Meshing of Engineered Barrier System

SIMULATION RESULTS: 5a) TEMPERATURE DISTRIBUTIONS

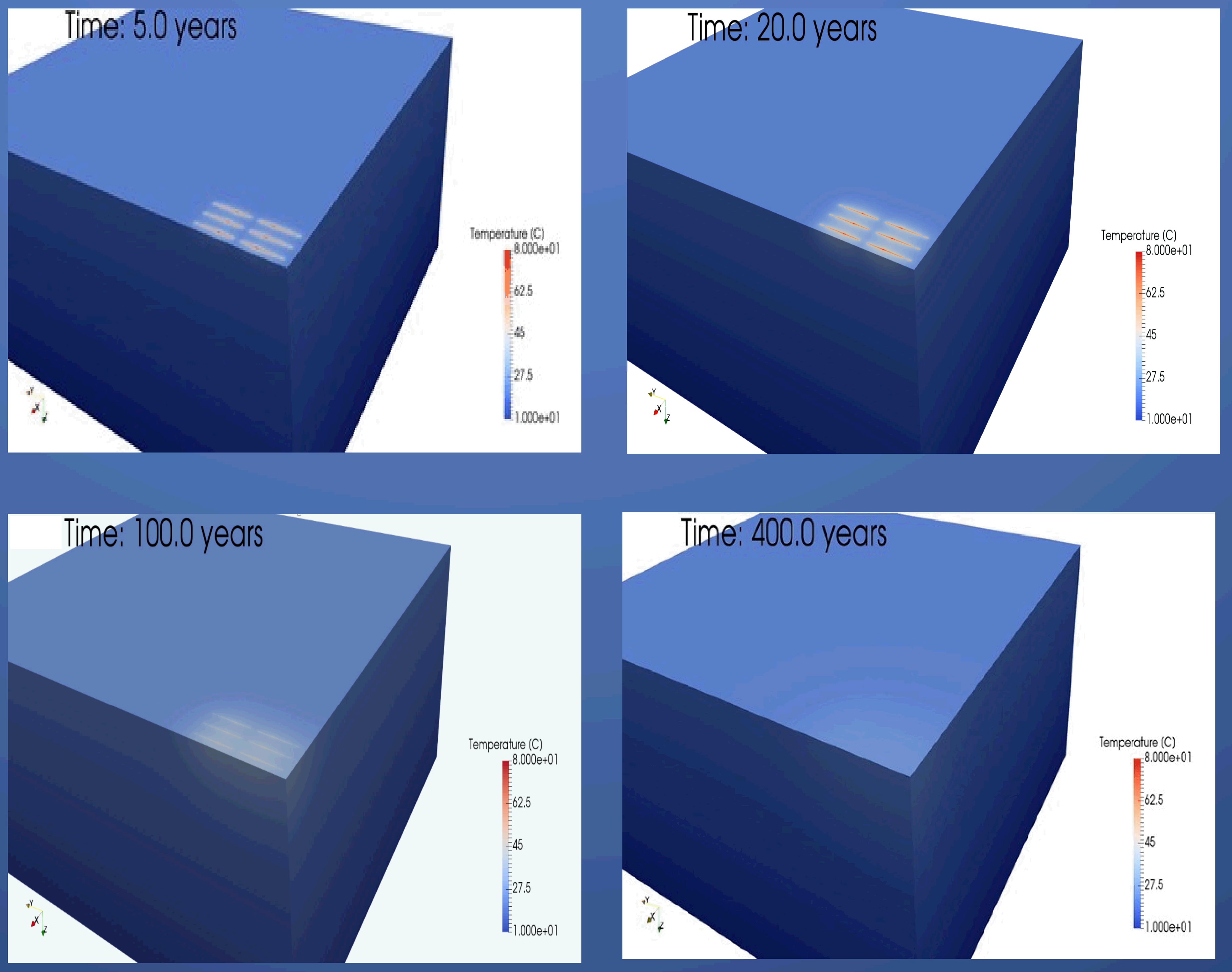

Fig. 5. Model Results: Temperature Distribution at Different Simulation Times

5b) TEMPERATURE HISTORY

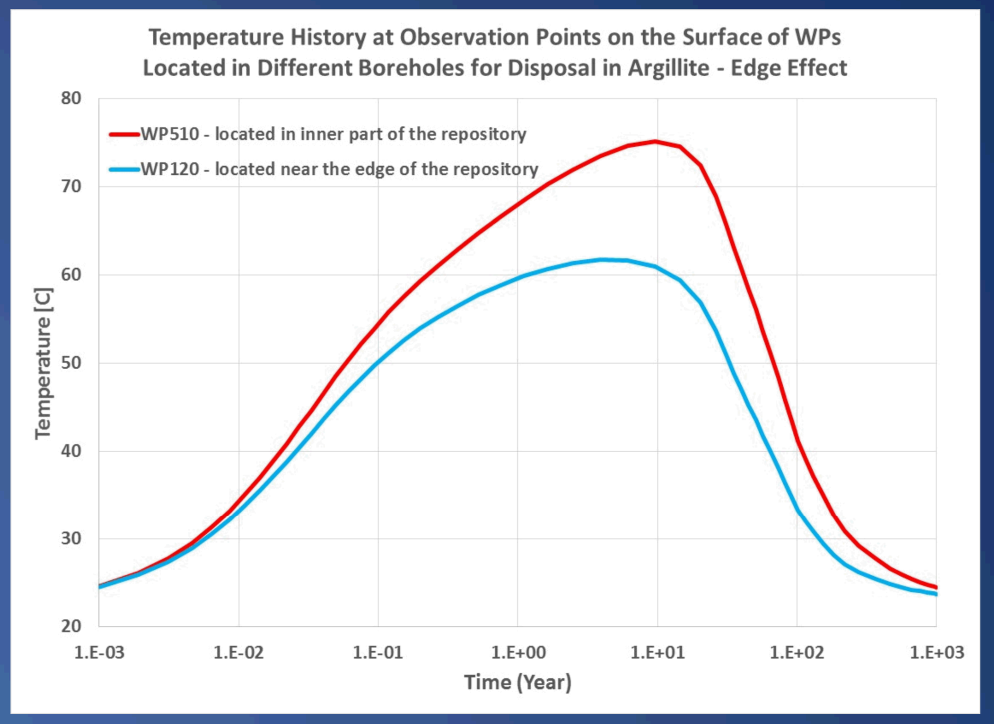

Fig. 6. Temperature at two waste packages: one near the center (WP510) and another near the edge of the repository (WP120)

6) SUMMARY OF RESULTS:

- **High performance computing provided efficient execution of the simulations. 2048 processors were used.**
- **Pressure and temperature conditions are below boiling due to the low output thermal decay source and hydrostatic pressures at repository level.**
- **Low buffer thermal conductivity strongly affects temperatures in the near field as shown in sensitivity analyses not illustrated here.**

7) CONCLUSIONS:

- **Simulated temperatures indicate that higher temperatures near waste packages are short lived, and decrease with distance into the host rock.**
- **The results indicate that disposal of high-level radioactive waste in argillite host rock is a viable option.**
- **Further study will look into thermal conditions for emplacement of waste with higher thermal output including spent nuclear fuel.**

REFERENCES:

Hardin E., T. Hadgu, D. Clayton, R. Howard, H. Greenberg, J. Blink, M. Sharma, M. Sutton, J. Carter, M. Dupont and P. Rodwell 2012. *Repository Reference Disposal Concepts and Thermal Load Management Analysis*. FCRD-UFD-2012-000219, Rev. 2. U.S. Department of Energy, Office of Used Nuclear Fuel Disposition.

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