SUBJECT: MECHANICAL ATTRIBUTES OF WASTE PACKAGE ENVIRONMENT

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Outline

• Thermomechanical Effects of Waste Package Emplacement

• Borehole Stability

  Rock Properties

  Fracture Properties

• Modeling and Validation

• Summary
Thermomechanical Effects

Excavation increases stress

Increasing temperature affects
- Stress
- Moisture
- Strength
- Creep Rate
- May cause phase transformations

Decreasing temperature (cool down) affects
- Stress
- Moisture
Stress near a borehole—Uniaxial stress field

\[ \sigma_\theta \text{ (compressive)} = \frac{1}{2} \sigma_1 \left( 1 + \frac{R^2}{r^2} \right) - \frac{1}{2} \sigma_1 \left( 1 + \frac{3R^4}{r^4} \right) \cos 2\theta \]
Temperature Profile

8.55 PWR Spent Fuel
(Nitao, 1988)

Distance (m) from W. P.

Temperature (°C)

- 25 yrs.
- 400 yrs.
- 1000 yrs.
- Boiling point
- 1500 yrs.

0 10 20 30 40 50 60 70
Results from G-Tunnel show that moisture is redistributed as the rock is heated.
Borehole Stability

Mechanisms such as subcritical crack growth or creep, acting over long time periods may affect the borehole wall.

Our purpose is to increase confidence in the estimates of the amount and type of mechanical loading on the waste package by investigating these phenomena.
## Borehole Stability

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<td>Creep</td>
<td>Reduction of air gap</td>
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<td></td>
<td>Loading of container</td>
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Borehole Stability - Spalling

The rate of subcritical crack growth increases with increasing temperature and stress.

Spalling (post emplacement) may occur due to growth of cracks near the borehole wall.

Over long times subcritical crack growth may be significant.

We will study this mechanism in the laboratory and with numerical models.

Note - Climax and G-Tunnel show no evidence of this effect in short term tests, but it must be examined.
Schematic stress intensity factor/crack velocity diagram

Increasing Temperature $p(H_2O)$
Influence of temperature and water vapor pressure on crack velocity in Westerly granite

(Atkinson, 1987)

\[
\begin{align*}
\text{Westerly granite} & \\
\bullet & 2.5 \text{ kPa } p(H_2O) \\
\circ & 15 \text{ kPa } p(H_2O)
\end{align*}
\]

\[
\begin{align*}
-\log_{10} \text{crack velocity (ms}^{-1}) & \\
\log_{10} K_I (\text{MPa m}^{1/2}) & \\
-10 & -0.5 & 0 & 0.5 & 10 & 15 & 20
\end{align*}
\]

300°C  200°C  20°C  100°C
Water can react with glass and cause it to crack more easily.

(Michalske & Bunker, 1987)
Molecular size of chemical substance affects its ability to speed the growth of cracks in glass.

(Michalske & Bunker, 1987)
Early stage of fracturing in Indiana limestone

(Ewy, 1989)
Advanced fracturing in Indiana limestone

(Ewy, 1989)
Borehole Stability - Block Stability Analysis

- Identify blocks and shapes based on distribution of fractures.

- Determine kinematic stability to identify keyblocks and associated failure modes.

- Conduct stability analysis for selected keyblocks.

- To be initiated when ESF becomes available.
Modeling and Validation

- Develop required conceptual models for
  - Time dependence
  - Temperature dependence
  - Effects of radiation
  - Mineral phase transformations
- Evaluate existing codes
  Spalling & Creep
  FEFFFLAP
  SANCHO
  HEFF
  Block Stability
  BSTAB3D
- Simulate laboratory tests as part of validation
SUMMARY

The purpose of this task is to characterize the mechanical behavior of the WP environment (post-emplacement).

Focus is on time dependent and temperature dependent mechanisms.

Work is in the planning phase.