Salt Coupled THMC Modeling including Borehole Heater Tests

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Overview of Activity

- THMC code development and validation
  - TOUGH-FLAC with Clausthal Technical University Salt Constitutive Model

- Peer-reviewed journal papers published

- Developed continuum model for brine-inclusion migration
  - Important for modeling brine-inflow mechanisms

- Code verification for strong THM coupling (BenVaSim)
  - Verify TOUGH-FLAC sequential coupling

- THM modeling of small borehole experiment (ongoing)
  - THM mechanisms of brine-release
  - Predicting borehole closure and brine-inflow
Connection to Bigger Picture

- **Performance Assessment**
  - Disturbed zone (DRZ), potential path for nuclide transport
  - Pore-pressurization and host rock percolation
  - Compaction, sealing and healing (solidification)

- **Safety Case**
  - Post-closure SA [4.2], including barrier/safety function
  - Post-closure FEPs [3.3], including host rock/DRZ
  - Confidence enhancement [4.3], including validation

- **Roadmap**
  - THMC model development
  - Model validation against field (WIPP) and lab experiments
  - THMC model demonstration (long-term, GDSA)

- **International**
  - Salt constitutive model development and validation with Clausthal Technical University (Germany)
  - Code verification/validation projects (e.g. BenVaSim)
  - Access to field test data in various salt types (e.g. bedded vs domal salt in Asse Mine URL)
International: Heater Test at Asse Mine

How long does it take until complete solidification of EBS?
Modeling: Long-term Compaction and Sealing

- THMC modeling of compaction and salt dissolution/precipitation effects in backfill (Blanco-Martin et al., 2018)
- Thermal-mechanical-induced compaction and sealing of EBS most important

Modeling WIPP Borehole Experiments

- **Pre-test coupled THM modeling**
  - How much heat load to apply?
  - How much will the borehole close?
  - What inflow rates to expect?
  - Design monitoring (e.g. borehole and sensor locations, mechanical, pressure, ERT)

- **Post-test coupled THM modeling**
  - Model observed brine inflow and closure
  - Calibrate and fine-tune constitutive model parameters (creep and damage)
  - Learn about brine migration (intergranular, intragranular (brine-inclusions), thermal pressurization, damage induced)?
• Damage induced near borehole wall
• Thermal pressurization away from borehole
• High rate of creep closure after heater turn-on
• About 1 cm borehole closure after 90 days heating
• **Highest inflow after heater turn-off due to cooling-induced damage**
• **Can be managed with staged heat reduction**
### Relationship to 2012 UFD Roadmap and R&D Priority Ratings

<table>
<thead>
<tr>
<th>UFD FEP ID No., Title, and Media</th>
<th>Overall Priority Score</th>
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<tbody>
<tr>
<td>2.2.08.01 - Flow Through the Host Rock - Salt</td>
<td>7.73</td>
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<tr>
<td>2.2.08.06 - Flow Through EDZ - Salt</td>
<td>7.73</td>
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<tr>
<td>2.2.08.04 - Effects of Repository Excavation on Flow Through the Host Rock - Salt</td>
<td>7.10</td>
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<td>2.2.01.01 - Evolution of EDZ - Salt</td>
<td>2.58</td>
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- **One of the highest priority ratings in the 2012 UFD Roadmap**
- **Effect of excavation on flow also high rating**
- **Thermal-mechanical compaction and sealing of EBS should be most important for PA and the Safety Case (described in 2012 Roadmap, but not rated)**
More validation efforts against field experiments are critical for better parametrization (parameters for creep and permeability evolution, back-fill compaction)

The planned phased field test coupled with model development and validation will be important

2D cross-section model simulations of DZ and EBS evolution can be done for output to PA model simulations

3D model simulations of single emplacement tunnels can be done, but may not be able to make large number of simulation cases
Questions?
Back-Up Slides (optional)
Heated borehole

TANGENTIAL STRESS (MPa)

TIME (days)

0 50 100 150 200

Initial stress -14.8 MPa

Borehole wall in tension after cooling

Tensile

Compressive

r = 0.35 m

r = 1 m

r = 0.067

creep relaxation

r = 0.17 m