FY18 LBNL Crystalline R&D updates

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Overview of Activity

**Laboratory Study of Excavation-Induced Damage Zone**
- Reproduce and examine the geometry of damage around an excavation (drift tunnels, boreholes)
- Examine the geophysical (seismic) property changes both passively (MEQ/AE) and actively (velocity tomography)
- Determine the hydrological properties of the damage zone
- The hydrological-mechanical-chemical (HMC) changes of the damage zone over time
- Address the scaling problem using the “shaped slab test” method

**Anisotropic Fracture Transmissivity Measurements at Core Scale**
- Constructed apparatus to provide multiple flow paths across a natural fracture to measure potential anisotropic transmissivity
- Problems with damage to fracture edges have potentially caused fast flow paths circumferentially along the edge of the fracture
- Conducting transmissivity measurements on a artificial fracture with known fracture geometry
- Developed improved sleeve design to prevent circumferential flow
- Utilizing CT scanning to verify fracture flow path

Large-scale EDZ of a mine tunnel (Martin, 1997)
Development of an excavation damaged zone (EDZ) around the mined openings of an underground repository represents a potential risk because preferential flow pathways could be created. If this zone develops higher permeability, it could provide a path for transport of radionuclides if released from a waste package.

In a crystalline-hosted repository, fractures are the dominant feature controlling permeability (and thus flow and transport). Models tend to simplify fractures as features with uniform aperture; however, natural fractures are irregular, with anisotropic permeability. Preferential flow will proceed in zones with higher permeability. Use of an “average” fracture aperture may underestimates the permeability of these faster flow pathways.
Integration with GDSA/PA and/or the Safety Case

- The extent and nature of excavation damage zones will depend on the geometry of the excavation, the rock type in question, and the local stress regime.

- Laboratory measurements and associated numerical modeling can provide constraints on the long-term evolution of the hydrological and mechanical properties of EDZs, which are important inputs into GDSA/PA models involving crystalline host rock.

- Core-scale transmissivity experiments provide key insights into flow anisotropy within fractures – can help constrain fracture flow properties in flow and transport models.

- **Output** to the PA model would include the changes in flow properties (e.g. permeability and porosity) in the near-field (including the EDZ) obtained from modeling of damage zone development using TOUGH-RBSN method.
Sample 1—Intermediate damage: Loading stopped before catastrophic failure

- Pre-failure damage in an EDZ can be seen in seismic velocity drops
- Seismically detected damage extends away from visible surface failure
Results (Damage Zone Study)

Sample 2— Extensive EDZ formation (or borehole breakout)

- Spalling failure (breakout)
- Shear band developed during the final, catastrophic failure
- Correlation with AE locations (not shown here)
**Initial confining pressure increase**
- Large transmissivity decrease as fracture “settles”
- Begin to see anisotropy with paths 1-5 and 2-6 showing lower transmissivity

**Repeated cycling of confining pressure**
- Much smaller transmissivity dependence on confining pressure
- Consistent anisotropy results

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**Increasing Confining Pressure**

- Transmissivity vs. Confining pressure
- Paths 1-5, 2-6, 3-7, 4-8

**Decreasing Confining Pressure**

- Transmissivity vs. Confining pressure
- Paths 1-5, 2-6, 3-7, 4-8
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<td>Fractures- Host Rock- Other Geologic Units - Granite/Crystalline</td>
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<td>Effects of Repository Excavation on Flow Through the Host Rock - Granite/Crystalline</td>
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Current State of the Art and Past Accomplishments

Current State of the Art:

- Laboratory Study of Excavation-Induced Damage Zone
  - Shaped rectangular granite slabs provide means to upscale laboratory experiments to drift scale geometries

- Fracture Transmissivity
  - Anisotropic transmissivity observed in natural fractures in core
  - Aperture mapping of artificial and natural fractures to assist modeling efforts

Past Accomplishments:

- Laboratory Study of Excavation-Induced Damage Zone
  - Conducted initial laboratory borehole breakout experiments by using flat, rectangular slabs of novaculite – this extremely fine-grained crystalline rock was selected to reproduce mineral grain size to borehole diameter ratios similar to field conditions
  - Rock was found to be extremely (or excessively) strong; no breakouts were produced

- Fracture Transmissivity
  - Laboratory transmissivity values were much higher than those inferred from field measurements using FFEC method
Scaling of core fracture permeability results can be related to:

- DECOVALEX 2019 Task E - Upscaling of modelling results from small scale to one-to-one scale

Laboratory study of EDZ in core samples can be related to:

- DECOVALEX 2019 Task G - EDZ evolution in sparsely fractured competent rock
- SKB Long Term Sorption and Diffusive Transport Experiment at Äspö
Future R&D & Integration Timeframe

- Laboratory Study of Excavation-Induced Damage Zone
  - Characterization of permeability changes in the samples will be conducted using subcores taken out of shaped slabs
  - More experiments using different types of tight rock are planned
  - Discrete numerical modeling of damage zone development using TOUGH-RBSN (rigid-body-spring network) method is planned
  - Laboratory investigations of the long-term evolution of the hydrological and mechanical properties of EDZs planned

- Anisotropic Fracture Transmissivity Measurements at Core Scale
  - Use improved sleeve design to prevent circumferential flow for repeat experiments
  - Conduct experiment on artificial fracture with known geometry
  - Aperture mapping of fractures to assist modeling efforts
  - Write up journal article summarizing findings of this work
Questions?
Planned EDZ Permeability Tests

Permeability measurement of EDZ using mini cores

- Confining pressure
- Flow-through triaxial cell
- Sample with an “EDZ”
- Mini-core
- Planned coring locations
- Jacket
- Coring drill