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Monitoring and Repair of Damaged Cement-Geomaterial Interfaces in High Pressure, High Temperature Repository and Borehole Scenarios

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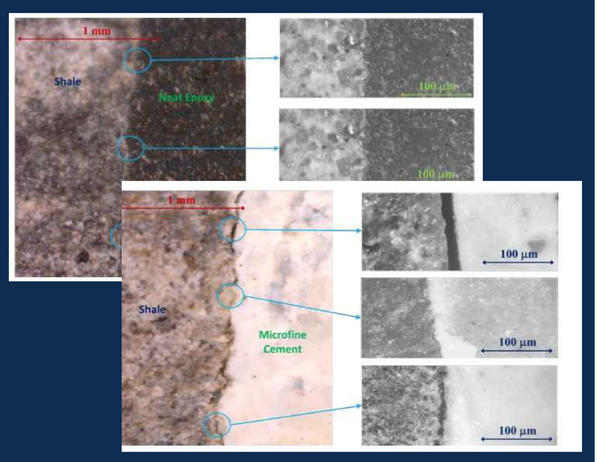
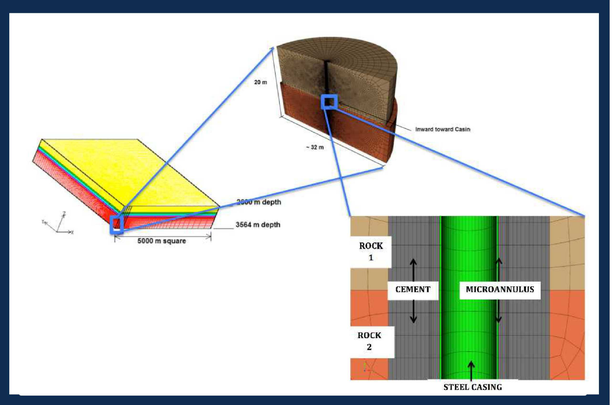
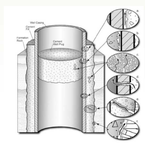




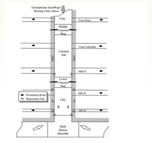
UNM

TEXAS Geosciences
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

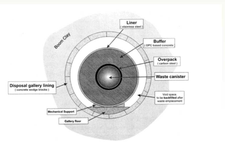
Problem: Seals are guardians of conduits that pass through stratigraphy. When a seal fails there is potential for direct communication between the subsurface, hydrogeologic units, and the surface.



Wellbore Seals



Shaft and Drift Seals

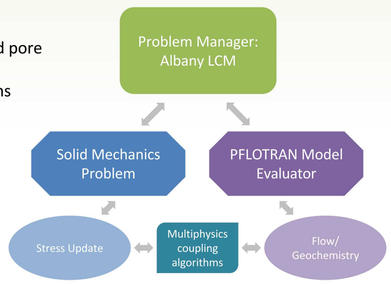


Engineered Barrier System Components

Albany/PFLOTRAN Integration to Couple Solid Mechanics and Reactive Transport

Complete:
- Modified version of PFLOTRAN that is callable by Albany
- PFLOTRAN model evaluators in Albany
- Two way coupling between PFLOTRAN and Albany
- Deformation passed from Albany to PFLOTRAN and pore pressure passed from PFLOTRAN to Albany
- Implementation of multiphysics coupling algorithms

Next Steps:
- Analysis of target problems using Albany built-in material library
- Installation of Kayenta in Albany



Goals and Technical Approach:

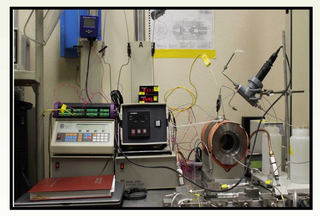
The overarching technical goal for this project is to develop fundamental understanding of cement-geomaterial interfaces via an experimental and modeling study that incorporates chemo-mechanical coupling at high-temperature, high-pressure conditions.

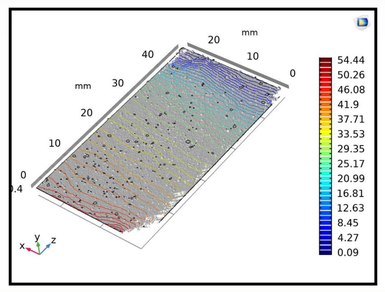
Objectives:

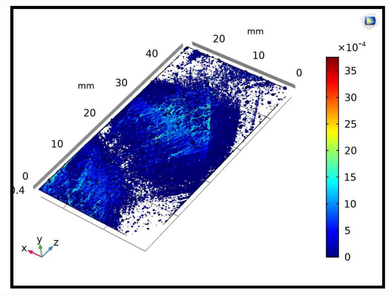
1) Characterize the chemistry and physics of cement-geomaterial interfaces
2) Develop modeling capability for coupled chemo-mechanics
3) Develop and evaluate next-generation seal repair materials suitable for the expected shaft/wellbore environments

Benchtop Flow Experiments to Expose Cement and Geomaterial Samples to *In Situ* Subsurface Conditions

- Cement leaching experiments coupled with ultrasonic techniques to measure cement degradation (*top right image)*
- Cement-geomaterial flow-through experiment at *in situ* temperature and pressure, also (*bottom right image)*
- Advanced analytical methods to characterize cement-geomaterial interfaces, including micro-CT, EDS elemental mapping, and nano-indentation to characterization to measure mechanical properties of degraded cement matrix



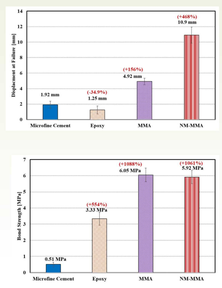




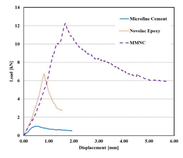
Significance of Results:

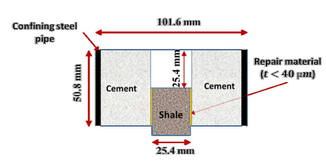
- Greatly advance our fundamental understanding of interface failure, rate dependencies of these processes, and coupled chemo-mechanics at *in situ* subsurface conditions
- Experimentally validated, model-based predictive capability applicable to large domains and long time scales
- Fit-for-purpose seal materials with IP potential and high-utility for subsurface environments

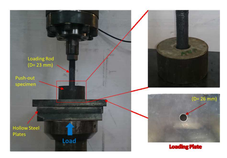
Mechanical Testing/ Seal Repair Material Design



- Bond Strength testing of cement/shale interface (*bottom three images)*
- Development and testing of a new, polymeric seal repair material that outperforms conventional seal repair materials – *Patent filing in process (comparison of materials in 2 images at left).*
- Integrated testing of cement-shale and cement-steel specimens with different size microannulus cracks repaired using polymer nanocomposites.
- Durability testing of polymer-nanocomposite repair materials under brine and chemical exposure with high temperature and pressure.
- Preliminary testing of sensors embedded in cement (in collaboration with UT-Austin BEG partners).





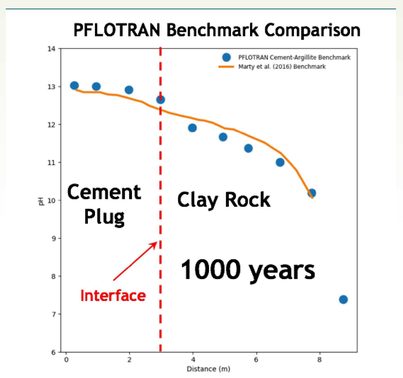


PFLOTRAN Benchmark for Reactive Transport Modeling of Cement-Geomaterial Interfaces

PFLOTRAN reactive transport simulations:
- Full saturation
- Diffusion only
- Isothermal
- Kinetic rate & equilibrium scenarios

Comparison with parameters & results from multicomponent reactive transport between cement – clay rock (Marty et al. 2015)
- Comparison of species concentration with distance profiles across 1-D domain
- Effective diffusivities defined for each medium
- Effects of cement/mineral phase kinetic rate law parameters
- Phase volume fraction & transport parameter sensitivities

Preliminary Results
- Good agreement on pH predictions at 1000 years
- Still working on comparisons with other chemical components



Summary:

- 1D reactive transport modelling of cement-geomaterial interfaces
- Experiments to complement reactive transport
- Experiments to characterize cement degradation and degradation at cement-geomaterial interface
- Advanced characterization to characterize chemical and mechanical alteration of cement-geomaterial interfaces
- Interface testing of cement-geomaterial bond, bond strength testing of novel seal repair materials
- Joint non-provisional patent filed by SNL/UNM teams: *Fit-for-purpose Methyl Methacrylate Nanocomposites (MMNC) for Wellbore Seal Repair and Integrity*.

Built on LDRD Laboratory Directed Research and Development

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