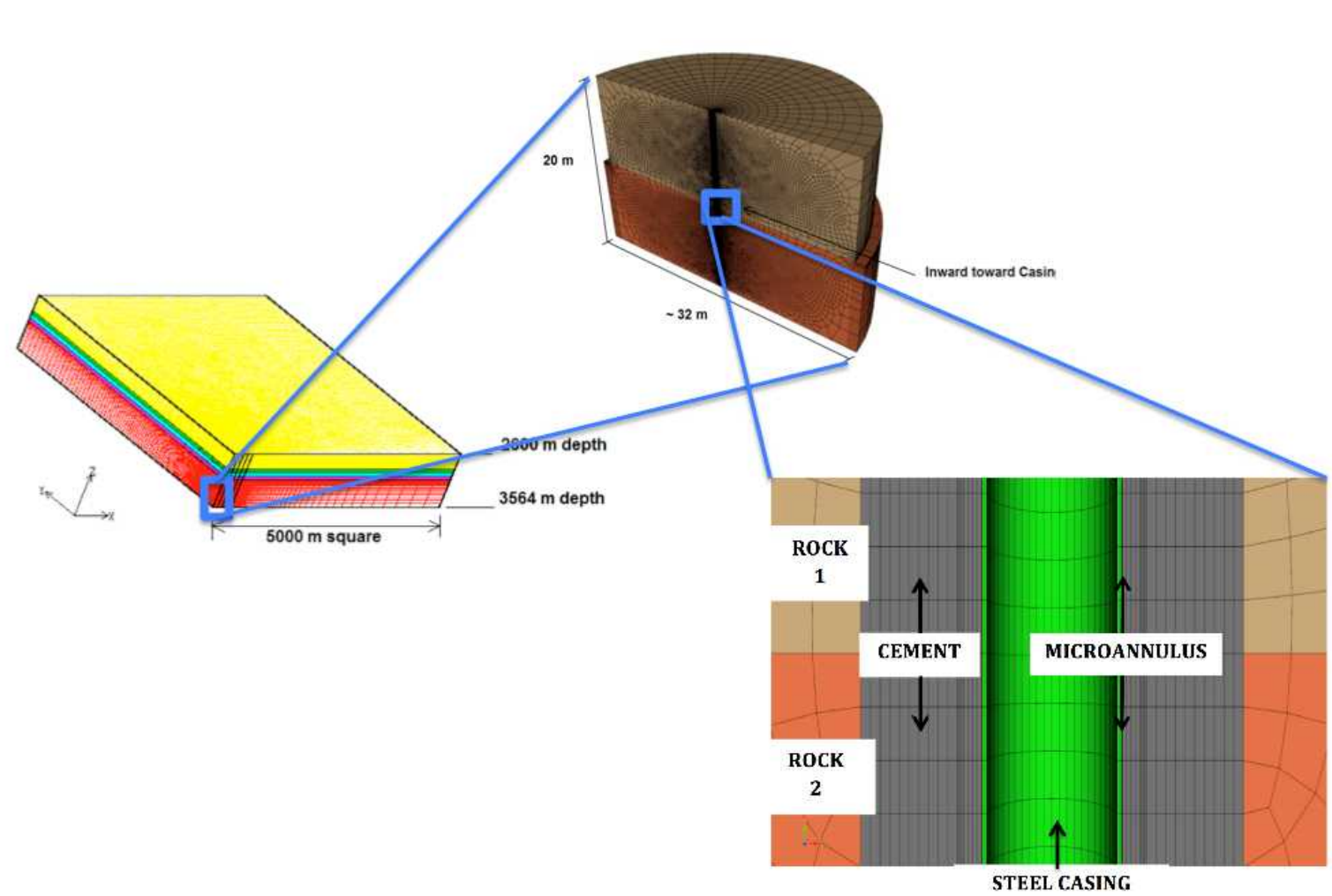
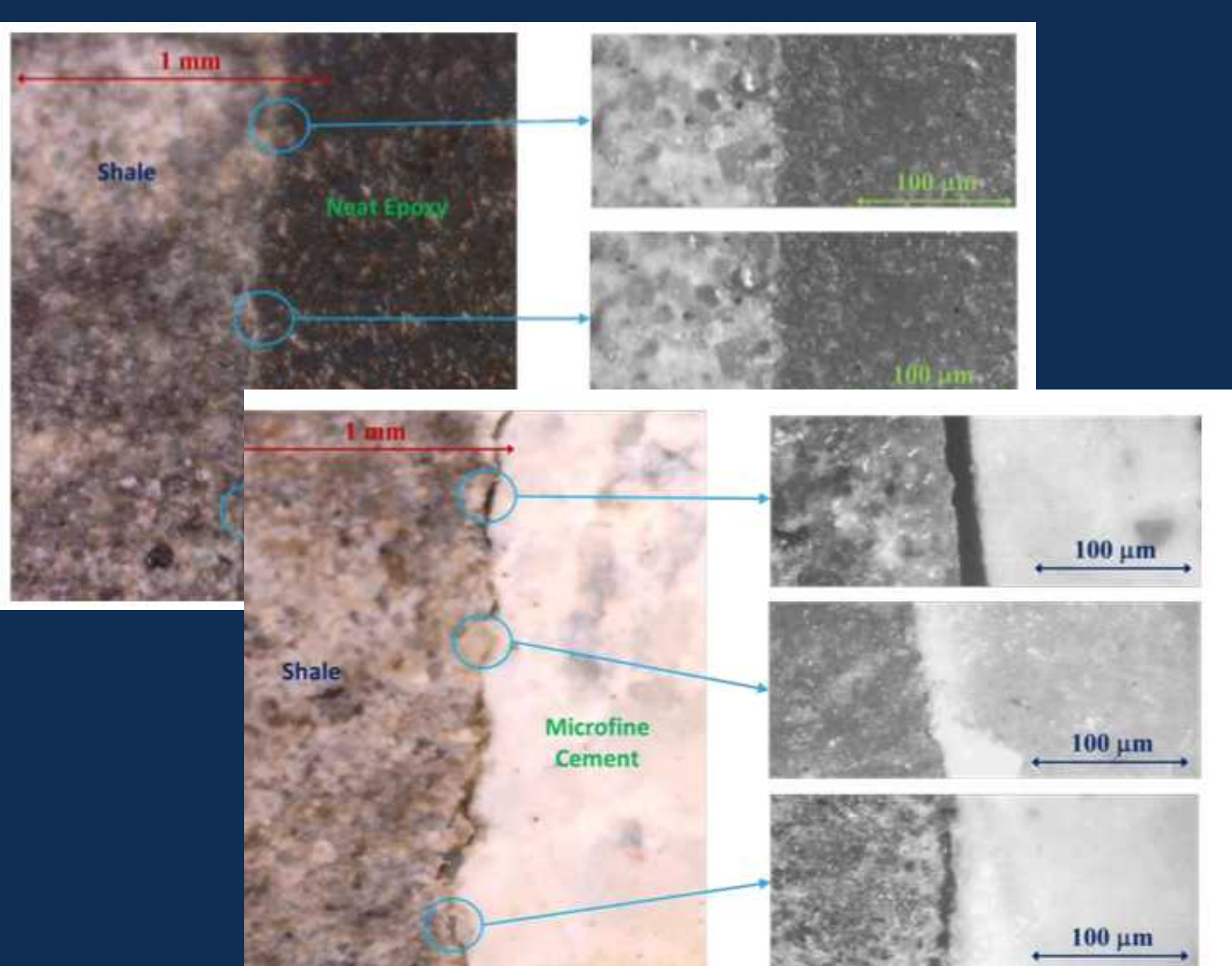
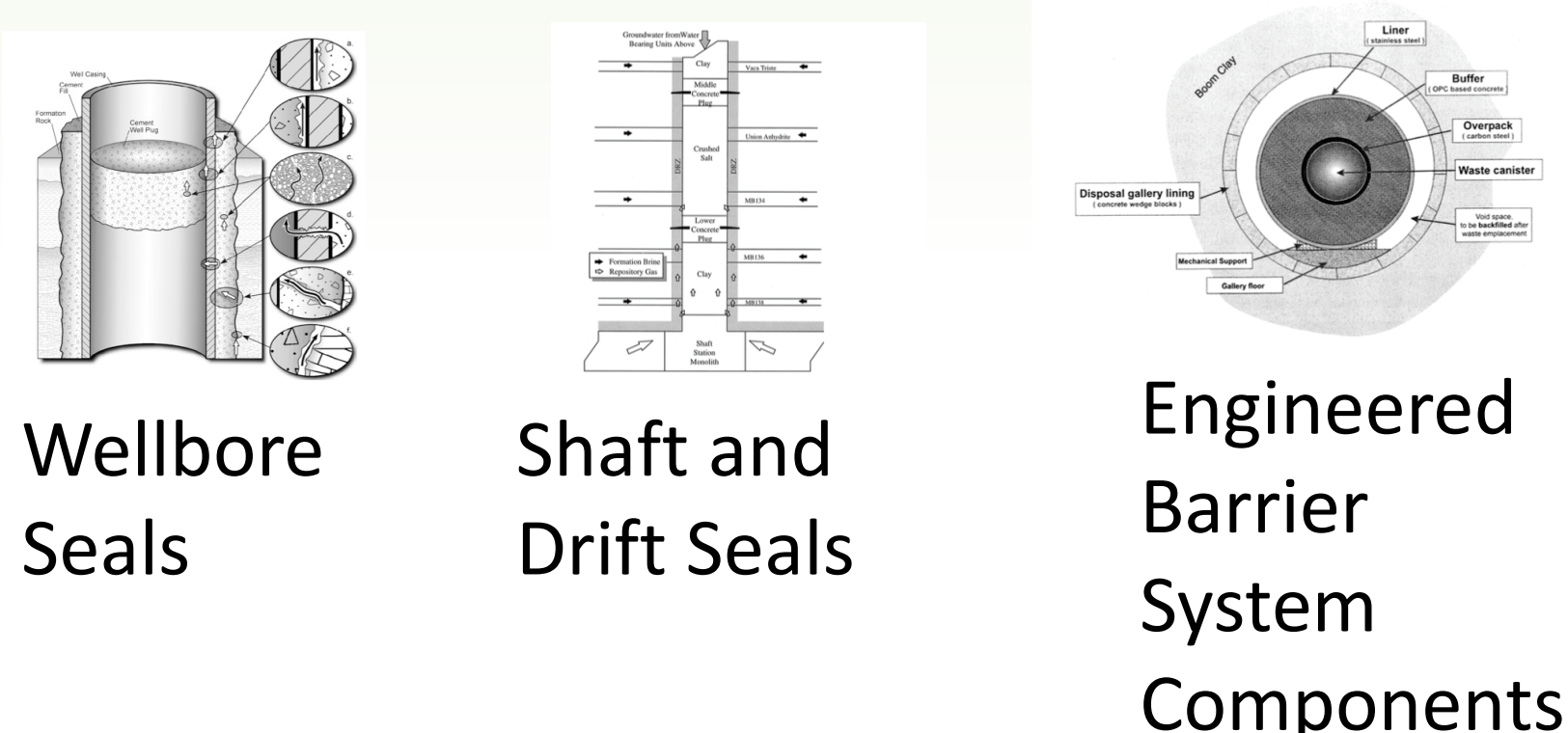


Monitoring and Repair of Damaged Cement-Geomaterial Interfaces in High Pressure, High Temperature Repository and Borehole Scenarios

Ed Matteo, Tom Dewers, Tim Fuller, Carlos Jové-Colón, and Joseph Mohagheghi (SNL)
John Stormont and Mahmoud Taha (UNM)
Jay Kipper and David Chapman (UT-Austin BEG)

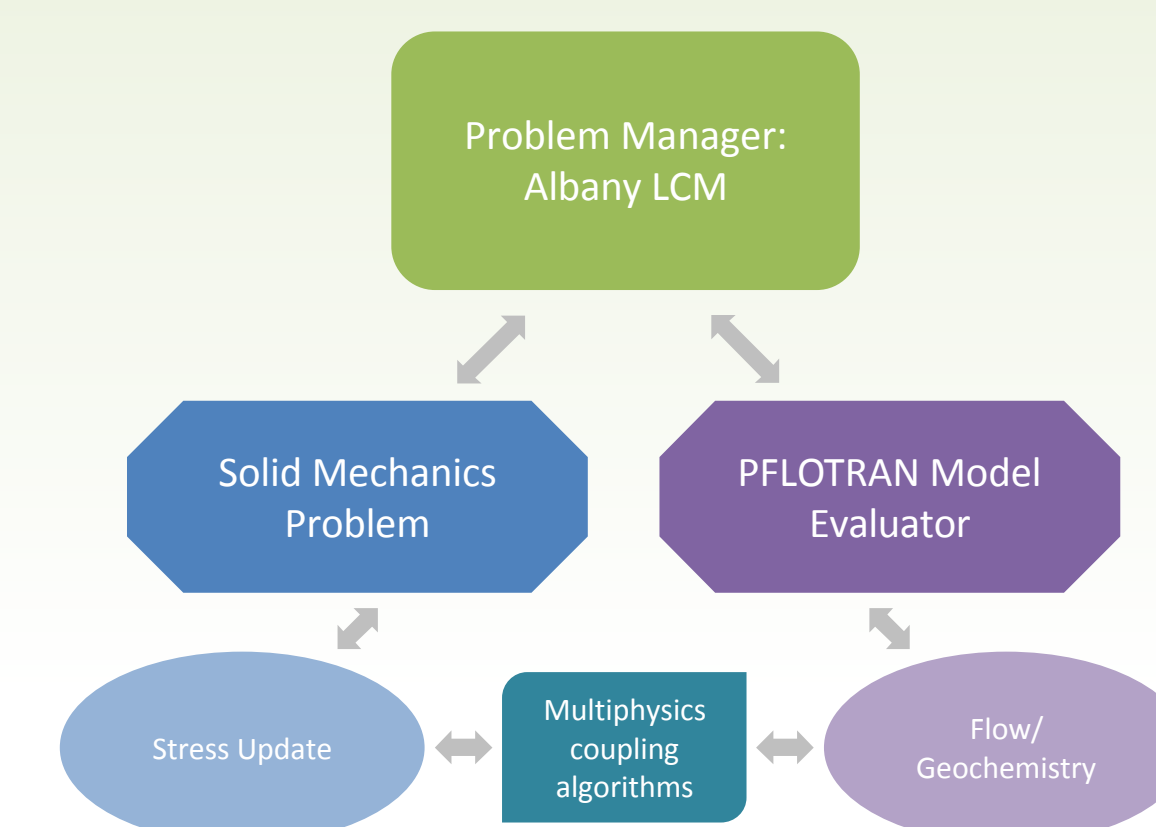


Problem: Seals are guardians of conduits that pass through stratigraphy. When a seal fails there is potential for direct communication between the subsurface, hydrogeologic units, and the surface.



Albany/PFLOTRAN Integration to Couple Solid Mechanics and Reactive Transport

- Modified version of PFLOTRAN that is callable by Albany
- PFLOTRAN model evaluators
- One way coupling from PFLOTRAN to Albany
- Pore pressure passed from PFLOTRAN to Albany
- Implementation of multiphysics coupling algorithms



- Next Steps:**
- Two way coupling
 - Modified timestepping to allow path dependent problems
 - Installation of Kayenta in Albany

Goals and Technical Approach:

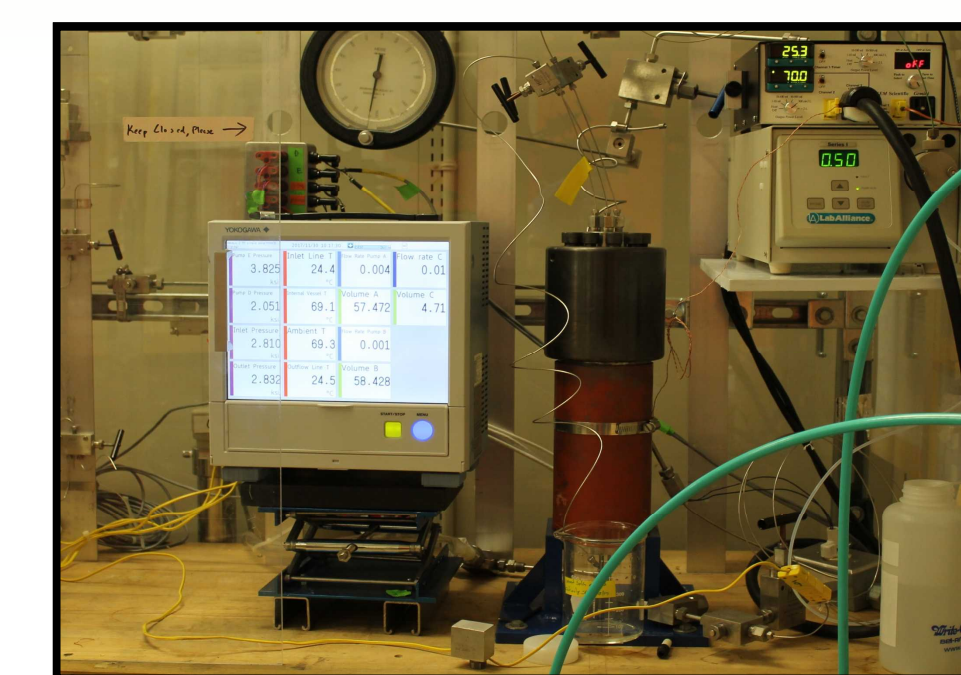
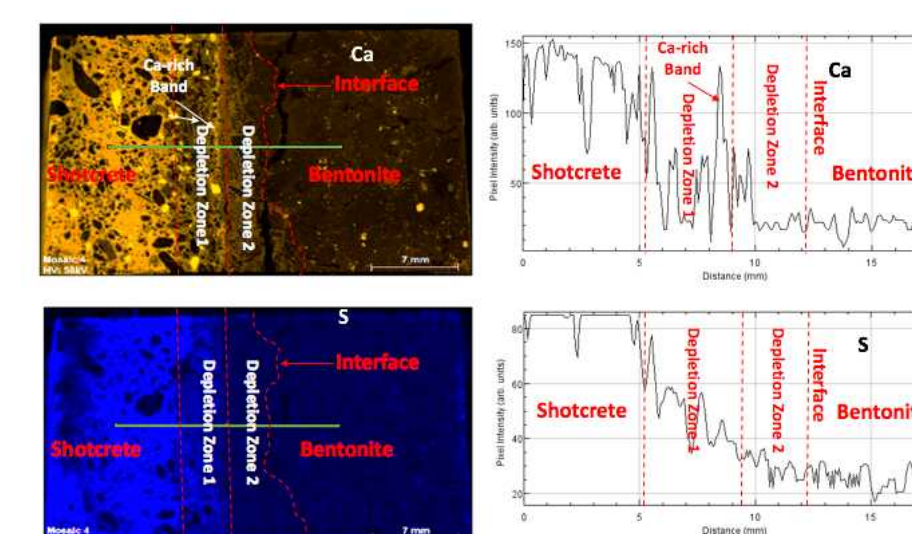
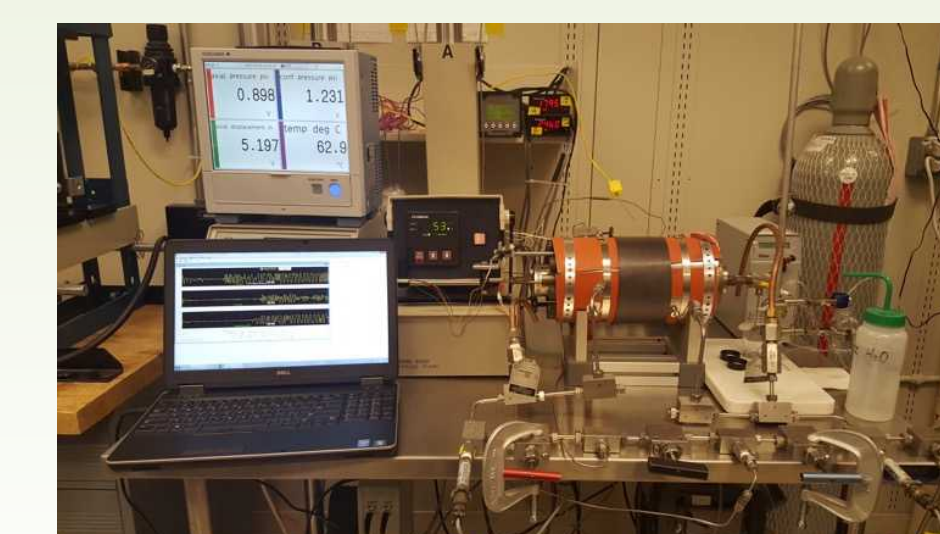
The overarching technical goal for this project is to develop fundamental understanding of cement-geomaterial interfaces via an experimental and modeling study that incorporates chemo-mechanical coupling at high-temperature, high-pressure conditions.

Objectives:

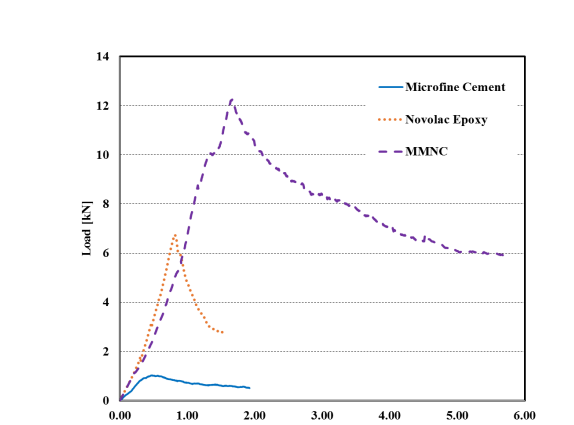
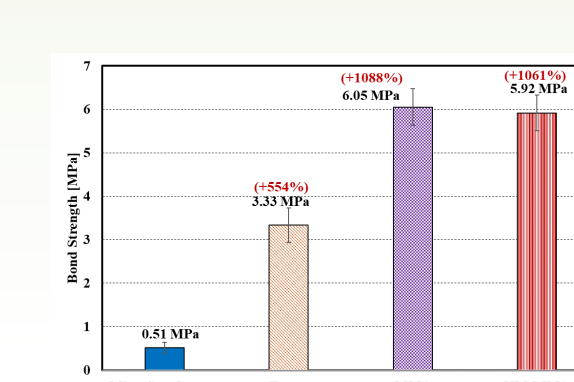
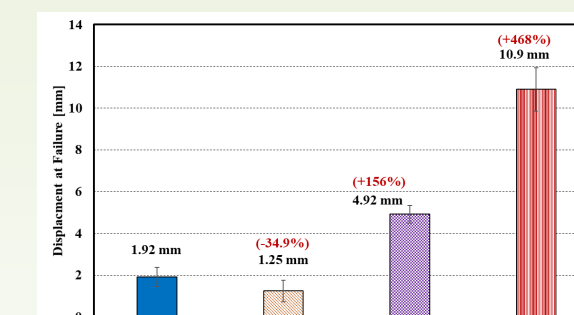
- 1) Characterize the chemistry and physics of cement-geomaterial interfaces
- 2) Develop modeling capability for coupled chemo-mechanics
- 3) Develop and evaluate next-generation seal repair materials suitable for the expected shaft/wellbore environments

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

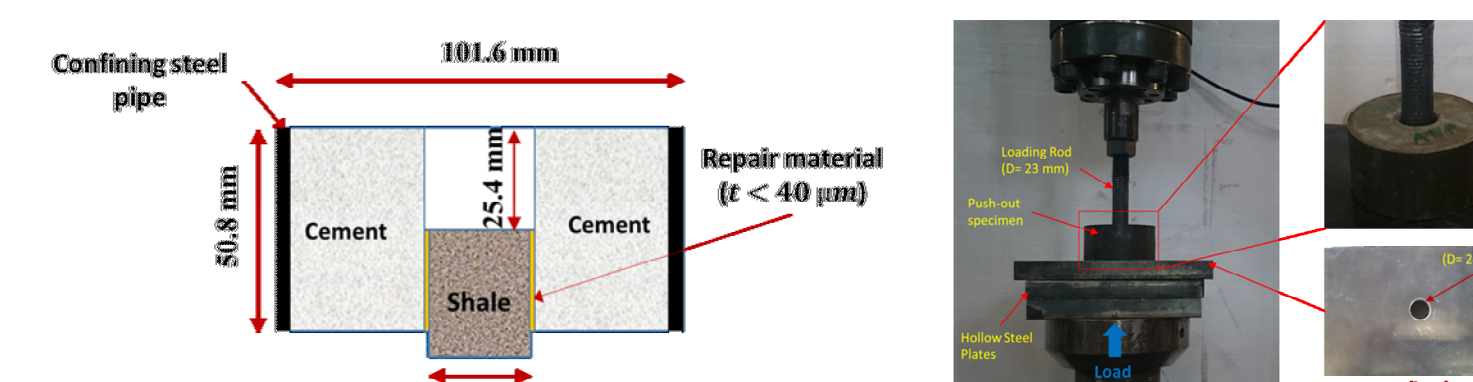
- Cement leaching experiments coupled with ultrasonic techniques to measure cement degradation (top right image)
- Cement-geomaterial flow-through experiment at in situ temperature and pressure, also (bottom right image)
- Advanced analytical methods to characterize cement-geomaterial interfaces, including micro-XRF of FEBEX shotcrete-clay interface (below), and high-throughput multi-beam Scanning Electron Microscopy (mSEM) Mapping of Interface Pore Structure
- Nano-indentation to characterize to measure mechanical properties of degraded cement matrix



Mechanical Testing/ Seal Repair Material Design



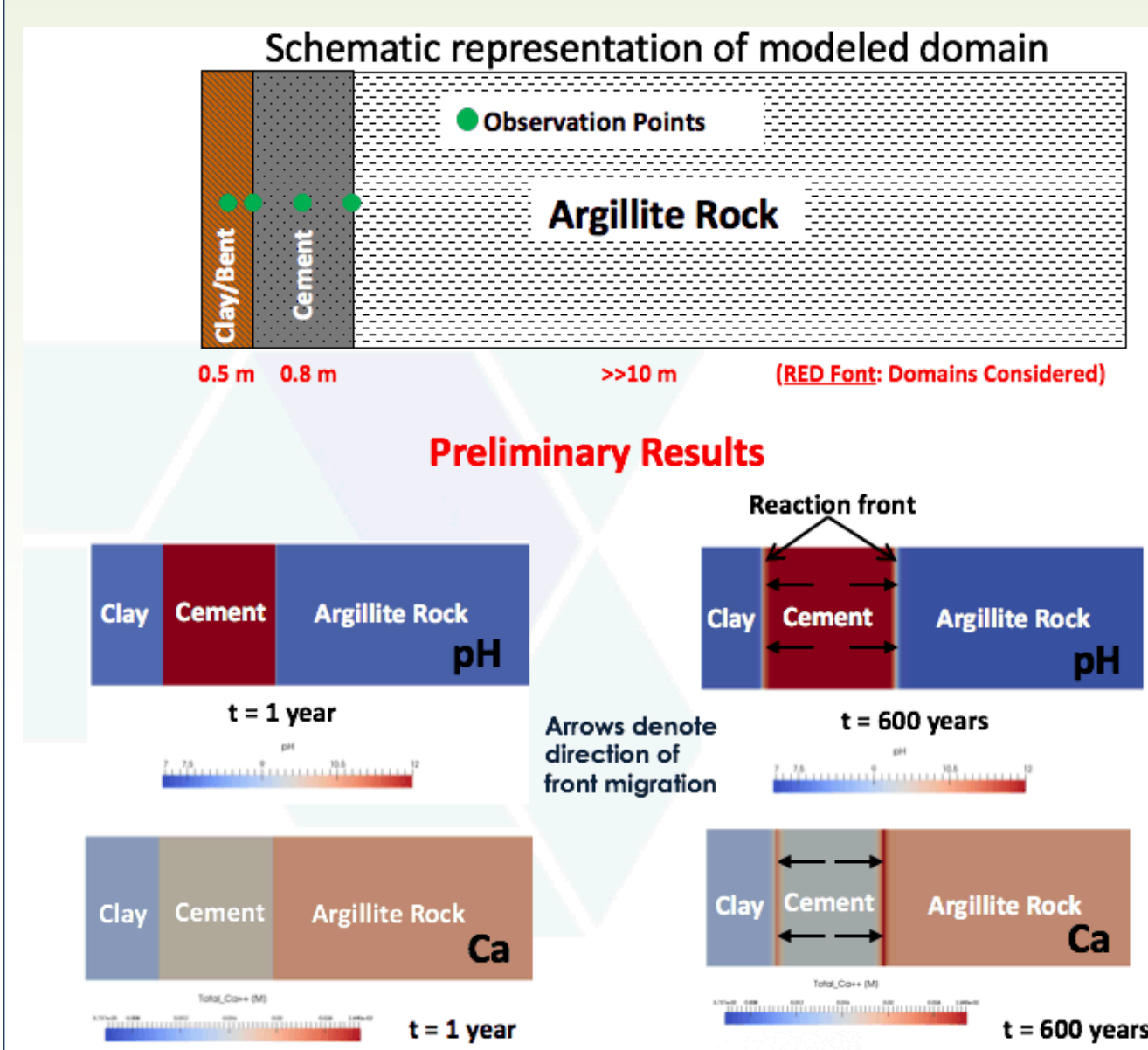
- Bond Strength testing of cement/shale interface (bottom three images)
- Development and testing of a new, polymeric seal repair material that outperforms conventional seal repair materials – Patent filing in process (comparison of materials in 2 images at left).
- Integrated testing of cement-shale 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).



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

PFLOTRAN for Reactive Transport Modeling of Cement-Geomaterial Interfaces



- 1D reactive-transport PFLOTRAN simulations:**
- Simulate development of reaction front between cement and interfacing materials
 - 3 material domains: clay/bentonite, cement, clay-rock
 - 3 distinct pore solution chemistries
 - Cement resembling OPC composition: portlandite, CSH(1.6), calcite, and ettringite
 - Focus on reactivity at interfaces and reaction front migration
 - Next → Interrogate simulation results:
 - Pore solution chemistry
 - Secondary phases
 - Influence on porosity

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 Technical Advance filed by SNL/UNM teams: *Fit-for-purpose Methyl Methacrylate Nanocomposites (MMNC) for Wellbore Seal Repair and Integrity.*

