

# Design of Fit-for-Purpose Cement to Restore Cement-Caprock Seal Integrity



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## 1) Overview and Background

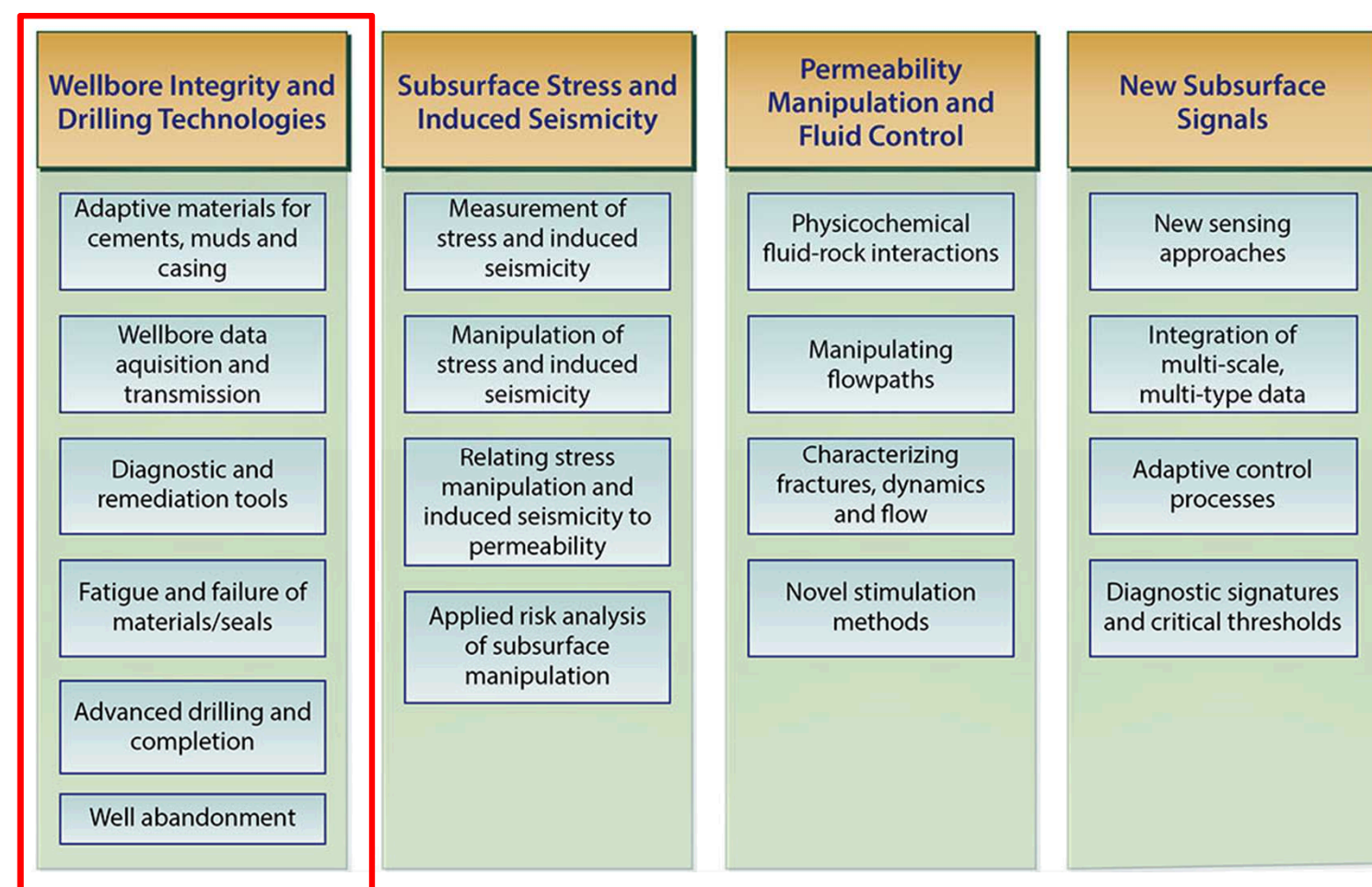


Figure 1. SubTER pillars (vertical columns enclosed in green boxes) – the Wellbore Integrity and Drilling Pillar is pertinent to this study.

This project aims to complete a scoping study of critical research needs in the area of rock-cement interfaces, with a special focus on crosscutting applications in the Wellbore Integrity Pillar of the SubTER initiative. This study will focus on linking institutional capabilities to design and test fit-for-purpose cement formulations.

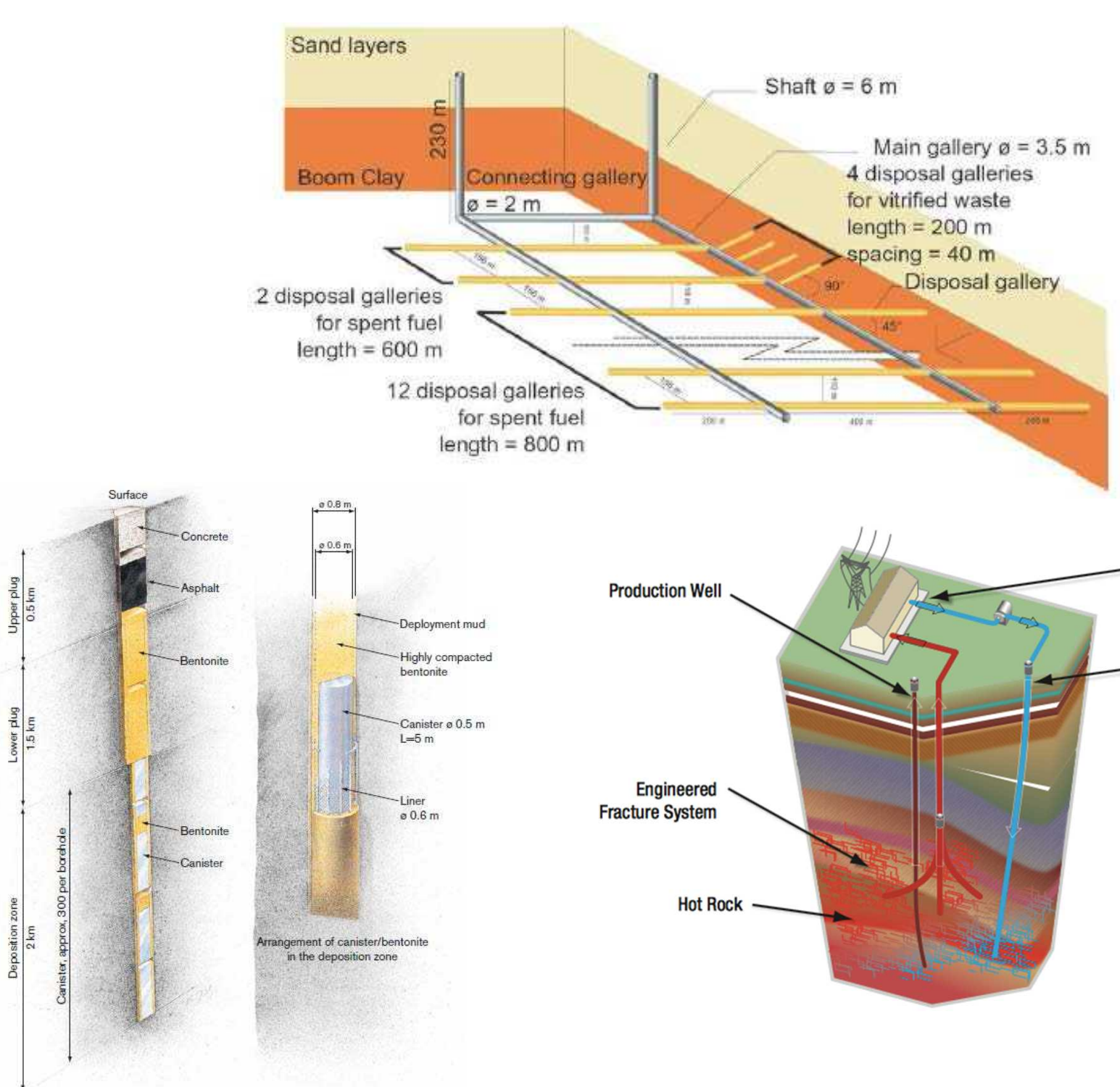
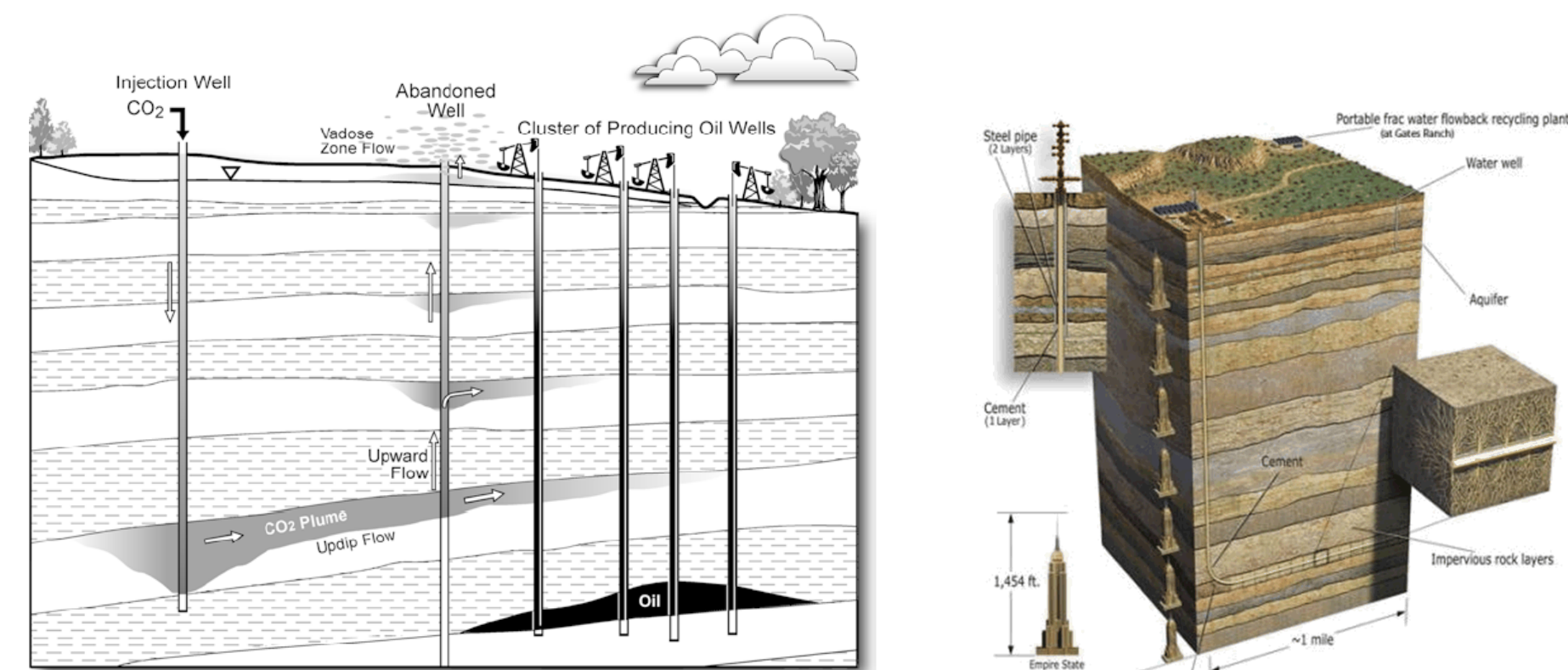


Figure 1. Cement-rock interfaces are critical in a number of subsurface engineering applications, including geologic carbon storage, oil and gas production, nuclear waste disposal (both mined and deep bore hole disposal), and enhanced geothermal energy production. Design parameters for cementitious materials will be specific to technology and geologic setting.

## 2) Goals and Objectives

The goals of this project are as follows:

- 1) perform preliminary study of dispersing nanomaterial admixtures in Ordinary Portland Cement (OPC),
- 2) characterize the cement-rock interface, and
- 3) identify potential high-performance cement additives that can improve sorption behavior, chemical durability, bond strength, and fracture toughness, as appropriate to specific subsurface operational needs.

## 3) Testing Cement-Shale Bond Strength

### Sample Preparation

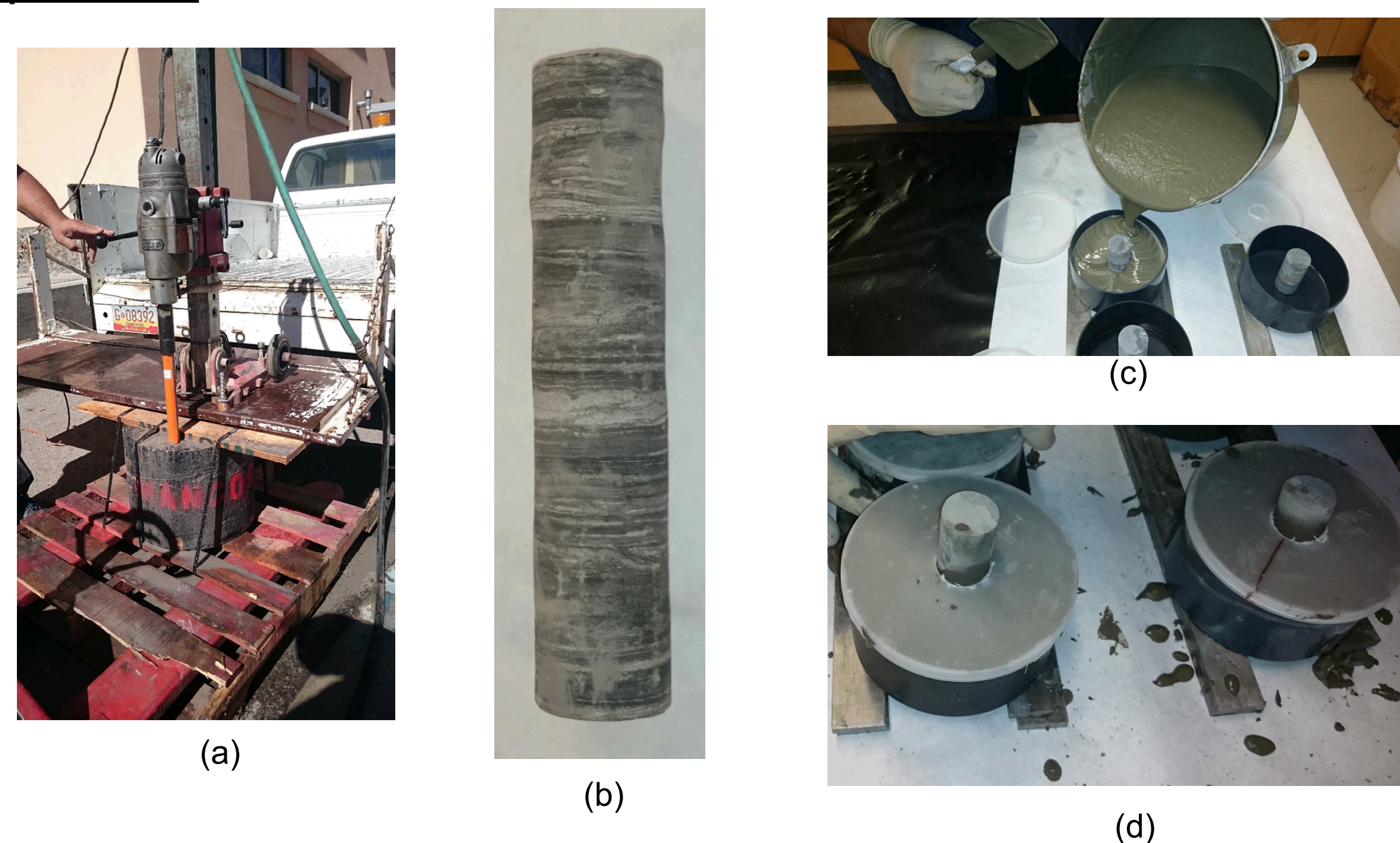


Figure 2. Sample preparation proceeds through several steps: First, shale samples are cored into 1 inch cylinders, as shown in (a) and (b). Next, cement-shale samples are prepared by casting a cement annulus around the shale core in a custom mold, shown in (c) and (d). Samples are then ready for push-out testing (see below).

### Push-out Test to Determine Cement-Shale Interface Strength

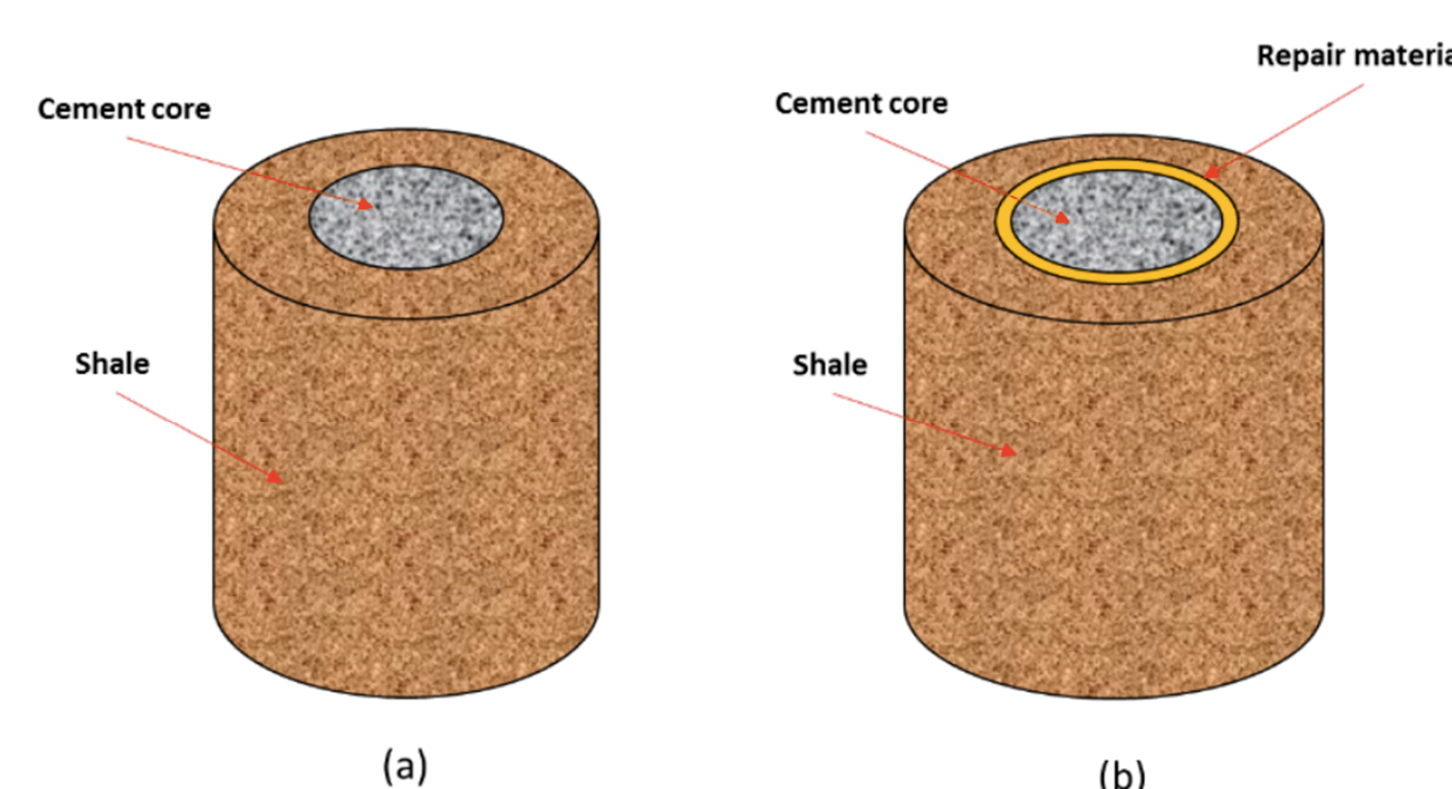


Figure 3. Test specimens can be prepared to test the cement-rock interface, as shown in (a), or to test the performance of specific repair materials injected into the cement-rock interface, as shown in (b).

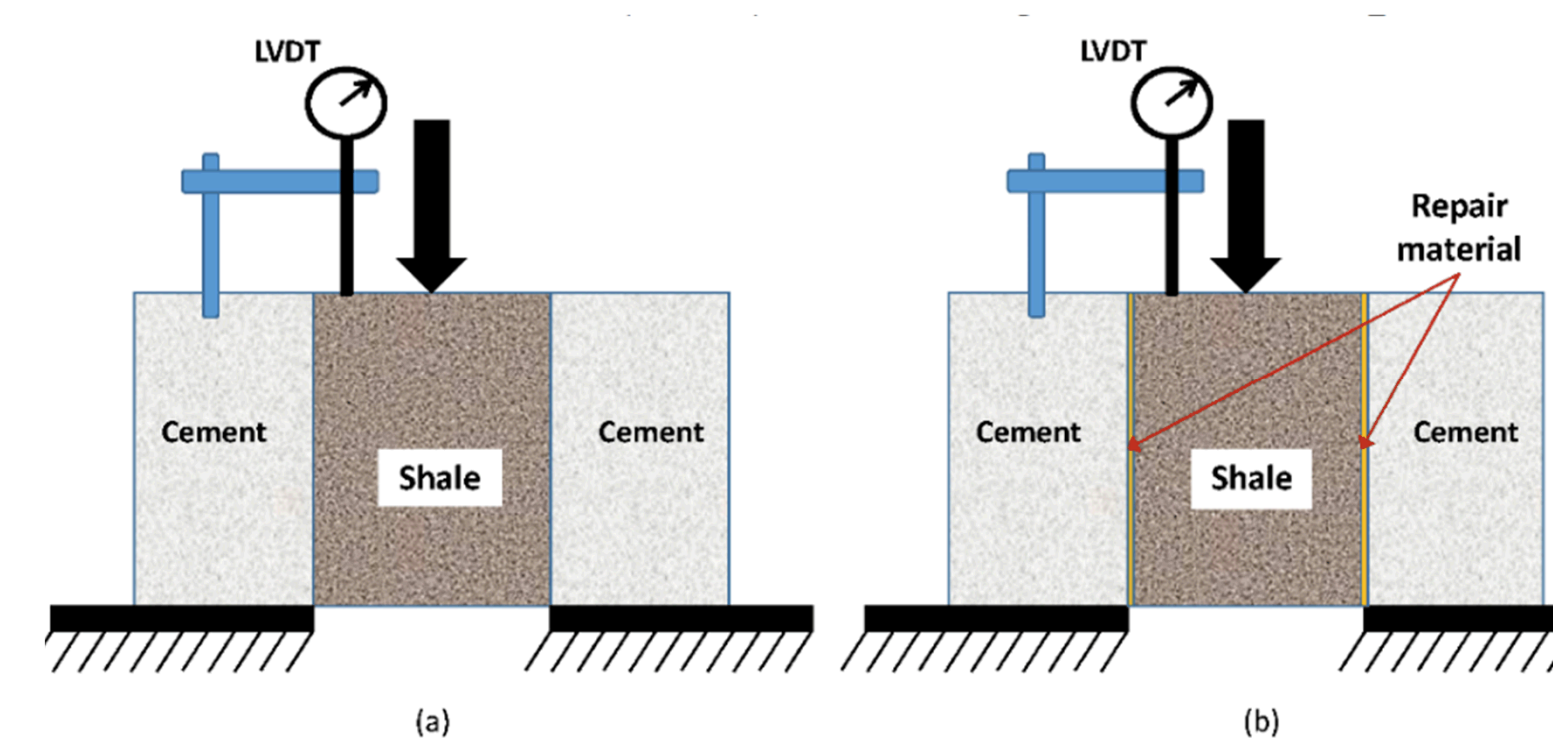


Figure 4. Push-out tests can be performed on the cement-rock interface, as shown in (a), or to test the performance of specific repair materials injected into the cement-rock interface, as shown in (b).

## 4) Modeling Bond Strength Tests

Computational modeling is being used to complement bench-top mechanical testing of bond strength (i.e., push-out tests). This approach will allow for verifying the applicability of this test method to characterize bond strength, as well as to better understand limitations of the measurement technique.

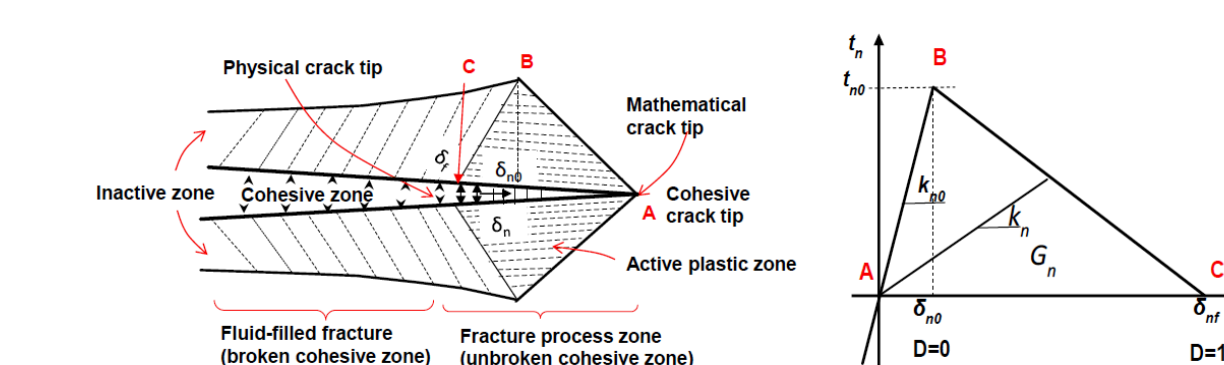


Figure 5. Cohesive zone modeling will be used to understand the failure behavior of the cement-formation interface based on the law of traction separation. According to the cohesive zone method, the interface will fail, or separate, when a critical traction is applied (imgae courtesy of Wang 2014).

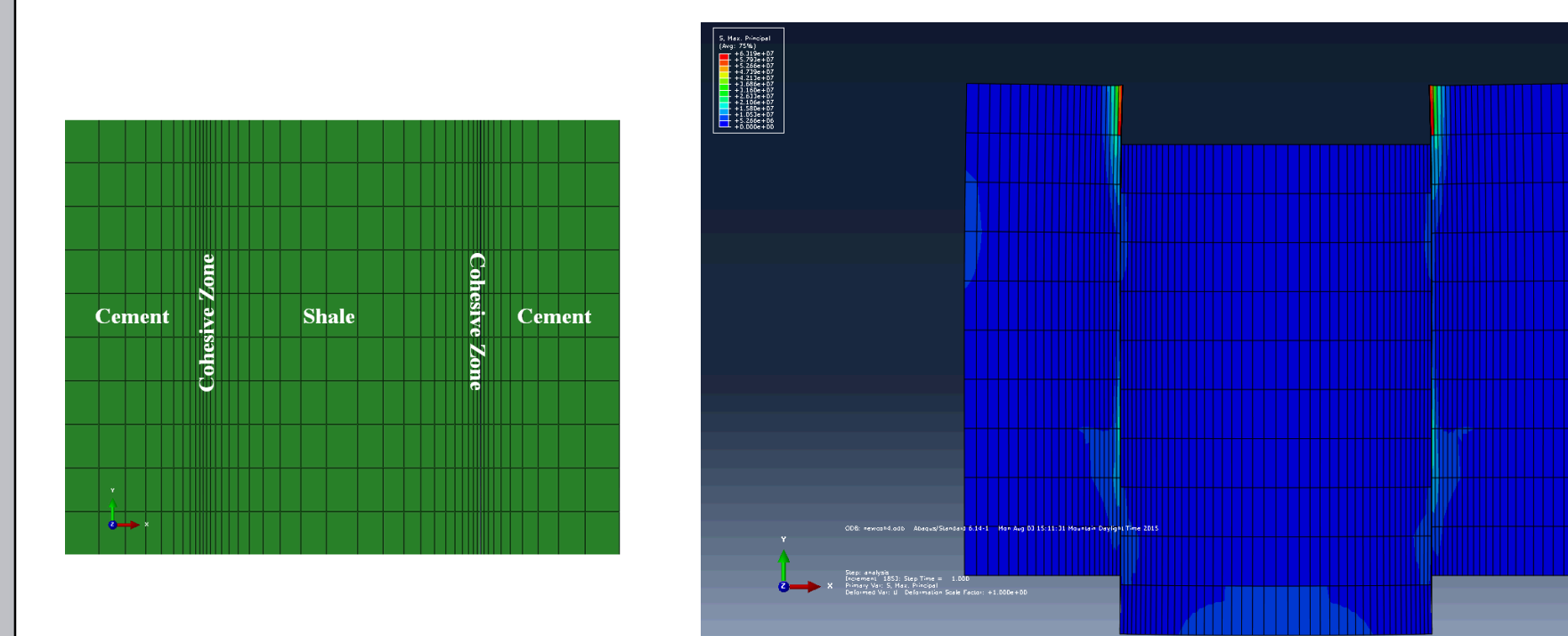


Figure 6. As a first approximation ABAQUS was used to setup a simple finite element model of the push out test.

## 6) Next Steps

Run mechanical tests on matrix of cement formulations to identify admixture effects on bond strength.

Refine and validate computational tools, compare bench-top tests with simulation.

## References

Gasda, S., M. Celia, and S. Bachu (2004). Spatial characterization of the location of potentially leaky wells penetrating a deep saline aquifer in a mature sedimentary basin. *Environmental Geology*. Vol. 46, 6-7, 707-720.

Hardin, E., J. Blink, H. Greenberg, J. Carter, M. Dupont, M. Sutton, M. Fratoni, R. Howatrd. *Generic Repository Design Concepts and Thermal analysis (FY11)*. SAND Report: SAND2011-6202. Sandia National Laboratories.

Ladva, HKJ, Craster, B. Jones, TGI, Goldsmith, G. Scott, D (2005) The Cement to Formation Interface in Zonal Isolation. *SPE Drilling & Completion*, 20 (3), 186-197.

USDOE-EERE, 2008. *An Evaluation of Enhanced Geothermal Systems Technology*.

Wang, Wei (2014). *Emergence of Delamination Fractures Around Casing and Its Stability*. PhD Thesis. University of Wyoming.

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