Intermediate-Scale Hydraulic Fracture and Stimulation Field Laboratory in a Deep Mine for the Investigation of Induced Seismicity and Fracture Flow

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OBJECTIVES

Investigate relationship between fractures (natural and induced) and stress field, rock fabric, and stimulation approach to inform engineering of fractures for EGS and other energy applications.

Investigate microseismicity arising from fracturing as analog for deep basement-rock induced seismicity underlying deep injection sites.

Carry out laboratory experiments and modeling to complement field studies.

Evaluate sites for a deep mine SubTER field-test facility, e.g., at SURF (see below), the Edgar Mine (CO), and others.

Establish the first SubTER field-test facility at SURF, with the name

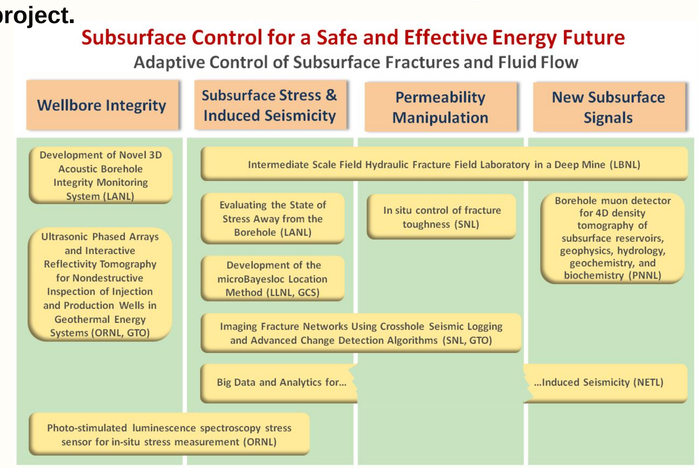
kISMET = permeability (k) and Induced Seismicity Management for Energy Technologies

BACKGROUND

SubTER Crosscut = DOE effort to integrate subsurface research across the FE (oil, gas, and geologic carbon sequestration), EERE (geothermal), and NE (nuclear waste and energy) offices.

The overall goal of SubTER is to develop ways to adaptively control fracturing and fluid flow.

Four pillars of research have been defined, and 10 seedling projects have been funded, among which is this project.



METHODOLOGY

Select a site to drill and core borehole(s) for fracture stimulation and monitoring

Characterize the site

- Lithology, rock fabric, structure, hydrology
- Stress state (local and mine-wide), e.g, using extensive existing borehole breakout data
- Existing fractures (map orientations, size, aperture, etc.) at the site

Instrument the site and surroundings to monitor fracturing, seismic response, and to characterize and image the resulting fracture(s)

Carry out coupled hydrogeomechanical modeling of stress, fracturing, and fluid flow (pre-injection and interpretive)

Carry out hydraulic fracturing in the borehole

Carry out flow tests (e.g., permeability and tracer testing) to characterize stimulated permeability

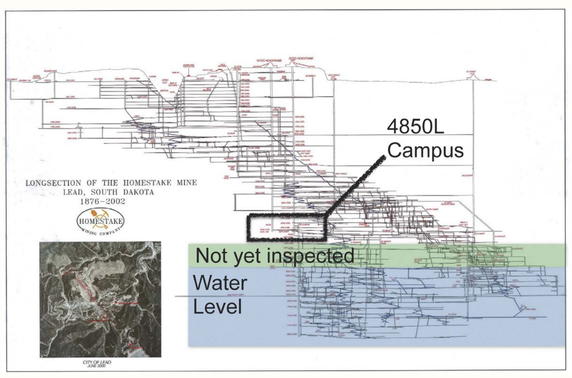
Analyze seismic, ERT, induced seismicity data to characterize fracture(s)

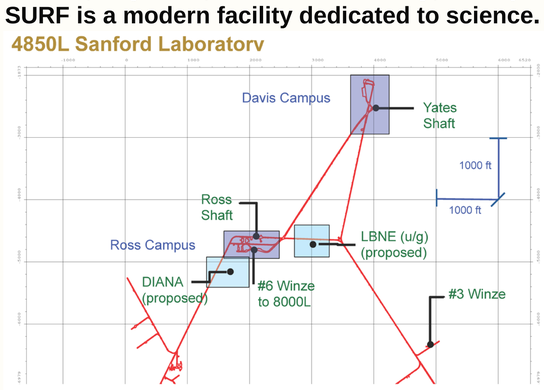
INITIAL SITE IS THE SANFORD UNDERGROUND RESEARCH FACILITY (SURF)

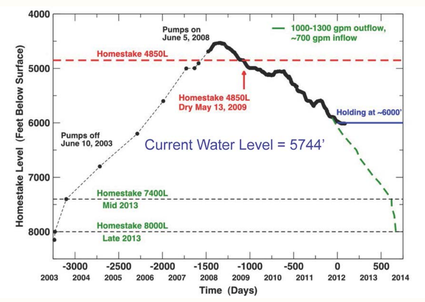
SURF is located in the old Homestake Gold mine in Lead, SD. SURF was founded in 2009 with NSF funding. DOE assumed responsibility for SURF in FY12, with LBNL providing management and oversight through a contract to the South Dakota Science and Technology Authority (SDSTA).

Key staff at LBNL/UCB and SDSTA work under DOE support maintaining and overseeing facility operations, engineering, science, and EH&S.

DOE's interest is principally physics (e.g., LUX Dark Matter, Majorana, Double Beta Decay, LBNE). With approx. ten years of physics research history, SURF is a modern facility dedicated to science.







Brief Description of SURF

Deep (>8000 ft) gold mine operated for over 100 years

Extensive workings, boreholes, core, geologic database

Crystalline Pre-Cambrian schist and amphibolite

The rock is intensely folded, moderately fractured, very hard, low-permeability

There are two shafts (Yates and Ross) for access

The maintained physics labs are at the 4850 ft level

There is plenty of space at the 4850 ft and 4100 ft levels.

QUESTIONS BEING ADDRESSED

How does the stress field vary as influenced by extensive workings, from large- scale (mine-wide) to intermediate scale (kISMET site) ?

How does rock fabric (e.g., foliation in schist) affect fracturing under a given local stress field?

How do existing fractures affect fracturing and stimulated permeability?

Can distributed permeability be created in a foliated crystalline rock?

Can permeability be controlled, e.g., to eliminate fast-flow paths, by injection of engineered fluids?

Can Continuous Active Source Seismic Monitoring (CASSM) and near-real time ERT be used to image fracture dynamics? What are the best methods to image fracture generation in real time?

Can induced microseismicity be used to map the fracturing process, and how does that seismic energy propagate within the deep mine?

Can upscaling of geomechanical properties of core from the site upscale to agree with intermediate-scale rock properties measured during fracturing at kISMET?

RESULTS AND ACCOMPLISHMENTS

Reached out to researchers with long experience at SURF and built relatively large university and national lab team for initial characterization and follow-on scope (seedling extension proposal).

Visited SURF to tour prospective kISMET sites on the 4850L and 4100L.

Selected prospective site on the 4100L for Phase 2 (FY16-funded) activities.

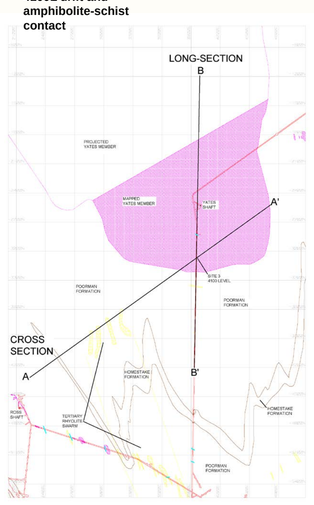
Requested and received bids for alcove excavation, drilling, and coring.

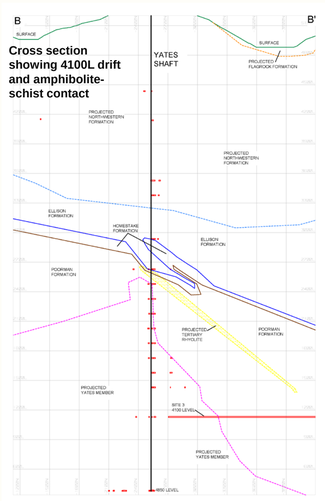
Wrote seedling extension proposal for Phase 1 activities.

Submitted abstract to the SURF Science Conference to be held in May in Rapid City, SD.

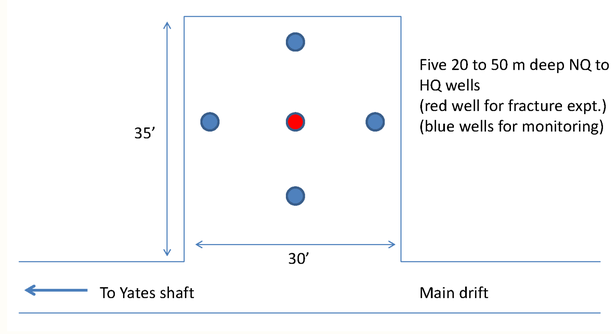
Developed concept for test configuration.

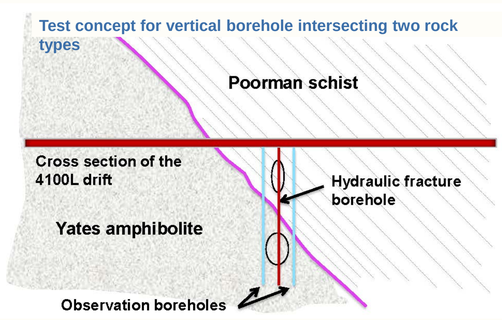
Long section of the 4100L drift and amphibolite-schist contact





Plan view of possible layout on 4100L





COLLABORATORS AND SEEDLING EXTENSION PROJECT SCHEDULE

Univ. of Wisconsin (Wang), Golder (Doe), Stanford (Zoback) In LBNL budget: Stress field at the mine using existing data

SDSMT (Roggenthen) In LBNL budget: Site characterization, site development, stress field

SNL (Moo Lee) In LBNL budget: Fracturing, stress characterization)

LLNL (White, Morris) Existing seedling: microBayesloc for locating seismic events; seismic scatterers

LANL (Coblentz, Johnson) Existing seedling: stress state from plate to local scale

Internal funding: Seismic monitoring

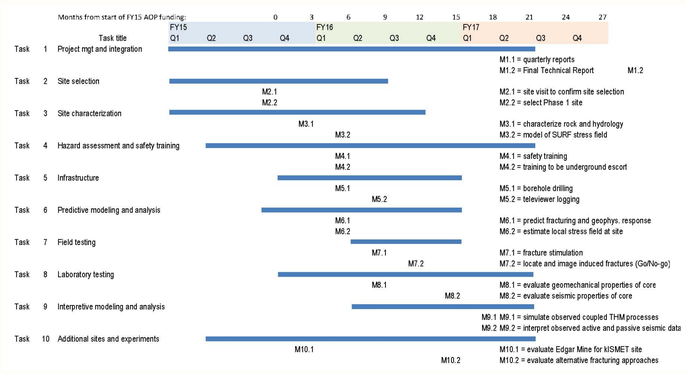
Also funding LBNL from LANL seedling for data acquisition and transfer

INL (Huang, Mattson) In LBNL budget: discrete fracture modeling

PNNL (Johnson, Brown) In LBNL budget: near-real time ERT, fiber optic, tracers

NETL (Rose, Bromhal) Existing seedling: assimilation and analysis of induced seismicity data

Gantt chart for proposed seedling extension



ACKNOWLEDGMENTS

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