Geothermal Technologies Office 2017 Peer Review

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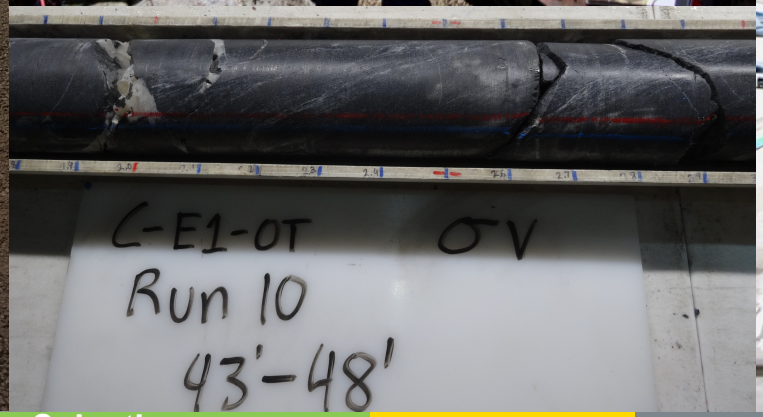



# EGS Collab Project (Task 2/7): Site Selection, Preparation, Drilling and Coring, Characterization (EGS Experiment 1)

Project Officer: Lauren Boyd

Total Project Funding: PY1 - $9M, PY2 – $10.7M

November 13, 2017

**Task PI Patrick Dobson (LBNL) and the EGS Collab team**

Track 2: EGS Collab

# Relevance to Industry Needs and GTO Objectives



The primary objectives of our project are to:

- Develop **~10 m-scale field sites** where the subsurface modeling and research community will establish **validations** against controlled, small-scale, **in-situ experiments focused on rock fracture behavior, permeability enhancement, and fluid flow**.
- Provide the opportunity for **reservoir model prediction and validation** and **in-depth fracture characterization**
- Identify and quantify the **nature of stimulation** (e.g., hydraulic fracturing, shear stimulation, mixed-mode fracturing, thermal fracturing) and other key governing parameters that impact permeability.
- Test **novel monitoring methods** to detect fracturing and fluid flow, and constrain coupled process models

# Relevance to Industry Needs and GTO Objectives



Task 2 is an integrated component of this project:

- Site selection, test bed preparation and characterization, geologic framework model and drilling based on needs for Experiment 1 (hydrofracturing and flow experiments)
- Key input provided by:
  - Task 3 (test and monitoring design and modeling)
  - Task 4 (hydraulic stimulation)
  - Task 5 (interwell flow test)

The expected outcome of this project is:

- Prepare, validate, and improve **tools for FORGE and EGS**
- The end result will **accelerate a commercial pathway to future deployment of EGS resources**

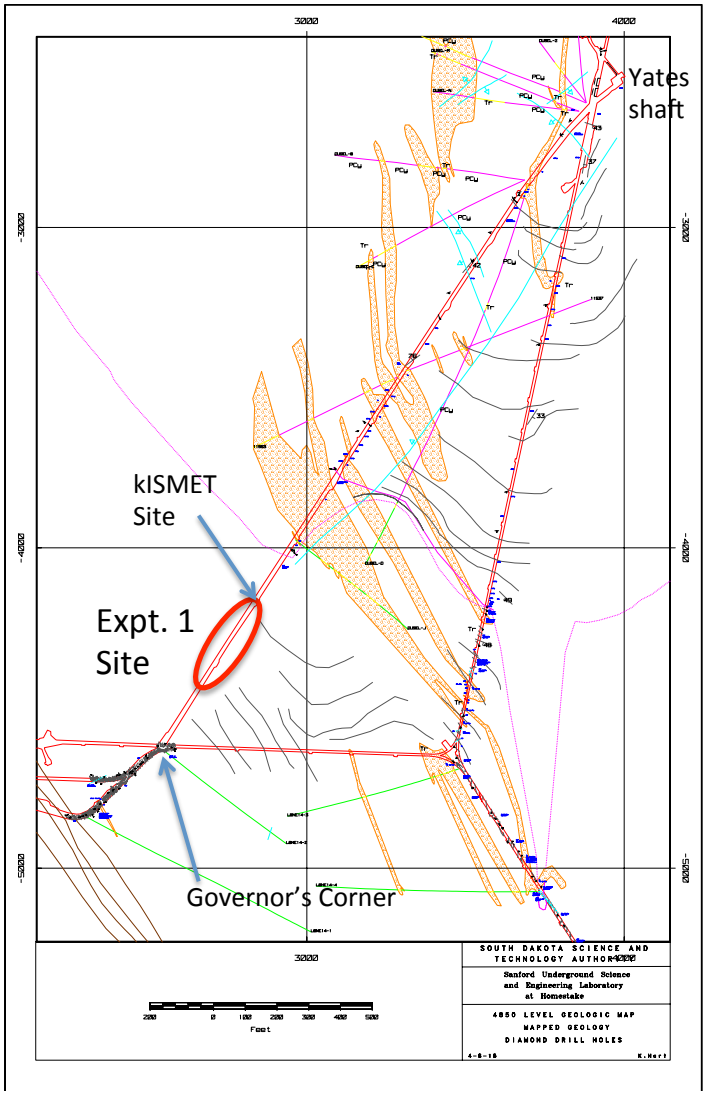
# Methods/Approach – Task Overview



In Task 2, we will develop a test bed for Experiment 1

Key activities include:

- Select and characterize a test site
- Perform pre-stimulation modeling
- Design and prepare the test bed
- Drill needed boreholes
- Collect new detailed site information from boreholes and cores
- Construct a geologic framework model




4850 level, Sanford Underground Research Facility

# Methods/Approach – Site Selection

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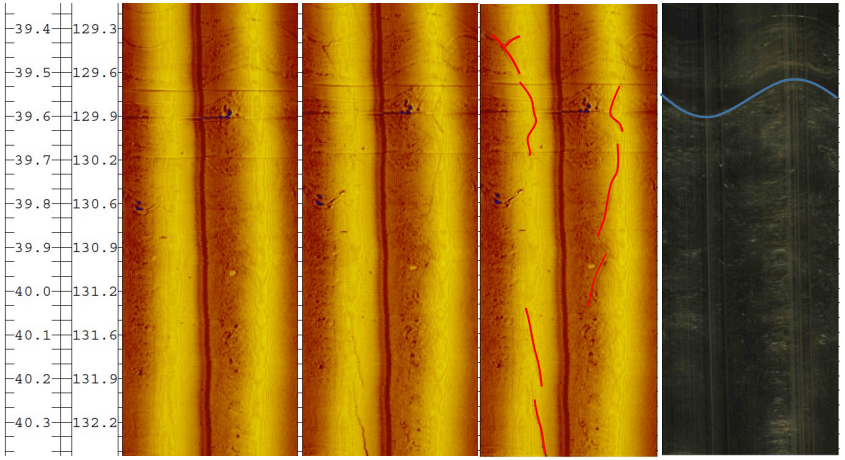
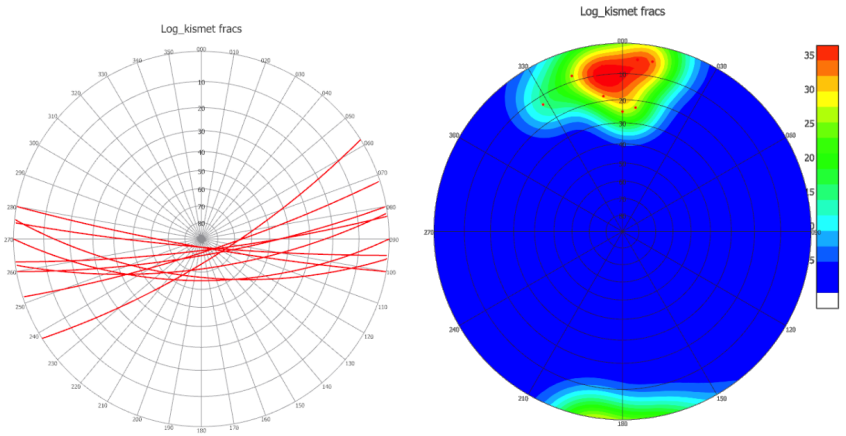
- Visit was made to SURF on 4/12/17 to evaluate potential sites for Experiment 1
- Selected area near kISMET site on West Drift
- Advantages of site include:
  - Well characterized rock mass
  - Few existing fractures
  - Double wide drift
  - Good logistical support available
- Initial borehole design developed based on drift geometry, orientation of $\sigma h_{min}$




Hydrofracture images at 40.28 m

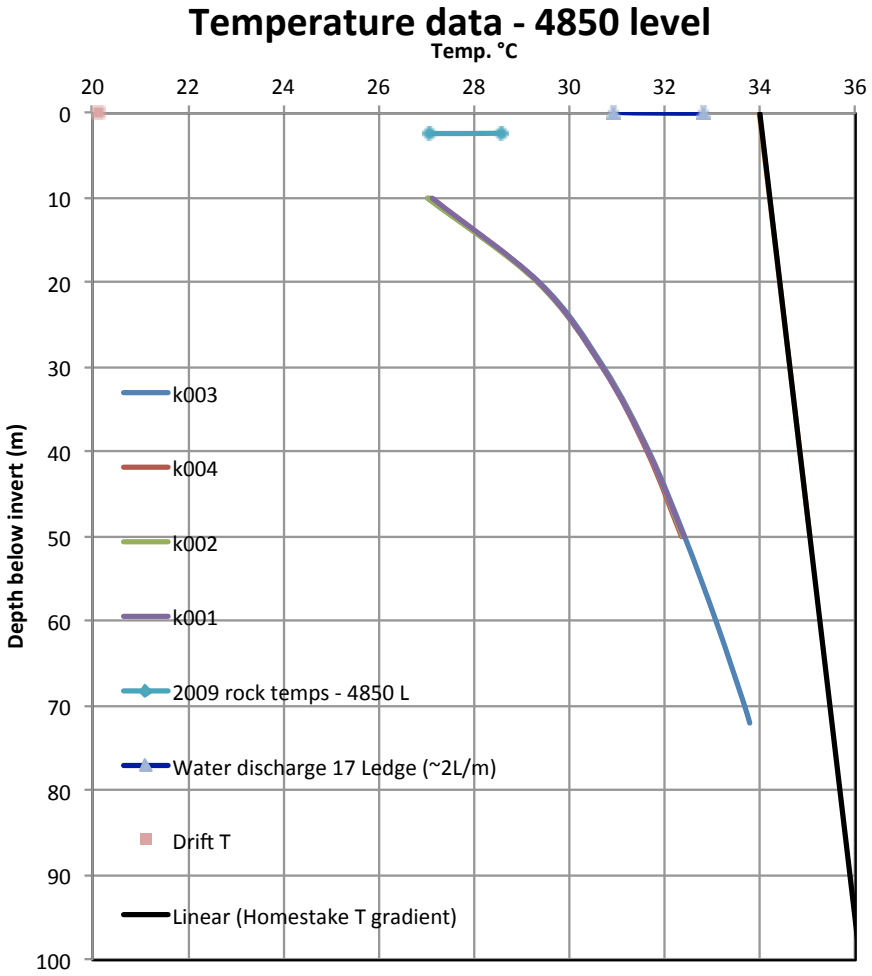



$\sigma_{hmin}$ = 21.7 MPa trending N4°W

# Methods/Approach – Site Characterization



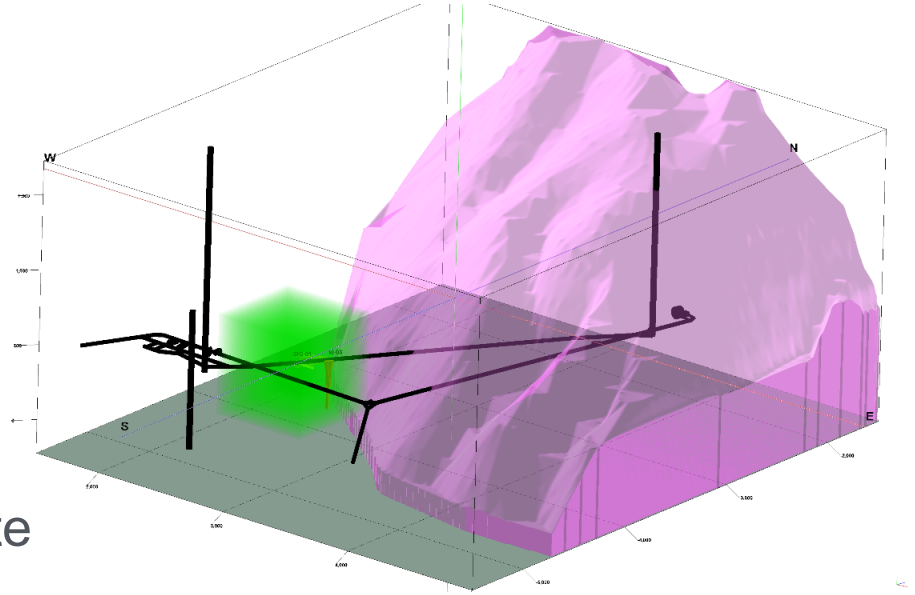
- Compilation of all existing geotechnical data from SURF
- Review and evaluation of stress indicators from boreholes on 4850L
- Mapping of fractures, seeps, and weeps on 4850L
- Temperature measurements in kISMET boreholes
- Crosswell sonic logging and vertical seismic profiles using kISMET boreholes
- Deployed environmental monitoring sensors (T, relative humidity, barometric pressure)
- Selected core samples for laboratory rock property measurements



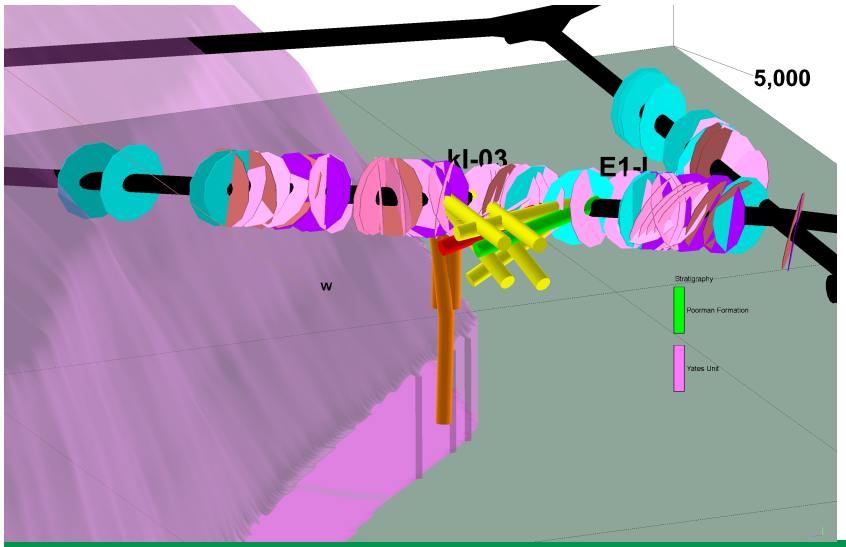
# Methods/Approach – Geologic Framework Model



- Review and selection of geologic modeling software (RockWare)
- Transfer of geologic data from SURF Vulcan database
- Compilation of rock property data
- Development of local, intermediate, and regional scale models
- Development of procedure to populate THMC numerical models




Intermediate scale model - Pink/ magenta surface separates the Yates amphibolite unit from the Poorman phyllite. The green cube represents the lithology model for Experiment 1.




Structural features on 4850L – Foliations (brown), major fractures (purple), minor fractures (pink), weeps (aqua)

# Methods/Approach – Pre-stimulation Modeling

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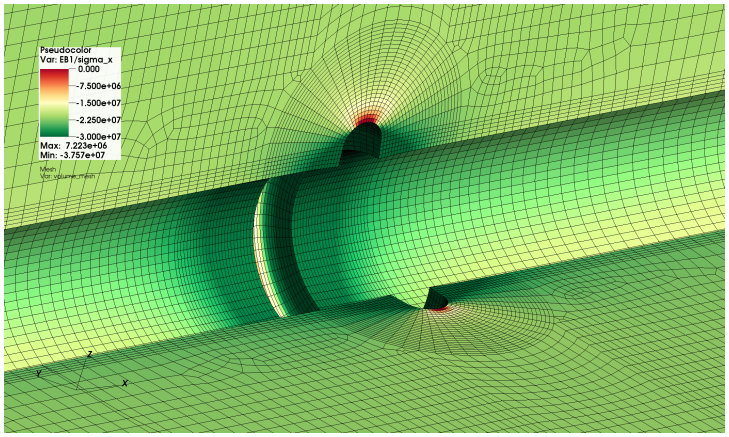
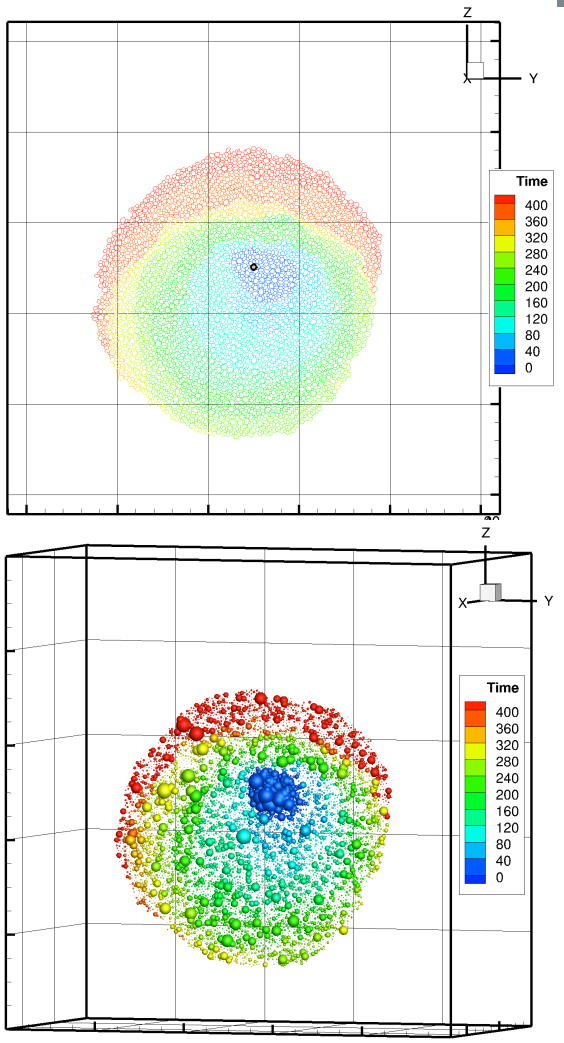
Modeling group led by Mark White developed numerical models to guide experiment design. Specific questions addressed include:

- What is the preferred stimulation borehole orientation?
- Is notching needed to promote propagation of transverse fractures?
- How does notch geometry impact stimulation pressure and near wellbore impedance?
- What are the anticipated number and magnitude of seismic events associated with the hydraulic stimulation?
- What is the required duration for a chilled circulation experiment conducted at pressures that avoid fracture propagation?




Transverse fracture during simulated hydrofracture resulting from borehole notching

Pencheng Fu




Hai Huang

Simulated fracture geometry and seismicity after the injection of 45L fluid

# Methods/Approach – Testbed Design

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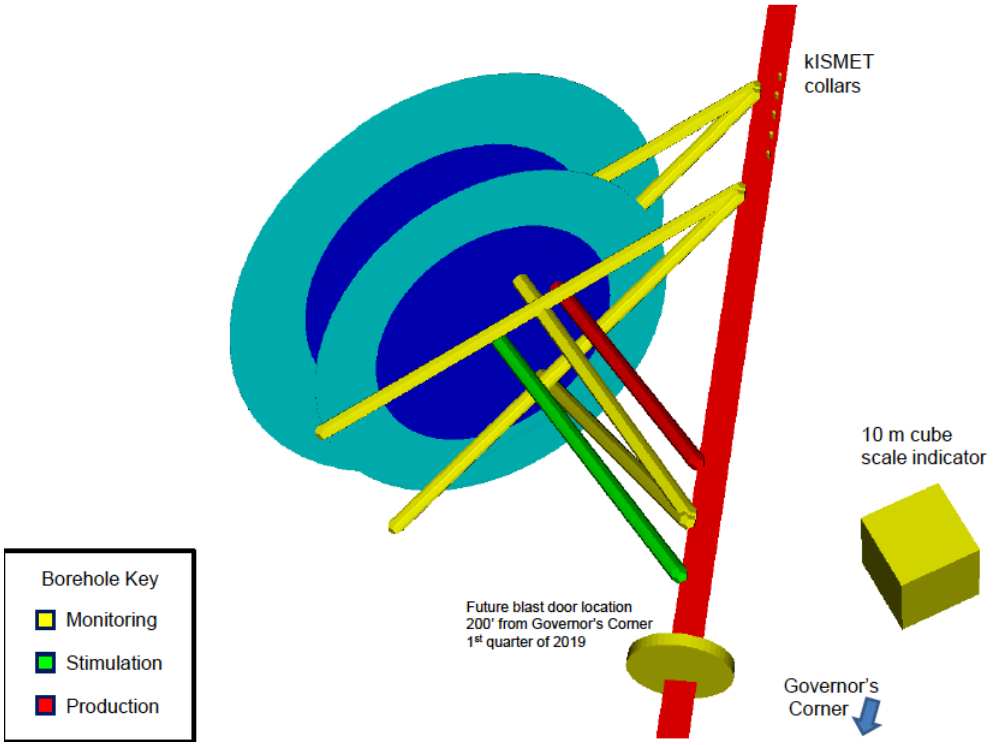
Experiment Design group led by Joe Morris developed borehole configuration for Experiment 1. Testbed requirements include:

- Stimulation and production boreholes are parallel to $\sigma H_{max,}$ and are 10 meters apart
- Fracture initiation locations are located far enough from drift to avoid fracture reaching drift
- Monitoring boreholes are close enough to planned hydrofractures to effectively monitor fracture growth and fluid flow
- Boreholes all dip downwards so that they will be fluid filled to facilitate logging efforts
- Borehole collar locations are in the double track portion of the West Drift, between the kISMET boreholes, and beyond the proposed blast door location 200' from Governor's Corner
- Drill holes must fit into drilling budget




Blue and green discs represent 20 & 30 m radius fractures, respectively

# Technical Accomplishments and Progress - Highlights



- Experiment design team (Task 3) developed 8 well configuration for Experiment 1 testbed on West Drift of 4850 level − key component in developing drilling requirements document
- Pre-stimulation modeling summaries prepared by modeling team
- Geologic framework model developed for Experiment 1 area
- Experimental Planning Statement for Experiment 1 submitted to SURF as draft on 7/10/17, revised version approved 9/25/17
- Authorization to Proceed with drilling activities issued on 9/28/17
- Site preparations and logistical support provided by SURF − water, power, ground support, internet, lighting, waste water disposal
- Drilling crew on site on 10/2/17, started drilling on 10/4/17
- Borehole locations surveyed according to test plan, hole orientations guided by rig alignment tool, monitored downhole with gyro tool
- EGS Collab crew photographing and describing core samples

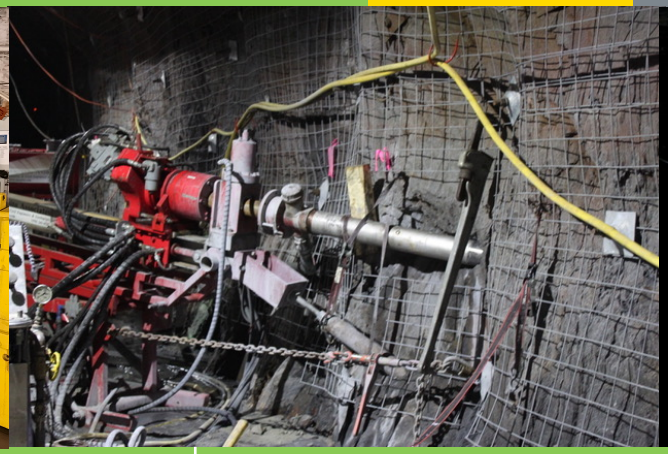
# Technical Accomplishments and Progress − Logistical Issues



- Selection of drilling contractor
  - Request for proposal released to four drilling companies on 7/25/17
  - Three proposals were received on 8/18/17
  - After technical review using the following criteria (Prior drilling experience and suitability of rig and crew to this project (40%); Cost (25%); Safety (20%); Schedule and availability (15%)), a final award was made to Agapito Associates on 9/13/17
- A subcontract with Professional Mapping & Surveying LLC was signed on 9/25/17 for well location surveying and a drift laser scan
- A subcontract with Sanford Underground Research Laboratory (SURF) to cover test bed preparation and logistical support was signed on 9/26/17
- All required safety documents (Job Hazard Analysis, Work Process Control, and safety training matrix) and underground safety training completed and approved prior to initiation of drilling work

# Technical Accomplishments and Progress



| Original Planned Milestone/ Technical Accomplishment | Actual Milestone/Technical Accomplishment | Date Completed |
|---|---|---|
| Identify Experiment 1 site at SURF | Site visit on April 12th – selected area on 4850 level near kISMET location | 5/26/17 |
| Develop Geologic Framework Model | 3 geologic models (at different scales) developed using RockWorks | 6/30/17 |
| THMC and geophysical modeling to constrain experimental design and monitoring system | Numerous simulations generated by EGS Collab working groups – papers presented at 2017 GRC meeting | Ongoing |
| EGS Experiment 1 – Refine Stimulation Test Design | Experiment Planning Statement approved by SURF, Authorization to Proceed with drilling granted | 9/28/17 |

# Research Collaboration and Technology Transfer



- Four papers and one poster presented at 2017 Geothermal Resources Council annual meeting related to Task 2 activities
  - Dobson et al. – An introduction to the EGS Collab project
  - Knox et al. – Fracture and flow designs for the Collab/SIGMA-V project
  - White et al. – The role of numerical simulation in the design of stimulation and circulation experiments for the EGS Collab project
  - Huang et al. – Numerical modeling of seismic and displacement-based monitoring for the EGS Collab project
  - Neupane et al. – Earth Modeling for EGS Collab
- Met with Jeremy O'Brien of ARANZ Geo to discuss testing Leapfrog geothermal modeling software for this project
- Discussions with Dr. Hiro Asanuma (geothermal lead, AIST), Dr. Chang Gao (geothermal lead, Sinopec), Dr. Florian Amann (Grimsel geothermal underground lab, ETH Zurich/RWTH Aachen) on research collaboration opportunities
- Data sharing with LBNF geotechnical team

# Future Directions – Tasks 2 & 7 (FY18)



- Complete drilling and logging of stimulation, production, and six monitoring boreholes at Experiment 1 site
- Using core and log data, identify and notch zones for fracture stimulation
- Install and grout in monitoring sensors in monitoring boreholes
- Complete characterization of testbed prior to stimulation experiment
- Update geologic framework model and coupled process models from field and lab data – refine stimulation plan
- Begin work to identify location for Experiment 2 (fracture shear) – Task 7

| Milestone or Go/No-Go | Status & Expected Completion Date |
|---|---|
| Prepare test bed suitable to perform stimulation tests | Drilling of test bed for Experiment 1 currently in progress (December, 2017) |
| **Go/No Go:** Select and approve one appropriate site that will support drilling of at least 2 subhorizontal boreholes, four monitoring boreholes, and adequate work space | Site meeting these needs currently under construction that will support proposed activities for Experiment 1 |

# Mandatory Summary Slide – Task 2



- A test bed location was identified for Experiment 1 on the 4850 level of the Sanford Underground Research Facility
- Characterization of the Experiment 1 test site builds upon the kISMET study, supplemented by new field data
- Close collaboration between different EGS Collab teams led to the design of the test bed
- Following development of a comprehensive experimental plan and safety program, the EGS Collab team was authorized to proceed with the first phase of field activities
- Drilling of the boreholes was initiated on Oct. 4, 2017, planned to be completed in 2017
- After characterization of the boreholes and installation of permanent monitoring sensors, testbed will be ready for suite of hydrofracture and flow experiments in early 2018

# Additional Information - Photos

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