Geothermal Technologies Office 2017 Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Enhanced Geothermal System Testing and Development at the Milford, Utah FORGE Site

Project Officer: R. Vagnetti

Total Project Funding: $9,907,709

November 13, 2017

Principal Investigator: Joseph Moore

Organization: University of Utah

Track Name: General Session

Milford Utah FORGE Site

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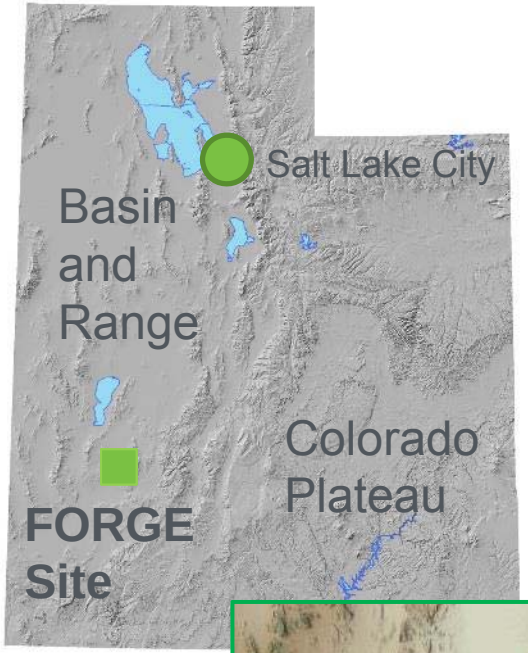

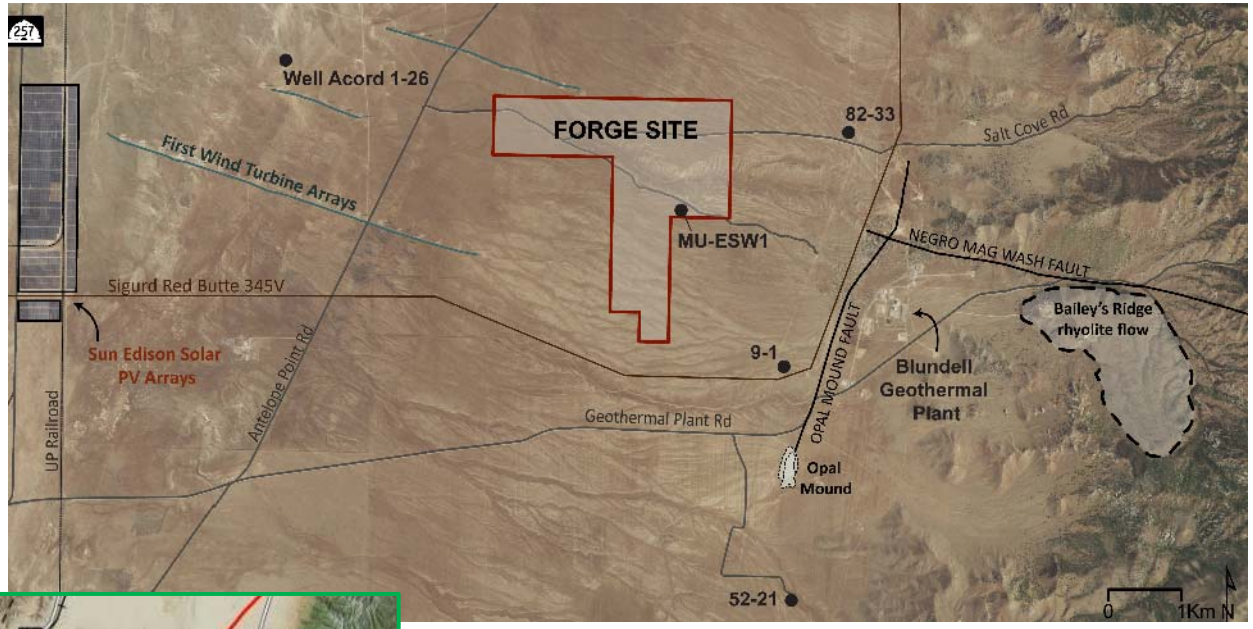

Existing Infrastructure within the Utah Renewable Energy Corridor

- 2 geothermal fields, windfarm, solar field, biogas facility
- roads (interstate, paved and dirt roads)
- railroad
- airport
- motels/eating establishments

Relevance to Industry Needs and GTO Objectives: 1

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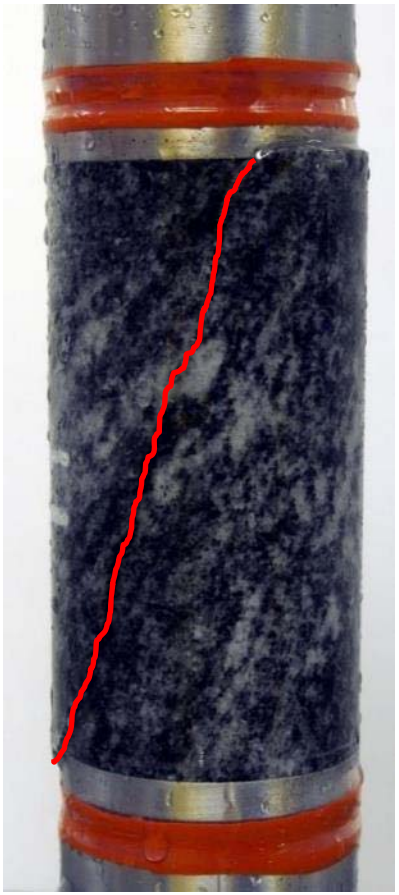
FORGE will be a dedicated laboratory for developing new tools and technologies for creating, monitoring and managing EGS reservoirs. It will provide opportunities to develop:

- Novel stimulation and well completion methodologies to produce fracture networks in hot, crystalline rocks
- Techniques to modify/manage the stress field to take advantage of existing fractures
- High-temperature drilling tools, zonal isolation technologies and cost-saving drilling techniques,
- Methods to manage and forecast induced seismicity
- Best EGS management practices
- Predictive numerical models

FORGE will:

- Provide educational and research opportunities at all level
- Showcase to the public, stakeholders, and the energy industry that EGS technologies can contribute to power generation



- Compressive strength at confining pressure 8000 psi = 9 x 10^4 psi
- Porosity = 0.13%
- Permeability = 0.3 microdarcies

Relevance to Industry Needs and GTO Objectives: 2

- Utah FORGE will stimulate commercial-scale development of EGS reservoirs and lower costs of conventional geothermal development. It will:
  - Demonstrate creation and management of an EGS reservoir
  - Reduce costs of EGS development by funding new and improved technologies and tools including those from the oil and gas industry (e.g. isolation and stimulation technologies, horizontal drilling)
  - These technologies can also be applied to subcommercial wells to improve their performance
  - Demonstrate geothermal development can occur anywhere
- Fund research into monitoring and mitigating risks associated with seismicity
- Demonstrate how EGS can be part of the renewable energy scene. Location within Utah Renewable Energy Corridor (geothermal, wind, solar, biogas)

Methods/Approach

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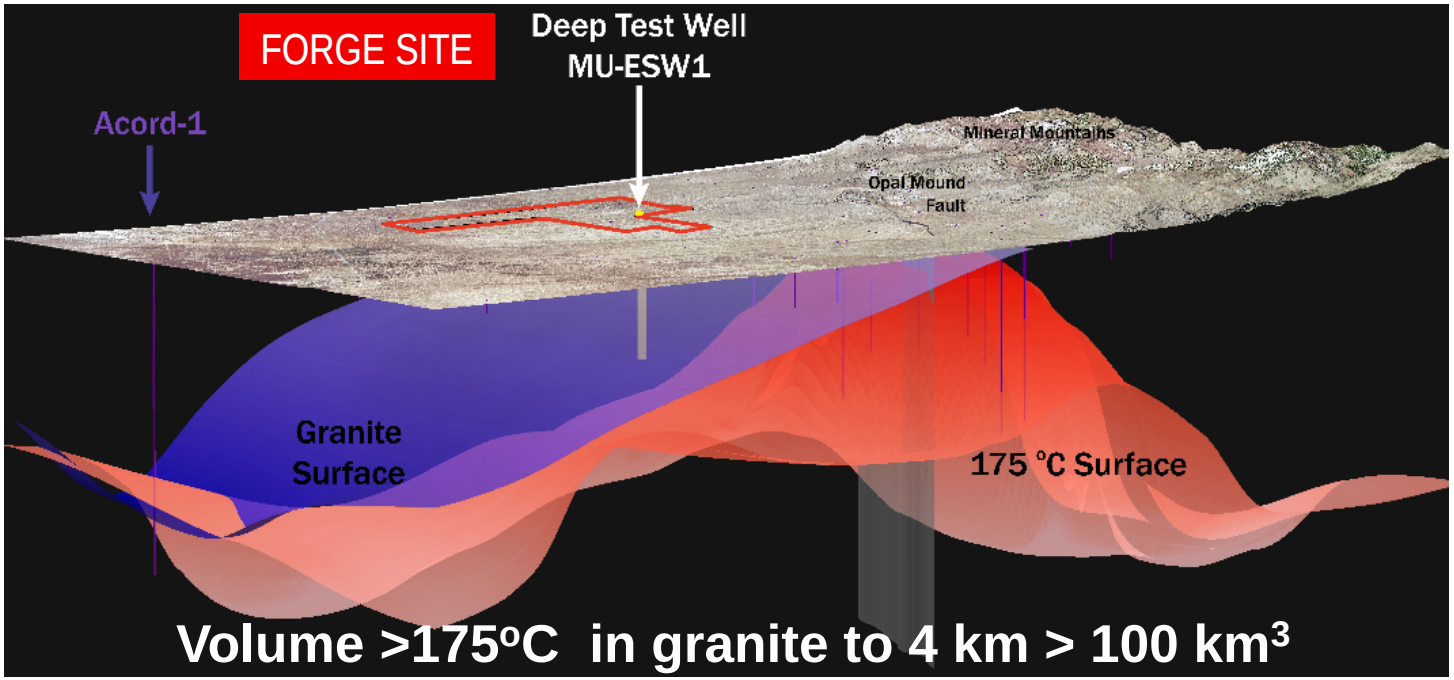
- Phase 1 and 2A: Staged program to demonstrate the Utah FORGE site meets requirements for EGS development (appropriate temperature, depth, rock type, permeability; no environmental or cultural restrictions impacting development, adequate existing infrastructure, low seismic risk)
  - Phase 1: Compile and analyze existing geoscientific data; determine permitting requirements, conduct preliminary environmental/cultural and infrastructure assessments
  - Phase 2A: Prepare detailed EIV, conduct Techno-Economic analysis, demonstrate NEPA requirements can be met, expand existing telemetered surface seismic array



Methods/Approach

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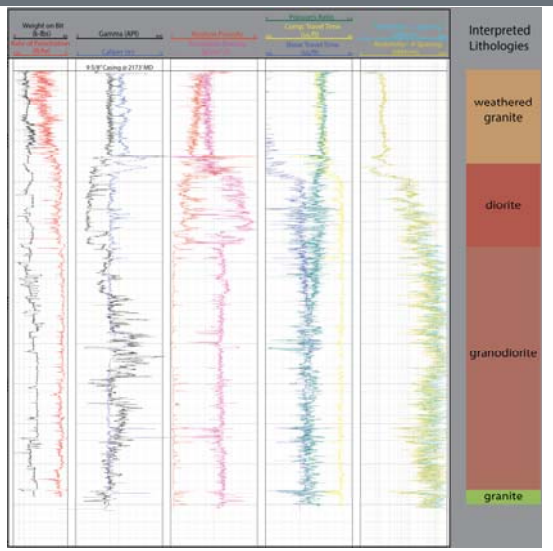
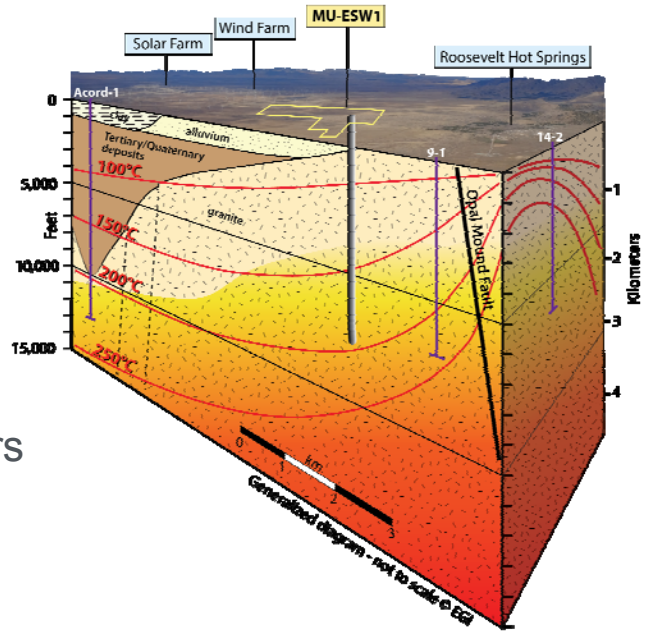
- Phase 2B (to be completed by March, 2018): Prove subsurface conditions, bring site to full NEPA compliance, analyze seismic risk
  - Drill 7536 ft well to demonstrate required conditions
  - Complete cultural and environmental surveys; prepare EA
  - Continue seismic monitoring and analysis; prepare Induced Seismicity Mitigation Plan
  - Update geologic model
- Phase 2C/3: Build infrastructure, drill deep wells and establish the Utah FORGE laboratory. The Utah FORGE team, as mandated by the DOE, will:
  - Establish/maintain infrastructure for the Utah FORGE laboratory
  - Convene a Science and Technology Advisory Board to establish research needs
  - Issue and oversee research projects performed by others
  - Conduct essential monitoring activities (e.g. seismic monitoring)





Technical Accomplishments and Progress

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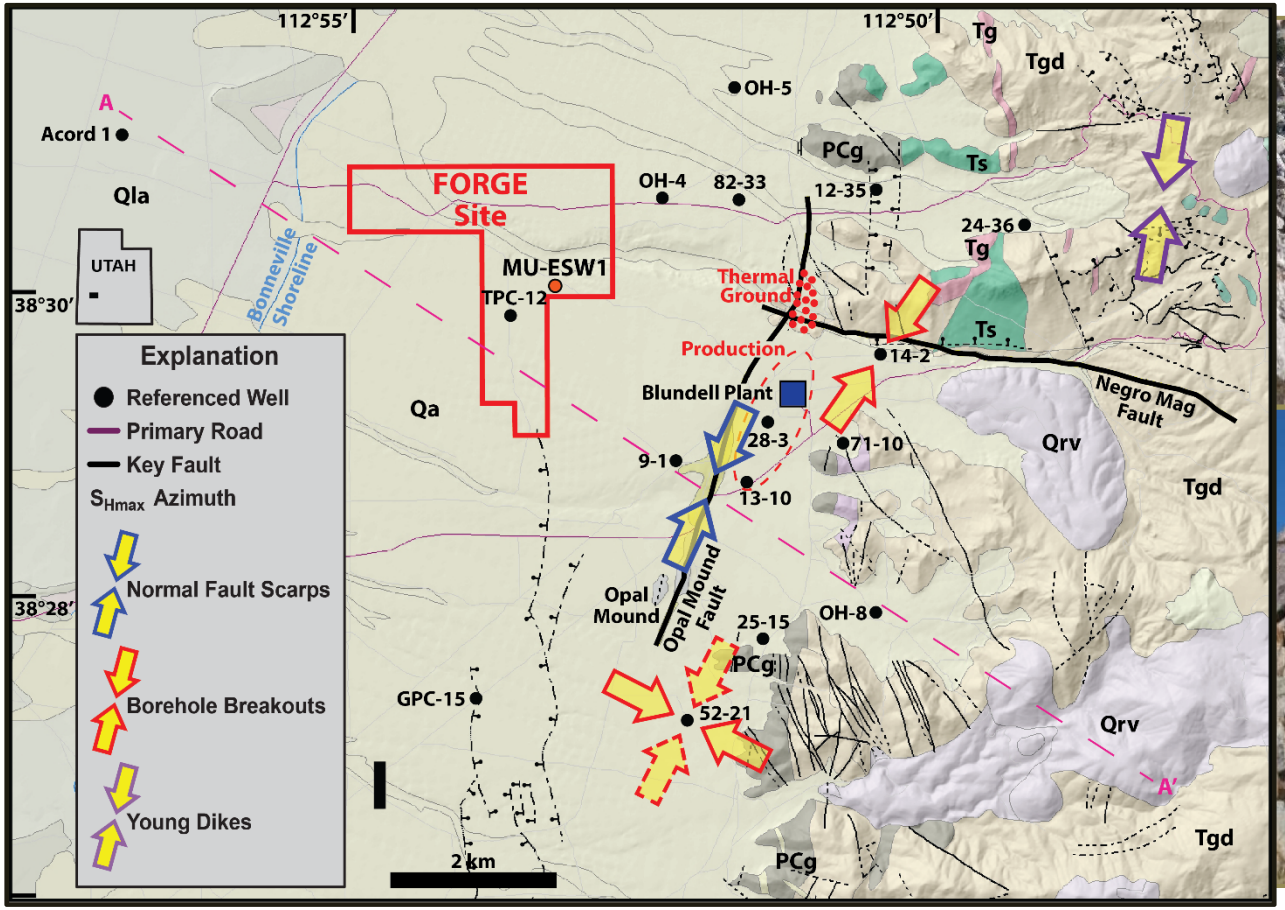
Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Phase 1: Desktop Study/Conceptual Geologic Model	Competed as planned	April 27, 2016
Phase 2A: Prepare EIV, Techno-Economic Assessment, establish telemetered array	Completed as planned	March 2017
Phase 2B: Drill and test 7536 ft well	Completed as planned	Sept. 2017
Phase 2B: Refine fault/fracture maps	Completed as planned	Sept. 2017
Phase 2B: Soil gas survey	Completed as planned	Sept. 2017
Complete geophysical surveys (gravity, LiDAR, TEM)	Completed as planned	Sept. 2017

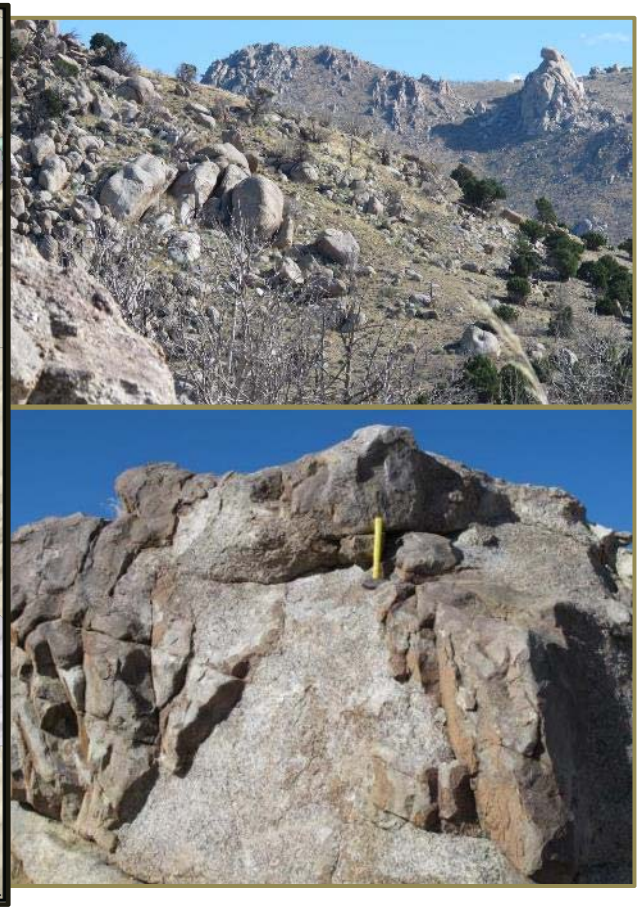
Challenges:

Design and cost deep well based on predicted reservoir conditions beneath the site

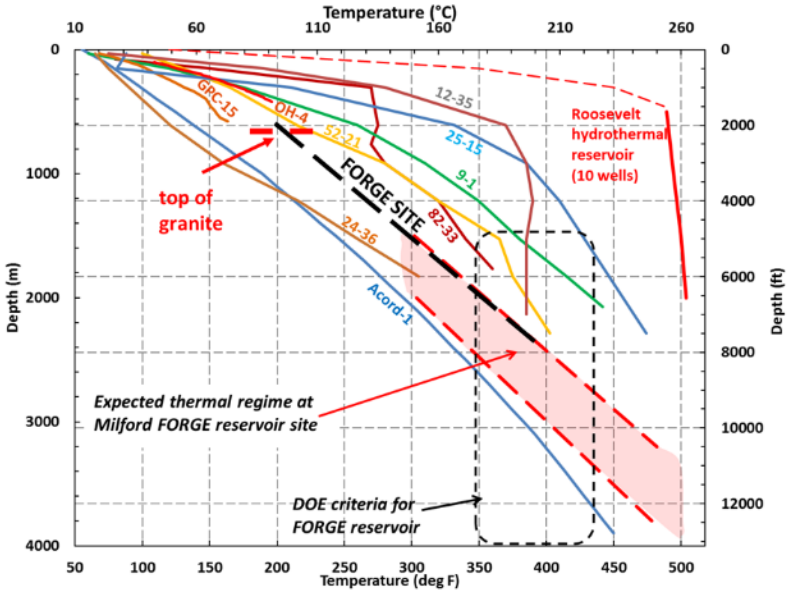
Drill and test deep well within budget

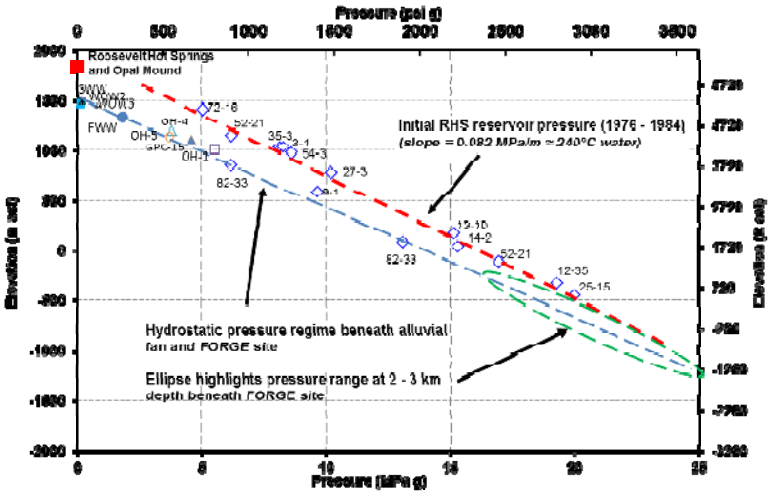
Technical Accomplishments and Progress: Geologic Setting

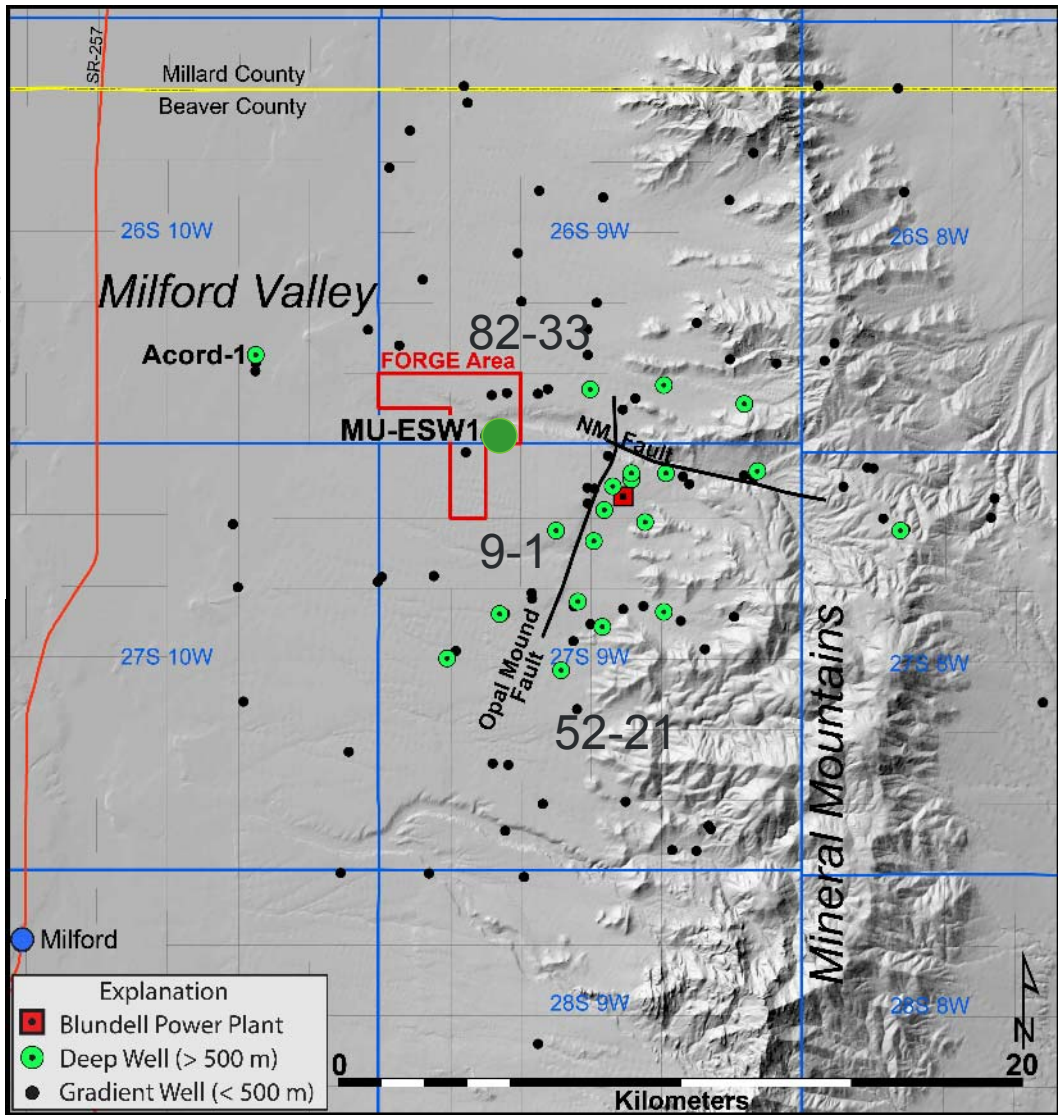




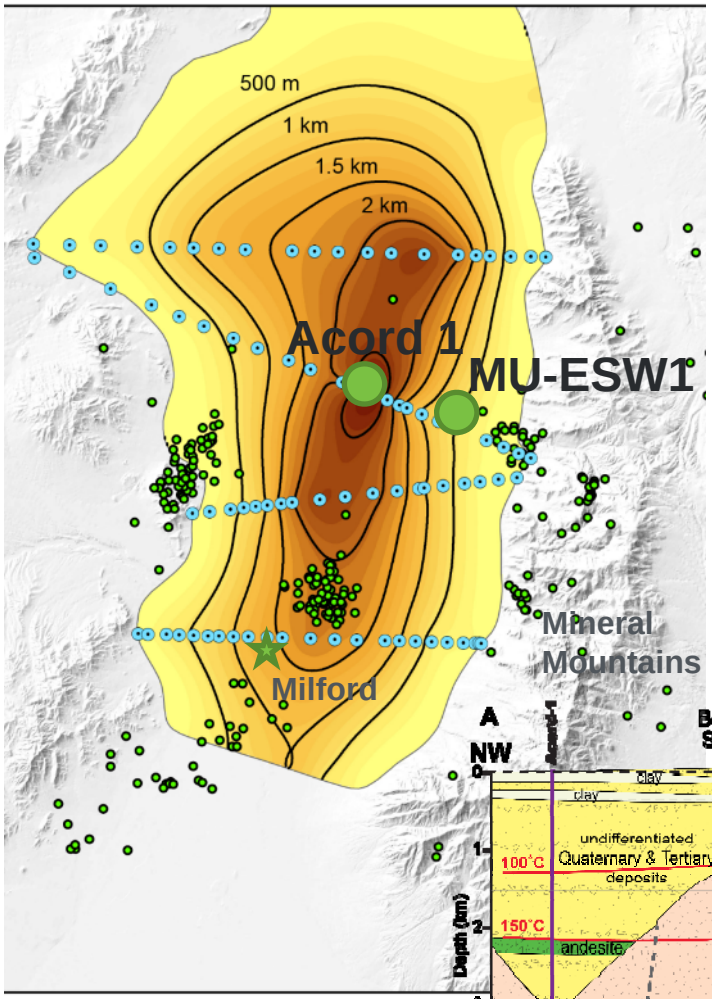
Technical Accomplishments and Progress: The Existing Database



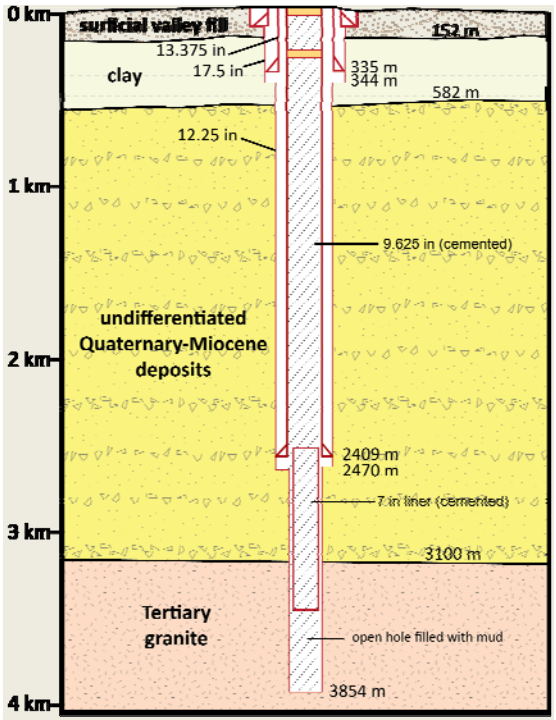




Technical Accomplishments and Progress: Geologic Modeling



Gravity Model



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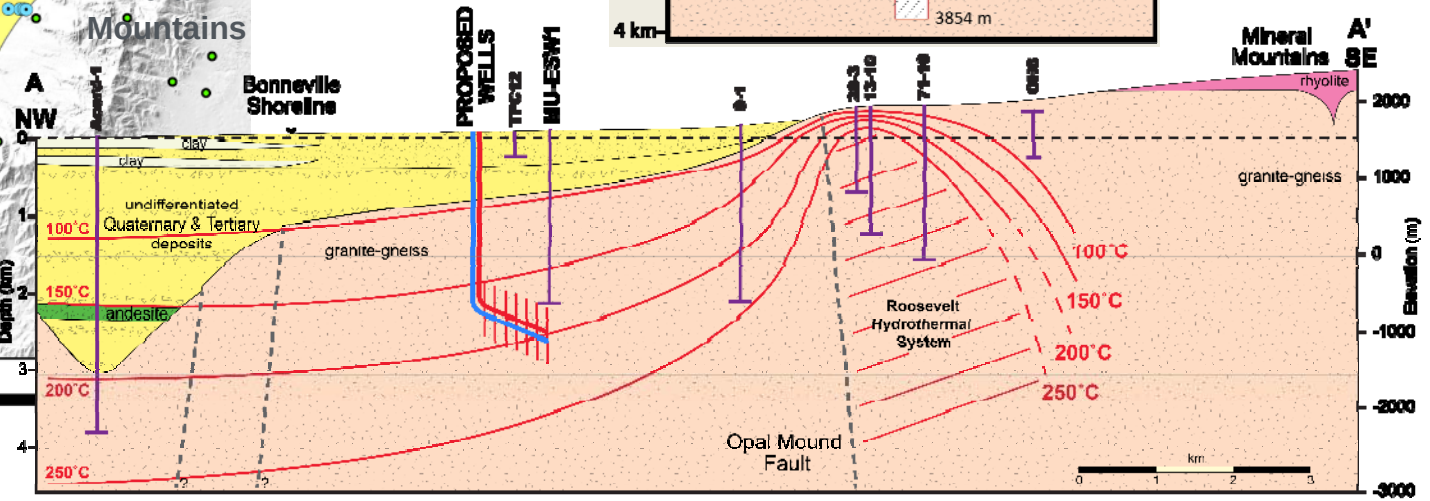
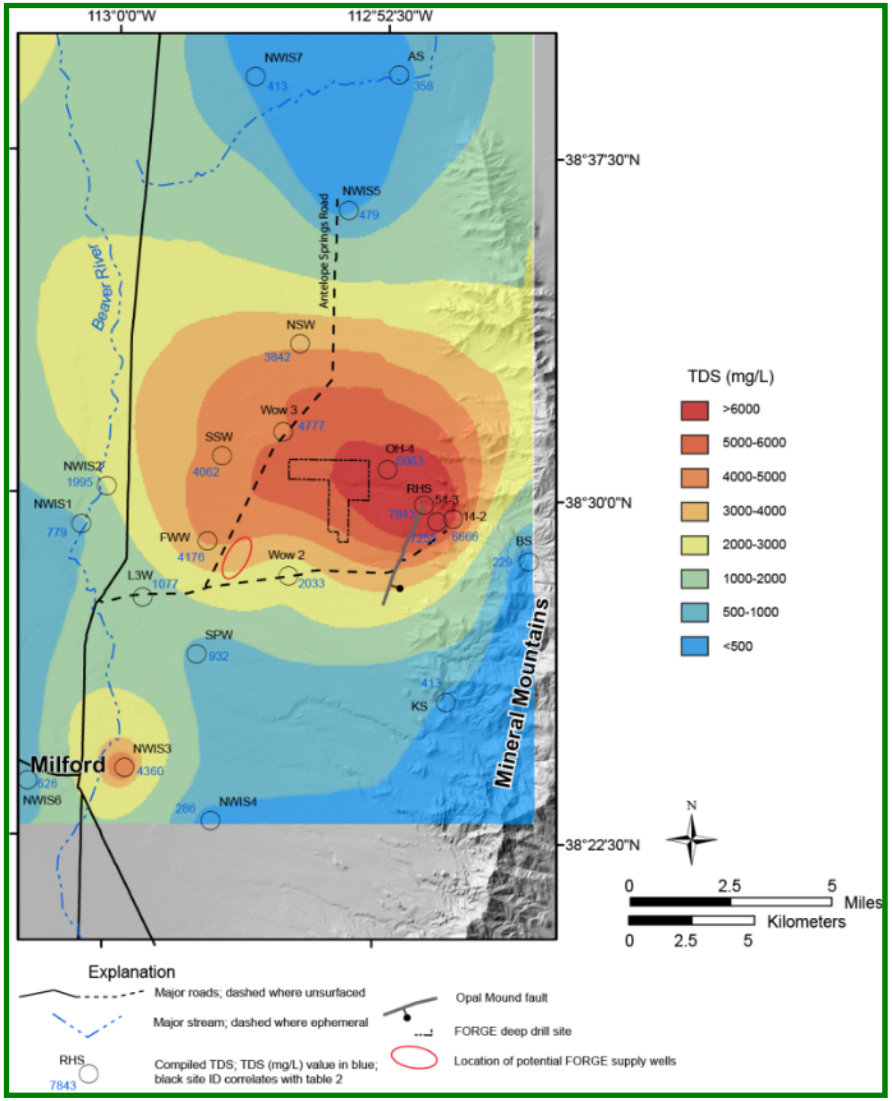


Technical Accomplishments and Progress: Geochemistry



- The groundwater is mixed with the natural outflow from Roosevelt Hot Springs
- Benign chemistry
- Water not fit for human consumption or for agricultural uses
- Sufficient water rights secured

Technical Accomplishments and Progress: Analysis of Seismic Data

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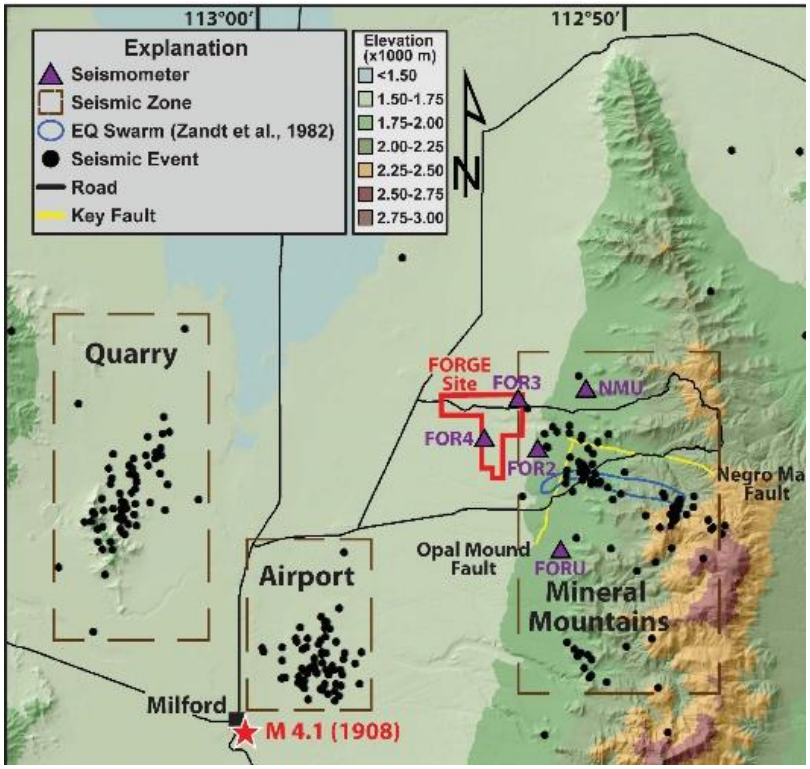
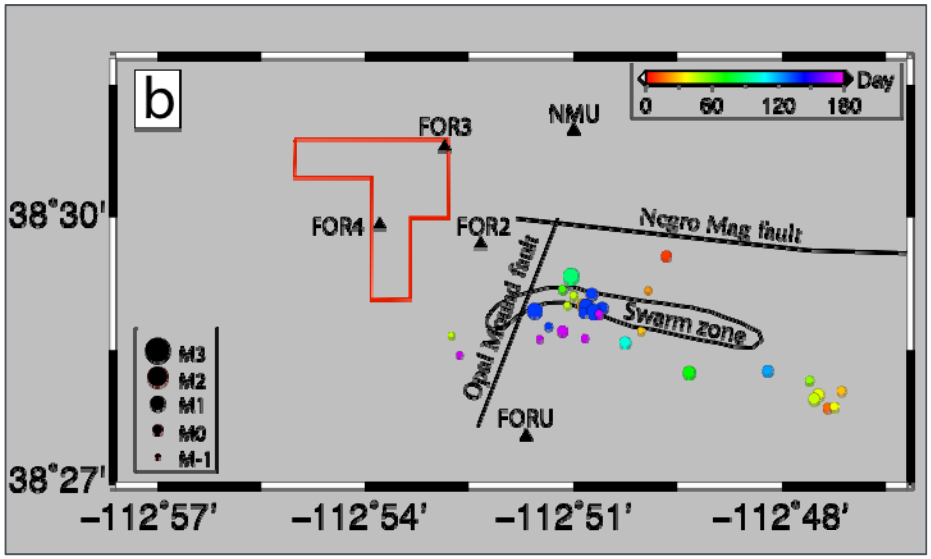
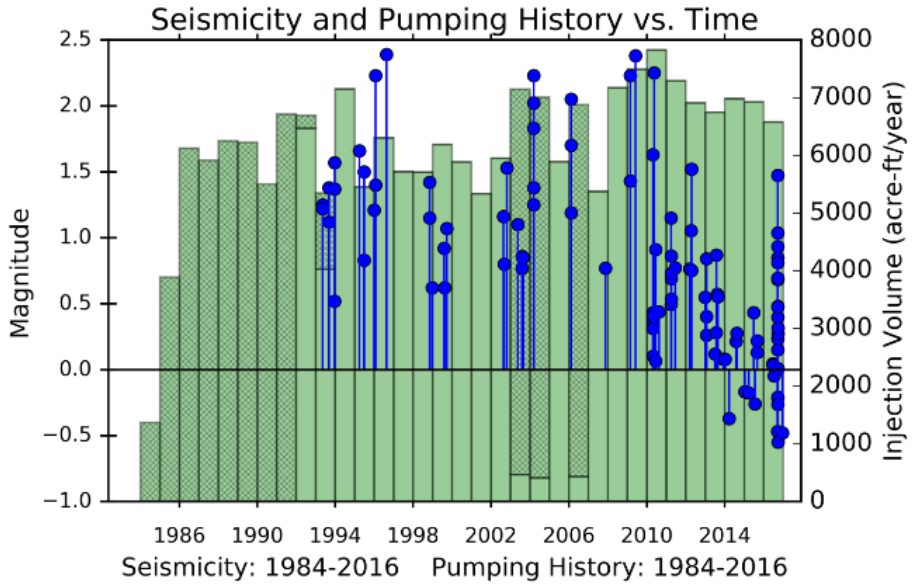
- Seismicity monitored since 1981
- No seismic events recorded beneath the Utah FORGE site
- Low seismic activity at Roosevelt Hot Springs despite injection since 1984
- Risk of induced seismicity and seismic hazards are low



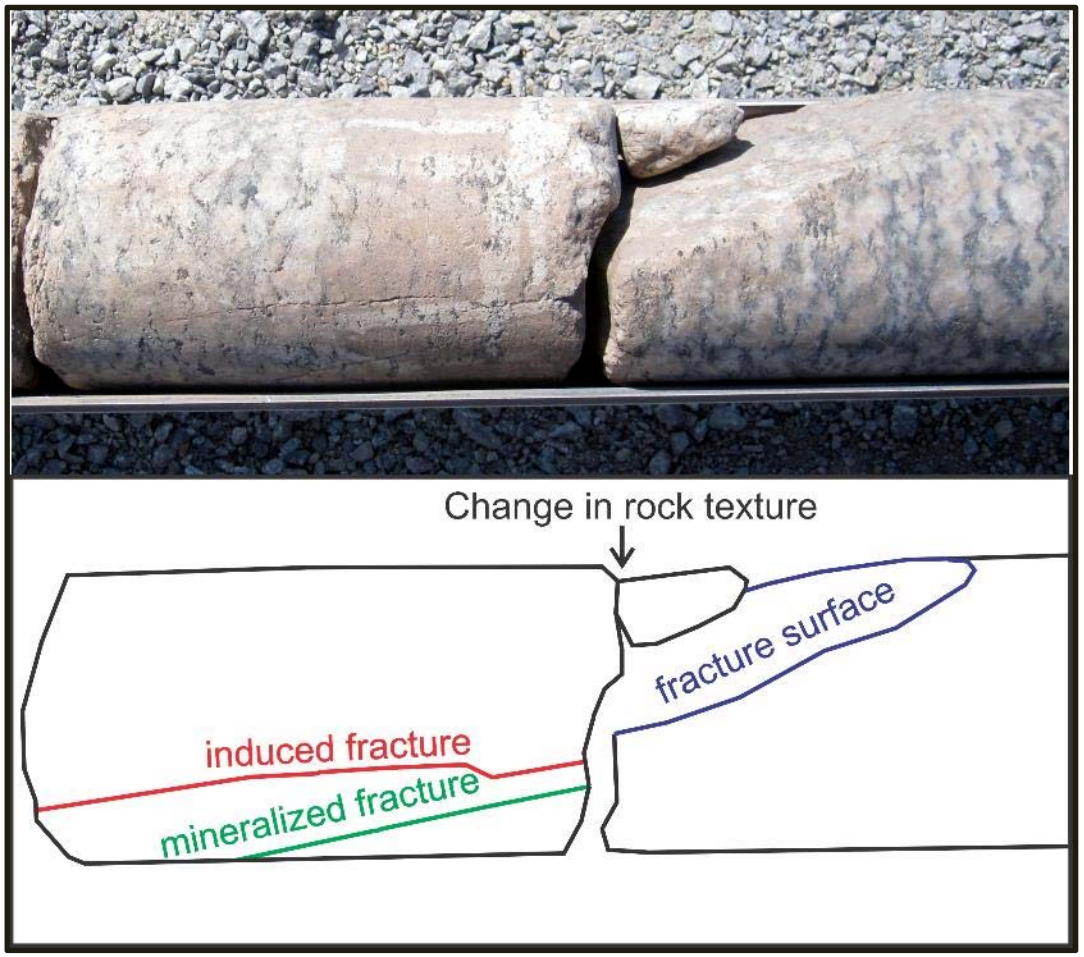




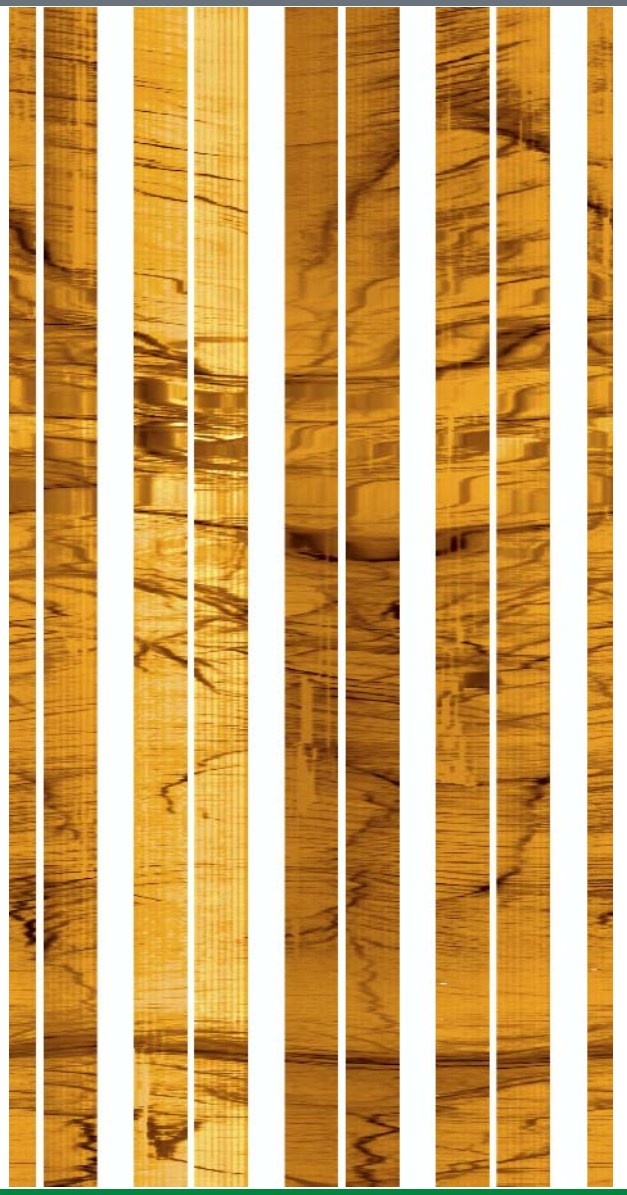
Technical Accomplishments and Progress: Direct measurement of reservoir conditions

- Completed, and tested well to 7536 ft
- Demonstrated the required temperature, rock type (granite) and low permeability exist within the reservoir
- Despite challenging drilling conditions, two fishing jobs and several broken tools, MU-ESW1 was drilled deeper than planned but still within budget
- Ran full suite of geophysical and image logs
- Cored two intervals within the reservoir section
- Performed a minifrac test.

Technical Accomplishments and Progress: Fracture characterization



6804 ft



Research Collaboration and Technology Transfer

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Collaborations: Utah Geol. Survey, Geothermal Resources Group, Idaho Nat. Lab., U. Oklahoma, U. New Mexico, PacifiCorp, Cyrq Energy, SITLA, Smithfield, oil/gas/geothermal consultants, Golder Associates, Amec Foster Wheeler Environment and Infrastructure, Schlumberger, SWCA Environmental Consultants, drilling/support companies.

Technology Transfer

Results of Phases 1 and 2A shared through papers/presentations and submitted to GDR. 50% of Phase 3 monies will fund research through annual FOA's. Tools and technologies will be put in public domain.

Outreach

- Website, Facebook, videos,
- Press releases, radio and newspaper interviews
- Publications and presentations
- Fieldtrips for regulators, stakeholders, students
- STEM modules/educational tools for K-12

Turning thermal energy into electricity; Dr. Tony Butterfield

Future Directions

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- Expected outcomes of Phase 2B
  - Demonstrate Utah FORGE site meets all technical and environmental criteria for an EGS research facility.
- Future activities: Successful demonstration of EGS technologies, reservoir creation and monitoring
  - Build infrastructure required for EGS development at the Utah FORGE site
  - Drill deep injection and production wells
  - Create and monitor the reservoir and conduct long-term testing
  - Issue FOAs and research contracts annually based on recommendations from the STAT
- The Project Management Plan directly addresses decision making and alternative pathways to mitigate risks
  - Issues are reviewed by the Project Management Team consisting of 3 Co-PIs and the Managing Co-PI
  - Managing Co-PI serves as point of Contact with DOE, manages budget and has authority to make decisions requiring immediate attention
  - Alternative sites for the necessary infrastructure (e.g. water wells, electric lines, office site, well locations, water sources) have been proposed and approved by regulatory agencies

Future Directions

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Milestone or Go/No-Go	Status & Expected Completion Date
Complete EA, achieve NEPA compliance	In Progress; Jan. 2018
Complete Induced Seismicity Mitigation Plan	In Progress; Jan. 2018
Update Geologic Model	In Progress; due March 2018
Submit 2B final report	In Progress; due March 2018
Final Down select by DOE (Go-No/Go decision)	March 2018
Phase 2C: Build Infrastructure and convene STAT	August 2019
Phase 3: Initiate production/injection wells and long-term testing	August 2024
Phase 3: Issue FOAs annually and manage research contracts	August 2024

Summary: Strengths of Site

- Completed deep well proved the accuracy of the conceptual geologic model. Site meets requirements of temperature, depth, rock type, and permeability
- The reservoir is enormous (>100 km^3)
- Well developed existing, local infrastructure (roads, motels, eating establishments, support services, railroad, airport)
- No nearby high security operations, site on private land
- No endangered/threatened flora or fauna
- Groundwater not potable; necessary water rights secured
- Strong support from local community, landowners, state and federal regulatory agencies
- Unencumbered, year round, public access to a scenic vista encompassing a host of operating renewable energy projects, including multiple geothermal fields, a wind farm, solar field, and biogas plant


FORGE Deep Well completed Sept. 27, 2017