Concept Testing and Development at the Raft River Geothermal Field, Idaho

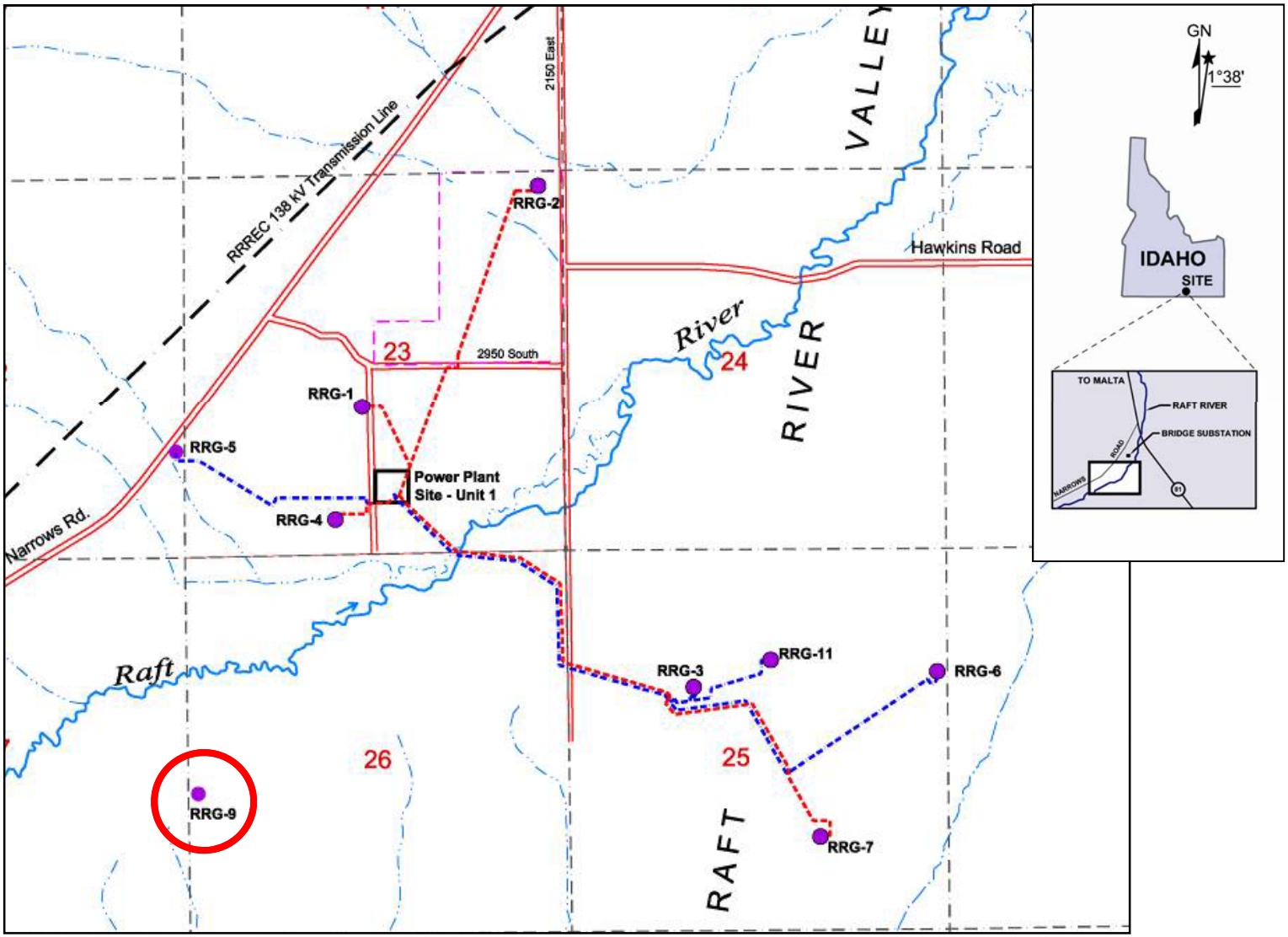
May 18, 2010

Principal Investigator: Joseph Moore

Organization: University of Utah

Track Name: Engineered Geothermal Systems, Low Temp, Exploration Demonstration Projects

Introduction: Field Infrastructure



Introduction: Geologic Setting of the Raft River Geothermal Field

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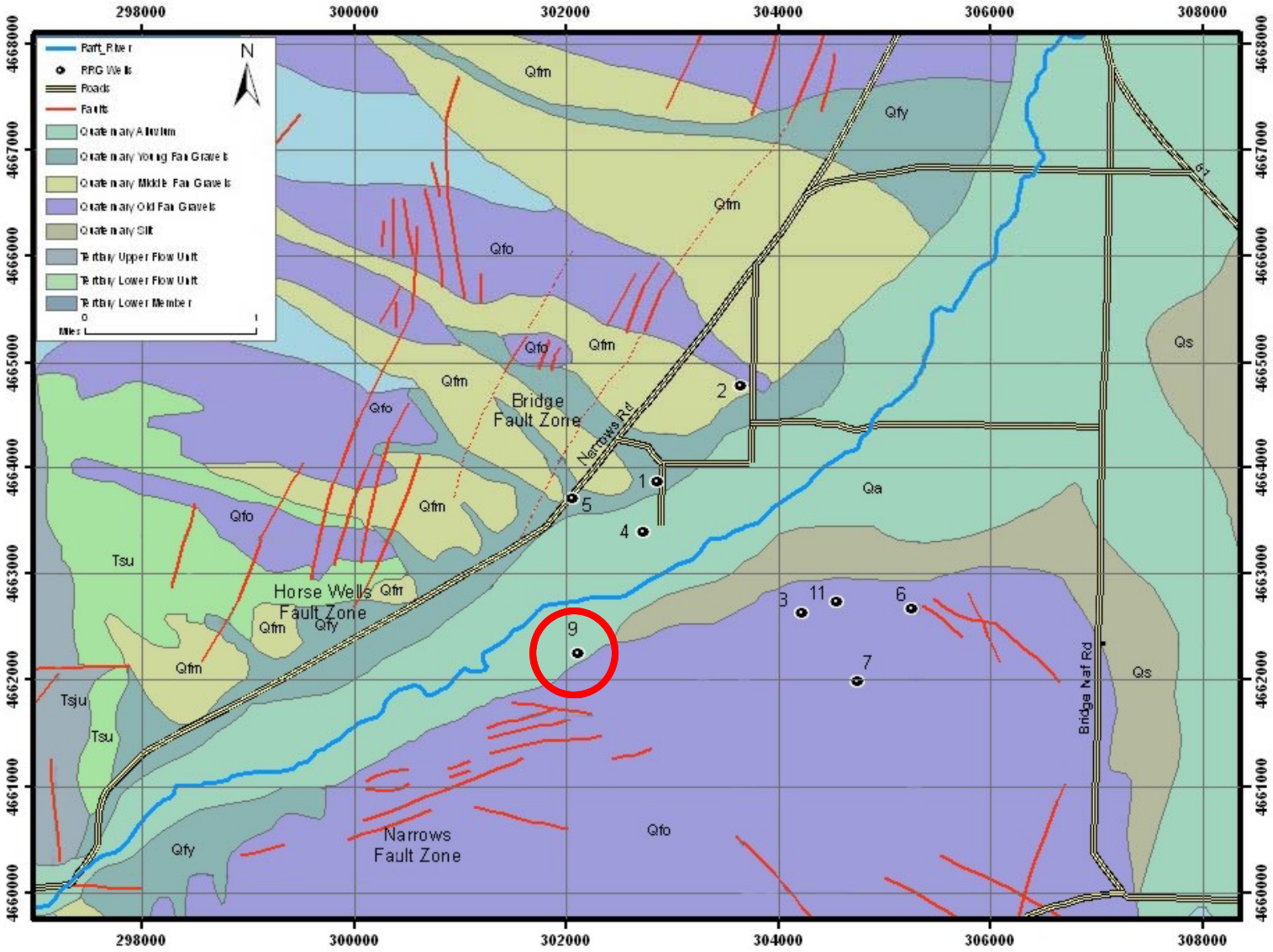
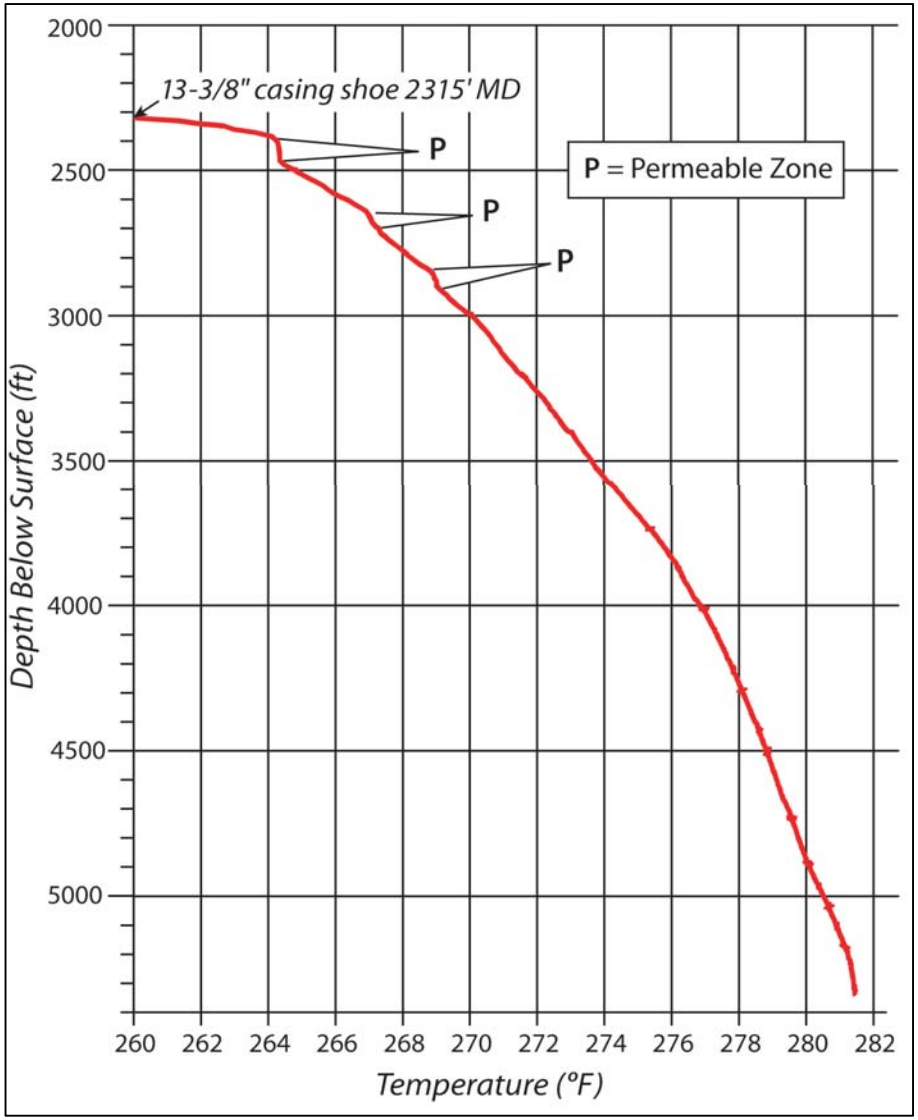
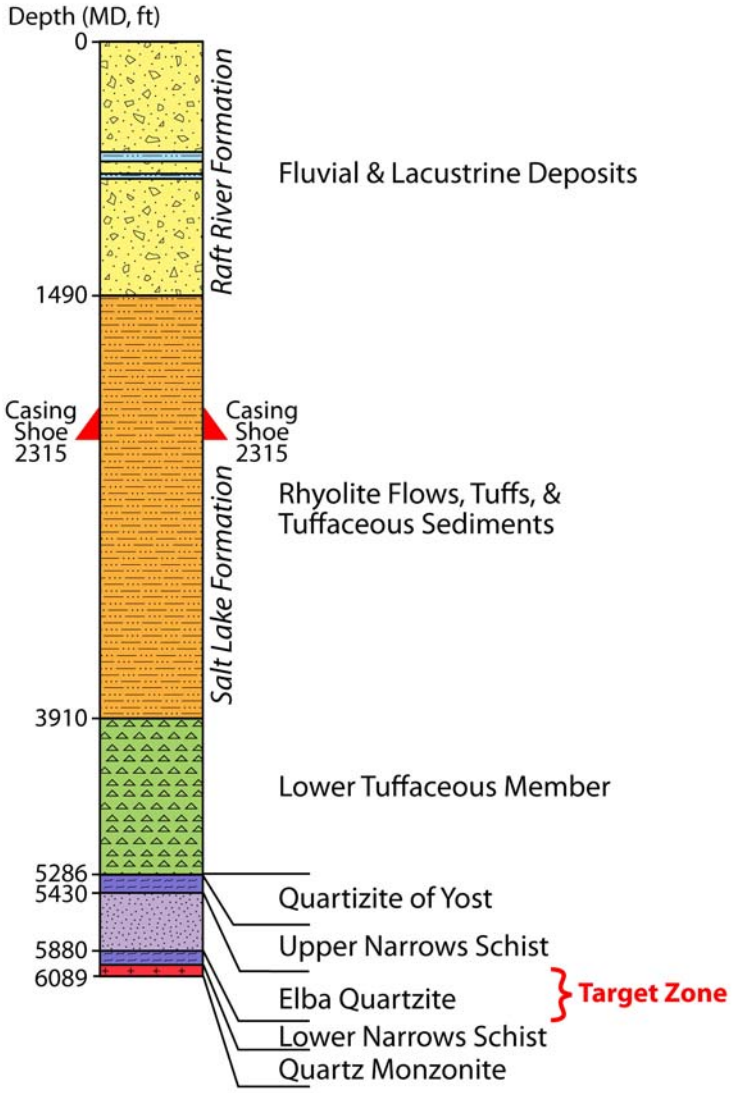


Introduction: The Target Stimulation Well, RRG-9, and Proposed Casing Plan





Overview of Timeline

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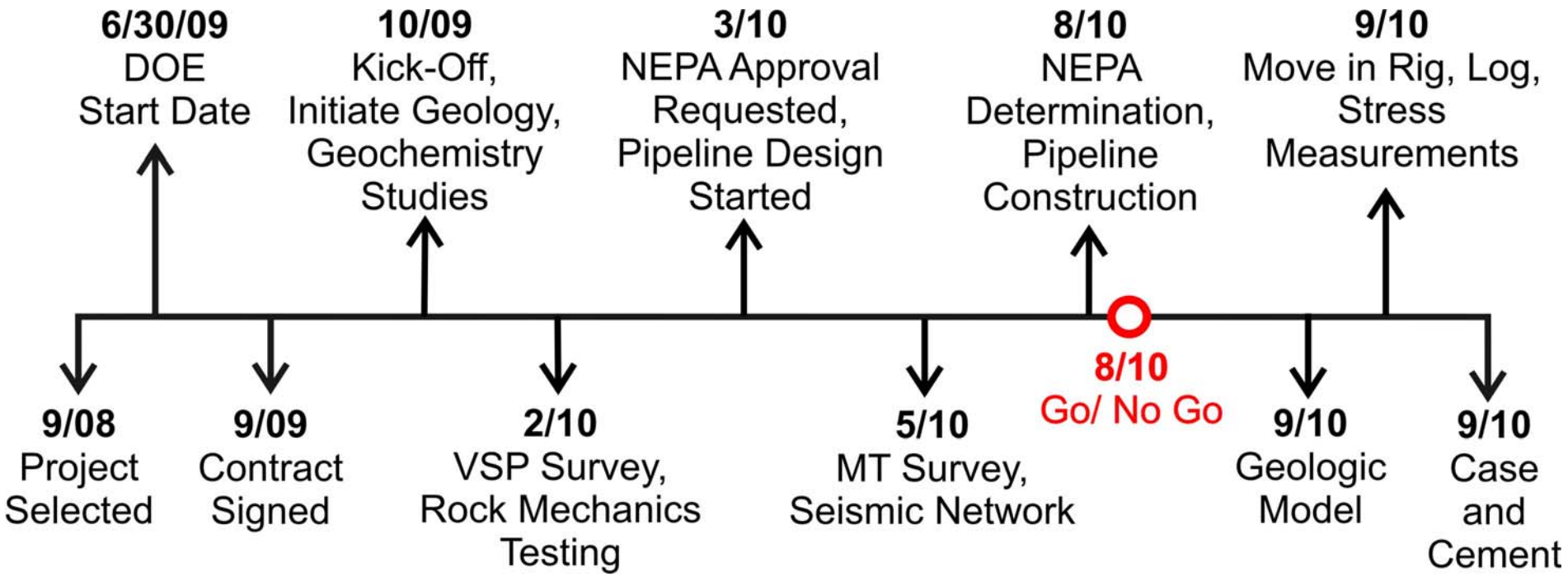
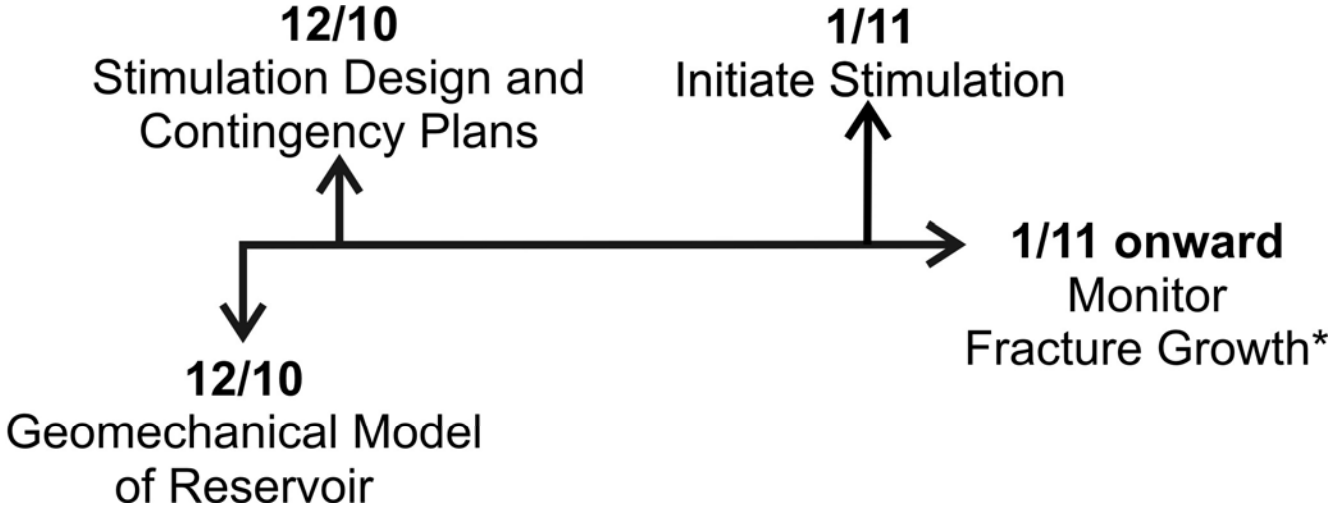
Phase 1 (FY 10)

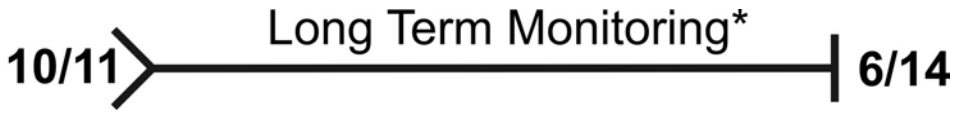


Overview of Timeline

Phase 2 (FY 11)



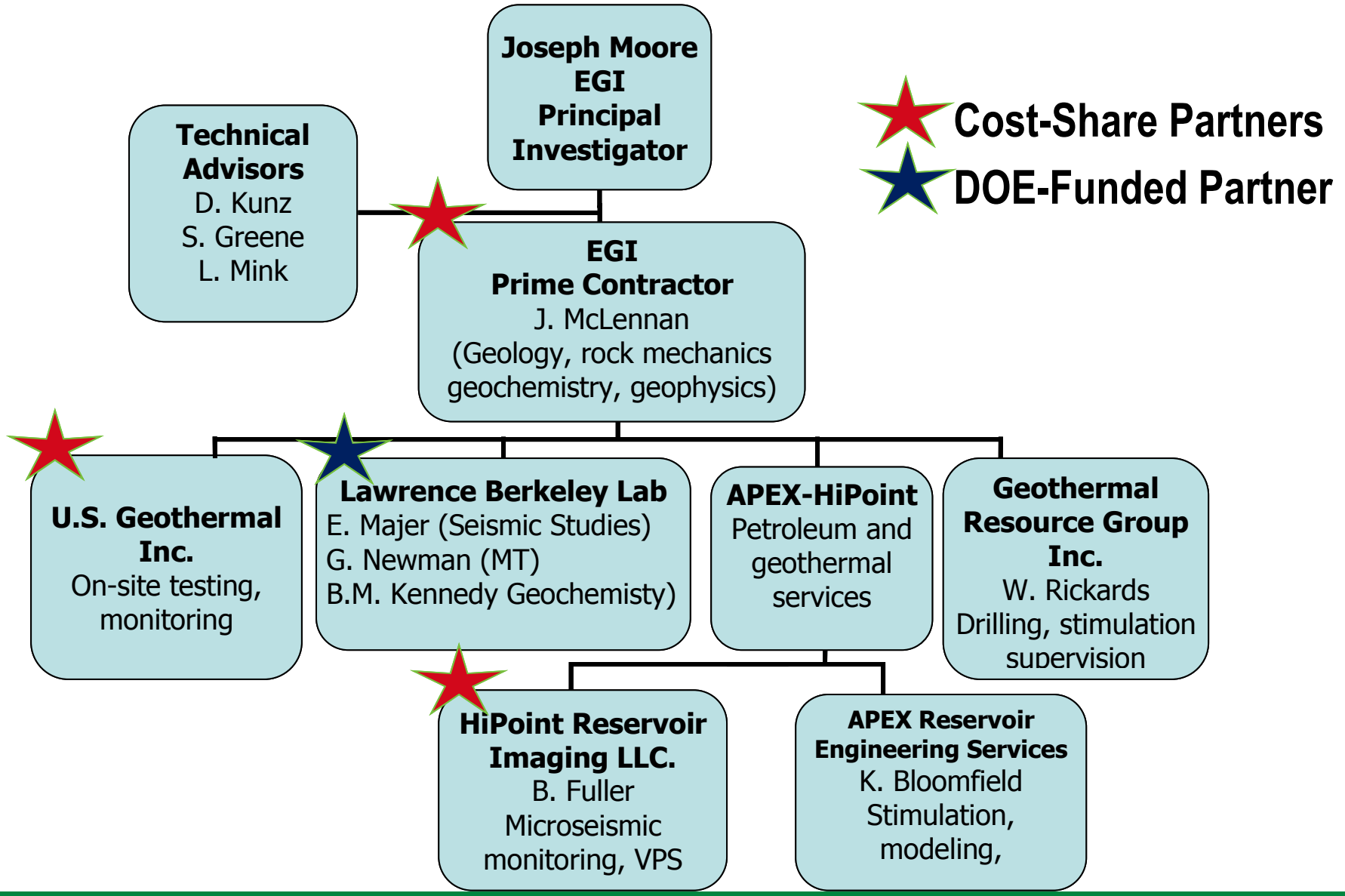
Phase 3 (FY 12-14)



*Includes seismic, production, tracer, and geochemical monitoring

Project is 10% complete.

Overview of Team



Overview of Budget and Barriers

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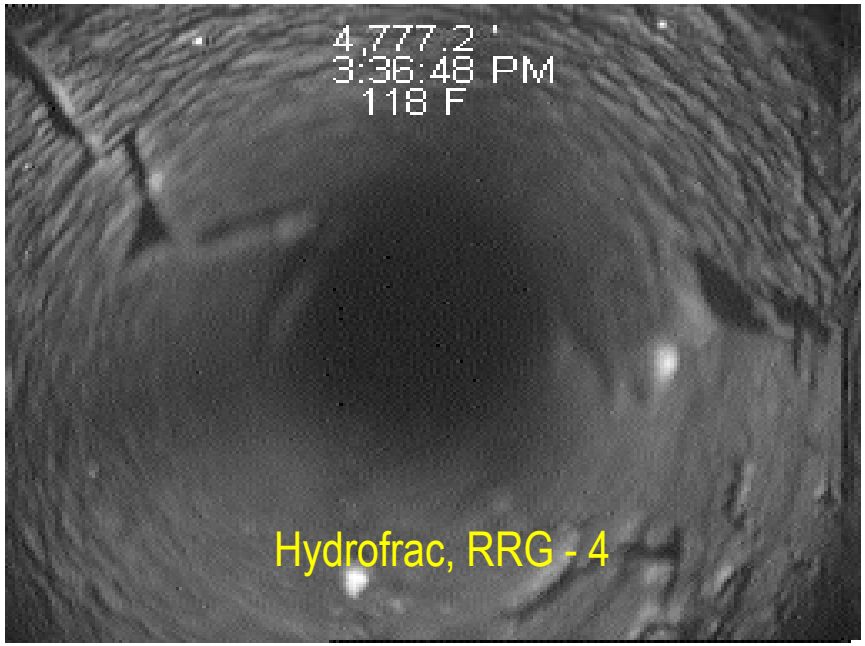
	DOE Share	Awardee Share	Total
Project Funding	$ 7,391,766	$ 2,823,221	$10,214,987
Funding Received (Not obligated by year)	$ 5,966,500		

- This project directly addresses the following barriers to EGS reservoir development:
  - Well site characterization
  - Reservoir creation
  - Reservoir validation
  - Interwell connectivity
  - Long term reservoir sustainability
  - Induced seismicity

PROJECT OBJECTIVES

1. Develop and demonstrate the techniques required to form and sustain EGS reservoirs including combined thermal and hydraulic stimulation and numerical modeling

2. Improve the performance and output of the Raft River geothermal field by increasing production or injectivity.



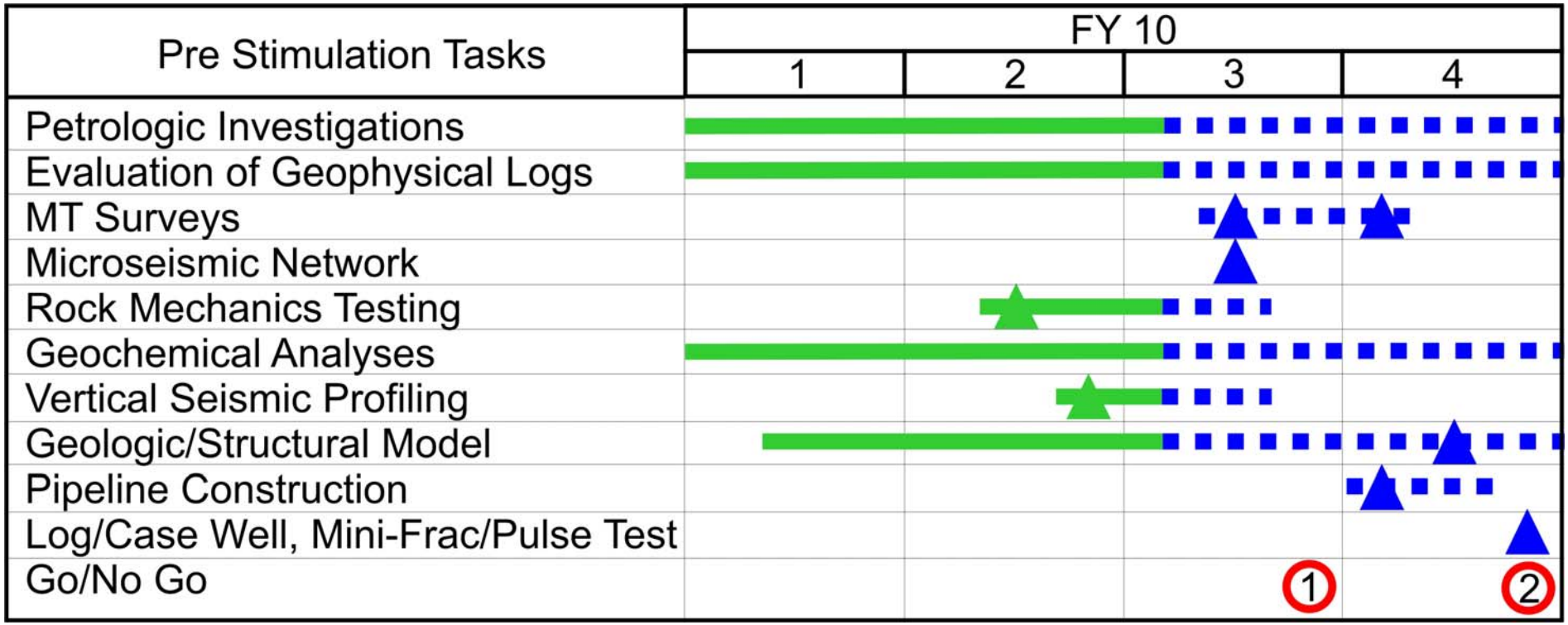
Relevance/Impact of Research

- Provide essential test of EGS reservoir development. Such tests are necessary but currently lacking within the US.
- Moderate temperature resources are abundant and accessible at shallow to intermediate depths. Can be developed at lower cost than deeper, high temperature resources.
- Reservoir rocks appear to be excellent candidates for EGS reservoir development.
- The stimulation will employ a novel multistage approach using thermal and hydraulic fracturing. This could lead to lower cost, more effective stimulation programs.
- The project builds on expertise from the geothermal and oil and gas industries.
- New geothermal scientists are being trained.
- The response of the stimulation to seismic activity will be measured and modeled.
- Phase I on schedule.

Developing an EGS Reservoir and Stimulation Plan

1) Understanding the resource's structural setting:
   - Petrologic analyses of well cuttings and cores,
   - Analysis of geophysical logs
   - Field data (MT, gravity, seismic, geochemistry)
   - Rock mechanics testing
2) Understanding permeability, mechanical properties and in-situ stresses of the target zone
   - Borehole imaging,
   - Step rate/step down pulse and mini-frac tests
   - Fracture simulation modeling
   - Numerical simulations (earth model assessing fractured domain, induced seismicity, production potential)
3) Develop a stimulation plan and stimulate the well
4) Monitor growth of fracture volume

Scientific/Technical Approach: Milestones



Red circle1 = Approval for pipeline construction; Red circle 2 = Approval for well completion
Green triangle = milestone met; blue triangle = future milestone

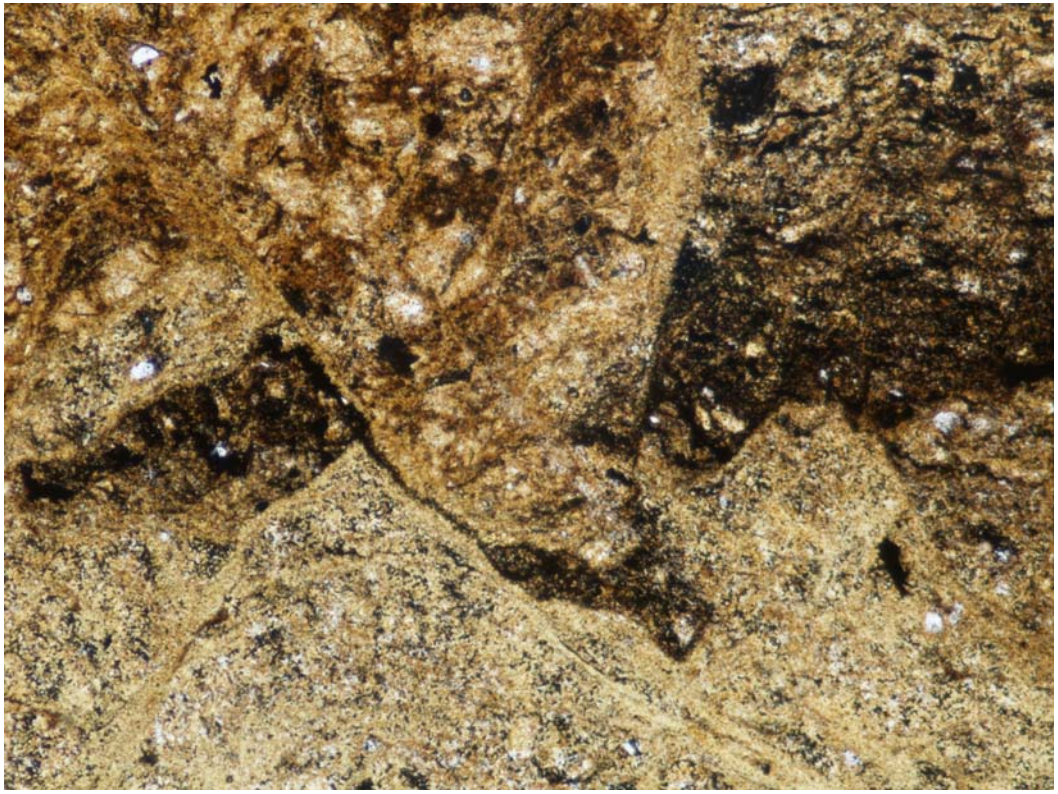
Scientific/Technical Approach: Required Approvals

- Go/no-go decisions and required approvals:
  - NEPA determination for pipeline construction and well stimulation
  - DOE approval to install casing in well
  - Go/no-go decision to stimulate well (DOE)
  - Archeological and wildlife restrictions (BLM)
- All requests for NEPA determination have been submitted

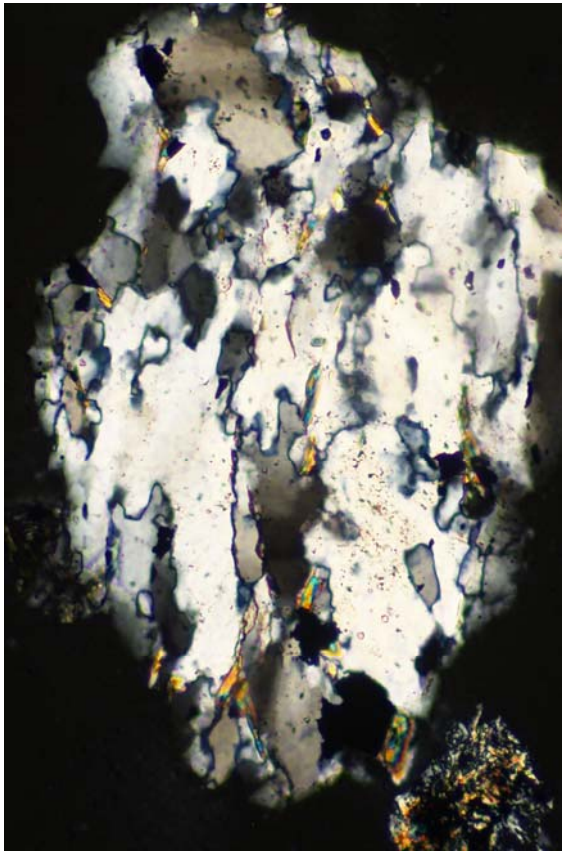
VSP Survey; seismic sondes

Rock Characterization

Thin section and X-ray diffraction (whole rock and clay separates) analyses of rock samples from wells RRG 1, 2, 3, and 9 at 50-100 ft intervals conducted (total of ~160 analyses).

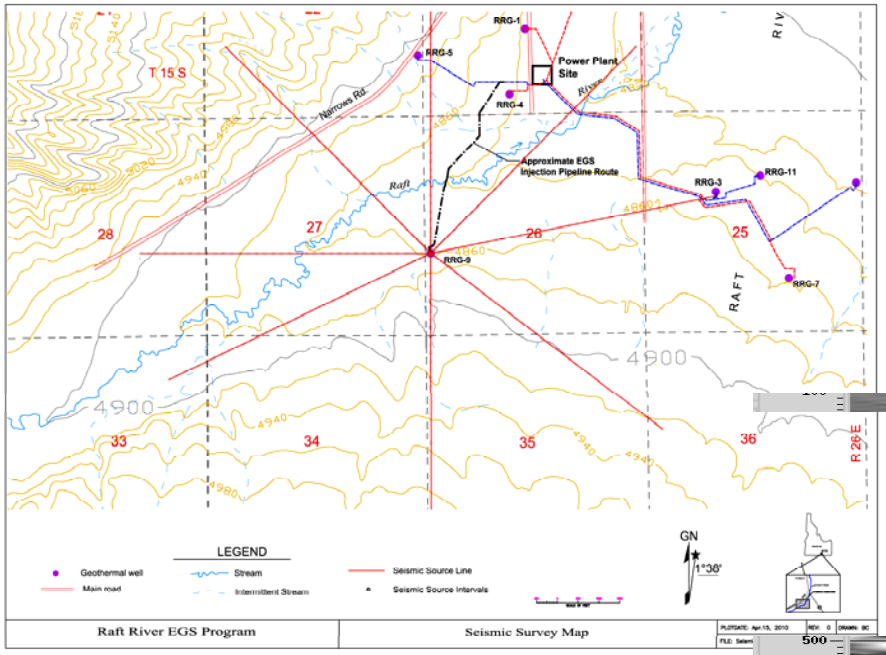


Upper Narrows Schist (core 5270 to 5772 ft; RRG-3)



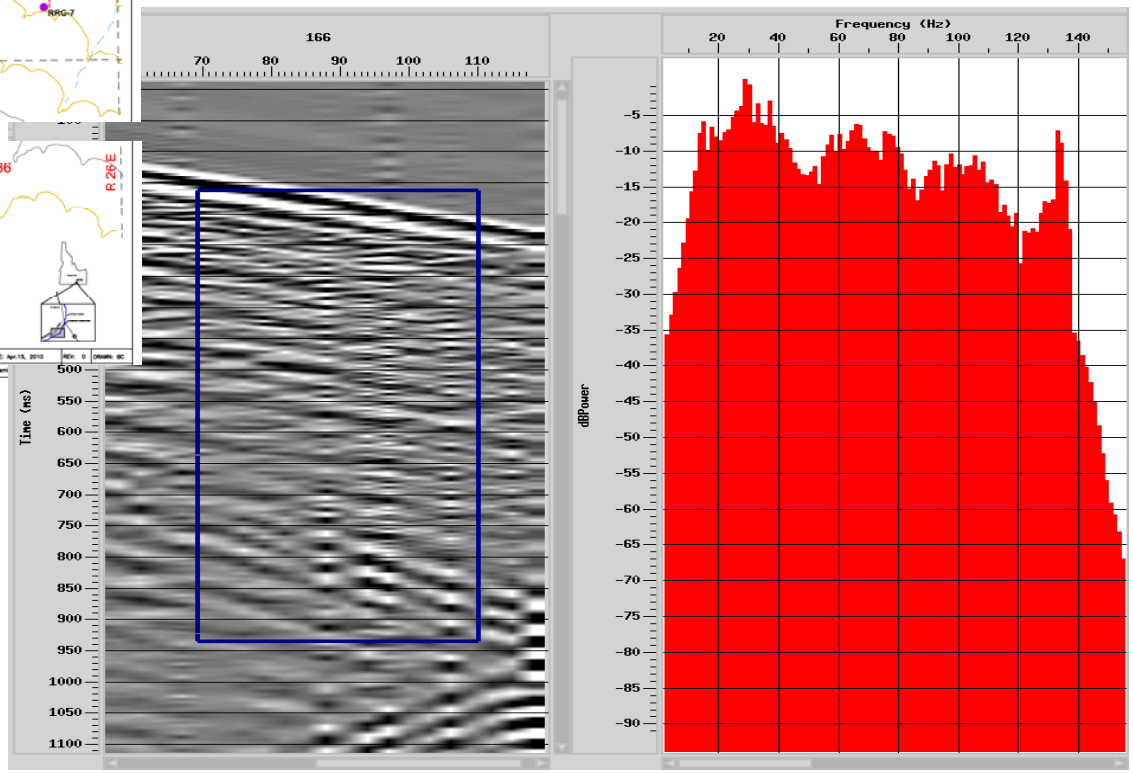
Elba Quartzite (5900 ft; RRG-9)

VERTICAL SEISMIC PROFILE SURVEY



255 source points on 8 radial spokes

40 3-component geophones set to 2235 ft

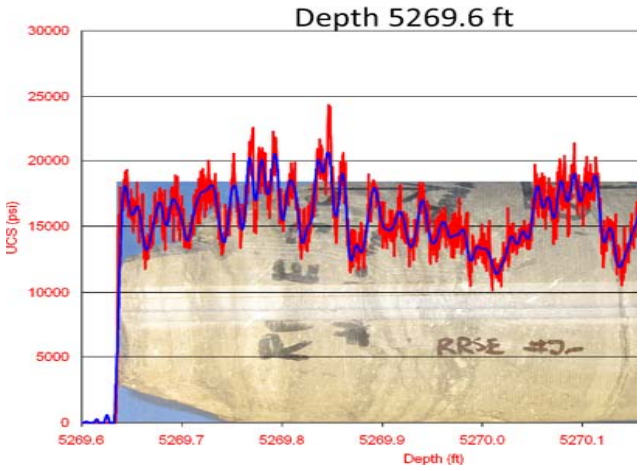


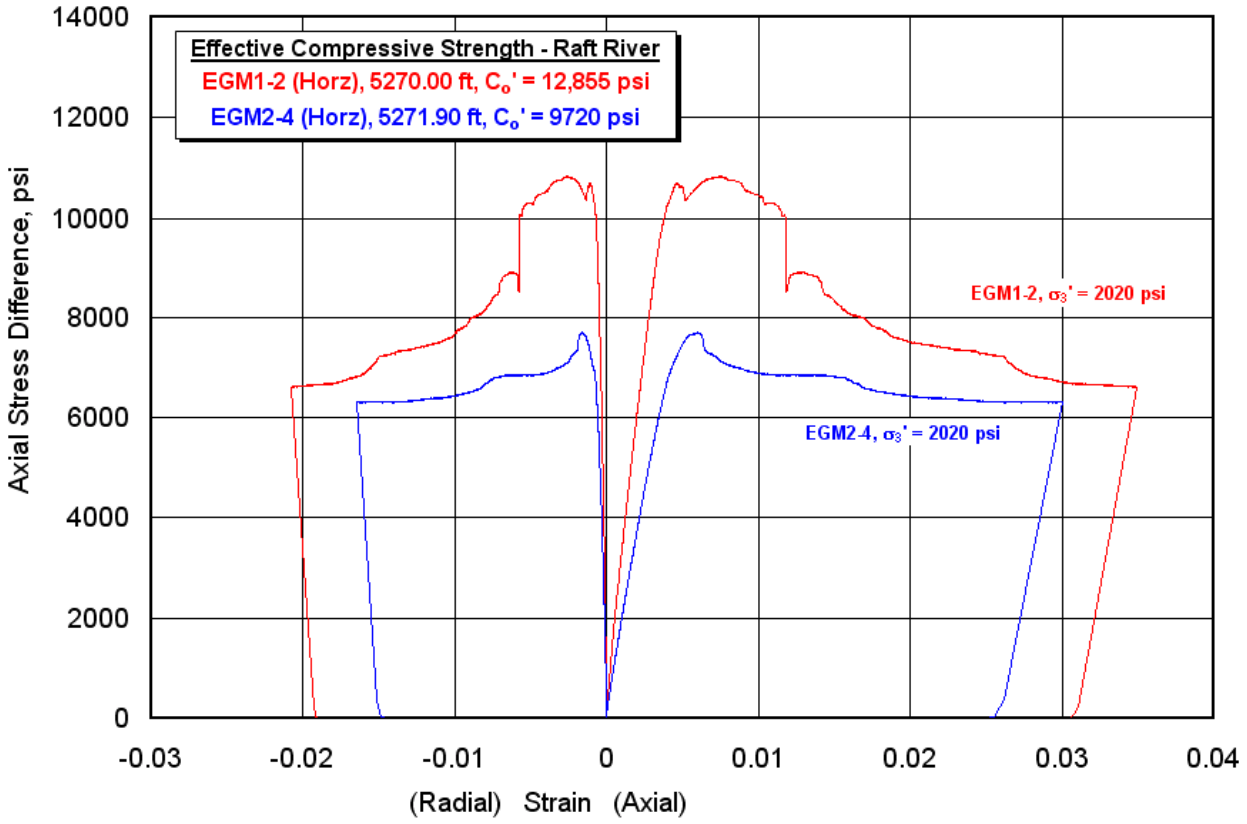
Left: Typical amplitude spectrum from the vertical component of a source point (without signal processing); Right: power frequency spectrum

ROCK MECHANICS TESTING

Tests completed: uniaxial compressive strength, CT scans, density, porosity, TSI UCS, tensile tests (Brazilian tests), triaxial tests, thermal conductivity.

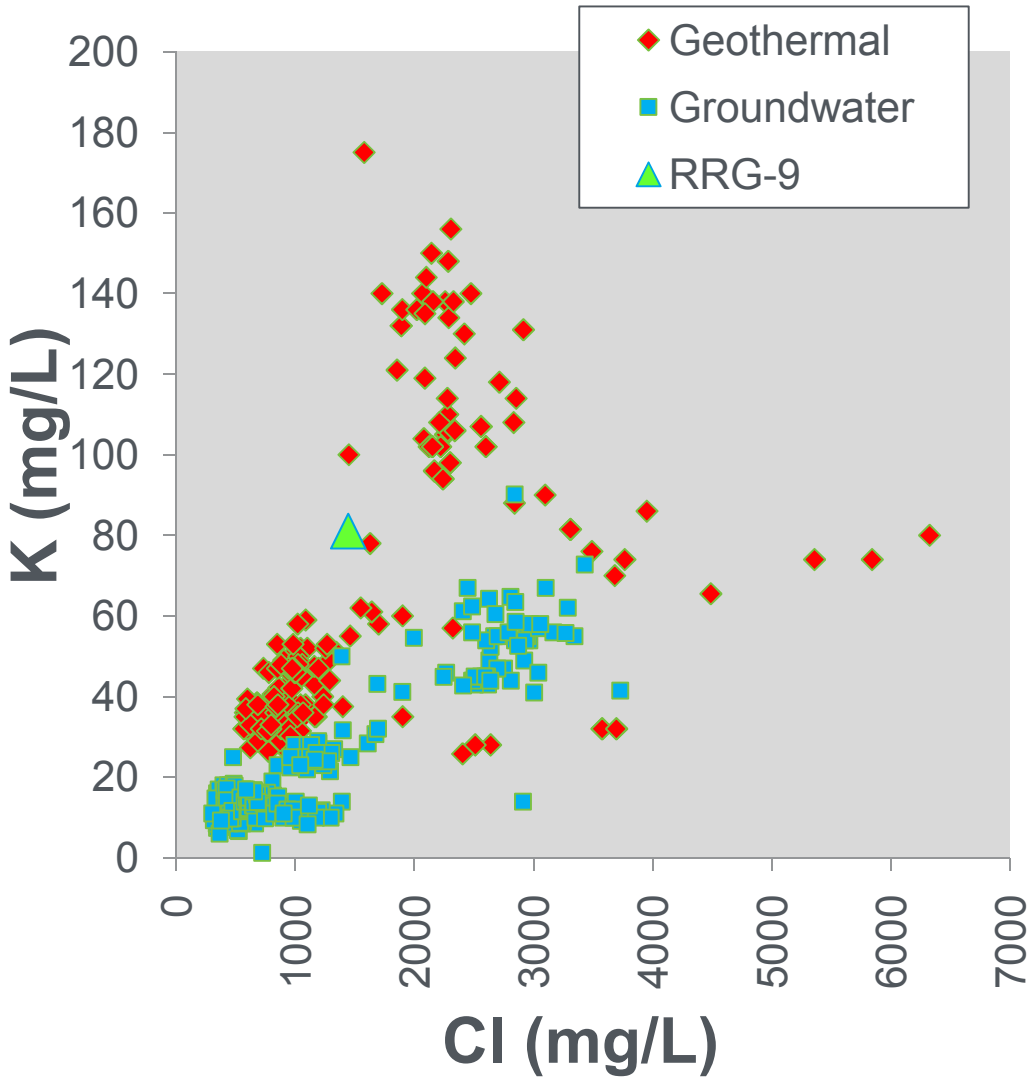
Scratch Test Profile





ADDITIONAL MAJOR TECHNICAL ACCOMPLISHMENTS

- Developed searchable database of thermophysical rock properties.
- Analysis of well logs and correlation with mineral compositions is underway.
- Geochemical data compilation and evaluation underway.



Accomplishments, Expected Outcomes and Progress: Team Qualifications

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EGI: J. Moore (geology, geochemistry); J. McLennan (rock mechanics, design and modeling of hydraulic stimulations); P. Wannamaker (MT, geophysics); P. Rose (tracers)

U.S. Geothermal: K. Kits, D. Crea (drilling and well testing; field development and operations); W. Teplow (geothermal exploration and development)

Apex HiPoint: Design, management and modeling of microseismic surveys, management and monitoring of well stimulations for oil and gas industry; on-site management of hydraulic stimulations

Geothermal Resources Group: W. Rickards (well design and drilling management of geothermal and oil and gas wells)

Lawrence Berkeley Laboratory: E. Majer (microseismic monitoring); G. Newman (MT); B.M Kennedy (geochemistry)

Facilities and software: core and data libraries, X-ray, petrographic and tracer, laboratories, in-house algorithms for interpretation of seismic, MT, and rock mechanics data

Project Management/Coordination

- Principal Investigator: Dr. Joseph Moore (EGI)
  - Oversees work on this project and
  - Coordinates communication and reporting activities among team members and with the DOE program managers.
  - Serves as the point of contact with DOE, other government agencies, and contractors
  - Assumes overall responsibility for budget

- Leveraging of funds: U. of Utah providing cost share for students; partners providing cost share contributions; U.S. Geothermal providing access to field infrastructure and cost share.

- Coordination and integration with other projects:

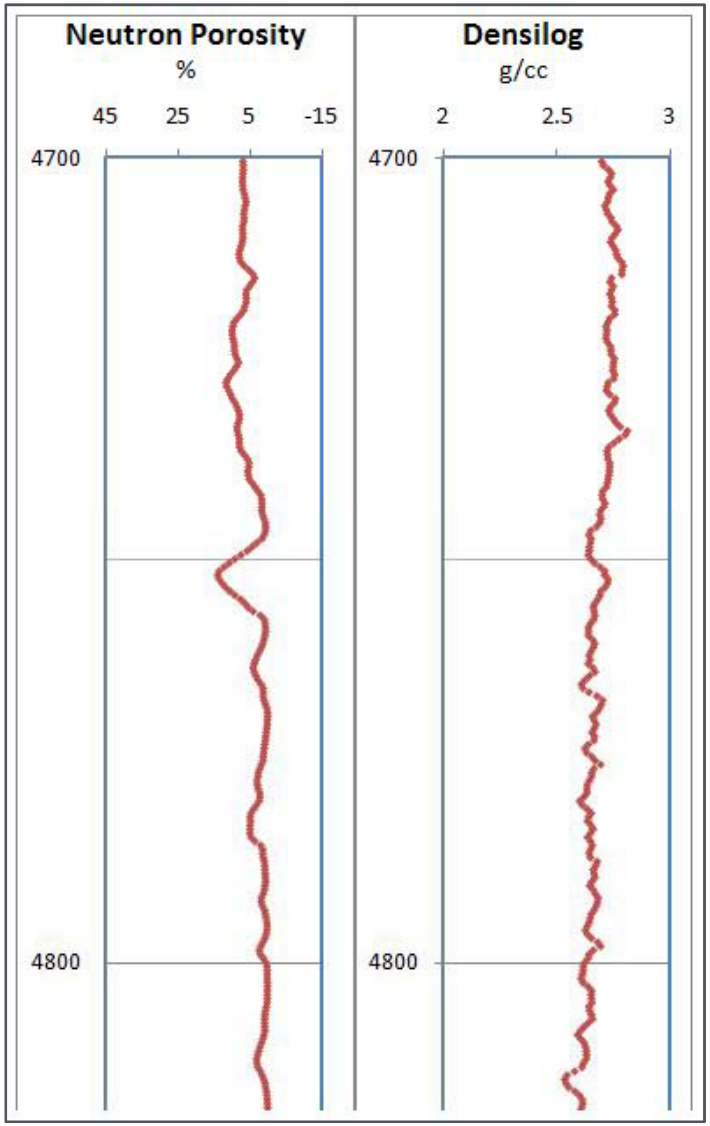
  1) Several of the team members are also part of other demonstration teams allowing cross fertilization of results and approaches

  2) The DOE Technical Review Team provides appropriate suggestions and guidance as necessary.

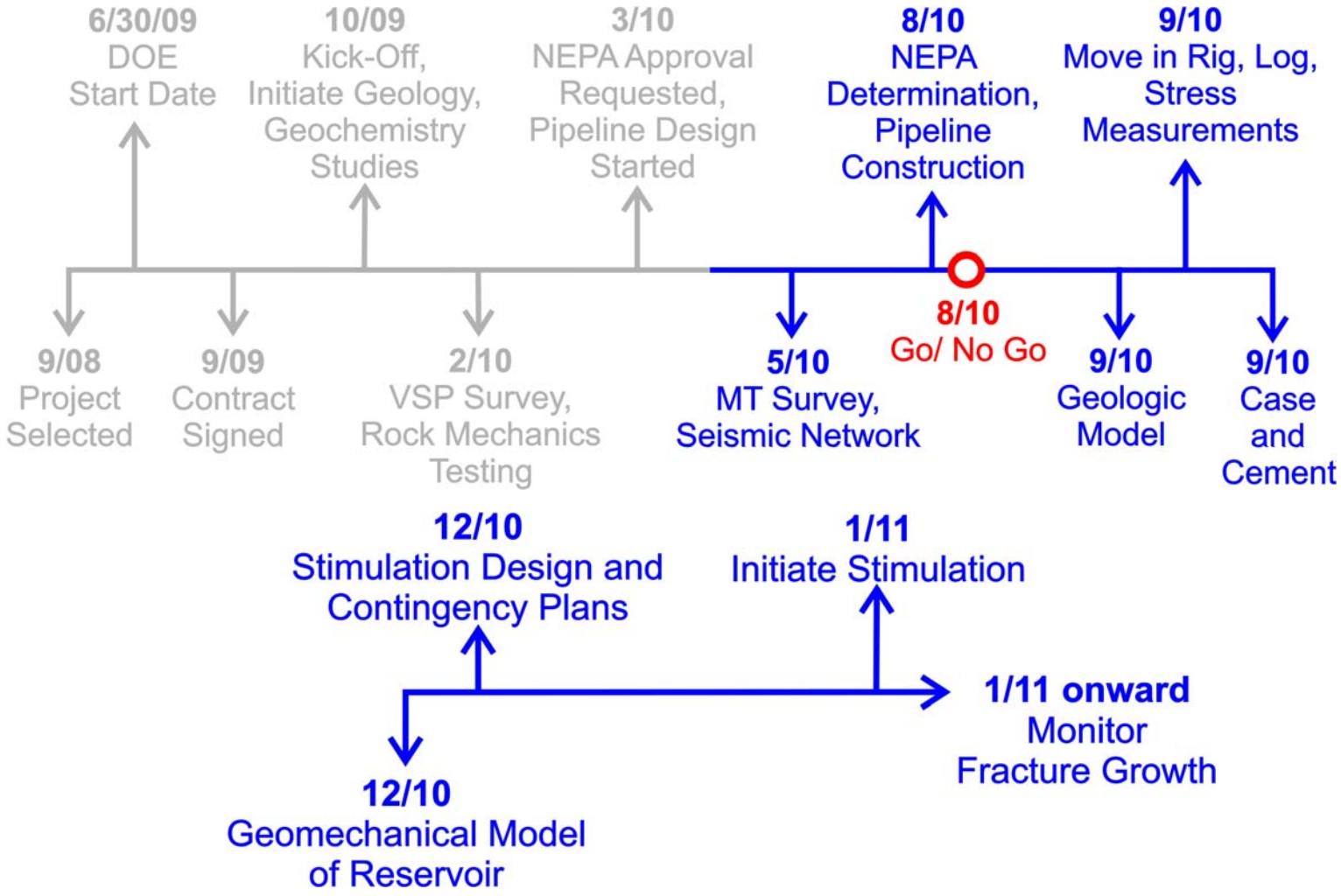
Project Management/Coordination: NGDS

Use as a demonstration pilot project

– Consider:
  - Protocols for data submission (e.g. legacy data, newly acquired data)
  - Data transparency
  - Access to public domain and proprietary data
  - Potential tools for data manipulation



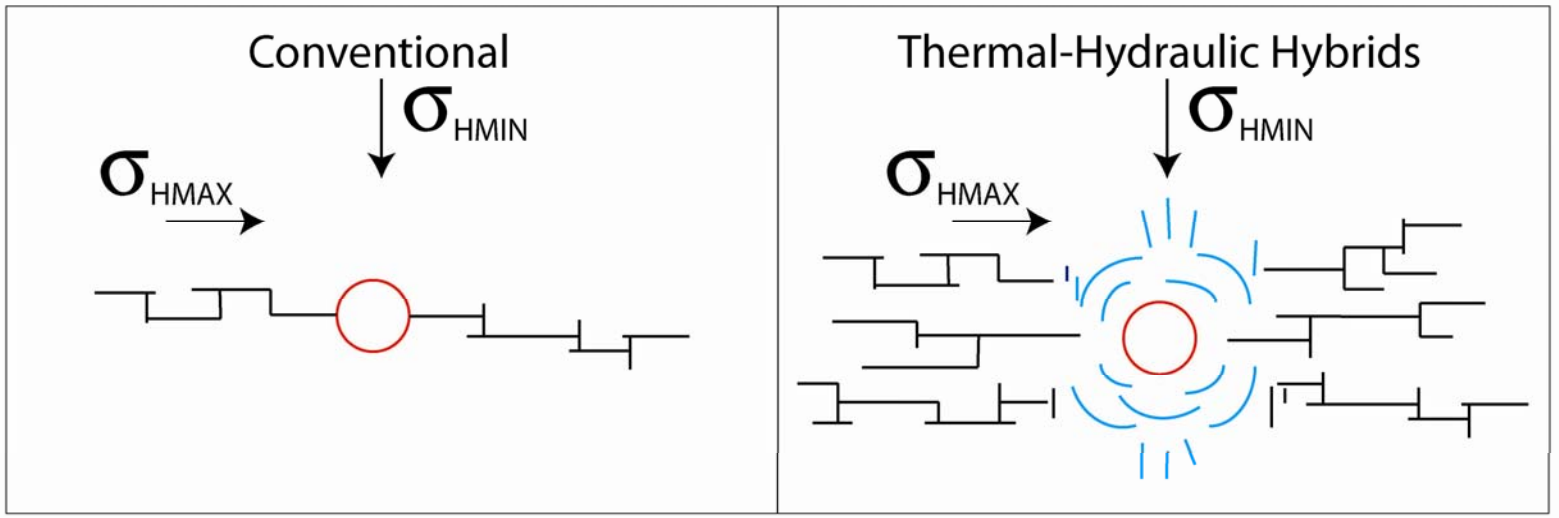
Future Directions: FY 10-11 Key Milestones



Future Decision Points: Maintain close contact with DOE Program Managers. Review alternatives with DOE and the Technical Review Team

Summary: Key Points

- The team amalgamates significant geothermal and oil and gas experience.
- The project is well defined, the infrastructure is in place, U.S. Geothermal is committing significant resources and data to the project, and a substantial database already exists on the resource.
- The target well is in excellent shape, and completed in reservoir rocks well suited to EGS development.
- Five students are conducting independent research.
- Novel approach to geothermal reservoir stimulation. 2 stages thermal stimulation followed by hydraulic stimulation



Publications

- Britton, D., Moore, J., T. Dung, McLennan, J., and Jones, C., Predicting Thermophysical Properties of Geothermal Reservoir Rocks: in press, to be presented at the 2010 annual Geothermal Resources Council meeting.

- T. Dung, Britton, D., Jones, C., Moore, J., and McLennan, J., Rock Characterization at the Raft River Geothermal Reservoir for Hydraulic Fracturing Stimulation: in press, to be presented at the 2010 annual Geothermal Resources Council meeting.