Alum Innovative Exploration Project

May 19, 2010

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Sierra Geothermal Power

Validation of Innovative Exploration Technologies

Alum Innovative Exploration Project Summary

- Awardee: Sierra Geothermal Power (SGP)

- Timeline
  - Started: October 2009
  - Award Effective Date: January 21, 2010
  - Planned finish: August 2011
  - 37% complete on a budgetary basis

- Budget
  - DOE Share: $5,000,000.00
  - SGP Share: $7,356,546.00
  - Total: $12,356,546.00

Overview

- Multi Year RD&D Plan Barriers addressed
  - Barrier C: EGS Well Construction Capability
- Partners
  - Conrad Wright, SpecTIR LLC
  - Chris Kratt, Desert Research Institute
  - Roger Henneberger, Chris Klein, Eduardo Granado, and Rob Stacey; GeothermEx, Inc.
  - Jerry Hamblin, Thermasource
  - John Deymonaz
  - Stephen Hallinan, Western Geco
  - William Cumming, Cumming Geoscience
  - Joe Moore, EGI
  - Dan Moos, GeoMechanics International, Inc

Relevance/Impact of Research

Objective #1: Confirm the presence and characteristics of the geothermal resource at Alum

- Sierra Geothermal Power's corporate goal is to bring 30 MW of geothermal power online at the Alum project site in 2014

Objective #2: Validate new exploration techniques

- Hyperspectral imaging survey
  - Identify surface geothermal indicator minerals from the Visible-Near Infrared (VNIR) region of the spectrum at spatial resolutions of 3 - 5 m^2
  - Access the value of hyperspectral imaging for the discovery of blind geothermal resources
- Coiled-tube drilling
  - Demonstrate coiled tube drilling in a geothermal environment

Scientific/Technical Approach

- The airborne hyperspectral survey will be validated through the comparison of identified mineral anomalies to the temperature anomalies identified by:
  - Airborne thermal infrared survey,
  - Shallow (6 foot) temperature probe survey and
  - the results of temperature gradient drilling.
- Coiled-tube vs Core Slimwells vs Full Diameter Exploration Wells
  - Drill one well of each type
  - Keep detailed records of the time and cost of drilling
  - Side by side comparison of
    - Cost / Risk assessment
    - Time
    - Geologic information obtained

Scientific/Technical Approach

- Temperature Gradient Hole Site Selection
  - Use near-surface exploration techniques to guide selection of shallow temperature gradient (TG) drill site locations.
- Geological and geophysical techniques used to assist in identifying deep geothermal drill targets for Phase 2 drilling are:
  - Detailed geologic and structural mapping
  - 2D & 3D modeling of gravity and magnetic data
  - 2D & 3D modeling of magnetotelluric and ZTEM data
- Improve selection of deep geothermal drill targets by
  - the integration and interpretation of the results of the above datasets
  - combine with detailed geologic and structural mapping and temperature data from TG holes, exploration well and slimwells

Scientific/Technical Approach

- Resource and well targeting risk management
  - Use standard resource decision tools adapted to the geothermal industry's sparse case history data sets.
  - Drilling target alternatives based on the conceptual model(s) inferred from geology and geophysics will be tested using decision tables.
  - Complete risk analysis that illustrates temperature and permeability uncertainty in exploration and resource capacity uncertainty in development.
  - Resource capacity uncertainty will be characterized using a small number (~5) of realistic cases consistent with injection capacity case histories and a lognormal distribution of resource sizes based in part on a volumetric heat-in-place approach.

Scientific/Technical Approach

Task #	Milestone	Date	Status
Task 1.0	Surface and near surface investigations	June 2010	Aerial thermal survey pending dry weather.
Task 2.0	Build 3D model	Complete	Modeling completed, seismic data for validation not acquired.
Task 3.0	3D subsurface resistivity study	Complete	
Task 4.0	Exploration well drilling	Complete	Well 25-29 was completed to a depth of 1,005 m in Q4 2009.
Subtask 5.1	Drill slimwell with coiled tubing drill rig	Complete	Well 26-19 was drilled to a depth of 1,341 m in Q1 2010 with the coiled tubing rig.
Subtask 5.2	Drill slimwell with coring rig	August 2010	Pending results of exploration.
Task 6.0	Integration of exploration data	August 2010	
Task 7.0	Phase 1 Report / Go No Go decision point	September 2010	

Accomplishments, Expected Outcomes and Progress

Geothermal exploration surveys completed:

- Airborne hyperspectral imaging survey
- Shallow (6 foot) temperature probe survey
- Collection of field data on the magnetic susceptibility and density of major rock types
- Ground-based magnetotelluric survey
- Airborne ZTEM survey

Analysis/modeling completed:

- Eight 2D geologic profiles modeled from gravity & magnetic data
- Two 3D lithologic horizons modeled from gravity data
- One 3D resistivity inversion block model derived from magnetotelluric data
- Sixteen 2D resistivity profiles derived from 2D inversion of ZTEM data
- Geomechanical model constructed from well 25-29 data

The following drilling activities have been completed:

- Well 25-29 was drilled to 1,006 m, the maximum temperature reached was 130°C at depth of 619 m.
- Well 26-19 was drilled to a depth of 1,341 m with a coiled-tube rig. Unable to complete well as planned due to wellbore stability. Coring rig moved on location.

Project Management/Coordination

- Project Responsibility Matrix
  - Summarizes participants involvement in each task
- Project Schedule
  - Maintained in project management software
  - Schedule is aggressive
  - Project is one of SGP's Tier 1 projects and corporate objectives are major schedule driver
- Project Budget
  - Maintained in spread sheet software linked to project management software
- Risk Assessment
  - Preformed during well planning
  - Resource risk assessment for Phase Gate 1

Future Directions

Near-surface techniques

1. Complete thermal survey
2. Select temperature gradient (TG) holes locations
3. Drill TG holes
4. Assess the usefulness of these methods in selecting TG drill sites

Phase 1 Drilling

1. Select core well location
2. Drill well location

3D model of the subsurface

1. Integrate geophysical and geological data
2. Conduct synthesis of temperature data with the 3D geologic model
3. Develop conceptual model(s) and identify deep drill targets
4. Complete risk analysis

Summary

- Large and diverse, well-qualified team
- Project incorporates several innovative techniques
  - Coiled-tube drilling
  - Hyperspectral survey
  - ZTEM
- Combination of innovative and proven techniques being applied which assists in the validation of the innovative techniques
- Aggressive schedule with several tasks already completed