



Bradys EGS Project

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Ormat Nevada Inc.

Innovative Exploration Technologies

- Timeline
 - Project start date: September 2008, contract was signed on June 2009
 - Project end date: June 2012
 - percent complete: ~10%
- Budget
 - Total project funding: \$5,100,600
 - DOE share: \$3,374,430
 - Awardee share: \$1,726,179
 - funding received in FY09: \$97,152
 - funding for FY10: \$800,128
- Challenge: Coordinating other DOE funded projects focused on Brady's EGS (LANL, Hi-Q, UNR) and integrating results
- Partners: GeothermEx, Inc., GeoMechanics International, Lawrence Berkeley National Laboratory, Nevada Bureau of Mines and Geology / GFZ (Germany), Pinnacle Technologies, TerraTek, University of Nevada, Reno, University of Utah

Project Goals:

- Stimulate Permeability in Tight Well 15-12 and Improve Connection to Rest of the Field
- Improve overall Productivity or Injectivity
 - Common EGS/Geothermal development goal
- Successful stimulation yields more production and enables more power generation
- Bradys methodologies can apply to other EGS projects – “Toolbox”

Well Selection:

- Located in developed geothermal field – “In Field” EGS
- High Temperature
- Favorable rock formations amenable to hydraulic stimulation

Project Management

- Signing Subcontracts - (UNR, GMI, USGS, Temple, TerraTek)
- Cooperative Research Workshop – April 2010
 - DOE, GeothermEx, UNR, USGS, LBNL, LANL, NETL, Hi-Q, Bestec, GMI, Temple U., TerraTek, NBMG / GFZ
 - Presentations from each party on their plans and results to date
 - Site visit / field trip
 - Defined scientific work plan

Research

- Borehole Logging (wellbore image and other logs)
 - Existing FMS in 15-12 OH; new FMS and borehole televiewer log to be run in 15-12 ST1
- Core Recovery
 - Cores from BCH-3 organized and catalogued to enable selection for testing
- Seismic Network
 - Shallow downhole array installed with 8 3-component stations
- Conceptual Structural Model
 - Detailed geologic mapping completed (Faulds, 2004) and update underway
- Petrologic Analysis of Cuttings
 - Sample splits obtained from wells 15-12 and 26-12, in process now
- Review of Existing Geophysical Data and Seismic Reflection Survey
 - Review has enabled design of seismic survey

Bradys, Nevada

Active Producers

Active Injectors

Well 15-12

Well 26-12

Well 88-11

Nevada

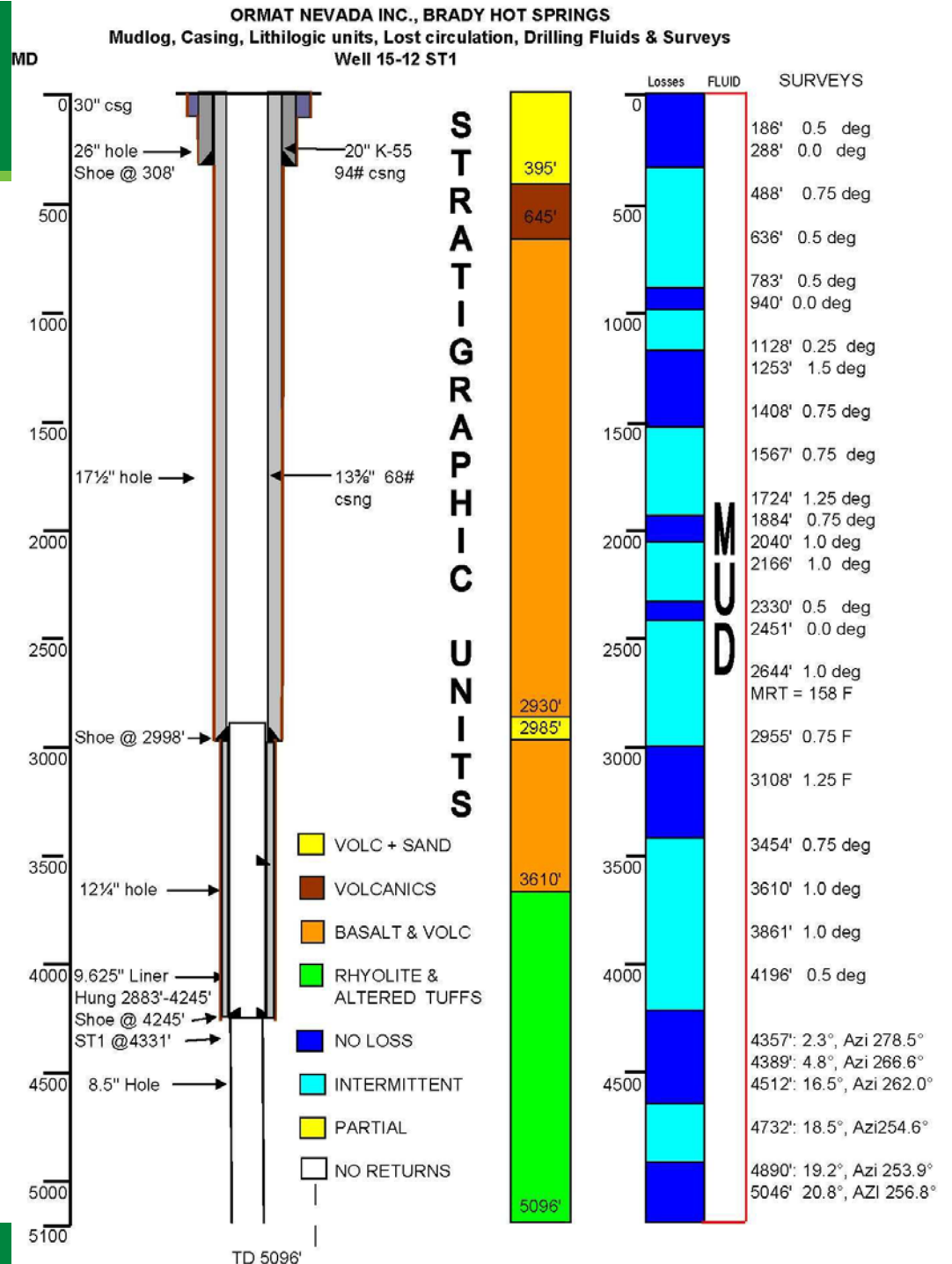
EXPLANATION

Qa	Alluvium, beach and pediment gravels, playa deposits
Qtb	Capping basalt and basalt tuff breccia
Tt	Truckee Formation Lacustrine sediments, interbedded siltstone, sandstone, mudstone, volcaniclastic sediments, tuffs and fossiliferous limestone
	Fault, bar on downthrown side with dip in degrees
	Lineament, probable major fault
HYDROTHERMAL ALTERATION	
	Siliceous sinter, silicic alteration. Solid where certain, outline where inferred. Circle where examined.
	Calcareous tufa and calcite veins. Veins solid. Circle where examined.

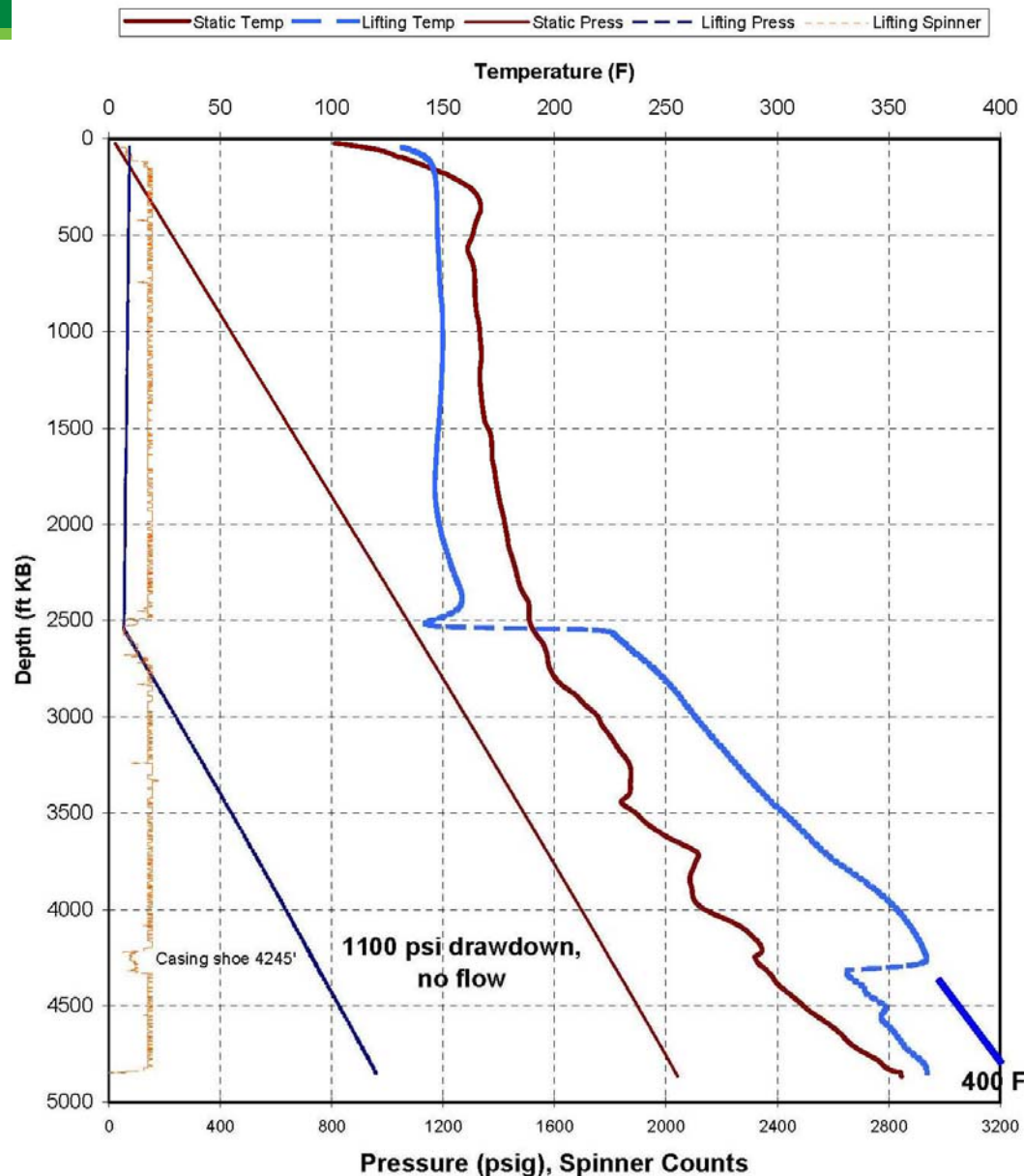
Bradys 15-12

Rationale:

- Recent Completion- 2007
- 9 5/8 inch liner to 4245 ft
- 8 1/2 inch OH to 5096 ft
- 850 feet of open hole in competent, fractured rocks with sub-commercial permeability
- temperatures exceeding 400°F
- Located adjacent to existing core hole BCH3
- Located within several hundred feet of commercially productive wells
- Located within several hundred feet of two other non-commercial wells that are open and accessible (88-11 and 26-12)
- Location within or near the Bradys Fault and the likely trend of maximum horizontal stress, has the potential to be connected with other Bradys wells.



Brady's 15-12 Temperature & Pressure Profiles
 Welaco PTS Logs, Both up Passes
 Static April 6 and Lifting with Air at 2500 ft April 7, 2007



- OH reached TD on April 4, 2007
- Continued circulating on April 5th
- Static temp log on April 6th
- Air lift attempt on April 7th
- Deep temperatures are expected to be ~400°F (204°C)
- Ran FMS log on April 13th
- Plugged back to 4,331 feet for ST1
- Start ST1 on April 16th
- Drilled to 5,096 feet without significant losses
- Performed injectivity test on April 21st
- Well has low permeability
- Injectivity Index < 1 gpm/psi

Seismic monitoring array (LBNL)

- An 8 station array capable of detecting and locating in real time MEQ events down to mag 0 or better.
- Surface stations - three component 4.5hz geophones buried in the near surface. *Installed and online.*
- Downhole stations – three component 8hz geophones installed at ~100'. *Equipment and boreholes by mid-June.*
- The data is transmitted to a central site with spread spectrum radios over an RS232/ internet compatible digital link at real time data rates with time stamped data using GPS corrected data.

http://esd.lbl.gov/research/projects/induced_seismicity/egs/desert_peak_brady.html



- Image logs – Formation Micro Scanner (FMS) Analysis
 - Natural Fractures (distribution, attitude and characteristics)
 - Bed Dips
 - Lithologic Boundaries
 - Stress Directions & Magnitudes
 - Borehole Condition
- Temperature-Pressure-Spinner Flowmeter logs:
 - Fluid inflow and outflow zones
- Density logs:
 - Vertical Stress Magnitude, Rock Mechanics, Porosity
- Velocity logs:
 - Rock Mechanics
- Mud logs and cuttings analysis
 - Cuttings Lithology, Alteration, Texture
 - Mud Losses
 - ROP

- Summarized management activities :
 - Maintaining project timetable and resources allocation
 - Monitoring funds/budget/spend plan
 - Executing on-site activities
 - Information flow: conducting quarterly meeting and workshops

(UNR) George Danko: A new Analytic-Adaptive Model for EGS Assessment, Development and Management Support
Hi-Q Geophysical Inc. (John H. Queen): Seismic Fracture Characterization Methodologies For Enhanced Geothermal Systems

LANL (Lianjie Huang): Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in Enhanced Geothermal System (EGS) Reservoirs

NMBG / GFZ: Detailed Structural Mapping and Surface Stress Indicators

- Evaluate relevant technologies , i.e. Tilt Metering survey, Shot calibration ...
- Progress Reporting
- Prepared Induced Seismicity protocol and installed passive monitoring array
- Coordinating UNR & BLM stimulation monitoring and activities

- The Bradys EGS Project Emphasizes the Importance of:
 - Strong research team plus dedicated field operations partner
 - Integration of tectonics, geology, petrology, rock mechanics and stress
 - Well designed MEQ system that has been deployed early in the project
 - Protocol for monitoring and managing Induced Seismicity
- Our Goal: Enhance permeability in 15-12 ST1 to increase generation at the Bradys Power plant by 2-3 MW

- **Ormat** (field owner / operator) – oversight, organization, drive, interface with DOE, drilling, field operations
- **GeothermEx** – technical management, hydraulic testing, modeling, evaluation
- **Jim Faulds (UNR)** **Inga Moeck (GFZ)** – geologic mapping, structural model, 3D geologic model, surface stress indicators
- **USGS:** 1) **Steve Hickman, Nick Davatzes** (now Temple University) - stress field analysis, rock mechanics, mini-frac, structural modeling; 2) **Bruce Julian, Gillian Foulger** – seismic monitoring and analysis
- **EGI :** **Peter Rose** – tracer testing, geologic modeling
- **LBNL :** **Ernie Majer** (seismic monitoring and analysis); **Mack Kennedy** (fluid and isotope geochemistry)
- **Schlumberger TerraTek** (**Susan Lutz**) – petrology, stratigraphy, core testing
- **GMI** (**Daniel Moos**) – logging analysis, stimulation planning
- **Roy Baria (Miltech)** and **Dimitra Teza (Bestec)** - project peer review and stimulation planning