Newberry EGS Demonstration

Project Officer: Lauren Boyd
Total Project Funding: $43.8 m
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AltaRock Energy

EGS Demonstration Projects

This presentation does not contain any proprietary confidential, or otherwise restricted information.
Relevance/Impact of Research

**Project Objective:** Demonstrate the development and operation of an Engineered Geothermal System

**Project Site:** NWG 55-29, TD 3067 m, BHT 331°C

**Phase 1 (2009-11):** Complete site investigation, permitting and planning with historical data review and baseline data gathering

**Phase 2.1 (2012):** Install Microseismic Array
  Create EGS reservoir around NWG 55-29. Stimulate at least three fracture zones using diverter technology.

**Phase 2.2-2.5 (2013-14):** Drill two production wells into seismically mapped fracture network
  Test well connectivity, productivity and reservoir characteristics.

**Phase 3 (2014):** Develop conceptual modeling of commercial-scale EGS wellfield and power plant.
Innovation 1: AltaRock TZIM Technology

**Challenge:** Low flow per EGS well

**Solution:** Multiple zone stimulation through thermally-degradable zonal isolation materials (TZIM)

- Non-mechanical zonal isolation material
- No rig required during treatment
  - Major cost savings
  - Reduces operational risk
  - Create fractures in succession without moving packer and waiting on rig
- Breakdown products are non-hazardous
- A suite of materials developed that degrade with time and temperature
  - Lab tested from 74°C-315 ° C
Innovation 2: EGS Characterization tools

Challenges: Predicting induced seismicity, mitigating seismic risk, and characterizing EGS reservoir

Solutions

• Stress and fracture analysis from BHTV
• Hydroshear model (AltaStim™)
• Induced Seismicity Mitigation Plan to meet 2012 DOE Protocol
• Distributed Temperature Sensing (DTS) system to track zone isolation
• Combination of conservative and non-conservative tracers injected to assess surface area and temperature of stimulated zones.
Innovation 3: Stimulation pumps

**Challenge:** Stimulation pump reliability, suitability, and high rental cost

**Solution:** Lease-to-own, electric pumps

- Two 14 stage centrifugal pumps connected by 10 inch pipes & four valves
- HP (Newberry) Mode: in series with bypass line to allow sufficient flow to keep pumps cool when injecting to very low permeability wells
- LP Mode: in parallel for ~1000 psi WHP and ~2000 gpm

![Pump curves for HP Mode](image-url)
### Accomplishments, Results and Progress

<table>
<thead>
<tr>
<th>Milestone/ Technical Accomplishment</th>
<th>Date Completed</th>
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<tbody>
<tr>
<td>Phase 1 Planning Report Submitted</td>
<td>August 26, 2011</td>
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<tr>
<td>Stage Gate Passed</td>
<td>November, 2011</td>
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<tr>
<td>Environmental Assessment Submitted</td>
<td>December 20, 2011</td>
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<tr>
<td>BLM and DOE Issue Finding of No Significant Impact</td>
<td>April 5, 2012</td>
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<tr>
<td>Phase 2.1 Begins</td>
<td>April 5, 2012</td>
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<tr>
<td>MSA Acceptance</td>
<td>August 29, 2012</td>
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<tr>
<td>Stimulation Begins</td>
<td>October 16, 2012</td>
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<tr>
<td>Demobilization for Winter Complete</td>
<td>December 20, 2012</td>
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<tr>
<td>Phase 2.1 Report</td>
<td>In Progress (April 2013)</td>
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Mapping EGS with Microseismic Array

Phase II array
- Replaced Phase I (bkg) array
- 15-stations
- 8 borehole geophones
- 7 surface geophones
- Real-time telemetry

Strong motion sensor
- near Paulina Lake Visitor Center (NNVM)
• **Boreholes drilled to get below to water table**
  - 4 existing BH (one deepened)
  - 4 new BH drilled 210-250 m
  - Average 11 drilling days each
  - 3 months total

• **BH geophones**
  - with hole locks for orienting sensors
  - to enable source mechanism calculations.

• **Surface instruments at 7 sites**
### Stimulation of NWG 55-29

<table>
<thead>
<tr>
<th>Activities</th>
<th>Week Beginning Monday</th>
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<tr>
<td></td>
<td>Oct</td>
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<tr>
<td>Site Preparation – Rig-up</td>
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<tr>
<td>Step rate injectivity test</td>
<td></td>
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<tr>
<td>Stimulate 1st zone</td>
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<tr>
<td>Pump diverter #1</td>
<td></td>
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<tr>
<td>Stimulate 2nd zone</td>
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<tr>
<td>Pump diverter #2</td>
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<tr>
<td>Stimulate 3rd zone</td>
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<tr>
<td>Well heat up</td>
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<tr>
<td>Flow back test attempt</td>
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<tr>
<td>Rig-down and demobilize</td>
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<tr>
<td>Step rate injectivity test-Fluorimeter</td>
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<tr>
<td>Inject to cool - BHT survey</td>
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</tbody>
</table>
Hydroshearing initiated at WHP 12.5 MPa (1800 psi)
Seismicity continued at lower pressure
Total 227 locatable events including 22 events in 2013
EGS Reservoir Created: Map View

EGS Reservoir
- Elongate NE-SW
- 1.5 x 0.7 km
- $V_{\text{stim}} \approx 1.5$ km$^3$
- NW-SE lineaments
Stimulation Depths

1. Possible high permeability dikes, or

2. Aseismic slip in softer tuffs

Looking North

Looking West

1 km
Stage 1 DTS Results in Open Hole

- Two or more permeable zones between 2880 and 2950 m take majority of the injected fluid at start
- Darker red color after higher pressures indicates improvement – zones take for fluid and therefore cool more
- Stimulated at pressures above 12.5 MPa
- Other small permeable zones exist around 2550m, 2670m and 2850m
- DTS #1 failed on Nov. 9
- DTS #2 lowered on Nov. 25 but only reached 2105m before likely settling on ledge, just 130 m into open hole
• Although seismicity occurred above depth of 1500 m bgs, temperature profiles and gradients over 550 hour period indicate majority of fluid exited below 2500 m depth.
WHP, Flow and Injectivity

- Step-Rate Injection Test
- Stage I Stimulation
- Stage II Stimulation
- Stage III Stimulation
- Pump Repair

- Injectivity, L/s/MPa
- WHP, MPa
- Flow Rate, L/s

Graph showing changes in wellhead pressure, flow rate, and injectivity over time.
TZIM and Stage II

Increasing injectivity while cycling injection pressure.
Stage III and shut-in

- Injectivity, L/s/MPa
  - TZIM 7-10
  - TZIM 11-14

- WHP, MPa
- Flow Rate, L/s

- Shut-in
Multizone Stimulation Results

Stage 1 – Deep zones 2880-2950m stimulated
- 10/27/2012-11/2/2012: 27% V\text{tot}
- Total HP pumping time – 104 hours
- Maximum WHP 13.8 MPa (2040 psi)

Stage 2 – Pump TZIM 1
- 11/25/2012-12/3/2012: 22% V\text{tot}
- Seal permeable zones between 2880-2950 m
- At end of stage zones around 2080 m open up
- Total HP pumping time – 130 hours
- Maximum WHP 15.2 MPa (2200 psi)

Stage 3 – Pump TZIM 2
- 12/3/2012-12/07/2012: 14% V\text{tot}
- Seal permeable zones ~ 2080 m
- Total HP pumping time – 101 hours
- Maximum WHP 16.7 MPa (2420 psi)

All Stages – (incl. LP stage 11/3-11/24: 37 V\text{tot})
- Total injected volume 41,325 m³ (11,000,000 gal)
- Maximum WHP 16.7 MPa (2420 psi)
- 227 seismic events located 10/29/2012-02/18/2012
Future Directions

• Finish Phase 2.1 report and pass DOE Go/No-Go
• Possible flow test and fluid sampling for tracer returns/geochemical sampling
  – Collaborators: LBNL, LANL, INL, EGI/Utah, NETL/OSU
• Conduct post TZIM degradation injectivity and fall-off analysis
• Low-amplitude seismic emission analysis: vert. array of 12 geophones in 6 holes
• ExPro-video run to 2105 m (6900 ft) (check ledge and possible fish)
• BHTV and fluorimeter run (requires inject-to-cool)
• Design well course from stimulation seismicity
• Drill first production well (Q3/Q4 2013)
• Stimulate production well, if needed - conduct 7-day connectivity test
• Plan and drill second production well (2014)
• Conduct 30-day multi-well connectivity test

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<thead>
<tr>
<th>Milestone or Go/No-Go</th>
<th>Status &amp; Expected Completion Date</th>
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<tbody>
<tr>
<td>Post-stimulation Stage Gate</td>
<td>Report in progress: Complete Q2 2013</td>
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<tr>
<td>Post-stimulation well tests</td>
<td>Planning: Complete June 2013</td>
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</table>
• In April 2012, after more than two years of permitting and planning BLM & DOE issued FONSIs on stimulation
• Phase 2.1 began with ordering of pumps and MSA equipment followed by extensive field preparations for stimulation
• Seven week stimulation: Oct. 17 – Dec. 7, 2012
• EGS reservoir created with potential volume of 1.5 km$^3$
• TZIM allowed stimulation of multiple zones
• MSA performed well
• Challenges overcome
  – Accelerated procurement and installation
  – Winter weather starting in October
  – Pump breakdowns
  – Interpretation of shallow seismicity (in progress)
Collaborative projects

- Ghassemi/OkU: Geological and Geomechanical Framework for the Analysis of MEQ in EGS Experiments
- P. Rose/ EGI-UU: Tracers: Fracture Evolution following Hydraulic Stimulation within an EGS Reservoir
- Waibel/Davenport: Validation of Innovative Exploration Technologies for Newberry Volcano
- O’Connell/WLA-Fugro: Noise and Coda Correlation Data into Kinematic and Waveform Inversions With Microearthquake Data for 3D Velocity ...
- Templeton/LLNL: Matched field processing for EGS
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<th>Forum and Date</th>
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<th>Authors</th>
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<tr>
<td>GRC 2010 - Presentation and Publication</td>
<td>Newberry Volcano EGS Demonstration</td>
<td>Osborn, Petty, Nofziger and Perry</td>
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<tr>
<td>GRC 2010 - Presentation and Publication</td>
<td>Injection Induced Seismicity and Geothermal Energy</td>
<td>Cladouhos, Petty, Foulger, Julian and Fehler</td>
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<tr>
<td>AGU 2010 - Abstract and Presentation</td>
<td>Stimulation Controls and Mitigation of Induced Seismicity for EGS Projects</td>
<td>Petty, Cladouhos, Osborn, and Iovenitti</td>
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<td>GRC 2010 - Presentation and Publication</td>
<td>Development of a Downhole Fluorimeter for Measuring Flow Processes in Geothermal and EGS Wellbores</td>
<td>Rose, Fayer, Olsen, Petty and Bour</td>
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<td>Stanford 2011 - Presentation and Publication</td>
<td>Fluid Diversion in an Open-Hole Slotted Liner – A First Step in Multiple Zone EGS Stimulation</td>
<td>Petty, Nofziger, Bour and Nordin</td>
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<td>The role of a stress model in stimulation planning at the Newberry Volcano EGS Demonstration</td>
<td>Cladouhos, Petty, Callahan, Osborn, Hickman and Davatzes</td>
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<td>GRC 2011 - Presentation and Publication</td>
<td>Newberry Volcano EGS Demonstration Stimulation Modeling</td>
<td>Cladouhos, Clyne, Petty, Osborn, Nofziger, Callahan, Nordin, Sonnenthal, Davatzes, and Hickman</td>
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<td>Newberry Volcano EGS Demonstration – Phase I Results</td>
<td>Osborn, Petty, Cladouhos, Iovenitti, Nofziger, Callahan and Perry</td>
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<td>Newberry Volcano EGS Demonstration—Phase I Results</td>
<td>Cladouhos, Osborn, Petty, Bour, Iovenitti, Callahan, Nordin, Perry, and Stern</td>
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<td>AGU 2012 - Abstract and Poster</td>
<td>Newberry Volcano EGS Demonstration: Plans and Results</td>
<td>Cladouhos, Petty, Moore, Nordin, De Rocher, Callahan, and Perry</td>
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<td>Stanford 2013 - Presentation and Publication</td>
<td>Microseismic Monitoring of Newberry Volcano EGS Demonstration</td>
<td>Cladouhos, Petty, Nordin, Moore, Grasso, Uddenberg, Swyer, Julian, and Foulger</td>
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<td>Improving Geothermal Project Economics with Multi-zone Stimulation: Results from the Newberry Volcano EGS Demonstration</td>
<td>Petty, Nordin, Glassely, and Cladouhos</td>
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Project Tasks Include All Essential Elements of EGS Development

Phase I (actual)

• Site Selection - surface analysis, well logs and well construction
  – Selected NWG 55-29 from two available, existing full-size bore holes as stimulation candidate and verified excellent well bore conditions.
  – Contributed to Oregon LiDAR Consortium for enhanced surface faulting and topographic imaging.
  – Developed comprehensive local and regional geoscience model based on existing and recent data.
  – Temple/USGS conducted borehole televiewer survey (see supplemental slide)
    • From casing shoe at 6435 ft and 200ºC, to 8860 ft and instrument thermal saturation at 265ºC.
    • Identified 351 fractures and; dominant fracture sets oriented NNE-SSW, dipping 50ºE and 50ºW
    • Clearly defined borehole breakouts, and measured consistent azimuth of minimum horizontal stress, $S_{min}$, oriented at $092º ± 16.6º$, as predicted by initial resource model.
  – Conducted baseline injectivity test, identifying minimum stimulation pressure of 1153 psig
  – Maximum stimulation pressure limited by casing burst rating of 3566 psi

• Reservoir Characterization - downhole instruments and use of data in modeling
  – Installed and calibrated surface seismometers; designed borehole seismometer network
  – Texas A&M measured cuttings and core rock properties
  – LBNL constructed native state THMC model
  – Compiled AltaStim fracture model of stimulation plan
Phase II (actual)
  • Reservoir Creation - establish permeability maintain open cracks with hydroshearing
    – Stimulate injection well using chemical diverters.
    – Monitor fracture growth using focused surface- and borehole-deployed MSA.

Phase II (planned)
  • Reservoir Validation - fracture imaging tools
    – Repeat borehole televiewer to assess effects of hydroshearing
    – Inject tracers and execute single-well flow test methods to measure fracture volume and fluid velocity
    – Use distributed temperature sensing to identify flow zones in injection and production
  • Interwell Connectivity - tools to ensure that suitable flow path connects wells, such as tracers
    – Conduct two-well and three-well connectivity tests
    – Analyze conservative and non-conservative tracers to assess effective fracture volume, fluid velocity, etc.
    – Conduct dual-well stimulation, if necessary

Phase III (planned)
  • Reservoir Scale-Up and Sustainability - tools for selecting additional locations for wells, and long-term operation and maintenance of an economic EGS installation
    – Calibrate numerical models with real EGS performance data
    – Forecast reservoir performance over typical plant and field design life
  • Energy Conversion – suitable energy conversion systems
    – Build conceptual model of commercial-scale power plant and wellfield
    – Estimate capital and operating costs of conceptual system