Well Construction Technology Efficiencies - Research Efforts of the United States Department of Energy, Geothermal Technologies

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Stephen Bauer
Sandia National Laboratories
representing
U.S. Department of Energy
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sjbauer@sandia.gov

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Presentation Objective

- **Provide an overview of US DOE well construction research**
- **Broad portfolio – Description necessarily incomplete**
- **Examples are provided but biased by presenter's affiliation**

EGS Cost Analysis – Well Construction Costs

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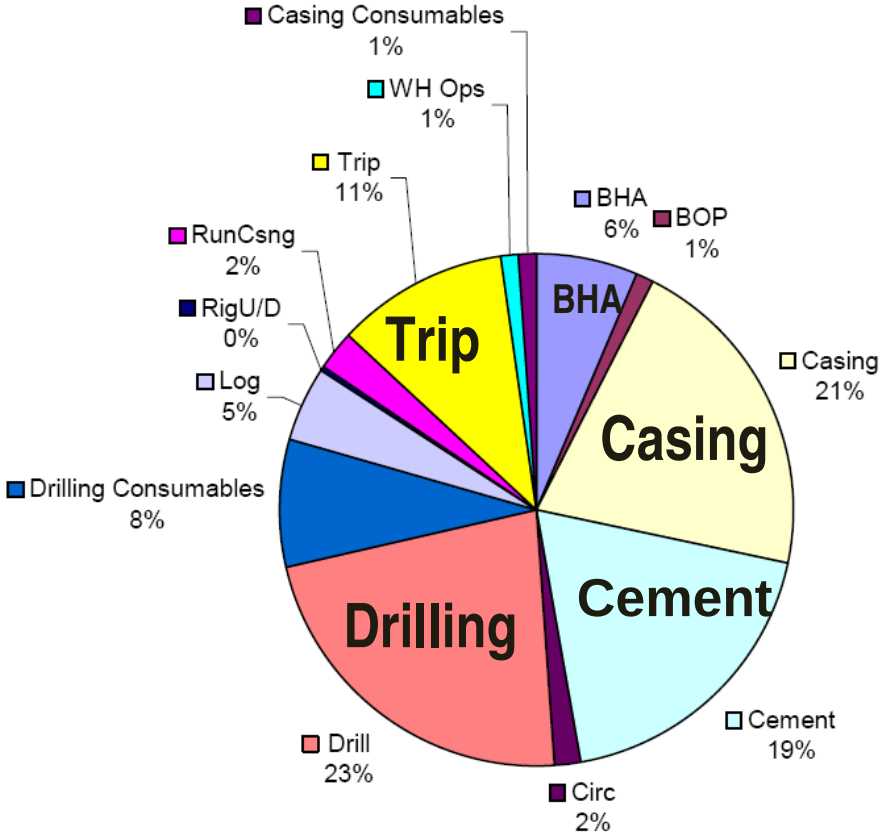
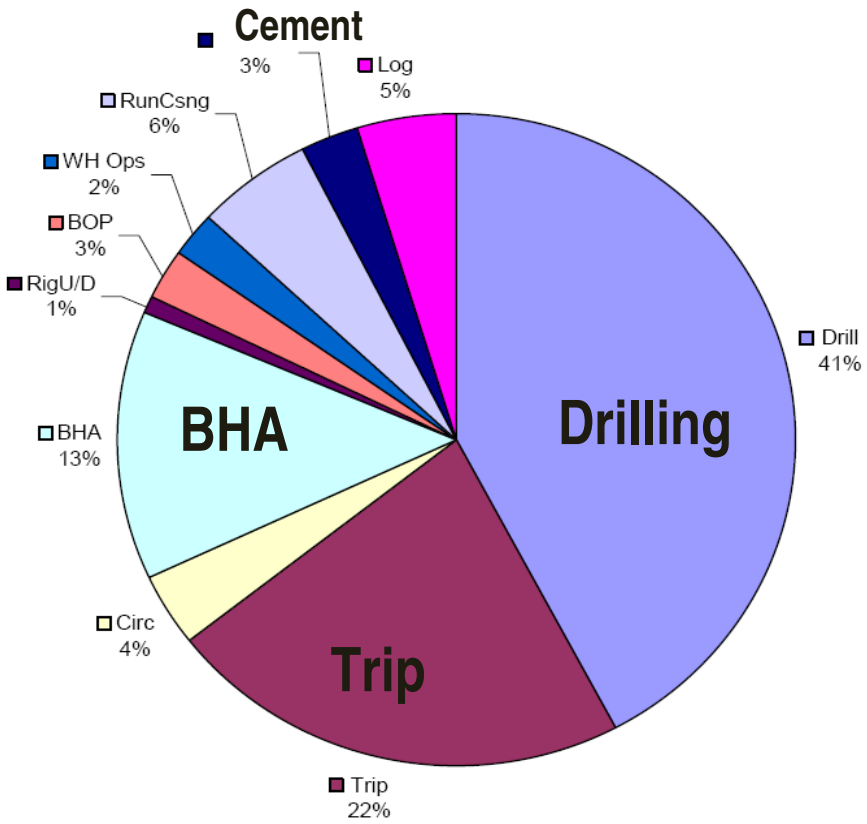
SAND2008-7866 (2008)



Well cost (%) breakdown by task.



Well construction task time percentages.

Research Portfolio Intended to Address Major Cost Drivers

Drilling Technologies

- ❑ Pressure/Temperature Gradient Induced Drilling (Los Alamos National Lab)
- ❑ Microholes with Abrasive Slurry Jet Technology (Impact Technologies, LLC)
- ❑ Stinger Enhanced Bits (Novatek, Inc.)
- ❑ Wear-Resistant NanoComposite Coatings (Oak Ridge National Lab)
- ❑ HT Directional Drilling Systems (Baker Hughes, Inc.)
- ❑ Field Trials of Drilling Systems (Sandia National Labs)
- ❑ HT Auto Indexers for DTHH (Sandia National Labs)
- ❑ HT Downhole Motors (Sandia National Labs)

Casing and Cementing

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- Casing Material Corrosion/Erosion Studies (Oak Ridge National Lab)
- Improved Geothermal Cements (Trabits Group)
- Multi-Function Cement For Geothermal Wells – Self Degrading and Expandable Cements (Brookhaven National Lab)
- Expandable Casing for HT Wells (Geothermal Expandables)

Zonal Isolation / Completion

- HT/HP Gel for Lost Circulation Control (Clean Tech Innovations, LLC)
- Temporary Sealer to Address Fluid Loss (Brookhaven National Lab)
- Geopolymer Sealing Materials (Brookhaven National Lab)
- Consumable Structural Elements/Packers (Sandia National Labs)
- Temporary Bridging Agents (CSI Technologies, LLC)
- Perforating Systems (Schlumberger)-
- Controlled Rapid Wellbore Pressurization (Sandia National Labs)
- Acoustic Borehole Imaging (Baker Hughes)
- HT PT Flow Tools (Perma Works, LLC)

Enabling Technologies

- HT MWD Components (Honeywell International, GE Global Research, Sandia National Labs)
- Super Critical PTC / Fluid Sampler (Sandia National Labs)
- HT Borehole Seismic Monitoring Tool (Sandia National Labs)
- HT Copper/Fiber Wireline (Draka Cableteq USA)
- HT Fiber Optic Data Transmission System (Sandia National Labs)
- MCM Development for HT Accelerometer Measurements (Sandia National Labs)
- SiC Sensor Technologies (UC Berkeley)
- HT Circuit Boards (CTD, Inc.)
- HT Neutron Imaging (Oak Ridge National Lab)
- Acoustic Sensors for Fluid Monitoring (Los Alamos National Lab)
- Far Field Downhole EM (Argonne National Lab)

Field Trials of Drilling Systems

Sandia National Laboratories

- Apply mature/proven rock penetration systems used in Oil & Gas/Minerals industry to improve geothermal drilling technology
- Partner with
- Ormat
- Navy Geothermal Program
- Barber Drilling
- National Oilwell Varco Reed Hycalog
- Atlas Copco

Down The Hole Hammers Research

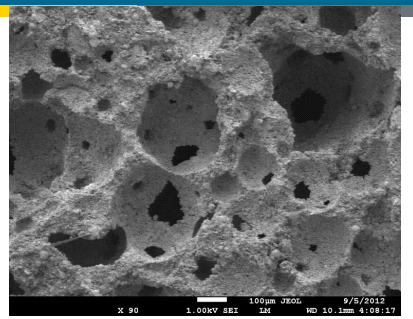
Sandia National Laboratories

- Hammers are a very efficient method to drill hard rock
- Current limitations in HT Environment
- Working with DOE and Industrial partners in HT hammers and down-hole motors

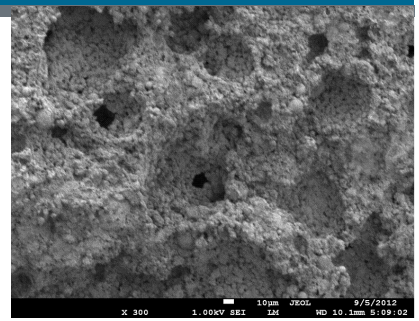
Cements

Brookhaven National Laboratory

- Corrosive-Resistant Foamed Cement Composites
  - Thermal shock resistant, self-healing, ductile, corrosive resistant, thermally insulating cement
  - Light weight (foam) cement capable of easy application.
  - Protect the wellbore integrity against common geothermal failure risks such as, thermal cycling, thermal expansion, corrosion by H_2S/carbonic acid.
  - Compressive strength > 1000 psi, 200 ^oC



Conventional foamed cement



Corrosion-resistant foamed cement

- Self-Degradable Temporary Cementitious Sealers
  - Developing a temporary cementitious sealer that is degrades through a combination of high temperature and water injection. Compressive strength >2000psi in most fracture networks
  - Provide the geothermal industry with the reduction of total costs of sealing and multi-fracture drilling operations.

Conventional well cement

Thermal shock-resistant cement

Before

After

water-catalyzed self-degradation of cement at 200°C

High-Rate Well Stimulation Methods

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- Develop new high energy stimulation techniques to enhance EGS permeability through dynamic loading of the formation
  - Enable near wellbore fracturing along with shear destabilization in the far field
  - Novel reactive gas generating materials and injection methods to fracture the formation are being developed suitable for use at EGS well temperatures

Perma Works

Nearing the completion of a well monitoring system for EGS.

- ❑ Pressure and Temperature already exists
- ❑ Solid-state flow testing underway
- ❑ Continuous monitoring up to 280 C
- ❑ 50 Hz recording
- ❑ Electronics are temperature tolerant and tolerant of exposure to geothermal brines

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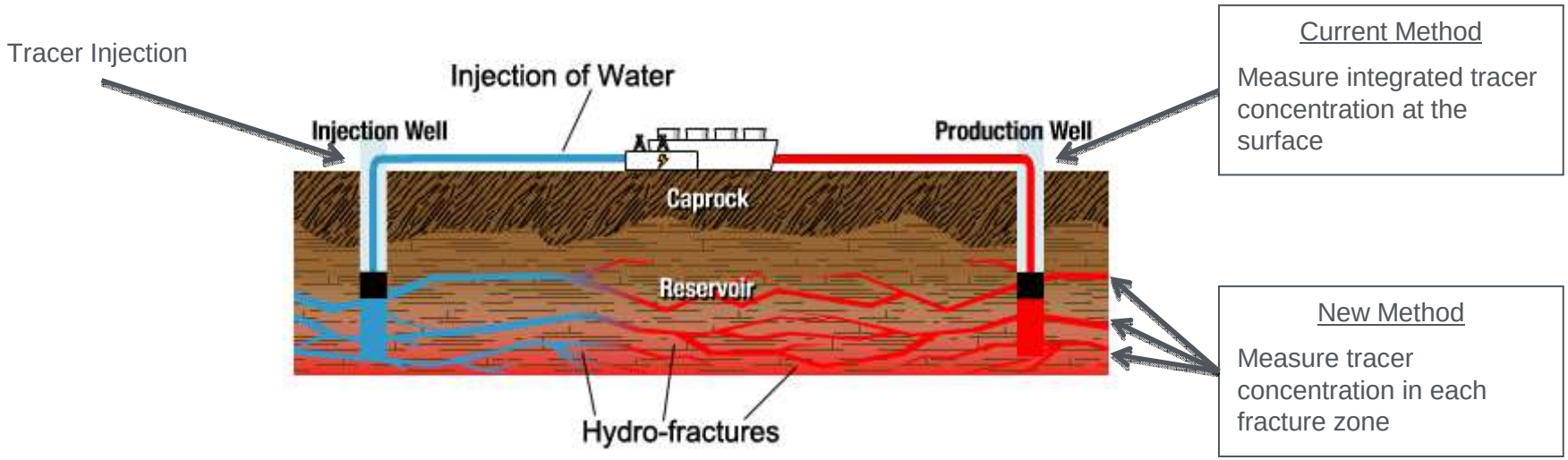
Goal: Design and built a prototype chemical sensing tool that can measure tracer concentration along the length of a wellbore

- This tool will increase data resolution and provide new types of data for the characterization of fracture networks in enhanced geothermal systems
- Joint effort between Geothermal Research and Chemical Sensing Departments



High Temperature Seismic Tool

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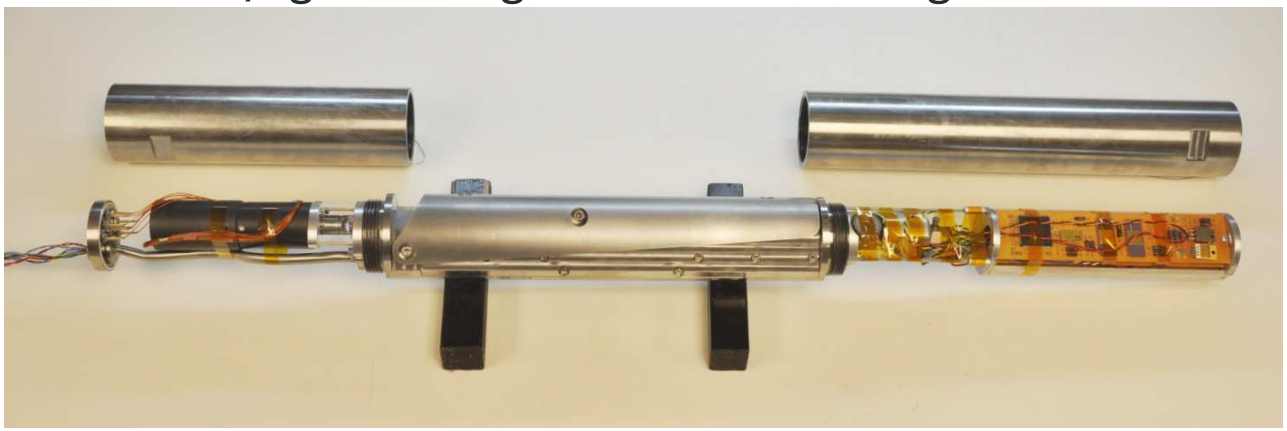
- Capabilities
  - Operation up to 210°C
    - SOI electronics except FPGA and Primary ADC
    - 24-bit ADC
  - Three-axis accelerometer measurements
    - 30 Hz – 1000 Hz bandwidth
    - 20 V/g sensitivity
    - 295 μ g – 165 mg measurement range



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- Physics based systems analysis for Economic Valuation and Risk Assessment
- Capture feedback between power production, reservoir performance, and system design
- Economic Valuation provided through two-way communication with GETEM
  - Industry standard for economic evaluation
- Risk Assessment
  - Probabilistic simulation of:
    - All GETEM inputs
    - Physical system inputs
  - Probability based outputs
- Stochastic reservoir performance modeling
  - Homogeneous
  - Heterogeneous
  - Well configuration (vertical, horizontal, etc.)

Example

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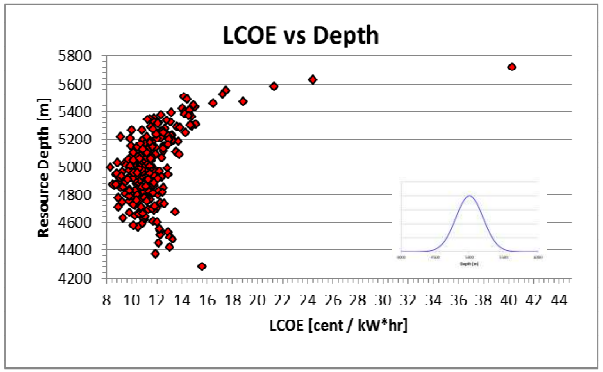
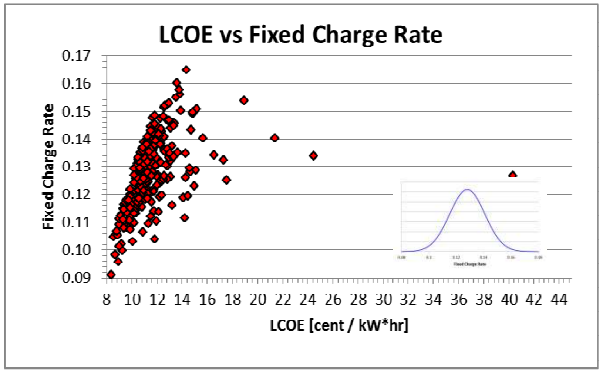
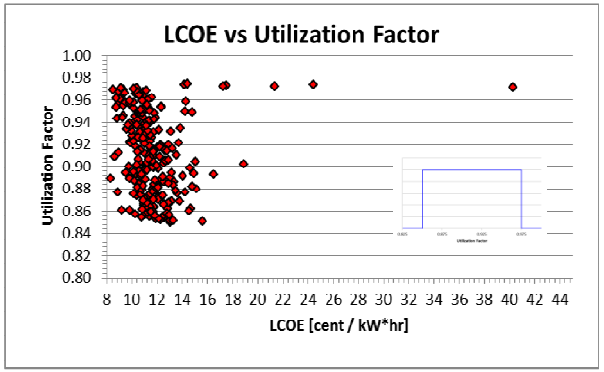
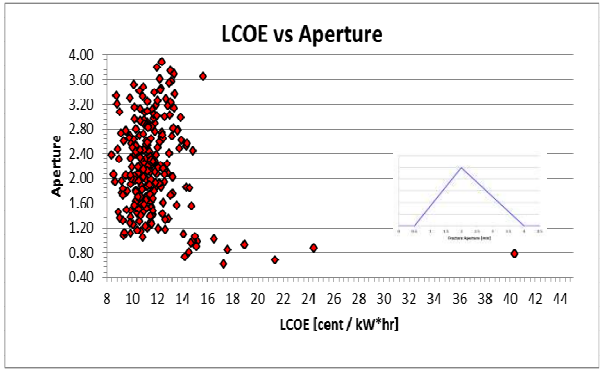
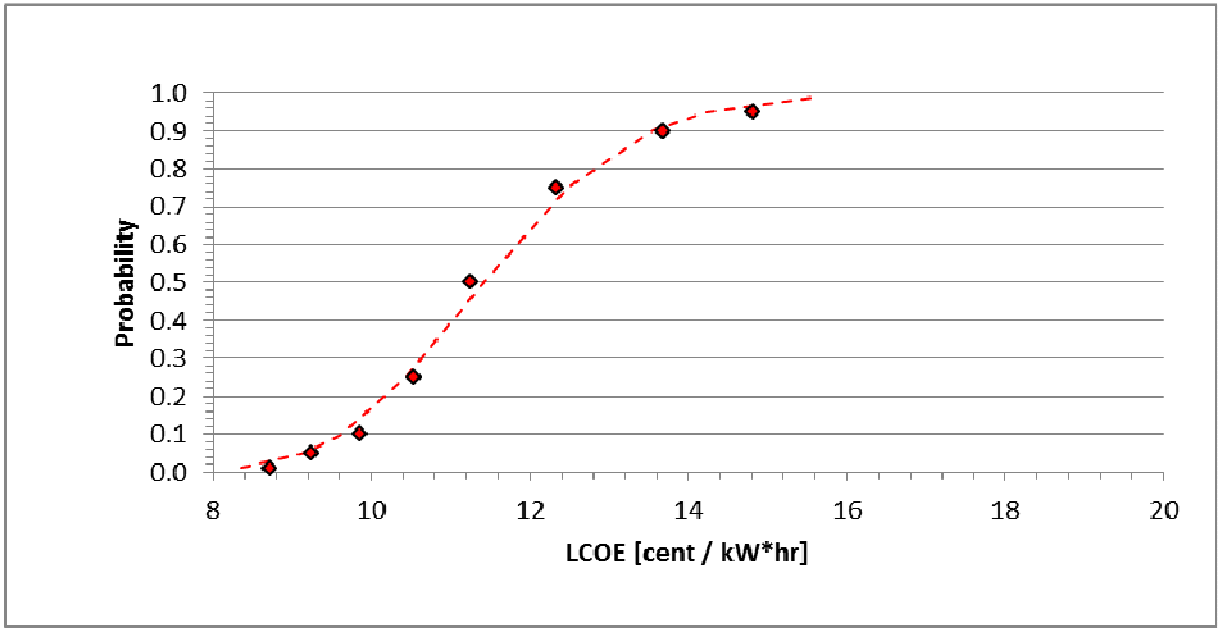










Handbook of Best Practices for Geothermal Drilling

Prepared for the International Energy Agency,
Geothermal Implementing Agreement, Annex VII

by

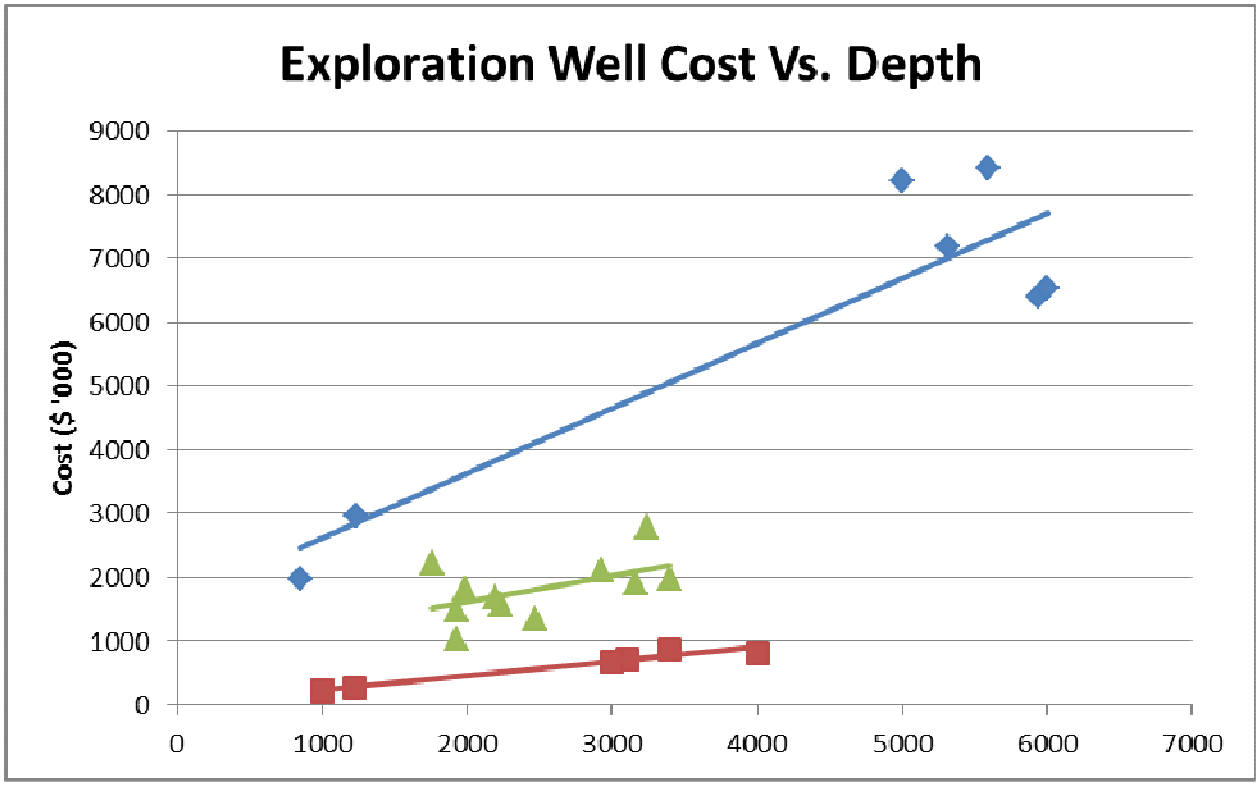
John Finger and Doug Blankenship
Sandia National Laboratories
2010

Abstract

This Handbook is a description of the complex process that comprises drilling a geothermal well. The focus of the detailed Chapters covering various aspects of the process (casing design, cementing, logging and instrumentation, etc) is on techniques and hardware that have proven successful in geothermal reservoirs around the world. The Handbook will eventually be linked to the GIA web site, with the hope and expectation that it can be continually updated as new methods are demonstrated or proven.

SAND2010-6048

Implementing Lower-cost Drilling Techniques



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