SAND2012-2553C

# Technology Development and Field Trials of EGS Drilling Systems

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**ARRA Funded R&D**

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# Overview



- Summary
  - Conventional geothermal drilling hampered by challenges of hard/ abrasive/fractured rock, high temperatures and loss of circulated drilling fluids to the formation
  - Apply mature/proven rock penetration systems used in Oil &Gas/Minerals industry to improve geothermal drilling technology

- Timeline
  - Project start date: Oct 2010 (startup activities in preceding 6 months)
  - Project end date: Sept 2012 (for ARRA-funded activities)
  - Percent complete: 75% (for Phase 1& 2 ARRA-funded activities)
    50% (if Secondary/Follow-Up field trials funded by DOE in FY13)

- Budget
  - Total project funding: $1,389,065*
  - DOE (ARRA-funded) share: $1,336,565
  - Subcontractor awardee share (cost share): $52,500
  - Total spent: 50% ** (ARRA funding)

* Funds reported last year included anticipated $25k cost share from drilling contractor

** Percussive hammer testing not realized in preliminary field trials as intended

# Project Management/Coordination



- Project Schedule
  - Phase 1 test schedule subject to integration with USN GPO drilling schedule
  - On-track to complete at end of FY12 with original ARRA funding
- Resource Application & Leveraging
  - Budget allocations proceeding per original plan
  - Project leveraging legacy skills from previous Sandia programs (DWD, PDC CRADA)
- Project Integration & Coordination
  - Synergistic with USN GPO project activities
  - Consistent with service company business development plans (NOV-RH, Atlas Copco)

# Collaborations



- Sandia National Laboratories Team
  - David Raymond, Steve Knudsen, Keith Barrett, Jiann Su, Dennis King & Doug Blankenship

- Project Collaborators
  - US Navy Geothermal Program Office (Geothermal Developer)
  - Barbour Well, Inc. (Drilling Contractor)
  - NOV Downhole/Reed Hycalog (Service Company - PDC Manufacturer )
  - Prospect Geotech (Mud-logging Company)
  - Atlas Copco Secoroc (Service Company - DTH Manufacturer)

- ARRA Impact
  - Employment opportunities created at Sandia, Atlas Copco & NOV Reed Hycalog thru project funding (equivalent of 3.5 - 4 FTEs) in FY11/FY12
  - Future jobs will result thru expanding geothermal market within drilling service companies

# Relevance/Impact of Research



- Objective
  - Develop fit-for-purpose EGS drilling solutions for geothermal exploration and production drilling
    - Hard/abrasive/fractured rock, high temperature, deep drilling
- Purpose
  - Improved drilling technologies that reduce costs by drilling faster with improved life, capabilities for improved hard stringer penetration, and are appropriate for deep drilling applications
  - Improved support for economic development of geothermal resources
    - Increase in the number of tools / options available for geothermal well construction
    - Service companies engaged in geothermal drilling market
    - Broad experience base to promote continued geothermal well construction

# Relevance/Impact of Research (continued)



- Challenges/Barriers addressed on this project
  - Risk Reduction
  - Limitations of Laboratory Testing
  - Service Company Investment
  - Drilling Industry Acceptance
- Impact/Performance
  - Potentially reduce geothermal drilling costs via improved ROP & increased bit life
    - Nominal baseline is sealed roller cone performance in hard abrasive rock (low ROP: 10-20 ft/hr, short life: 40 hrs)
    - PDC Bits / Pneumatic Hammers drill proportionally faster
  - Derive benefit from O&G/Minerals research in comparable domains
  - Catalyze industry via improved / economical deep hole access
- Innovation
  - Provides pathway for introduction of advanced technology with service company support

# Scientific/Technical Approach



## Overall Approach

Three Phases over Three Years (ARRA-funded for two of three years)

- Phase 1 - Preliminary field trials to demonstrate potential & highlight deficiencies (Yr 1: ARRA-funded)
- Phase 2 - Service company involvement in performance remediation and custom development (Yr 2: ARRA-funded)
- Secondary/Follow-Up field trials for verification & validation (Yr 3: Non-ARRA funded)
  - Demonstrate technology readiness for geothermal drilling
  - Verify design improvements realized in year two

## Highlights

- Direct partnership with geothermal operators/developers
- Service companies directly involved in development & testing

# Scientific/Technical Approach (continued)



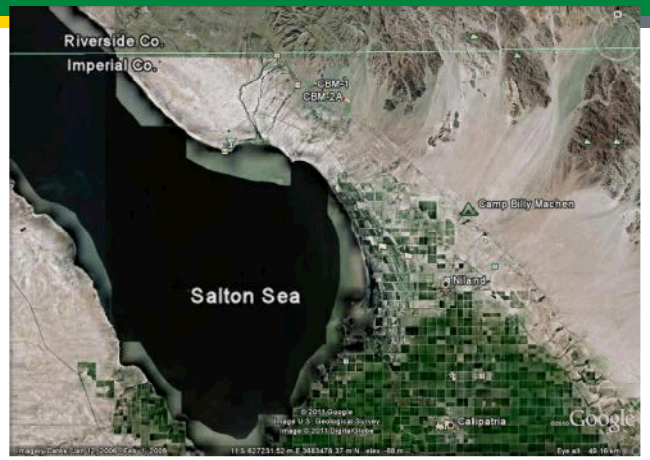
Overall approach includes following elements:

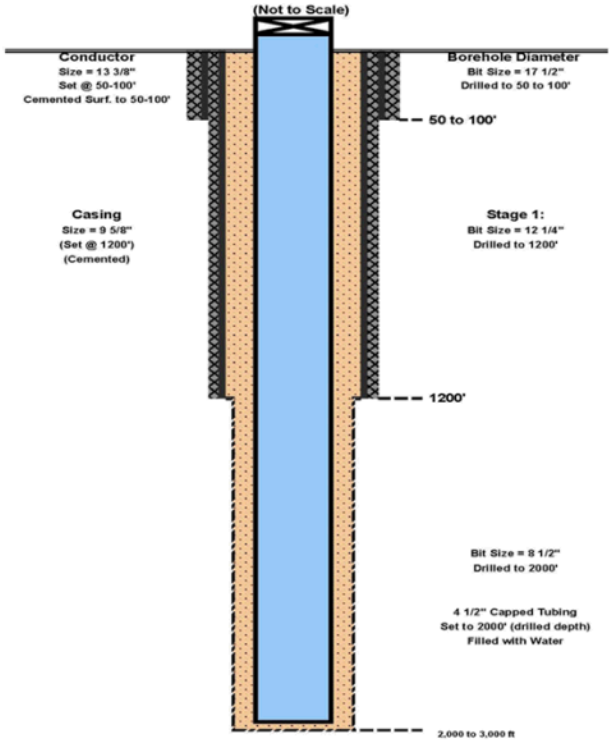
- Technical Interchange Meetings with Team
- Develop well-defined drilling plans
- Pre-selection of fit-for-purpose bit solutions
- Data acquisition system development
  - Surface system integration
  - Downhole via service company tools
- Sandia-monitored field drilling deployment with on-going monitoring activities
- Direct involvement of service companies during tool specification and field testing
- Data reduction and analysis
- Post-mortems on bit conditions
- Next generation bit development and testing

# Scientific/Technical Approach (continued)



- Identify Geothermal Developer/Drilling Company
  - US Navy GPO agreed to collaborate by providing wells of opportunity
  - MOU with Sandia/Navy (DOE/DOD)
  - Barbour Well, Inc.,
    - USN GPO drilling contractor
    - Provide drill rig time, integration, and coordination with test plan



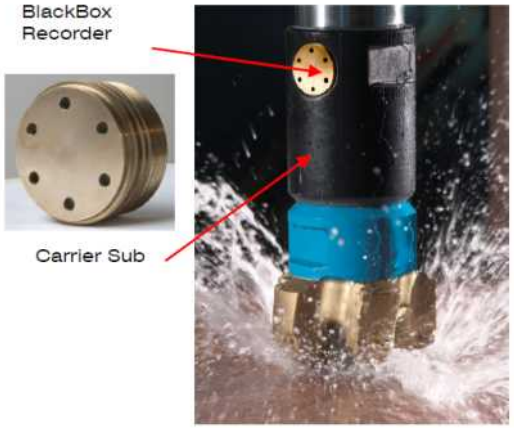




- Identify Test Site/Well of Opportunity
  - Chocolate Mountains Aerial Gunnery Range, CA
  - Two geophysical test holes planned; One pursued
  - Investigate temperature field/hydrothermal alteration
  - Metamorphosed volcanic rocks anticipated

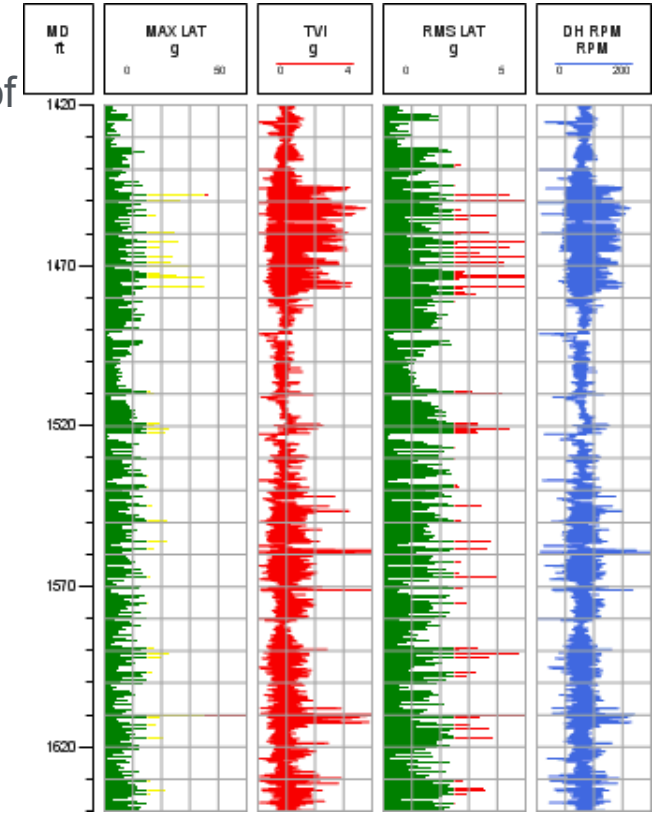
# Scientific/Technical Approach (continued)



- Contract with major service companies
  - NOV Reed Hycalog, PDC Bit manufacturer
  - Cost share contracts
    - Will provide internal R&D to foster development of appropriate product line




**Representative Fixed Cutter Bit per NOV Reed Hycalog**




Representative down hole data collect for performance analysis & diagnostics

- Phase 1 Testing Completed
  - Well Profile & Drilling Plan developed
  - Test Plan developed
  - Reviewed current product line offering for applicability and down select
    - PDC Bit abrasion resistance / impact resistance
    - Percussive hammer high temperature operation
  - Field Drilling Testing Coordinated
    - Data acquisition system developed & integrated with rig
    - Uncertainty in formation characteristics
      - Drilling contractor preferred PDC bits
      - Pneumatic Hammers tabled for this site
    - Daily drilling activities
    - Well logging/surface data integration

Barbour Rig @ CMAGR Site

Sandia real-time tool monitor and data collect

# Phase 1 Test Results

Bit 1A Average ROP per Stand

| Start Depth | Stop Depth | ROP (ft/hr) |
|---|---|---|
| 1337.7 | 1369.4 | 30.7 |
| 1369.4 | 1401.4 | 24.0 |
| 1401.4 | 1433.2 | 26.9 |
| 1433.2 | 1465.0 | 22.7 |
| 1465.0 | 1496.8 | 19.1 |
| 1496.8 | 1528.3 | 25.7 |
| 1528.3 | 1560.4 | 21.2 |
| 1560.4 | 1592.2 | 24.5 |
| 1592.2 | 1624.0 | 30.3 |
| 1624.0 | 1656.0 | 26.7 |
| 1656.0 | 1687.9 | 24.8 |
| 1687.9 | 1719.7 | 25.8 |
| 1719.7 | 1751.7 | 27.4 |
| 1751.7 | 1783.5 | 31.4 |
| 1783.5 | 1815.5 | 23.9 |
| 1815.5 | 1847.4 | 27.4 |
| 1847.4 | 1879.2 | 38.2 |
| 1879.2 | 1911.1 | 25.5 |
| 1911.1 | 1942.8 | 33.4 |
| 1942.8 | 1974.7 | 30.9 |
| 1974.7 | 2006.5 | 30.2 |
| 2006.5 | 2038.2 | 16.9 |
| 2038.2 | 2070.1 | 20.8 |

Bit 2A Average ROP per Stand

| Start Depth | Stop Depth | ROP (ft/hr) |
|---|---|---|
| 2073.0 | 2105.0 | 21.4 |
| 2105.0 | 2137.0 | 24.6 |
| 2137.0 | 2165.0 | 25.6 |
| 2165.0 | 2194.0 | 28.9 |
| 2194.0 | 2223.0 | 25.5 |
| 2223.0 | 2251.5 | 24.4 |
| 2251.5 | 2279.9 | 23.7 |
| 2279.9 | 2308.3 | 23.0 |
| 2308.3 | 2336.4 | 28.6 |
| 2336.4 | 2365.2 | 25.4 |
| 2365.2 | 2393.8 | 16.4 |
| 2393.8 | 2422.4 | 15.1 |
| 2422.4 | 2454.4 | 18.1 |
| 2454.4 | 2486.3 | 19.2 |
| 2486.3 | 2518.3 | 17.4 |
| 2518.3 | 2550.1 | 12.8 |
| 2550.1 | 2581.9 | 11.2 |
| 2581.9 | 2613.8 | 13.3 |
| 2613.8 | 2645.8 | 12.4 |

# Accomplishments, Results and Progress (continued)

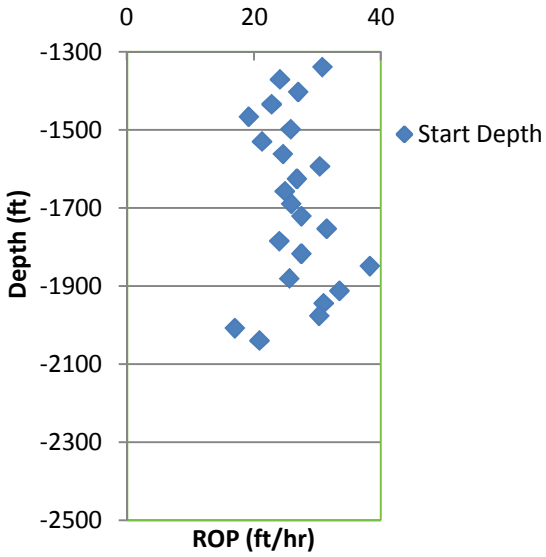


## Bit 1A Test Results

Bit 1A: Pre-Drill Sharp Condition

Bit 1A: Post Drill Condition (after 725 ft.)

Bit 1A stand average ROPs

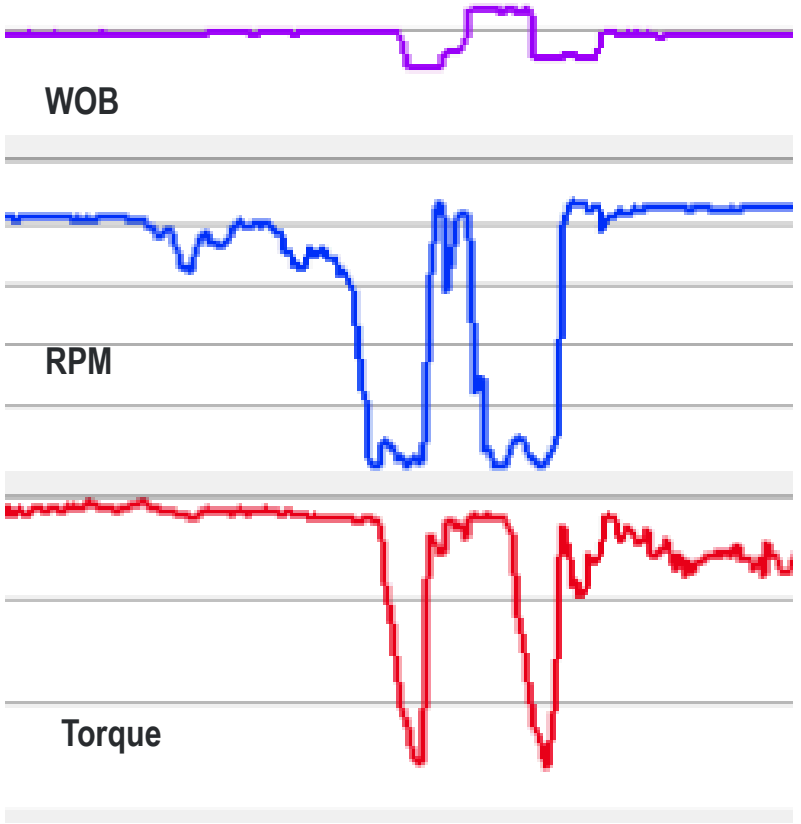



Bit 1A after drilling showing minor cutter damage

## Bit 2A Test Results

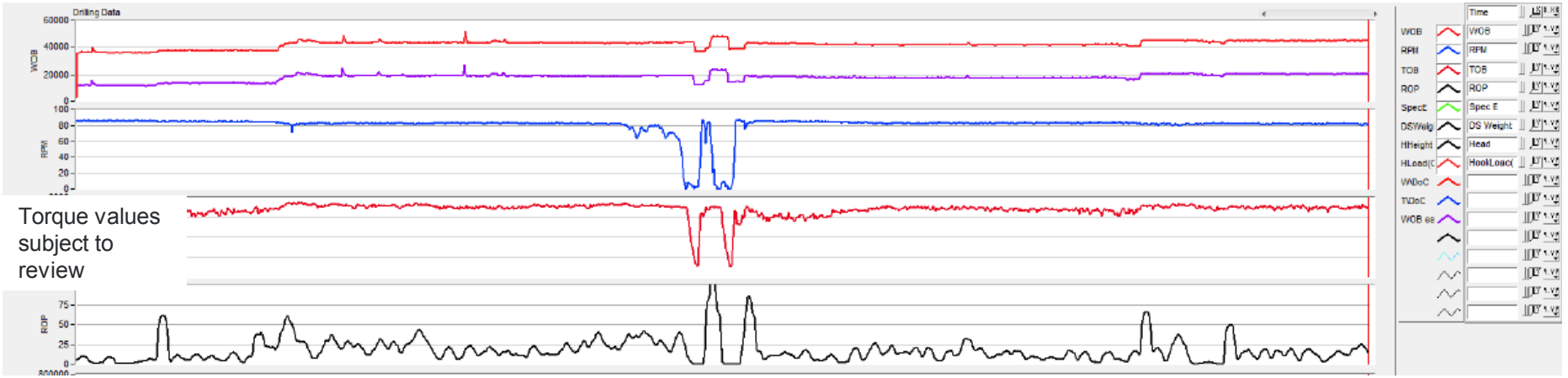
Bit 2A: Pre-Drill Sharp Condition

Bit 2A: Post Drill Condition (after 566 ft.)




Bit 2A – Driller response to excessive torque (typical)

## Bit 2A Drilling Record




Depth at stall 2407 bit 2 time 12:15 on day 342 12/008/2011

# Accomplishments, Results and Progress (cont.)



- Key Issues Currently Being Addressed
  - Phase 1 close-out
    - Data analysis (Surface and Black Box)
    - Reporting
  - Phase 2 startup
    - Sandia/NOV currently developing design concepts for second generation, geothermal-specific PDC Bits
      - Modified Bit 1 (8-blade bit, based upon Phase 1 baseline) to be made more “aggressive”
      - Modified Bit 2 (7-blade bit, based upon Phase 1 baseline) to be made more “durable”
    - Conduct verification testing in NOV Pressurized Drilling Laboratory
- PDC Bit / Key Issues
  - Thermally-Stable PDC Cutters
  - Cutting structure consistent with anticipated formation
  - Operating Conditions per Service Company recommendations
  - Down hole data collect for performance analysis & diagnostics

# Accomplishments, Results and Progress (continued)



- Major results from Phase 1 testing
  - 813 didn't have much impact damage
  - 713 had significant impact damage
  - Torque control components are key
  - Abrasion not an issue
  - Rig needs more torque capacity

- A 2.5-fold improvement in average rate of penetration has been demonstrated over conventional geothermal drilling technology in granitic basement rock

- Barriers overcome
  - reduced risk of PDC bit use in geothermal well construction
  - highlighted importance of field testing in identifying capabilities & limitations
  - achieved significant service company interest in geothermal market
  - garnered synthetic diamond acceptance within the geothermal drilling industry

# Data Sharing



Generated data will include

- *Drilling performance data (ROP, Life) for various systems (PDC Bits, Hammers) in typical geothermal rock types (alluvial fill, metamorphosed volcanics, granitic basement rocks)*
- *Compatibility format for DOE Geothermal Data Repository being addressed*
- *Draft technical report preparation underway*
- *A technical paper will be submitted to the Geothermal Resources Council (GRC) Transactions for publication in 2012*

# Future Directions



## Deployment Strategy

- Facilitates involvement of service companies in future BHA specification, development, deployment & operation
- Ensures valid outcome in drilling technology development thru early involvement
- Project will follow Stage/Gate strategy originally proposed

Future Research

- Remaining activities for Phase 1
  - Data analysis (Surface and Black Box)
  - Pursue comparable development with percussive hammer test and evaluation through contract with Atlas Copco

- To completion (FY12 ARRA-funding)
  - Collaborate with service companies
  - Verify improvements in test fixtures
- Identify Field testing opportunities for second generation bits (Yr 3/FY13)

# Mandatory Summary Slide



- Rock Reduction Technology
  - mature for conventional geothermal drilling
  - present technology will inhibit commercially – viable development of EGS resources
  - improvements are necessary to access EGS resources
- O & G/Mineral drilling systems will prove beneficial (PDC Bits verified, Percussive Hammers pending) for improved drilling
  - Backed by significant R&D
  - Drilling comparable rocks/depths
- Demonstration project has validated technologies for geothermal drilling
- Follow-on technology developments will further improve

| | FY2011 | FY2012 |
|---|---|---|
| Target/Milestone | Complete Initial Field Trials | Implement Design Changes from Initial Field Trials |
| Results | Completed Dec 2011 | In Progress |