SAND2007-6336P

Drilling and Completions Technology for Geothermal Wells

Douglas Blankenship[1], Arthur Mansure[1],
John Finger[2]

[1]Sandia National Laboratories
[2]Consultant

October 2, 2007
Geothermal Resources Council Annual Meeting

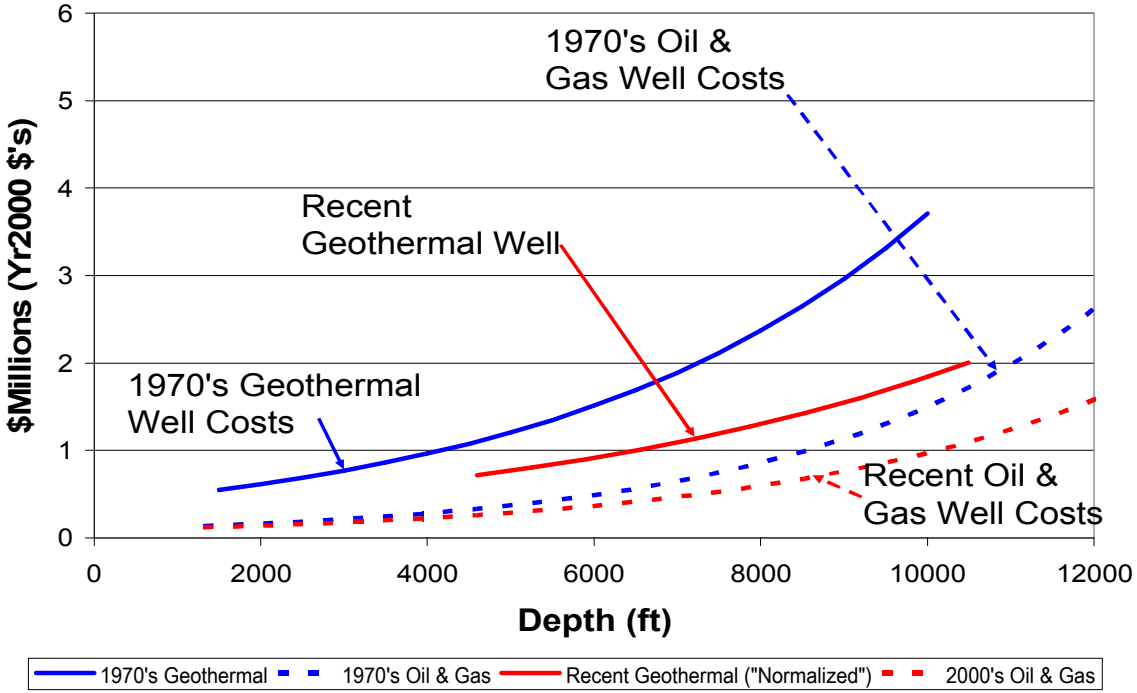
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Common Geothermal Drilling Issues

- The environment
  - High matrix compressive strength, rapidly changing and complex lithology, abrasive, fractured, under pressurized, corrosive fluids, and of course, high temperatures
- High mass flow rates
  - Large diameter wells compared to oil &gas
    - More rock removed, more steel, more cement
    - Higher priced wells for lower value commodity

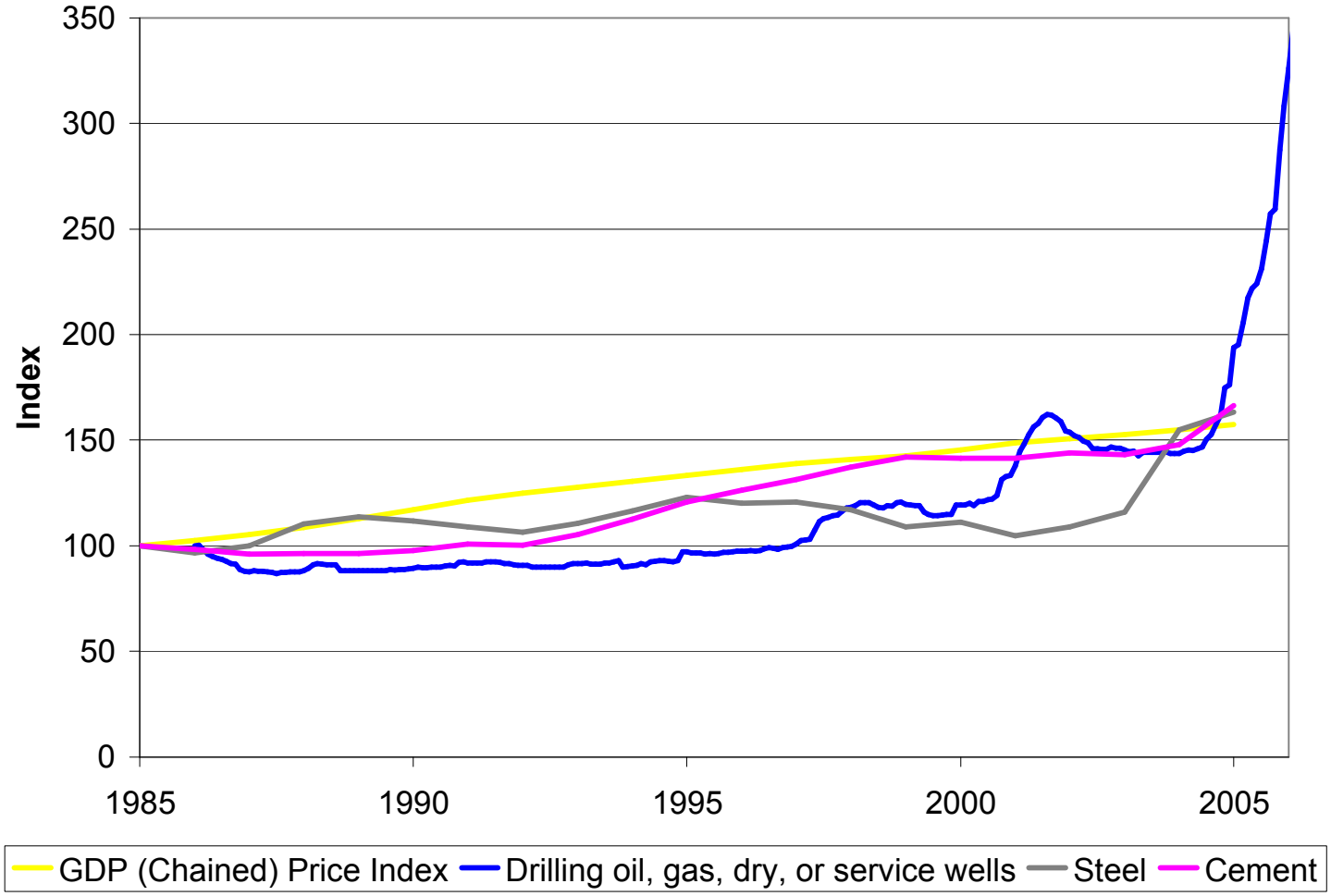
The measure of success: Have we reduced drilling costs?

- Data from 1970's through 2004 says yes
  - Until recently the cost of drilling (rig rates, cement, steel, etc.) was rising, on average, close to inflation (CPI)
- Geothermal well costs have been decreasing relative to O&G
- O&G wells get very expensive with depth, geothermal less so



Sandia National Laboratories

Changing cost of drilling



Sandia National Laboratories

Opportunities for Cost Reduction

- Drilling is complex → opportunities for cost reduction
- Improvements generally come in two ways
  - New technology introduced that reduces cost
  - We get smarter
- Industry and Labs have developed technologies that have not seen market penetration
  - Relatively small industry does not motivate service companies

Advances in Technology

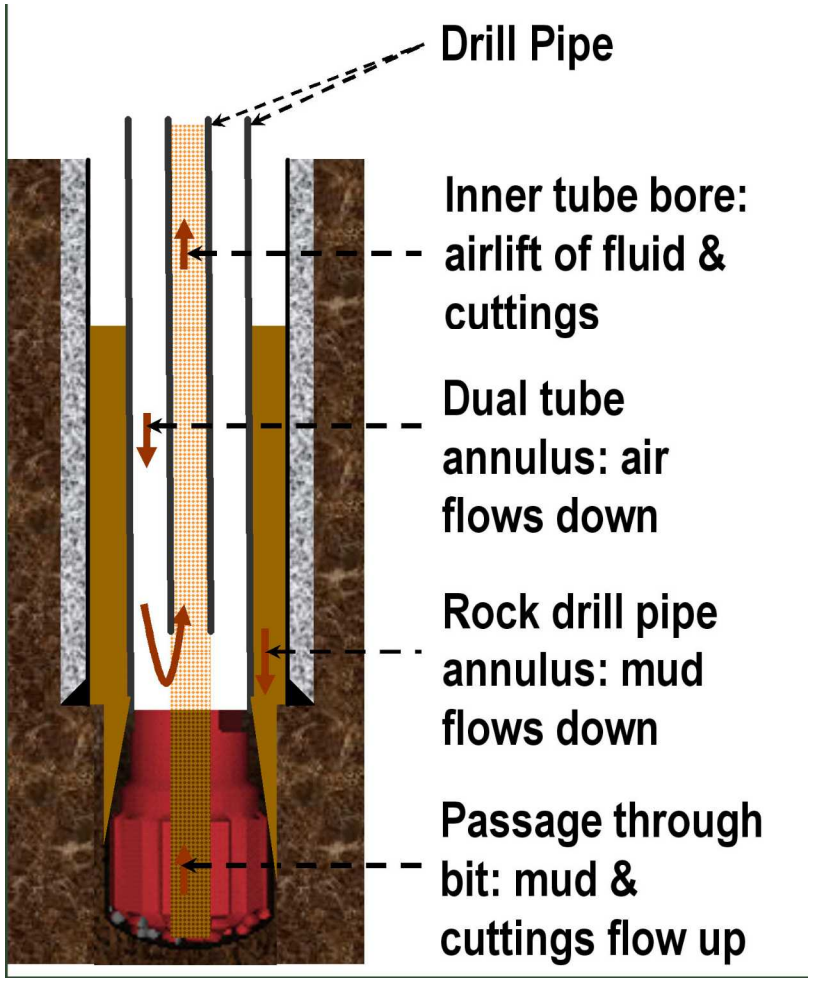
Bits

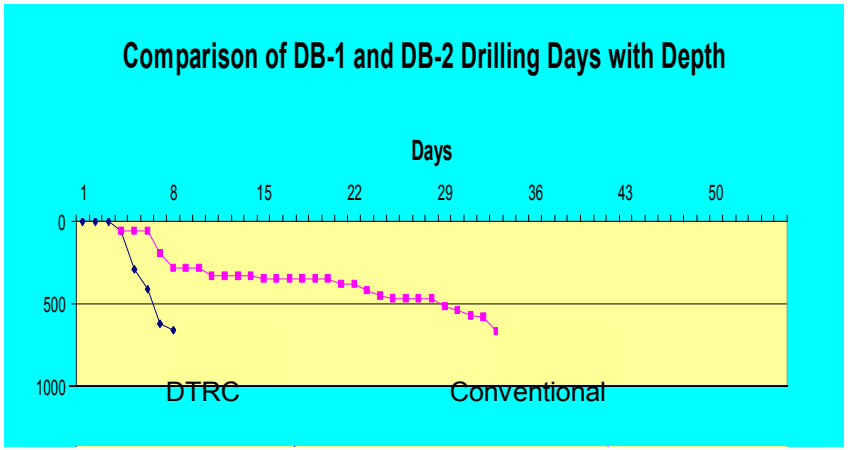
- PDC bits dominate O&G but potential for geothermal drilling is unfulfilled
  - O&G moving to harder rock and recent demonstrations hold promise
- Roller Bits
  - PDC's are used for gage protection enhancing roller bit survival
  - HT sealed bearings have increased life

Lost Circulation

- Lost circulation detection
  - Inflow advances
    - Stroke counter → Doppler flow meter
  - Outflow
    - Paddle meter → rolling float meter
  - Mud pit density metering
- Lost Circulation Remediation
  - HT drillable straddle packers (low P)
  - Cementation grout alternatives
    - Polyurethanes
      - Rye Patch demonstration
    - Sodium Silicates
      - Available from service companies
      - Advanced encapsulation methods

Dual Tube Reverse Circulation

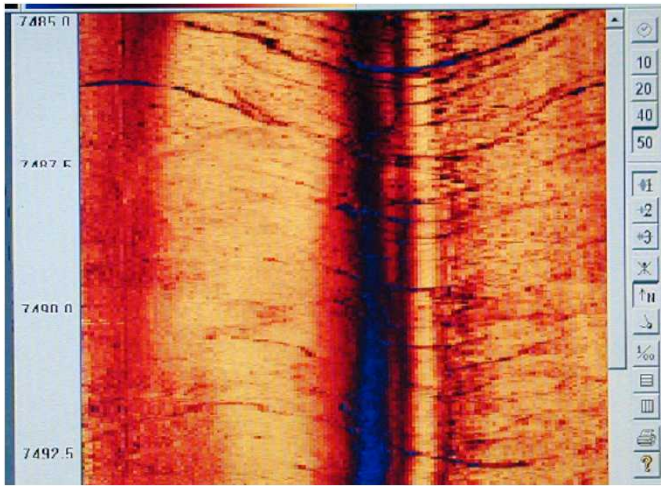




Sandia National Laboratories

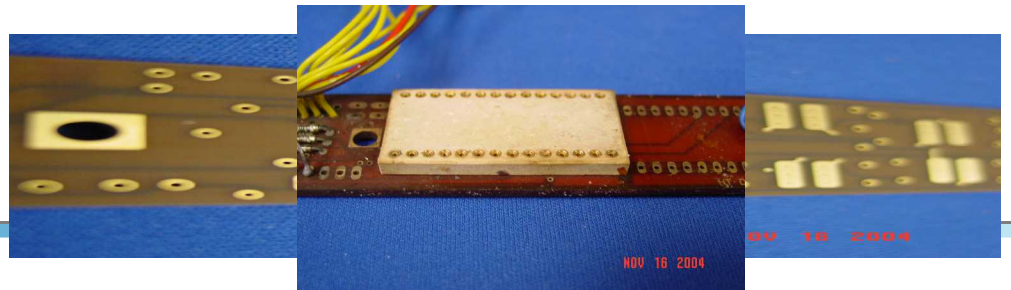
Logging and Monitoring

- Industry collaborative work to qualify and standardize HT electronics
- HT instrumentation starter kit
- 300ºC Borehole Televiewer
- Core-tube data-logger (CTDL)
- 300ºC P & T tools
- Downhole fluid sampler
- Support for optical fiber DTL logging
- Gamma & Spectral Gamma prototypes



Instrumentation Enabling HT Technologies

- SOI & SiC electronics including custom ASIC
- HT batteries (allows slickline tools)
- HT packaging including circuit boards, solders, connectors, and such
- Seals
- Sensors (HT magnotometer)



Downhole Communication: *225C DWD Tool*

RPM

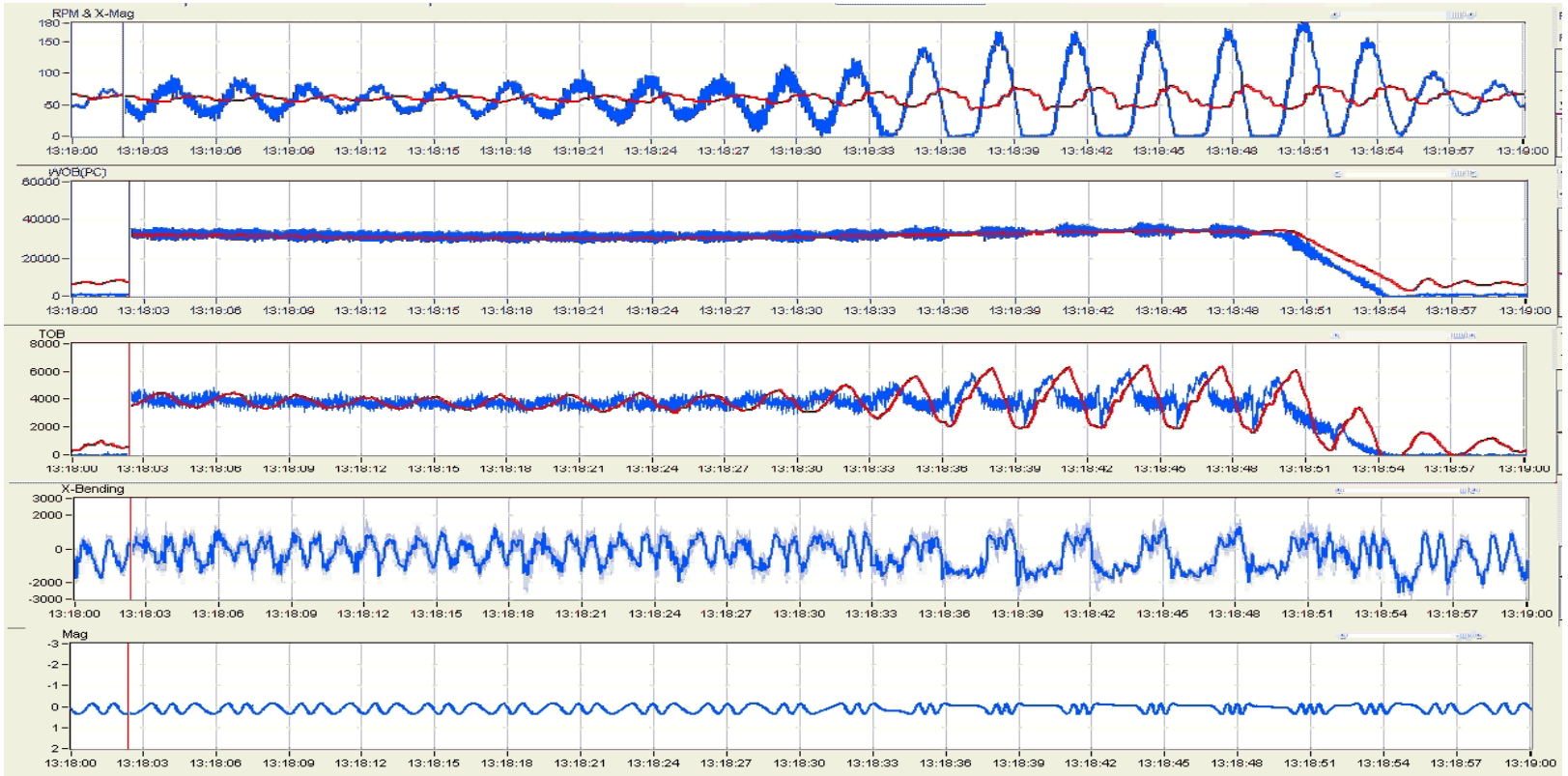
WOB

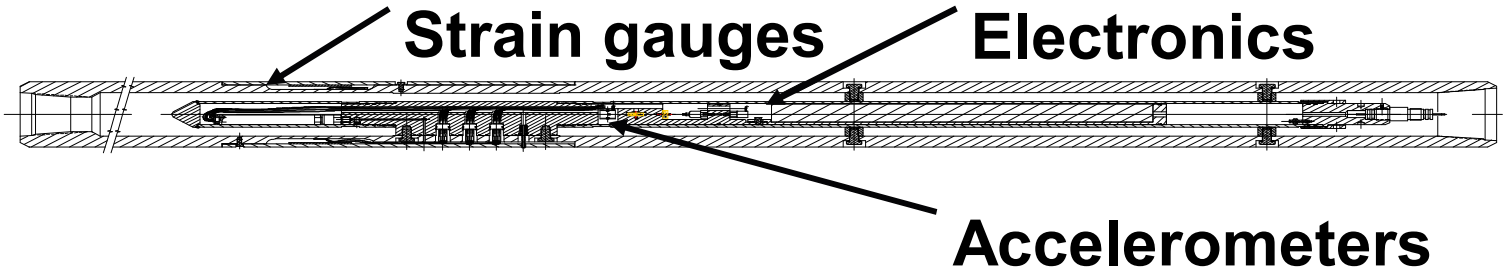
TOB

Bending

Mag.

Lateral Acc.



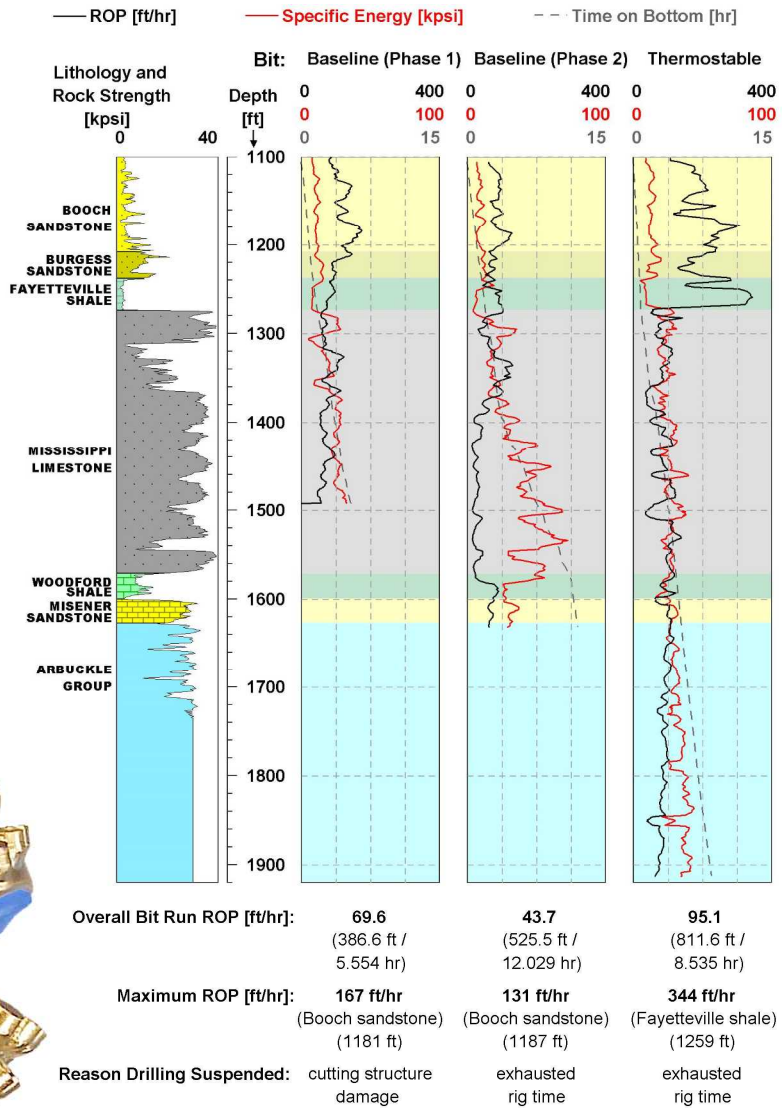


Downhole Communication: *CRADA BIT Tests*

- Baseline rollerbit drilling at TerraTek
- Baseline drag bit with and without DWD
- 4 best effort CRADA partner drag bits with DWD

Rollerbit

Drag Bits



Sandia National Laboratories

Downhole Communication: *CRADA BIT Tests*

Formation Name	Average Rate of Penetration (ft/hr)					
	Bit A (starting at 1102 ft)	**Bit B** (starting at 1166 ft)	**Bit C** (starting at 1103 ft)	**Bit D** (starting at 1105 ft)	**Phase 1 PD 5** (starting at 1105 ft)	**Phase 2 PD 5** (starting at 1106 ft)
Booch Sandstone	191.1	105.9	160.9	18.8	104.9	89.2
Burgess Sandstone	178.1	129.3	124.4	21.4	90.7	69.0
Fayetteville Shale	259.7	273.3	194.2	11.9	77.0	84.9
Mississippi Limestone	78.2	76.4	54.7	24.3 (to 1386 ft)	57.8 (to 1492 ft)	33.0
Woodford Shale	103.8	65.4	67.8	–––	–––	53.0
Misener Sandstone	93.8	35.2	13.5	–––	–––	67.0
Arbuckle Group	86.5 (to 1913 ft)	10.1 (to 1632 ft)	24.5 (to 1670 ft)	–––	–––	66.0 (to 1632 ft)
Overall Bit Run	**95.1** (811.6 ft/ 8.535 hr)	**73.8** (465.6 ft/ 6.311 hr)	**53.0** (566.3 ft/ 10.679 hr)	**19.4** (280.4 ft/ 14.480 hr)	**69.6** (386.6 ft/ 5.554 hr)	**43.7** (525.5 ft/ 12.029 hr)

Downhole Communication: *Acoustic Telemetry*

- Communication between the bit and the surface via pressure waves in the drill pipe
  - Downhole telemetry a big need with today's tools
  - Mud pulse the standard (2 – 5 bits/sec)
  - Acoustic telemetry ~ 10x mud pulse
- Enabled by Sandia's theoretical, manufacturing and testing capabilities
  - Physics issues – propagating waves through drill pipe
  - Engineering and Applications Codes
  - Design and manufacturing of prototypes
  - Field testing
- Product licensed to several entities
  - Commercially available through Xact (STV and Extreme Eng JV)

R&D 100 Award for *Acoustic Telemetry*

Slimhole Drilling

DEMONSTRATED LOWER COST
(30-55% improvement)

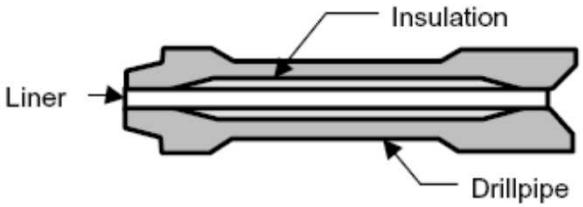
Drilling Cost, dollars/foot	
Well location	Slimhole/Rotary
Steamboat Hills, NV	150/377
Vale, OR	110/153
Ft. Bliss, TX	73/not available
Newberry, OR	200/331

SHOWED PRODUCTION CORRELATION
(Sandia field tests; analyzed large Japanese database)

- > 40 slimholes drilled
- Identifies potential problem zones during production drilling (core drilling less effected by problem zones)
- Useful during operations for reservoir monitoring

Geothermal Drilling Organization Projects

LEAMS (Low Emission Atmospheric Metering Separator
- R&D 100 award
- evolved to be highly portable



Insulated Drillpipe
- reduces bottom hole temperature by as much as 200ºC or more

Casing Remediation
- Seal off reservoir below so casing can be repaired without damaging reservoir

Valve-changing tool
- Allows valve changing without "killing" the well
- 335ºC, 200 psi.

Others:
- *Retrievable whipstock*
- *Rotating-head rubbers*
- *Expert system for lost circulation*
- *Foam cement*
- *Mud hammer*
- *Air motors*

Drilling Practices

- Liners and tie-backs at the Geysers
- Use top-drives to circulate and back ream
- Standardization
- Narrow-clearance casing strings