GEOTHERMAL DRILLING: HISTORY AND TECHNOLOGY IMPROVEMENTS

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SUMMARY - A world-wide review of geothermal drilling operations and technology developments indicates that geothermal drilling practices and equipment are derived largely from existing water-well, mining, and oil and gas developments. Technology improvements to enhance drilling performance in high-temperature and harsh geothermal conditions have been mostly limited to incremental adaptations. A design concept for an advanced geothermal system is presented.

1. INTRODUCTION

The history of geothermal drilling records the succession of attempts by geothermal developers in various parts of the world to adopt and adapt drilling operational experience and equipment from the water-well, mining and oil and gas industries. These efforts have made both exploration and production possible. But both technology advances and known improvements have been slow to be adopted. It is necessary to recognize that drilling is very traditional, experience-based, a field activity, and traditionally is often considered a proprietary or "trade secret" activity. Therefore, the nearly independent learning curve result in heavy front-end costs of initial development drilling due to reduced effectiveness. Reduced productivity of wells and slow drilling rates add to drilling duration and costs. Recently the geothermal community has an excellent study (Stefansson, 1992) that measures the effects of the learning curve from some twenty major geothermal reservoirs, and provides current data for average and ranges of values of the MW(e) produced per kilometer of drilled borehole. The specific problems and research and developments have been well documented (Rowley, 1985; Rowley, 1988; Rowley & Schuh, 1988; Kelsey and Carson, 1987; and Pye and Hamblin, 1992). These reviews typically relate to the incremental increase in "drilling effectiveness"; that is avoiding and solving downhole problems efficiently. And to increasing "drilling performance"; that is increasing productivity, for example rate of penetration. This paper reviews the common causes for reductions in both geothermal drilling effectiveness and performance and proposes a system design that in concept addresses these problems.

2. PROBLEMS

2.1 Reduced Effectiveness

A thorough study of the impacts of drilling problems has been summarized for eight US geothermal fields, Fig. 1; for some 300 wells drilled before 1983. As can be seen that lost circulation, and it's consequences, and cementing predominate. Thus major research projects have been focused on improved lost circulation control, for example by development of drillable cementing packers (Glowka and Schafter, 1993). Cementing improvements have progressed apace (Milstone, et al, 1986). Figure 2 plots the scatter diagrams of drilling effectiveness for the above data set, and it is seen that the large variation in well drilling-times reveals the variability in effectiveness, indicated by the nominal curves, that are caused by the drilling problems encountered.

2.2 Low Performance

The average, or nominal performance for the same data set is also shown in Fig. 2 by the dotted curves that represent the essentially problem free well drilling experience. Penetration rates are recorded to range from 3 to 5 m/h for the harder rocks found in geothermal reservoirs.

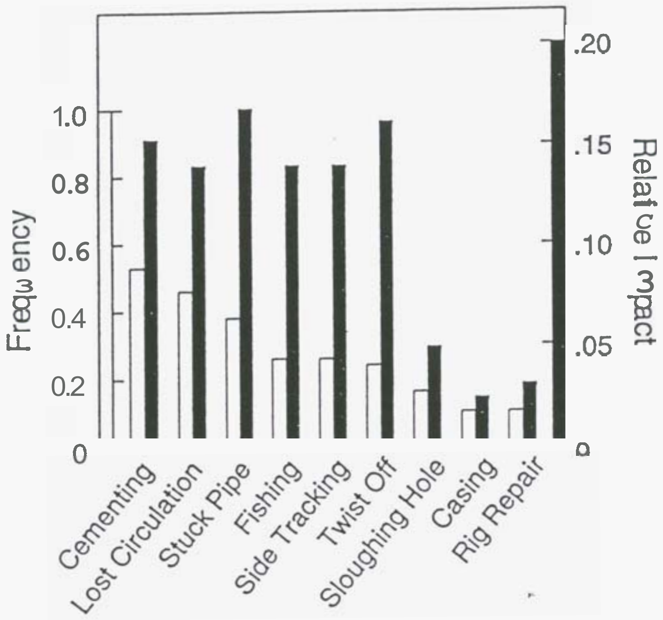
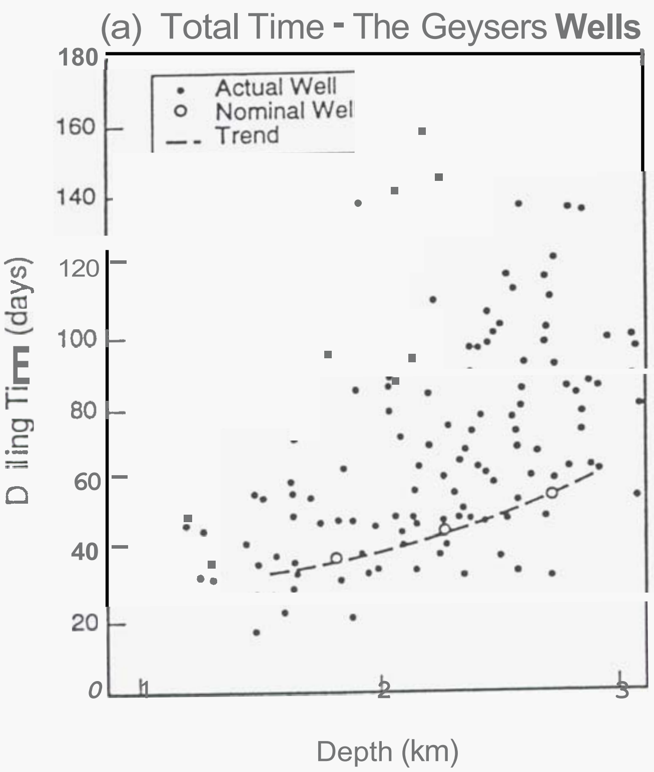


Fig. 1. Summary of frequency (open bar) and relative impact (solid bar) of geothermal drilling problems. Relative impact is problem'r frequency timer the number of days delay it causes.



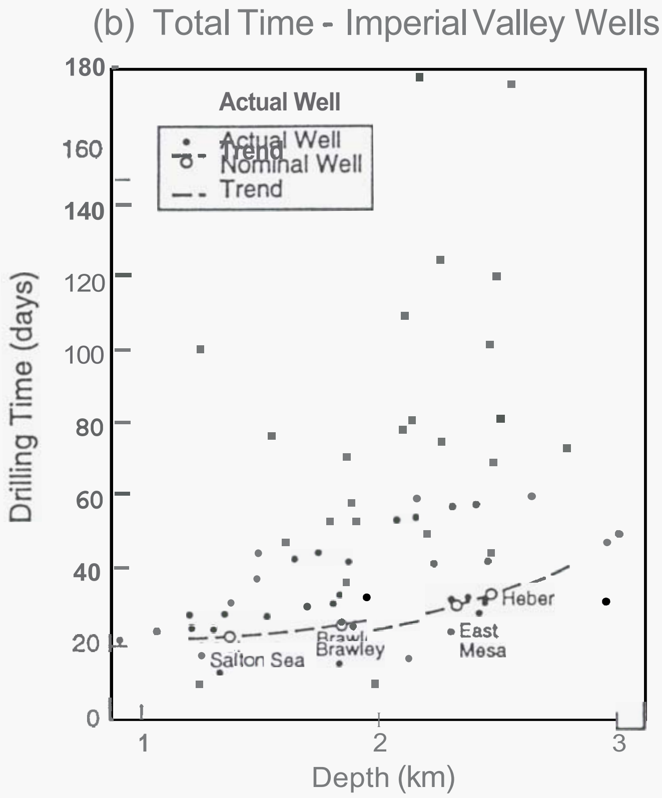


Fig. 2. Drilling times vs. depth for individual geothermal wellr. Geysers and Imperial Valley wells.

2.3 Costs

Figure 3 shows a summary in 1983 of the cost of drilling geothermal wells in the US, and records:

- Costs are about 2 to 4 times those for oil and gas wells of comparable depth.
  The cost-spread is due largely to variable effectiveness.
  Geothermal wells are about twice as deep as average oil and gas wells.

2.4 Performance

Review of numerous drilling records reveals that:

- The increases in costs over petroleum drilling are primarily due to lower performance; that is lower rate of penetration (ROP).
- And reduced bit life relative to drilling in sedimentary basins.

While use of downhole motors (Pye and Hamblin, 1992); can improve ROP and diamond enhanced button cutters (Lauren, et al, 1988) have resulted in significant improvements; within the 30 % range.

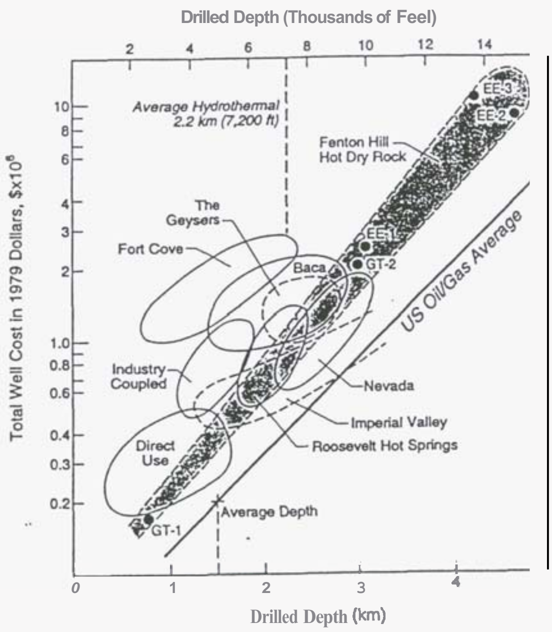


Fig. 3. Cost of United States geothermal wells to 1983 plotted versus drilled depth.

3. ADVANCED SYSTEM

A decade of involvement in geothermal R & D projects, discussions with many geothermal developers and drilling contractors, and a continuous monitoring of drilling technology trends has resulted in a proposed system that, if developed and fielded, should provide much more effective and higher-performance geothermal drilling system.

3.1 Goals

The goals of the advanced system are:

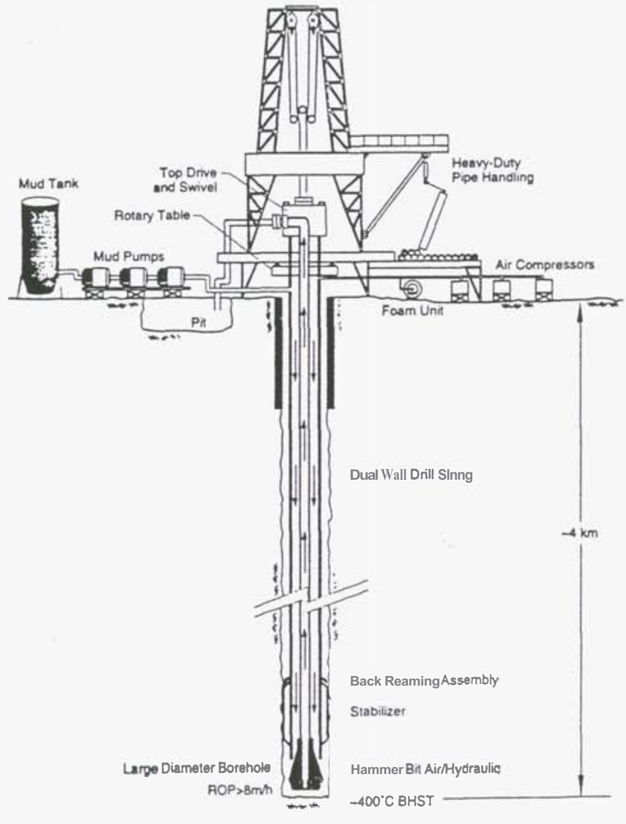
- Drill routinely to depths up to 4 km.
- Reservoir temperatures to 400 degs Celsius.
- Increase effectiveness by building in solutions to the most common problems, for example lost circulation.
- Provide enhanced ROP and bit life by choice of cutting tools; ROP > 8 m/h..
- Improve fluid circulation system to enhance temperature, and lost circulation control.
- Drill large diameter borehole, and provide casing while drilling capability.

3.2 Proposed Advanced System Components and Concepts

Figure 4 is a simplified schematic of the proposed advanced geothermal system (Rowley, 1994). It features:

- A dual-wall drill string.
- A fluidic driven hammer bit (Guangzhi, 1992).
- Hammer fitted with diamond coated TCI cutters.
- Designed, fabricated from high-temperature rated, wear-resistant and corrosion resistant materials,
- Forward or reverse circulation, and. provision for nitrogen drilling.
- Directional controlled hammer, and provision for wing extensions on bit for over-size hole and casing-while-drilling.
- A back reaming assembly at the top of the bottom hole assembly (BHA) .

The advanced, fluidic hammer is included to give excellent penetration performance in hard rocks as well as unstable, fractured or unconsolidated formations. The dual-wall string provides protection for the borehole wall, helps control lost circulation, and provides control of temperature of the BHA.



Pig. 4. Proposed advanced geothermal drilling system (Rowley, 1994).

3.3 Implementation

Because most geothermal developers do not do such developments as proposed, and most drilling contractors are not able to support such a large effort; one is forced to ask: "who might be interested in such an advanced geothermal drilling system?"

4. CONCLUSIONS

The combination of elements proposed should be able to achieve the goals set forth. The improvements and elements suggested above are all within the state-of-the-art, and new design methods and materials make such a system development feasible. There remains only to attract a sponsor.

5. ACKNOWLEDGEMENTS

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