Deep Wireline Coring in Geothermal Reservoirs

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Keywords

Reservoir characterization, formation damage recompletion, injection well drilling

ABSTRACT

Drilling costs are acknowledged to be a significant factor in the economic viability of developing geothermal resources. This paper describes a new wireline coring system that can contribute to improving the efficiency of geothermal drilling. The DOSECC Hybrid Coring System (DHCS) is a self-contained coring package that can be fitted to a wide variety of host rotary drilling rigs. It utilizes a hydraulic top-drive to rotate a wireline coring assembly. The depth capability of this system approaches 20,000 feet using "H" size rods in open hole and Hydril pipe within casing. In geothermal drilling, this rig has applications in reservoir characterization, prevention of formation damage, deepening and recompleting cased wells and drilling injection wells.

Introduction

The geothermal industry has utilized diamond coring technology for many years, although it was originally developed for the hard rock mining industry. Diamond coring is often used for drilling temperature gradient holes and collecting core for the evaluation of hydrothermal alteration, fracturing and lithology. Indeed, coring has been used as a method for reservoir assessment at The Geysers (Hulen *et al.*, 1994), Tiwi (Nielson *et al.*, 1996) and Awibengkok (Hulen and Anderson, 1998). In addition, Unocal used deep coring extensively in the characterization of the Silangkitang field in Sumatra, and Caithness used coring in the characterization of the Karaha field in Java (Moore *et al.*, 2000). An important line of investigation has been the correlation of reservoir measurements in slim holes with those in large diameter production wells (Garg *et al.*, 1996). This and similar studies have shown that it is possible to collect valid reservoir engineering data from slim holes. A strategy of deep coring and testing for reservoir characterization and confirmation followed by large-diameter drilling or recompletion appears to be cost effective.

It is generally acknowledged that drilling practices must evolve to lower the overall cost of drilling and completing wells and to reduce the risks associated with drilling into hostile environments. We are interested in not only increasing the rate of penetration, but also gaining more information from drilling activities. For instance, many operators are pursuing concepts of "smart wells" that transmit information on the formation as they are progressing. The term "measurement while drilling" is often applied to the collection of formation data during the drilling process and its transmittal to the surface. This technology has the promise of allowing active geological and engineering decision making during the drilling of the well.

Although the advantages of continuous core for lithologic characterization are widely recognized, deep wireline coring has other attributes that may be advantageous for geothermal operators. These include a diverse list of topics, from reduction of formation damage to deepening holes where access is limited by stuck casing, to the drilling of wells specifically for injection of fluids. In addition, this drilling methodology is well suited to the installation of instrumentation and collection of data from the subsurface.

DOSECC Hybrid Coring System

The DOSECC Hybrid Coring System (DHCS) is a significant advancement in the state-of-the-art for deep continuous coring. The DHCS combines wireline diamond coring technology and rotary drilling equipment that is commonly used in the geothermal and petroleum industries. The coring package is self-contained and organized as modular components that may be positioned in different configurations depending on the size and layout of the host rotary rig (Figure 1, overleaf). The DHCS is used for continuous wireline coring while the rotary rig is used for opening hole, tripping pipe, setting casing and cementing.

The DHCS consists of a rotating head supported by a hydraulic feed cylinder. The feed cylinder attaches to the elevators of a wide variety of rotary and workover rigs, having a mini-

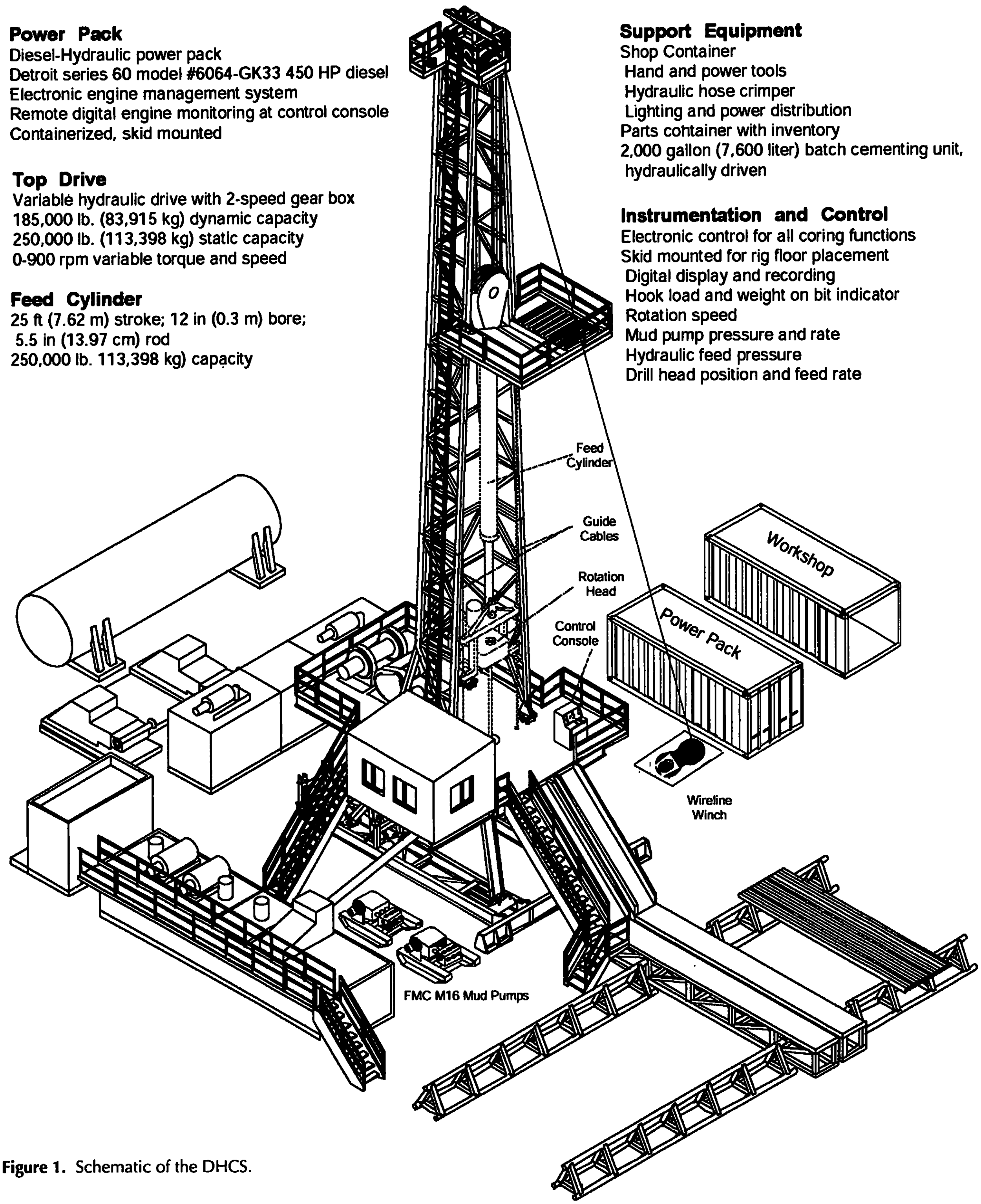

Figure 1. Schematic of the DHCS.

mum hook capacity of 250,000 lb. Power is provided by a 450 HP diesel-driven hydraulic system. The rotating head is a variable speed drive (up to 800 rpm) with a dynamic load capacity of 185,000 pounds. This translates into an estimated depth range of 20,000 feet for an H-size core string. The DHCS is controlled from an operator's console that allows the driller to precisely control (+/- 50 pounds) the weight on bit, the rotation rate, and the mud circulation while monitoring torque, depth, and rate of penetration. The operating parameters are input to a computer system for both digital and graphic display and database archiving.

Compared with rotary techniques, wireline diamond coring attempts to transfer as little energy as possible to the rock formation by using relatively high rotation speeds and low weight on bit.

Wireline coring utilizes flush-joint core rods that have a relatively large inner diameter compared with standard drill pipe. In order to achieve the depths greater than 6000 feet, we are utilizing a hybrid pipe string, consisting of Hydril tubing above conventional flush-joint core rods. Core rods and bits are available in standard sizes that allow a larger size to remain in the hole as casing and the next smaller size to continue drilling out the bottom of the larger assembly. This option can offer significant advantages when drilling in unstable formations. In addition, core barrels with liners that are termed triple tube systems can be particularly useful for drilling and retrieving soft and poorly consolidated formations or rocks where it is important to preserve delicate features or contained fluids.

Formation Damage

Geothermal systems are often sub-hydrostatic due to a component of steam in the reservoir or a relatively deep water table. Therefore, geothermal wells are often drilled under-balanced to help reduce lost circulation and resulting formation damage and stuck drill pipe. We believe that there are situations where wireline coring may be a viable alternative to under-balanced drilling.

Diamond coring using thin-kerf bits has several advantages in minimizing formation damage. First, much of the rock (up to 50%) is removed as core. Second, the cuttings produced by diamond coring are very fine grained, reducing the potential for blocking rock permeability. For specific applications, new bits and core barrels can be constructed to increase the core volume even further.

Wireline coring is commonly carried out with complete loss of circulation. This does not present drilling problems because of low circulation volumes and the fine-grained nature of the cuttings. Wireline methods also provide excellent core recovery, often approaching 100%. Delicate features such as open porosity, fractures and mineral fillings are routinely recovered.

Operational History

The DHCS was initially deployed in the summer of 1998 on the Long Valley Scientific Drilling Program near Mammoth Lakes, California. On that project, it cored to a depth of 9,831 feet setting a depth record for the collection of core of H (2.5 in.) size. The DHCS was mounted on a large rotary drilling rig (Nabors #202). Specific aspects of the well engineering and coring operations have been described by Finger and Jacobsen (1999).

In the spring of 1999, the DHCS was mobilized to the Island of Hawaii for drilling Phase 2 of the Hawaii Scientific Drilling Program (HSDP). The first segment of this hole was completed at a depth of 10,201 feet in fall 1999 with nearly continuous core collected. This hole will be reentered in fall 2001 and will be extended to a projected depth of at least 14,500 feet.

For the first phase of drilling, the DHCS was mounted on a large water well rig (Figure 2), resulting in a substantial cost savings over the use of a standard-size rotary rig. The hole was cored using HCMQ size generally running 10-foot wireline retrievable core barrels. Due to the depth of the hole, the HCMQ rods were connected to Hydril tubing within the cased part of the hole. Standard HCMQ diamond bits were used throughout the drilling.

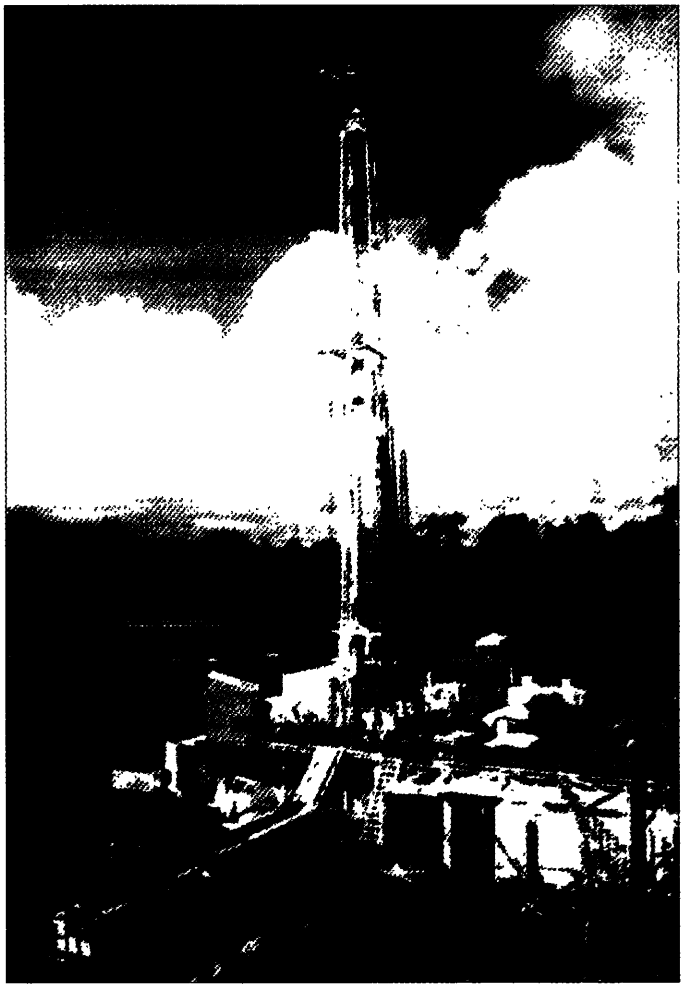

Figure 2. DHCS mounted on a water well rig.

Although neither of the projects on which the DHCS has been used penetrated high-temperature environments, the use of a smaller version of the DHCS at Silangkitang and Awibengkok demonstrated the ability to perform in high-temperature geothermal environments.

Geothermal Applications

Although improvements in drilling technology are generally discussed in terms of the reduction of drilling costs, it is better to consider it in terms of improvements in cost effectiveness. There are a number of aspects of geothermal drilling where deep wireline coring may be a cost effective technique.

Recompletion and Deepening

At times it becomes impossible to remove a casing string from a well and options of recompletion or deepening require the use of slim hole methods that can be used within the stuck casing string. Although this could be performed with rotary methods, the DHCS makes it possible to diamond core though the bottom of the casing. Use of the core rods as casing allows them to be drilled into position. Directional technology makes it possible to perform forked completions to improve production volume.

Injection Wells

Wells drilled specifically for injection do not require as large a diameter as wells drill for production of geothermal fluids. For instance, a 4" hole is sufficient to accommodate the injection of xx gpm of water into the reservoir. This is one aspect of a proposal to develop an Enhanced Geothermal System (EGS) beneath The Geysers steamfield in California (Nielson *et al.,* 2001).

Reservoir Characterization and Measurements

Diamond coring is typically used for the characterization of lithology. Wireline diamond coring is contrasted with conventional rotary coring in that it uses a low weight on bit and high revolutions per minute to cut the core. This is contrasted with rotary methods that use low rpm and high weight on bit to advance the drill string by crushing the rock. As a result, diamond wireline coring is often able to sample fractures including delicate hydrothermal mineral assemblages that are often not recovered from conventional core barrels.

The core barrel used in wireline coring is also useful housing instrumentation that can make measurements in the subsurface. The core tube data logger, developed at Sandia National Laboratory (Henfling *et al.,* 1997) is an example of this type of instrumentation. Technology under development may make it possible to orient the core collected that will have a tremendous impact on our ability to understand the structural settings of geothermal systems.

Summary

Wireline coring has traditionally been used to collect continuous, high-quality core samples from shallow to intermediate depths (<6,000 feet). However, several new rigs, including the DHCS descried here, have been developed to collect samples from depths up to 20,000 feet. Experience in high-temperature geothermal environments has shown the cost-effectiveness of coring for the characterization of reservoirs. We present here additional topics that may be addressed through the use of deep coring technology. These are: drilling of injection wells, recompletion and deepening of wells through existing casing.

Acknowledgements

The DHCS was developed under the sponsorship of the U. S. National Science Foundation and the University of Hawaii.

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