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EVOLUTION OF A HYBRID ROLLER CONE/PDC CORE BIT

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ABSTRACT

The development of the hot dry rock (HDR) geothermal resource, as presently being accomplished by the Los Alamos Scientific Laboratory (LASL), requires that sufficient quantities of good quality core be obtained at a reasonable cost. The use of roller cone core bits, with tungsten carbide inserts, was initiated by the Deep Sea Drilling Program. These bits were modified for continental drilling in deep, hot, granitic rock for the LASL HDR Geothermal Site at Fenton Hill, New Mexico in 1974. After the advent of monocrystalline diamond Stratapax pads, a prototype hybrid roller cone/Stratapax core bit was fabricated by Smith Tool, and tested at Fenton Hill in 1978. During the drilling for a deeper HDR reservoir system in 1979 and 80, six of the latest generation of these bits, now called Hybrid Roller Cone/Polycrystalline Diamond Cutter (PDC) core bits, were successfully used in granitic rock at depths below 11,000 ft.

INTRODUCTION

The energy extraction concept of the Hot Dry Rock (HDR) Geothermal Program, as developed by the Los Alamos Scientific Laboratory (LASL), is to "mine" the heat of the earth by creating a man-made geothermal reservoir at the Fenton Hill Site, in northern New Mexico. This concept has been successfully proven by drilling two holes deep into the low-porosity, granitic basement rock to a depth of approximately 3 km (10,000 ft) and a temperature of 200°C (400°F), and connecting the two boreholes with a large diameter, vertically oriented, hydraulic fracture. Water, circulating down one borehole (EE-1) is heated by contact with the hot rock, rises to the surface up the second borehole (GT-2) where the heat is extracted and the cooled water is reinjected into the underground circulation loop.

NECESSITY FOR OBTAINING CORES

Because the HDR Geothermal concept was (and still is) in the developmental stage, the obtaining of sufficient amounts of unbroken core was considered essential in determining a number of parameters of the reservoir. The need for this type of information is not encountered in either oil or gas wells or in conventional geothermal systems. Some of the more obvious items of information to be derived from core samples, according to Laughlin and Eddy (1977) and others, are listed as:

1. Existence and orientation of natural fractures.
2. Nature of fracture-filling minerals, if any.
3. Rock structure, as it might affect hydraulic fracturing.
4. Rock type and age.
5. Rock porosity/permeability.
6. Core orientation by paleomagnetism.
7. Acoustic velocity values.
8. Rock-water interactions.
9. Circulating fluid chemistry, as it might affect plating or fouling of heat exchanger tubing.
10. Calibration of geophysical logging tools.
11. Future bit design.

INITIAL CORING RESULTS

The preliminary plans for drilling Hole GT-2 in the Precambrian granitic basement rock at Fenton Hill called for continuous coring, using air as the circulating medium. At that time (1974), it was planned to use the continuous wireline retrievable coring system then in use by the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), commonly called the Deep Sea Drilling Program. Following the JOIDES design, Smith Tool manufactured 15 core bits for the HDR project, 9-5/8-in. o.d. by 2-7/16-in. i.d., with four carbide insert roller cutters to drill the hole and shape the core (Fig. 1). When used by the Deep Sea Drilling Program, the inner core barrel was normally dropped from the surface with the borehole full of water. For use in an air-drilled hole, modifications to the retrieval system were necessary. However, many mechanical difficulties were encountered, and after the first three coring runs in GT-2, the JOIDES bits were used in the conventional coring manner, with no further attempt at wireline recovery (Pettitt, 1975a).

When used as conventional core bits, the JOIDES design at first proved less-than-satisfactory, with poor core recovery and short bit life. Excessive wear on the inserts that trimmed the core caused the core to rapidly become oversize before it could enter the core barrel. This core recovery problem was solved by using harder grade inserts and a slight change of placement for the core-trimming inserts. The improved bit design, which subsequently nearly doubled the core recovery, began with Coring Run No. 12, and continued through Coring Run No. 27, the last core obtained (Pettitt, 1975b).

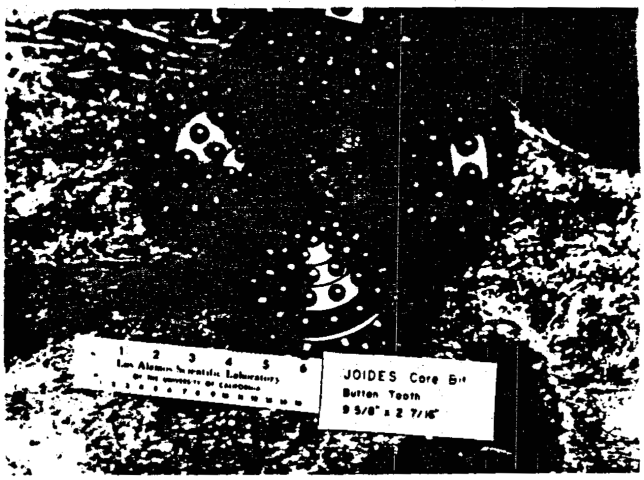

Fig. 1. Modified JOIDES core bit.

Conventional diamond core bits from two manufacturers were also used. Although good core was obtained, the cost was considered prohibitive as the expensive diamond bits were usually completely worn out in 10 ft or less of penetration.

FIRST HYBRID BIT FIELD TEST

In 1978, during a directional-drilling, sidetracking operation in GT-2 to obtain a better connection with the underground fracture system, several unsuccessful attempts with diamond core bits were made. Shortly before this, General Electric Company had created their monocrystalline diamond "Stratapax", and had successfully bonded it to a tungsten carbide stud (Jellison and Huff, 1978). Laboratory tests indicated that the Stratapax could cut various types of rock at phenomenal rates. Smith Tool saw the potential of using the Stratapax to trim the core as it entered the barrel, while using roller cutters with tungsten carbide inserts to cut the gage. A prototype bit was constructed, using four chisel-tooth, roller cone gage cutters from a five cone bit (Herrick, 1978). The rock core surface was cut and shaped by six of the Stratapax elements (Fig. 2). The bit was 7-7/8-in. o.d. by 4-1/2-in. i.d., and seemed so small and lightweight (as compared to the larger ineffective 9-5/8-in. o.d. diamond bits) that the drilling crews actually laughed when they saw it. First use of this prototype occurred on June 19, 1977.

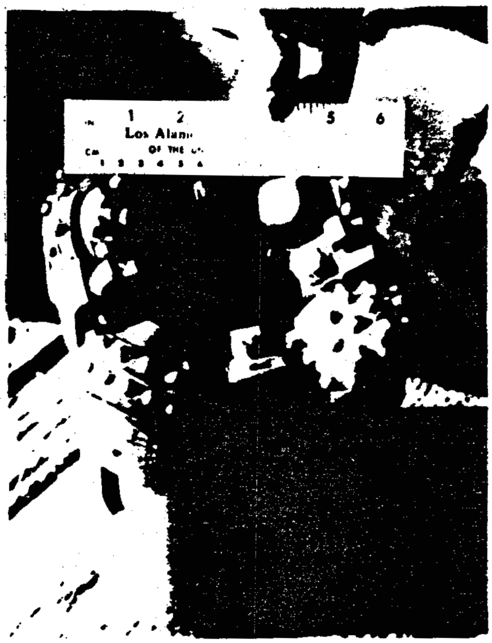

Fig. 2. Prototype hybrid roller cone/Stratapax bit.

Fig. 3. Prototype bit after usage.

The coring assembly consisted of a six point, 3-ft-long stabilizer immediately above the bit, followed by a 27-ft-long core barrel, a five point 5.4-ft-long stabilizer, and a three point reamer assembly. Coring began at a rotational speed of 32 rpm and a load of 15,000 lbs. The rotational speed was gradually increased to 48 rpm; and the rotational torque nearly doubled. Penetration rate averaged 2 ft/h. Examination after the bit was pulled showed three of the four studs broken off (Fig. 3). The cones were loose and the chisel teeth were worn almost smooth. From the 5 ft run, about 50 in. of broken cone was recovered (Pettitt, 1978).

RECENT HYBRID PDC CORE BIT DEVELOPMENTS

Drilling of the third well at Fenton Hill, Hole EE-2, began on April 1979 and was completed in May 1980 at a depth along the well bore of 15,292 ft and a temperature of 275°C (550°F). This well is the first of a pair to be connected by multiple, parallel hydraulic fractures, which could produce power from 15 to 20 MW (e). Below 8,000 ft, the holes are deviated to 35° from the vertical, and below 10,600 ft the hole diameter is 8-3/4-in. A program was designed to obtain cores at approximately 600 ft intervals below 11,000 ft, at depths which had not been investigated by Holes GT-2 and EE-1.

Six bits were purchased from Smith Tool of an improved hybrid roller cone-Stratapax design, now called Polycrystalline Diamond Cutters (PDC). The bits were 7-7/8-in. o.d. by 3-in. i.d., and consisted of four cones with tungsten carbide insert buttons, and four PDC pads mounted on tungsten carbide studs (see Figs. 4 and 5). Two Hycalog 6-1/4-in. o.d. by 15-ft-long core barrels were also purchased. The Hycalog service representative served as drilling engineer when the coring runs were made; Smith Tool design engineers were also present during the first few runs.

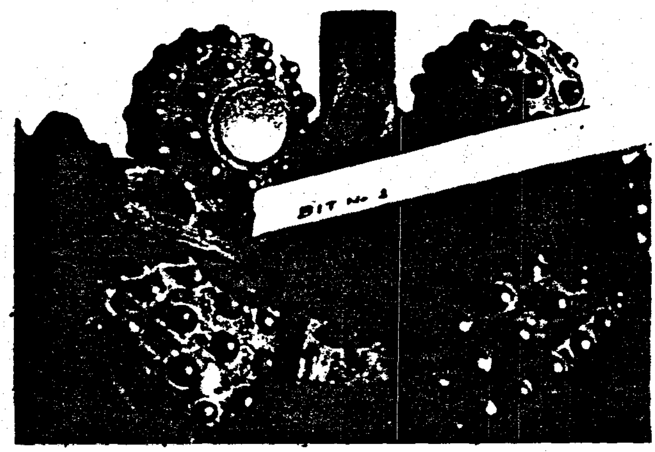

Fig. 4. Hybrid PDC bit after usage, note wear on PDC pads.

Rotational speed varied from 35 to 50 rpm, with 10,000 to 20,000 lbs. weight. When the penetration rate slowed to about half, the bit was pulled. See Table I for a summary of coring runs in EE-2. Bits from Runs 2 and 5 could have been rerun, as they remained in reasonably good condition. (In fact, Run No. 7 was accomplished with the bit from Run No. 2.) Bits from Run No. 1 and 3 could be used again if the PDC pads and studs were replaced. None of the PDC (Stratapax) posts were broken off, as occurred in the prototype run on June 19, 1977. No near-bit stabilization was employed on any of the runs in EE-2.

Orientation of the core was attempted in Core Runs No. 2 and 6. The first orientation used an Eastman Whipstock core orienting tool with a heat shield. The bit was pulled after cutting 9 ft to preserve the film in the orientation tool. However, the film was blackened and the tool suffered severe heat damage. There was no core recovery; cuttings indicated that the coring run had been attempted in a highly fractured, altered zone. The second orientation attempt was made with an Eastman Whipstock Magnetic Multishot, with a wireline insertion and recovery mechanism. During insertion, the overshot grapple on the wireline came unscrewed so that early recovery was impossible. The tool was withdrawn with the bit, and the excessive heat again damaged the film and tool.

The Hycalog core barrel performed well. On Core Runs No. 2 and 6, core scribers were installed for orientation purposes; and on Run No. 7 as a core stabilization aid. After coring, the scribers were found to be either broken or worn completely down, and no scribe marks appeared on any of the core.

CONCLUSIONS

Hybrid core bits, combining tungsten carbide inserted roller cones and diamond Stratapax core shaping cutters, have been successfully designed, fabricated, and tested. These bits now become a part of the line of advanced tools required for extending drilling operations into areas and depths of more difficult conditions. Improvements of these bits to increase their wearing life will undoubtedly follow, as well as the needed improvements in core barrel scribers and core orientation tools.

REFERENCES

Herrick, R. G., 1978, Roller Cone/Diamond Drag Core Bit, SPE Paper 7517, 53rd Annual Conference, Society of Petroleum Engineers; Houston, Texas.

Jellison, J. C., and Huff, C. F., 1978, A Review of Attachment of Stratapax Using Gas Pressure Diffusion Bonding, Sandia Laboratory report SAND 78-0318C.

Laughlin, A. W., and Eddy, A. C., 1977, Petrography and Geochemistry of Precambrian Rocks from GT-2 and EE-1, Los Alamos Scientific Laboratory report LA-6930-MS.

Pettitt, R. A., 1975a, Planning, Drilling, and Logging of Geothermal Test Hole GT-2, Phase I, Los Alamos Scientific Laboratory report LA-5819-PR.

Pettitt. R. A., 1975b, Testing, Drilling, and Logging of Geothermal Test Hole GT-2, Phase III, Los Alamos Scientific Laboratory report LA-5965-PR.

Pettitt, R. A., 1978, Testing, Planning, and Redrilling of Geothermal Test Hole GT-2, Phases IV and V, Los Alamos Scientific Laboratory report LA-7586-PR.

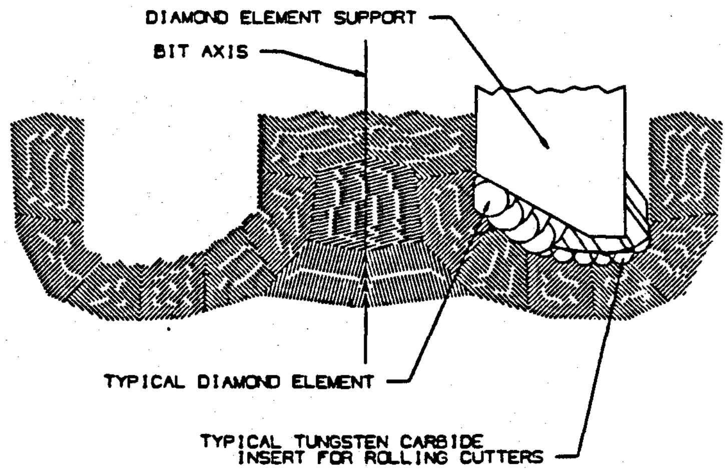

Fig. 5. Bottom hole profile of hybrid PDC core bit.

TABLE I
SUMMARY OF CORING OPERATIONS IN EE-2
(All bits were Smith Tool Hybrid Roller Cone/PDC)

Run No.	Date	Depth (ft)	Cored Interval (ft)	Recovery (%)	Penetr. Rate (min/ft)	Bit Condition: Cone Teeth	Bit Condition: Cone Bearings	Bit Condition: Gauge Wear	Bit Condition: PDC Pads	Remarks Recommendations	Rock Type
1	11/11/79	11,737-11,743	6	79	12	2	4	None	8	Rebuild and replace PDC studs; use again.	Biotite granodiorite gneiss; fracture oriented at 3° from vertical.
2	11/20/79	12,266-12,275	9	0	6	4	5	1/16"	2	Bit could be rerun as is.	No recovery; drilled through fractured/altered zone.
3	11/26/79	12,848-12,856	8	91	18	1	3	None	3	Rebuild and replace PDC studs; use again.	Metavolcanic (dacite) intruded by granodioritic material.
4	12/8/79	13,454-13,464	10	41	18	3	8	1/16"	8	Scrap pile.	Biotite granodiorite.
5	12/21/79	13,955-13,962	7.5	100	15	1	4	None	3	Bit could be rerun as is.	Biotite-amphibole-feldspar gneiss intruded by biotite granodiorite.
6	5/2/80	14,501-14,504	3.3	100	6	4	6	1/16"	8	Scrap pile.	Biotite-amphibole-feldspar gneiss, similar to Core Run No. 5.
7 Rerun No. 2 Bit	5/6/80	14,962-14,966	4	40	8	4	6	1/8"	8	Scrap pile.	Biotite granodiorite gneiss, similar to Core Run No. 1.

*Cone teeth and bearings, and PDC pads are rated on a scale of 1 (like new) to 8 (completely ruined).