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Testing, Drilling, and Logging of Geothermal Test Hole GT-2, Phase III

by

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TESTING, DRILLING, AND LOGGING OF GEOTHERMAL TEST HOLE GT-2, PHASE III

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ABSTRACT

Geothermal Test Hole No. 2 (GT-2) is a deep exploratory hole drilled into the Precambrian-age basement granitic rocks of the Jemez Mountains in north-central New Mexico. The purpose of the hole is to confirm the suitability of the Fenton Hill site for development of the world's first dry hot rock geothermal energy experiment. The drilling of GT-2 to a depth of 2042.6 m (6701.5 ft) was completed in September 1974, and represented Phase I of the Fenton Hill site evaluation. A series of hydraulic fracturing tests, conducted at specific depths in the granitic section of the hole, was completed in early October 1974. Following this second-phase work, the hole was deepened to 2932 m (9619 ft). Various diagnostic logging operations were performed after the drilling was completed. A 185-m-long (608-ft) liner assembly terminating at its upper end in a polished-bore receptacle was then placed and cemented in the bottom section of the hole. This report describes the third phase of the development of GT-2 including deepening and logging the hole and installing and testing the liner assembly.

I. INTRODUCTION

The primary objective of the Los Alamos Dry Geothermal Source Demonstration Project is to investigate and develop methods of extracting energy economically from hot rock in the earth's crust. This will involve large-scale field studies and demonstrations of drilling into hot rock, fracturing it by hydraulic pressure or by other methods to produce connected circulation paths through the rock, and then circulating water or other fluids through these channels to extract heat from the rock and transport it to the earth's surface. It will include research and development in those areas of geochemistry, geophysics, heat flow, fluid flow, rock mechanics, seismology, environmental effects, and related subjects, which are required to make such an energy-extraction system successful, economical, and environmentally acceptable.^{1,2}

Throughout the life of the project, a major objective will also be to make this new technology available to industry as soon as its usefulness has been demonstrated.

The geothermal source demonstration area is located on the Jemez Plateau, which is part of the western arm of the Rocky Mountains extending into northern New Mexico (Fig. 1). As a result of relatively recent vulcanism, a large amount of heat is

Fig. 1. Major structural features and area of investigation in north-central New Mexico.

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Fig. 2. Dry geothermal energy source demonstration site at Fenton Hill.

still retained in rocks underlying the entire area within a few kilometers of the surface.

The geology of this region was first described by Renich,³ and has since been described by Woods and Northrop,⁴ Smith et al.,⁵ Ross et al.,⁶ and Bailey et al.⁷ A regional geologic map was published by Smith et al.⁸ Fitzsimmons⁹ described some of the Precambrian rocks in the area, and West¹⁰ has discussed the geophysics of the Jemez Mountains.

The Los Alamos Scientific Laboratory (LASL) is located on the eastern flank of the Jemez Mountains, about 50 km (30 miles) by road from the demonstration area. On the basis of previous studies, surveys, and field experiments,¹¹⁻¹³ a specific site on the Jemez Plateau west of Los Alamos was selected as an appropriate location for development of the first dry hot rock energy experiment (Fig. 2). It has been officially identified as the "Fenton Hill Site," or TA-57 (LASL Technical Area 57).

This report presents a chronological history of the work done and some of the problems encountered in drilling, logging, and installing the bottom liner during the third phase of work in GT-2.

II. SUMMARY OF PRECEDING WORK

A. Phase I

Drilling began in GT-2 on February 17, 1974. Serious problems encountered in drilling the Permian-age red beds and the Pennsylvanian-age shales and limestones required a string of 34-cm-diam (13-3/8-in.) casing to be set to a depth of 488 m (1600 ft).

The Precambrian granitic surface was reached at a depth of 733 m (2404 ft) on March 30, but caving of the overlying sedimentary rock formations continued to present difficulties. A second string of 27.3-cm-diam (10-3/4-in.) casing was set from the surface to a depth of 773 m (2535 ft). Drilling continued in the granitic basement rocks to a depth of 1937 m (6356 ft).

The geologic section of the first phase of the project has been reported by Purtymun et al.¹⁴

B. Phase II

Following the drilling, a series of hydrology experiments was performed to determine the permeability of the granitic rock at depth. Hydraulic fracturing experiments were conducted at specific zones in the granitic section of the hole, using methods and equipment developed by the oil-well services industry. An additional 105 m (345 ft) of drilling were completed during this testing phase to allow experiments to be conducted in a "fresh" hole. Various diagnostic logging operations were performed during testing and drilling.

At the conclusion of the fracture experiments, the polished-bore-receptacle (PBR) liner assembly installed to facilitate hydraulic fracturing was drilled over and removed from the hole.

Detailed accounts of the planning, drilling, logging, and testing work performed during Phases I and II have been presented in previous reports.¹⁵⁻¹⁷

The elevation of the top of the Kelly bushing on the drilling rig was 2652 m (8701.5 ft) above mean sea level, and all depth in Phases I, II, and III were measured from this point.

III. DRILLING PLAN

After considering the costs that had already been incurred in drilling GT-2 to a depth of 2042 m (6701 ft), it was decided to deepen the hole to about 2743 m (9000 ft) and perform additional experiments at that depth. At relatively low cost, this would provide more information on the geology, hydrology and character of the rock at depth and would further confirm the suitability of the Fenton Hill site for an energy extraction demonstration.

A schedule was written to encompass the Phase III drilling through the beginning of the post-drilling diagnostic-logging operations. Based on past drilling performance, it was planned to drill

about 152 m (500 ft) with each bit, or 72 h at a penetration rate of 2 m/h (7 ft/h). At depths of approximately 2414 m, 2566 m, 2722 m, and 2877 m (7920 ft, 8420 ft, 8930 ft, and 9440 ft), the bit would be pulled, the hole circulated for cleaning, and a 24-h temperature measurement obtained. After pulling the temperature sonde, a 3-m (10-ft) core would be cut and recovered, then drilling would be resumed with a full-face bit.

After cutting the core at 2566 m (8420 ft), three impression packer tests were scheduled, followed by a tuboscope inspection of the drill pipe and a magnetic-particle inspection of the tool-joint connections.

At the conclusion of drilling, it was planned to set approximately 182 m (600 ft) of casing near the bottom of the hole, terminating in a polished-bore receptacle (PBR), to create a smooth-sided interval for seating the packers for the fracturing experiments. Perforation of the casing at some future time would also allow additional hydraulic-fracturing experiments to be performed from within the casing, perhaps followed by development of a one-hole circulation system.

IV. DRILLING PROGRESS

After the liner assembly used in the Phase II experiments had been retrieved from the hole, drilling ahead proceeded.

Using a 25.1-cm-diam (9-7/8-in.) Smith Q9TJL mining bit with junk basket, drilling began at 2:00 a.m. on October 12 at 2042 m (6701 ft). Drilling proceeded to 2047 m (6717 ft), the bit was pulled, and a magnet started down the hole. Fill was encountered at 24 m (80 ft) above the bottom, but was penetrated without difficulty. A large number of metal chips were retrieved, and drilling was resumed with a new Smith Q9JL bit. By October 16, a depth of 2165 m (7102 ft) had been achieved, the bit having drilled 117 m (385 ft) in 48 h of actual drilling time. The bit was badly worn, but was less than 0.3 cm (1/8 in.) out of gauge. During this 5-day period, five magnet runs were made and three separate batches of high viscosity mud, each consisting of 12 sacks of Aquagel and 4 sacks of Benex, were injected to clean the hole of the steel scraps left from the liner assembly.

Fig. 3. New and used Smith Q9 full-faced bits.

The final magnet run produced only a few small pieces of metal shavings. With the hole apparently clean, a coring assembly was made up with a 24.4-cm-o.d. by 11.4-cm-i.d. (9-5/8-in. by 4-1/2-in.) Christensen diamond core bit. A 0.6-m (2-ft) interval from 2165 to 2166 m (7102 to 7104 ft) was cored; recovery was approximately 75%. The core broke about 15 cm (6 in.) above the bottom of the cored interval, leaving the stub in the hole.

When the coring assembly was being pulled, one of the bolts from the elevators was accidentally dropped down the hole. When a subsequent magnet run failed to retrieve the bolt, the bolt was ground up with a used bit and the hole deepened to 2166 m (7107 ft) in the process.

Drilling was resumed on October 18, with a new Smith Q9 bit (Fig. 3). At a bottom depth of 2169 m (7117 ft), the drill pipe broke in the hole at about the 1829-m depth (6000-ft). The break was at the top of a tool joint, just inside the box end. The pipe had apparently been cracked for some time, as only about one-third of the cross section appeared to be fresh metal. Although magnetic-particle nondestructive-testing inspections had been made periodically on the drill pipe, the crack was in a location where it would not have been detected.

Fishing operations with milling tools and over-shot bits continued until October 20, when the broken pipe string was retrieved from the hole. Drilling was resumed with the same bit, until it was pulled on October 23 after having drilled 115 m (378 ft) in 67 h. A new Security 24.4-cm-diam (9-5/8-in.) H10J

Fig. 4. Security H10J full-faced bit.

bit was installed and drilling continued (Fig. 4). On October 26, the bit was pulled after drilling for 58.5 h and reaching a depth of 2413 m (7918 ft).

A 24-h temperature measurement was concluded on October 28, with a maximum bottomhole reading of 161°C, extrapolatable to 164°C. Coring operations with the Christensen diamond bit began after the temperature sonde was pulled. In 8.5 h of drilling, approximately 0.3 m (1 ft) of core was cut.

Drilling began again on October 29, using a new Security 24.4-cm-diam (9-5/8-in.) H10J bit. On November 2, at a depth of 2614 m (8577 ft), the bit was pulled after drilling 201 m (658 ft) in 81 h. The bit was 0.3 cm (1/8 in.) under gauge, but the cones were still reasonably tight. Hole deviation at this depth was 2-1/8 degrees from vertical.

Open-ended drill pipe was run down the hole to enclose the temperature sonde for a 24-h measurement. A coring assembly was made up with a 24.4-cm-o.d. by 6.2-cm-i.d. (9-5/8-in.-o.d. by 2-7/16-in.-i.d.) JOIDES core bit. A 3-m (10-ft) core run was completed through the 2614- to 2617-m interval (8577- to 8587-ft) with about 70% recovery.

Drilling was temporarily suspended from November 4 to November 7, during which time impression-packer tests were conducted in the 1992- to 2001-m interval (6535- to 6564-ft). A complete tuboscope and magnetic particle inspection of the drill pipe was also made at that time.

Drilling began again on November 7 and continued until November 9, when the water swivel ceased to turn. While a new swivel was being installed, the bit was pulled and changed. The old bit had drilled to a depth of 2695 m (8842 ft), approximately 78 m (255 ft) in 31 h, and was still in good condition.

On November 10, drilling ahead proceeded with a new Security H10J bit, and continued until November 13. After having drilled 205 m (672 ft) in 75 h, the bit was pulled. The cones were slightly loose, but only 0.3 cm (1/8 in.) under gauge. Open-ended drill pipe with a special phenolic end section was run down the hole for temperature measurements. The readings continued through November 15 to obtain additional data needed for cementing the casing in the lower section of the hole.

When the drill pipe was pulled, it was discovered that the phenolic end section had been left on bottom. A JOIDES core bit assembly was made up to drill out the phenolic section, and then continued drilling to obtain a core. A 2.4-m (8-ft) coring run was made from 2901 to 2904 m (9519 to 9527 ft), with about 50% recovery. An additional 3-m (10-ft) coring run was made to 2907 m (9537 ft), with the same percentage recovery.

Two Lynes packers were made up to obtain impressions of the fractures centered around the 1992-m (6535-ft) depth. The packers were left in the hole for 10 h, then pulled out, and the hole was reentered with a 20-cm-diam (7-7/8-in.) Smith Q9J bit. On November 19, a 3-m (10-ft) pilot hole was drilled to a depth of 2910 m (9547 ft). This bit was pulled and a coring assembly with a Christensen 20-cm-o.d. by 10.2-cm-i.d. (7-7/8-in. by 4-in.) diamond bit was made up and started down the hole.

Coring progressed very slowly at the rate of 0.8 m (2.7 ft) in 8 h. It appeared that the No. 2 rig pump wasn't operating effectively. New pump parts were installed, but as the circulating pressure was still insufficient for continued drilling the pipe was started out of the hole. A crack was discovered

Fig. 5. Crack in drill pipe which allowed loss of circulation at the core bit.

in the pipe which evidently was allowing the circulating water to leak out before it reached the bit (Fig. 5). After the pipe was withdrawn completely, it was found that the 8.5-m-long (28-ft) outer core barrel and the diamond bit and stabilizer were still at the bottom of the hole. Although the inner core barrel was retrieved, no core was recovered.

At 9:45 a.m. on November 21, when going in the hole to fish for the core barrel, the hydraulic brake on the drilling rig failed and the traveling block fell to the rotary table (Fig. 6). The 2804 m (9200 ft) of drill string remained in the elevators, and was thus prevented from slipping down the hole.

Fig. 6. Traveling block lying on the floor of the drilling rig after hydraulic brake failure.

However, after the damage had been repaired and the drill string pulled, it was found that about 1219 m (4000 ft) of pipe had broken off at a tool joint and had fallen to the bottom of the hole.

A drilling-rig mechanic from Farmington, New Mexico inspected the rig and the brake, and pronounced the drill rig safe but recommended a larger pump for the brake. A larger pump was installed, but the brake still did not function properly. After the 1219 m (4000 ft) of pipe had been fished from the hole, the brake was dismantled and sent to Farmington for repair. It was found to be in good condition and, according to the manufacturer, to have been installed correctly. However, when reinstalled on the drilling rig, it operated properly only after a small standpipe was plumbed into the water-supply line to insure that both ends of the brake were adequately supplied with water when a large braking load was suddenly applied.

Upon removal from the hole, 85 joints of pipe required straightening. The outer core barrel was removed from the bottom of the hole on November 29, but the stabilizer and the diamond core bit still remained and fishing for them continued.

Milling of the stabilizer and diamond core bit in the bottom of the hole continued until December 7. A total of one overshot bit, six rotary shoes and six mills, all dressed with crushed boron carbide, were used to drill out the stuck tools. In order to clean the hole, drilling with a 24.4-cm-diam (9-5/8-in.) bit proceeded to a depth of about 2920 m (9581 ft). On December 8, drilling of a 1.5-m-deep (5-ft) pilot hole began with a full-face 20-cm-diam (7-7/8-in.) bit made up on a 24.4-cm-diam (9-5/8-in.) stabilizer. At a depth of 2922 m (9586 ft), this bit was pulled and the tool string made up to continue drilling with the 20-cm-diam (7-7/8-in.) bit. A total depth of 2932 m (9619 ft) was reached at 5:17 p.m. on December 9; the hole was flushed and the drill pipe pulled.

The maximum total deviation of GT-2 was 5 degrees from the vertical, with the final deviation being only 2 degrees.

VI. PLACEMENT OF LINER ASSEMBLY

On December 11, a break in the 27.3-cm-diam (10-3/4-in.) casing at about the 76-m (250-ft) depth was cemented by Halliburton Oil Well Cementing Company. A 185-m-long (608 ft) section of 20-cm-diam

(7-7/8-in.) steel casing with a PBR assembly at the top end was run in the hole on December 13, and cemented into place. The bottom of this liner was landed on the shelf at the bottom of the 24.4-cm-diam hole (9-5/8-in.) at 2920 m (9581 ft). While the cement was setting, two Lynes impression packers were run down the hole and centered at depths of 1990.2 and 2001.2 m (6529.4 and 6565.5 ft).

The cement in the liner and the hole was drilled out with a 17.2-cm-diam (6-3/4-in.) bit on December 15. Logging operations began on December 10 and continued intermittently through December 17. The following day an attempt was made to insert an Otis casing packer (equipped with a plug-type valve) near the bottom of the liner. The packer seated prematurely at a depth of 2808 m (9212 ft). However, it was concluded that this would not seriously affect future operations, and the packer was left at that location. A PBR mandrel was then seated in the polished-bore receptacle at the top of the liner, with a string of 11.4-cm-o.d. (4-1/2-in.) tubing extending to the surface. Pressure tests indicated that the PBR seal was tight, but that the plug valve in the Otis packer might be leaking.

A summary of the drilling, casing, and geologic data is included as Appendix A.

The drilling rig was released at 7:00 p.m. on December 20, and dismantling began almost immediately. By December 22, the area around the hole was clear of drilling equipment. Before leaving, the drilling contractor installed a piece of 14-cm-diam (5-1/2-in.) casing in the 7.6-m-deep (25-ft) mouse hole.

VII. IMPRESSION PACKERS

The first attempt to obtain impressions of the sand-propped fractures that were opened during the Phase II fracturing experiments was largely unsuccessful. On November 5 and 6, two Brown Oil Tool impression packer assemblies were set at the 1992- and 2001-m depths (6536- and 6564-ft), but each time the packers ruptured during the initial pressurization (Fig. 7). Very faint impressions were obtained, but these were of doubtful significance.

On November 18, two Lynes packers were made up and centered at the 1992-m depth (6536-ft). Some trouble was experienced in inflating them and it was thought that one had ruptured. However, the packers were left in the hole for 10 h. Upon withdrawal, it

Fig. 7. Ruptured Brown Oil Tool packer from 1992-m (6536-ft) depth.

was found that both packers had been inflated and that discernible impressions had been obtained, but that the packers had been inadvertently set 27 m (90 ft) too high. Two days later, a second set of Lynes packers was made up and set at the correct depth. After they had been inflated for 10 min at 8.3 MPa (1200 psi), the packers burst. The impressions that were obtained were slightly better than those from the previous attempts (Fig. 8).

After the liner had been cemented in place, two Lynes packers were made up and spaced on the drill string to be centered at depths of 1990.2 and 2001.2 m (6529.4 and 6565.6 ft). The packers were pressurized to 6.9 MPa (1000 psi) and left in place for 6 h. Two good impressions were obtained of fractures that were nearly vertical and oriented in an approximate northeast-southwest direction (Fig. 9).

VIII. DRILL BIT PERFORMANCE

Phase III drilling began with a 25.1-cm-diam (9-7/8-in.) Smith Q9TJL mining bit using water as the drilling medium. Two successive drilling runs were made to a depth of 2281 m (7485 ft) using the Smith bits. Bit speed during these runs was 40 rpm, with the weight varying from 17.2 to 18.2 Mg (38,000 to 40,000 lb).

At that time, additional Smith bits of the desired gauge were not available, and the remaining major portions of the drilling were accomplished using 24.4-cm-diam (9-5/8-in.) Security H10J bits.

Fig. 8. Impressions on Lynes packers from 1992-m (6535-ft) depth, enhanced by chalk-rubbing.

Four major drilling runs were made with these bits, the longest run being 201 m (658 ft) in 81 h. The bit speed and weight were approximately those used with the Smith bits. When pulled, the Security bits showed a loss of gauge up to 0.3 cm (1/8 in.) and had one to six buttons missing. The life of the Security bits was surprisingly good, considering that the downhole temperature was in excess of 150°C.

Fig. 9. Pronounced impressions of fractures obtained with Lynes packers on the final test.

A summarization of the major drilling runs is shown in Table I.

IX. CORING

Coring in Phase III progressed essentially as planned, after the temperature measurements at the end of each major drilling run. The coring operations are summarized in Table II, showing the percent recovery of each core run, the type of bit, and rock formation. The first two core runs were made with Christensen 24.4-cm-o.d. by 11.4-cm-i.d. (9-5/8-in. by 4-1/2-in.) diamond bits. Penetration rates for these cores (No. 22 and 23) were 0.6 and 0.3 m/h (1.9 and 1.0 ft/h), respectively.

The next three cores were cut by 24.4-cm-o.d. by 6.2-cm-i.d. (9-5/8-in.-o.d. by 2-7/16-in.-i.d.) JOIDES-type bits manufactured by Smith Tool Company (Fig. 10). Penetration rates on these cores varied from 0.9 to 1.3 m/h (3 to 4.4 ft/h).

It was planned to obtain a core in the reduced-diameter bottom section of the hole. This core was being drilled with a Christensen 20-cm-o.d. (7-7/8-in.) diamond bit when the tools and drill pipe became stuck. During the ensuing washover and milling operations, the bit and the core were ground up and no recovery was made.

Because of the additional time and expense required to extract the stuck tools from the hole, the drilling of a bottomhole core was cancelled.

TABLE I

SUMMARY OF MAJOR DRILLING RUNS, GT-2, PHASE III

Drilled Depth	Drilled Interval	Drilling Time (h)	Rock Formation	Bit Wear (Loss in diam)	Average Penetration Rate
2047.3-2164.7 m (6717-7102 ft)	117.4 m (385 ft)	48	granodiorite, granite, quartz monzonite	0.32 cm (1/8 in.)	2.5 m/h (8.0 ft/h)
2166.2-2281.4 m (7107-7485 ft)	115.2 m (378 ft)	67	granodiorite, biotite gneiss, monzonite	0.32 cm (1/8 in.)	1.7 m/h (5.6 ft/h)
2281.4-2413.4 m (7485-7918 ft)	132.0 m (433 ft)	58.5	granodiorite, monzonite	0.16 cm (1/16 in.)	2.3 m/h (7.4 ft/h)
2413.7-2614.3 m (7919-8577 ft)	200.6 m (658 ft)	81	granodiorite, monzonite	0.32 cm (1/8 in.)	2.5 m/h (8.1 ft/h)
2617.3-2695.0 m (8587-8842 ft)	77.7 m (255 ft)	30.75	granodiorite	none none	2.5 m/h (8.3 ft/h)
2695.0-2899.9 m (8842-9514 ft)	204.9 m (672 ft)	75	granodiorite, monzonite	0.32 cm (1/8 in.)	2.7 m/h (9.0 ft/h)

TABLE II

SUMMARY OF CORING RUNS, GT-2, PHASE III

Core Run	Cored Interval, Depth	Recovery (%)	Core Bit ^{a,b}	Rock Type ^c
21 ^d	2040.6-2042.5 m (6695-6701 ft)	0	J	
22	2164.7-2165.3 m (7102-7104 ft)	100	C	biotite tonalite, monzogranite
23	2413.4-2413.7 m (7918-7919 ft)	100	C	leucocratic monzogranite
24	2614.3-2617.3 m (8577-8587 ft)	70	J	biotite monzogranite, pegmatite
25	2901.4-2903.8 m (9519-9527 ft)	50	J	biotite granodiorite
26	2903.8-2906.9 m (9527-9537 ft)	50	J	biotite monzogranite

^aJ - JOIDES-type bit.^bC - Christensen Diamond Products Company bit.^cAll rock types determined from petrographic examination of thin sections.^dPhase II core run.

Fig. 10. Cores obtained from Coring Runs No. 25 (top) and No. 26 (bottom).

X. TEMPERATURE MEASUREMENT

Three temperature measurements were obtained during Phase III, using LASL-designed probes. In order to further reduce convective circulation at the bottom of the hole, procedures and equipment were developed that were different from those used in the Phase I measurements.

Previous temperature measurements had been made by lowering the probe into the open hole on its conductor cable, and surrounding it by a slug of high-viscosity mud. The increased temperatures encountered at the Phase III depths tended to dehydrate the bentonitic mud, making it extremely stiff. This, coupled with the greater amounts of drill cuttings which accumulated at the bottom of the hole as the depth increased, increased the possibility of the temperature probe becoming stuck.

The Phase III procedure consisted of lowering the probe to bottom through open-ended drill pipe. A cloth-base phenolic adapter section was fabricated to fit on the bottom of the drill pipe, into which the lower end of the temperature sonde would be inserted. The phenolic section was 0.65 m long (25-1/2 in.), with a 19.7-cm o.d. (7-3/4-in.) and a minimum 7.0-cm i.d. (2-3/4-in.). The minimum diameter of the end section of the temperature probe was 6.4 cm (2-1/2 in.), Figs. 11 and 12. The low thermal conductance of the phenolic section prevented conductive cooling up the drill pipe from the bottom of the hole. Settling of drill cuttings between the phenolic section and the borehole wall prevented

Fig. 11. Cross section of borehole, phenolic adapter and temperature probe.

Fig. 12. End section of temperature probe and phenolic adapter.

convective fluid movement in the annulus at the bottom of the hole.

A. Circulation Procedure

1. After termination of drilling with a full-face bit, circulation was maintained to clean the hole by stages.

a. Pull bit 0.3 m (1 ft) off bottom and circulate drilling fluid 1 min.

b. Pull bit 1.5 m (5 ft) off bottom and circulate 5 min.

c. Inject drilling mud to assist in raising cuttings. The usual batch consisted of eight sacks of Aquagel, one sack of Cellex and one sack of Benex.

d. Pull bit until Kelly bushing is at full height and circulate 1 h 55 min.

2. Withdraw drill string from hole.

3. Run back into hole with phenolic section on open-ended drill pipe.

a. Wash to bottom, taking care to prevent hitting bottom with phenolic section.

b. Pull phenolic 0.3 m (1 ft) off bottom, circulate 30 min.

c. Set phenolic gently on bottom; set drill pipe in slips with approximately 1.4 Mg (3000 lb) remaining on the phenolic section.

4. Lower temperature probe to bottom.

5. Record bottomhole temperature for 24-h period.

B. Measured Values

The geothermal gradient in the Phase III section of the hole increased to approximately 60°C/km (42.7 °F/1000 ft). On November 14, the measured bottomhole temperature at a depth of 2900 m (9514 ft) was 180°C (356°F), and GT-2 could officially be classified as a "hot" geothermal reservoir. The final measured temperature at this depth was 184.8°C (364.6°F), with extrapolation possible to 195°C (384.4°F). The extrapolated equilibrium rock temperature at the terminal depth of 2932 m (9619 ft) was 197°C (386.6°F).

XI. LOGGING

Diagnostic logging operations were performed in the hole by a commercial logging company. A summary of this work is shown in Fig. 13, which designates the depth interval through which each type of log was run.

The logging operations began on December 10 and continued intermittently until December 17. The logging work was plagued by repeated failures of the transducers and cable-head connectors to operate satisfactorily at the temperatures and pressures

Fig. 13. Diagnostic logging services performed in GT-2 during December 1974.

encountered near the bottom of the hole. As the placement and cementing of the liner assembly was interspersed with the logging operations, repairs could be made on the logging equipment without loss of time.

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LOS ALAMOS DRY GEOTHERMAL SOURCE DEMONSTRATION PROJECT
GEOTHERMAL TEST HOLE NO. 2 (CONTINUED)
SUMMARY OF DRILLING, LOGGING, Casing, CEMENTING AND GEOLOGIC DATA
(Depth measured from Kelly Jackline. Stratcon 8291.3)

12

BIT RECORD

*DENOTE BY (N)-NO, (L)-LIGHT, (M)-MEDIUM OR (H)-HEAVY ROUNDING OF GAGE

SUBJECT TO PROVISIONS ON REVERSE SIDE

PM-68C