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DRILLING AND THERMAL GRADIENT MEASUREMENTS AT U.S. MARINE CORPS AIR GROUND COMBAT CENTER, TWENTYNINE PALMS, CALIFORNIA

Final Report for the Period October 1, 1983—March 31, 1984

By
Dennis T. Trexler
Thomas Flynn
George Ghusn, Jr.

Work Performed Under Contract No. AC03-83SF11956

University of Nevada, Las Vegas
Reno, Nevada

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DRILLING AND THERMAL GRADIENT MEASUREMENTS AT
U.S. MARINE CORPS AIR GROUND COMBAT CENTER
TWENTYNINE PALMS, CALIFORNIA

Final Report

October 1, 1983 - March 31, 1984

Dennis T. Trexler, Thomas Flynn
and George Ghusn, Jr.

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Environmental Research Center
University of Nevada, Las Vegas

as a result of the cooperative agreement between DOE's San Francisco Operations Office and the Naval Weapons Center, China Lake, California, for joint geothermal research and development at military installations.

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ABSTRACT

Seven temperature gradient holes were drilled at the Marine Corps Air Ground Combat Center, Twentynine Palms, California, as part of a cooperative research and development program, jointly funded by the Navy and Department of Energy. The purpose of this program was to assess geothermal resources at selected Department of Defense installations. Drill site selection was based on geophysical anomalies delineated by combined gravity, ground magnetic and aeromagnetic surveys, which were performed by the Geothermal Utilization Division, Naval Weapons Center, China Lake, California, or their contractors. Utilization of geothermal fluids for power generation and space heating represents a viable energy resource for many Department of Defense installations, particularly in the western United States.

Geothermal fluids are known to occur immediately south of the MCAGCC. Several northwest-trending faults, believed to be the principal structural controls for rising thermal fluids are located on the Center. In addition, a prominent northwest-trending lineament, defined by the alignment of closely spaced gravity contours, reflects a 17 milligal/mile anomaly, measured orthogonal to the trend, and indicates a large vertical displacement in the bedrock. This anomaly is located slightly east of the Center's administrative area and was the primary target for the initial drilling.

Drilling began January 3, 1984, and was completed on January 27, 1984. Depths ranged from 880 feet to 1,100 feet. After four non-thermal holes were drilled, the original drilling plan was modified. The fifth temperature gradient hole was drilled at a site originally selected. However, the final two holes were drilled at two alternate sites selected near Surprise Spring, which is located several miles northwest of the MCAGCC administrative area.

Temperature gradients ranged from 1.3°C/100 m (1°F/100 ft.) in hole No. 1 to 15.3°C/100 m (8.3°F/100 ft.) in temperature gradient hole No. 6. Large, positive geothermal gradients in temperature gradient holes 5 and 6, combined with respective bottom hole temperatures of 51.6°C (125°F) and 67°C (153°F), indicate that an extensive, moderate-temperature geothermal resource is located on the MCAGCC. The geothermal reservoir appears to be situated in old, unconsolidated alluvial material and is structurally bounded on the east by the Mesquite Lake fault and on the west by the Surprise Spring fault. If measured temperature gradients continue to increase at the observed rate, temperatures in excess of 80°C (178°F) can be expected at a depth of 2,000 feet.

ACKNOWLEDGEMENTS

Many people participated in the successful completion of this project and the authors would like to acknowledge their contributions. John Crawford and Bill Holman, of the San Francisco Operations Office of the U.S. Department of Energy, provided pertinent suggestions during site selection review and the drilling phase of the program. Geothermal Utilization Division, Naval Weapons Center China Lake, personnel were instrumental in conceiving the project, providing geophysical data used in drill site selection, and assisting in temperature gradient measurements and site restoration. Individuals of the Geothermal Utilization Division who provided this support are Carla Gerrard, Al Katzenstein, Jack Neffew and Ted Mort.

Logistical support during activities at the Marine Corps Center was provided by Lt. Col. C.E. Schaffer and the staff of the Installations Division, specifically Staff Sgt. William Flummerfelt, who provided assistance in acquiring necessary permits for drilling activities at the MCAGCC.

We would also like to acknowledge the drilling contractor, Fred Anderson and Son Exploration Drilling, Inc., for a job well done and for their patience while drill site locations and depths were changed because of data acquired during drilling.

Without the assistance and support provided by these individuals and organizations, this project would not have been completed.

INTRODUCTION

As part of a U.S. Department of Energy and U.S. Navy Cooperative Program Agreement, the Division of Earth Sciences, University of Nevada, Las Vegas, was selected to drill seven temperature gradient holes at the Marine Corps Air Ground Combat Center, Twentynine Palms, California. Interest in geothermal energy at the MCAGCC was stimulated by reports of 73°C (164°F) water flowing from a 400 foot deep well located 3.2 km (2 miles) southeast of the Center. Geophysical data delineated a structure that appears to be an asymmetric graben trending northwest-southeast beneath the Center's administrative area. The artesian well is located along this same trend.

The drill sites were selected on the basis of geophysical work performed by the Geothermal Utilization Division, Naval Weapons Center, China Lake, California. The original targets were suspected fault trends and magnetic anomalies associated with the graben-structure beneath the Center. Wells were drilled to a nominal depth of 1,000 feet or to bedrock, whichever came first.

Drilling commenced on January 3, 1984, and was completed on January 29, 1984. Completed depths ranged from 880 feet to 1,100 feet. Temperature gradient measurements were made on February 13-15, 1984, and again on February 27 and 28. A maximum temperature of 67.1°C was recorded at a depth of 1,100 feet in temperature gradient hole number 6. At drill site number 5, approximately 2 miles south of drill site 6 and along the same subsurface trend, a temperature of 51°C was measured at a depth of 940 feet. Temperatures measured in temperature gradient holes 1, 2, 3, 4, and 7 reflected the regional geothermal gradient, which is 2.5 to 3.0°C/100 m.

SITE CHARACTERISTICS

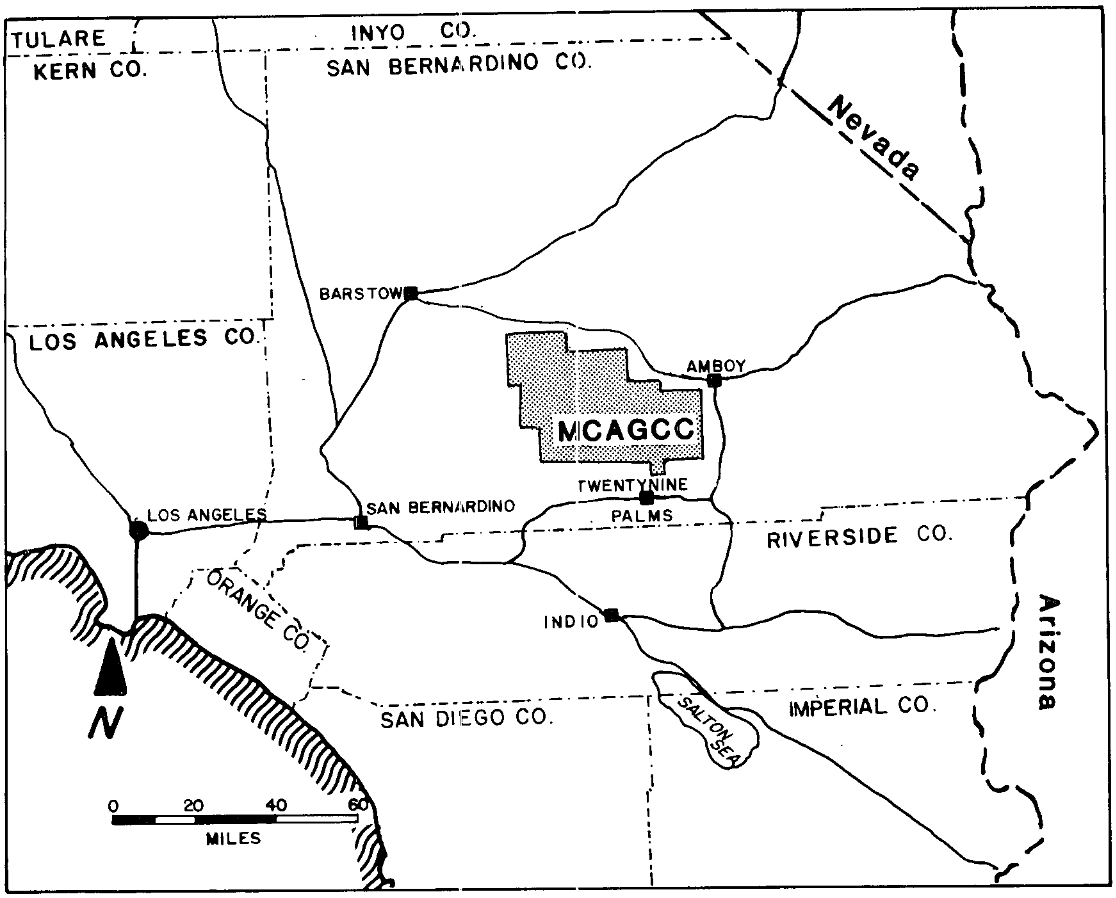
The Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, California, encompasses approximately 1,000 square miles of the southern Mojave Desert. The Center administrative and housing area is located 5 miles north of the city of Twentynine Palms, California (fig. 1). Large buildings such as offices, barracks and classrooms are heated by a central boiler plant employing a low pressure steam and distribution system. Individual and multiple family housing employ individual gas-fired forced air heating systems.

An expeditionary air field (EAF) is located at Camp Wilson, approximately 6 miles northwest of the Center's administrative area. The only permanent structures at Camp Wilson are 14 shower and lavatory buildings. Hot water for the buildings is heated by fuel oil.

The annual expenditures for heating oil and natural gas for the entire Center were $2,050,000 for fiscal 1983 (Facilities Engineer personnel per. comm., 1983).

GENERAL GEOLOGIC SETTING

The Mojave Desert is part of the Basin and Range physiographic province (Fenneman, 1931). Rocks exposed in the ranges are generally older than those found further north in the province. Precambrian gneissic rocks and intrusives of Mesozoic age comprise the bedrock areas surrounding the basins (Dibblee, 1968). Unconsolidated, very late Pleistocene and Recent deposits consisting of windblown sand, alluvium and clay comprise the surficial sediments of the valleys. These deposits are underlain by older, weakly consolidated alluvium and fanglomerate locally cemented by calcite. Thickness of these deposits is probably greater than 1,000 feet. They range in age from late to mid-Pleistocene to possibly late Tertiary.



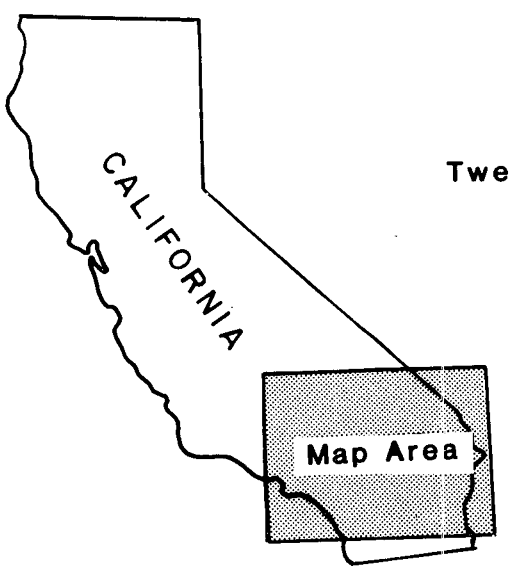


Figure 1.
Location map of the Marine Corps Air Ground Combat Center, Twentynine Palms, California (MCAGCC).

Geologic structure in the area is dominated by northwestward-trending faults. The southern boundary of the Mojave Desert in this area is the Pinto Mountain fault, located on the north side of the Little San Bernardino Mountains. Significant northwest trending faults, from east to west, in this area include the: 1) Bullion Mountain fault, 2) Mesquite Lake fault, 3) Surprise Spring fault, and 4) the Copper Mountain-Emerson fault system (fig. 2). Several unnamed subparallel faults are inferred between the Mesquite Lake fault and the Copper Mountain-Emerson fault system.

GEOTHERMAL OCCURRENCES

The occurrence of warm ground water in the Twentynine Palms area has been known for at least 30 years. Wells drilled for domestic water north of the city of Twentynine Palms have reported temperatures of 40-73°C (105-164°F). Higgins (1980) reported 3 wells ranging in temperature from 48°C to 63°C. The approximate boundary of the geothermal area in the vicinity of Twentynine Palms was described in Leivas and others (1981) as extending approximately 15 km (9 miles) in an east-west direction and 6 km (3.5 miles) north-south. However, this delineation was based on only 5 wells.

Interest in the potential for geothermal resources beneath the Marine Corps Air Ground Combat Center was stimulated by the reported existence of a well, 400 feet deep with a water temperature of 73°C (164°F), located 3.6 km (2 miles) southeast of the Center's boundary. Geophysical exploration by the Geothermal Utilization Division, Naval Weapons Center, China Lake, indicated a geologic structure, the Bullion Mountain fault, trending northwest-southeast beneath the MCAGCC administrative area and the above mentioned well.

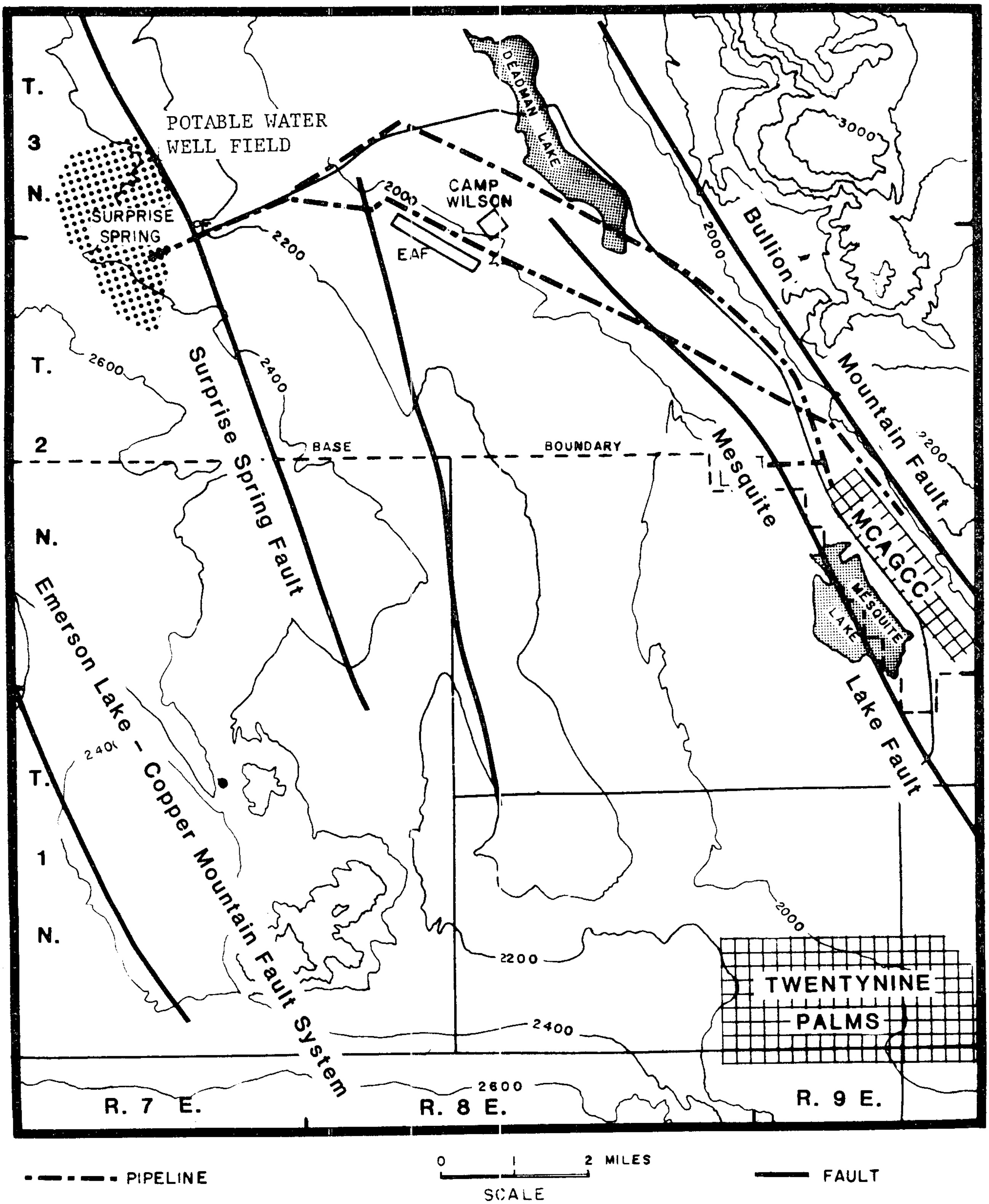


Figure 2. Major northwest trending faults in the vicinity of Twentynine Palms, California.

DRILL SITE SELECTION

A meeting was held at Naval Weapons Center, China Lake, California, to discuss drill site selection criteria. The meeting was attended by U.S. DOE, San Francisco Operations Office personnel and a Division of Earth Sciences representative. The seven drill sites (fig. 3) were selected from geophysical data gathered by Geothermal Utilization Division personnel or their contractors. An aeromagnetic survey, performed over the entire military reservation, showed several low-intensity anomalies. A marked linear increase in magnetic intensity appeared along the eastern side of the Center's administrative area (gray area on fig. 3). Gravity and ground magnetic survey data, concentrated in the southern portion of the MCAGCC, confirmed the existence of the steep northwest-southeast trending aeromagnetic anomaly. The magnetic and gravity anomaly appears to coincide with a fault inferred by Dibblee (1968), which has been named the Bullion Mountain fault.

Five drill sites (fig. 3) were selected around the administrative area to test the hypothesis that a buried fault in this area may provide a conduit for geothermal fluids. Site 81-21 is located on the upthrown (easterly) side of the fault to ascertain thermal gradient background. Site 78-16, located 3 miles west-northwest of the administrative area, is located on the eastern flank of a gravity high.

Drilling was to proceed at the selected sites in the following order: 1) 78-33, 2) 78-29, 3) 45-28, 4) 43-20, 5) 81-21, 6) 13-4, and 7) 78-16. The order of drilling and drill-site locations were altered and revised during drilling, however, as mud return temperatures and depth to bedrock data were obtained. The rationale for these changes is discussed in the "Summary of Drilling Activities" section of this report.

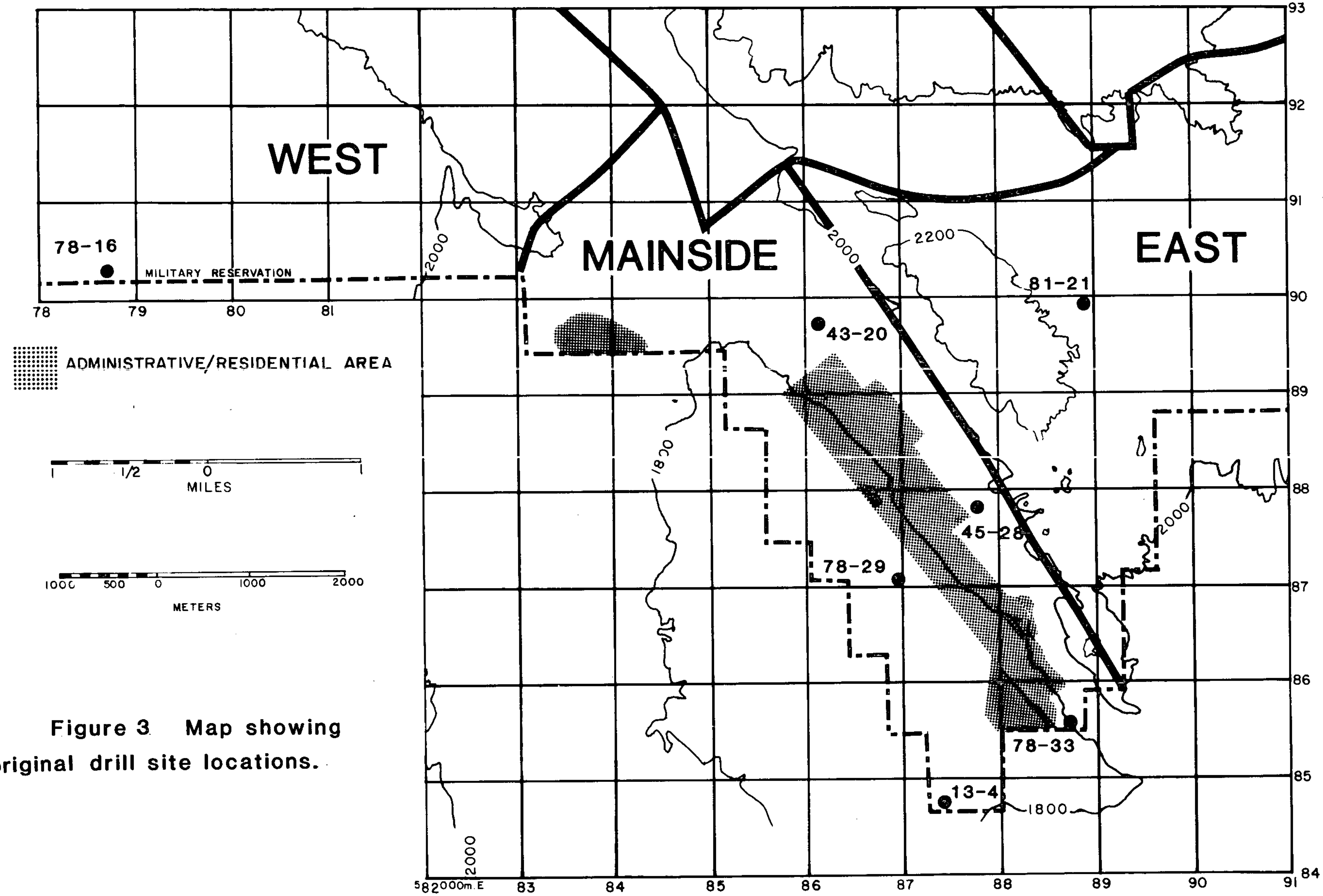


Figure 3 Map showing original drill site locations.

DRILLING SPECIFICATIONS

After the drill sites were selected, an on-site visit was made to ascertain the types of materials that would be encountered and to determine accessibility to drilling equipment. Initial drilling specifications were prepared and submitted to the Purchasing Department, University of Nevada, Las Vegas, for procurement. A copy of the drilling specifications is presented in Appendix A.

The temperature gradient holes were to be drilled to a depth of 1,000 feet or to bedrock. If bedrock was encountered before reaching 1,000 feet, drilling was to be terminated and the remaining footage used on additional holes. The total drilling contract was for 7,000 feet of 5 to 6 inch diameter hole cased with 2.5 inch black-iron pipe.

All drilling proceeded according to regulations described in the Geothermal Resources Operating Orders (GROO). In addition, DES personnel and contractors observed all safety and security regulations in affect on the MCAGCC.

Existing water wells in the area do not exceed 700 feet in depth and a blowout preventor (BOP) was used on the first temperature gradient hole. The use of a BOP was not included in the original drilling specifications. The modified drilling plan for use of BOP equipment required 8 5/8 inch casing to 100 feet. The 8 5/8 inch casing was cemented in place by forcing cement down the casing and up the annulus between the casing and the outside of the hole.

Bid packages were sent to ten drilling companies; only two companies responded. The low bidder, Fred Anderson and Son Exploration Drilling Inc., of Woods Cross, Utah, was awarded the contract.

PRE-DRILLING CONFERENCE

On December 13, 1983, personnel from the Division of Earth Sciences and the Geothermal Utilization Division, Naval Weapons Center, China Lake, briefed Marine Corps military and civilian personnel. Several topics were discussed including drilling contractor vehicle permits, access to the MCAGCC, safety, and logistical matters pertaining to availability of water and storage of casing. It was agreed by all parties that drilling would commence as soon as possible.

Marine Corps personnel were enthusiastic about the proposed drilling program and the potential for geothermal energy to reduce oil and natural gas consumption.

Staff Sargent W. Flummerfelt of the Natural Resources Division, Installations Division, was assigned to act as liaison for DES and the drilling contractor. S.Sgt. Flummerfelt provided invaluable assistance for the duration of the drilling program at the Marine Corps AGCC, Twentynine Palms.

SUMMARY OF DRILLING ACTIVITIES

As discussed previously, and shown on Figure 3, seven drilling sites were selected based on geophysical data supplied by the Geothermal Utilization Division, Naval Weapons Center, China Lake. The drilling sequence, as specified, was altered somewhat after bedrock was encountered at a depth of 690 feet in the first hole. In addition, low temperature mud returns, indicating no geothermal fluids, prompted a revision in the order of drilling sites 1 through 5. The original intent of the drilling program was to concentrate on sites located on the large gravity anomaly beneath the Center's administrative area (sites 78-33, 45-28, 43-20, 78-29 and 13-4, fig. 3).

The disappointingly low mud return temperatures (27°C) and the shallow depth-to-bedrock indicated that sites 45-28 and 43-20, located on the east side of the MCAGCC, would also be on the upthrown side of the Bullion Mountain fault and, therefore, unlikely prospects for geothermal fluids. After completion of temperature gradient hole No. 1 (78-33), it was mutually decided by DES, DOE San Francisco Operations Office, and Navy personnel to drill site 13-4, located 4,500 feet southeast of temperature gradient hole No. 1 and perpendicular to the trend of the Bullion Mountain fault. This site (13-4) is adjacent to the Mesquite Lake fault which was believed to be another likely target for geothermal resources.

Temperature gradient hole No. 2 was completed to a depth of 1,000 feet without encountering bedrock. Maximum mud return temperatures of only 27°C suggested that if a geothermal resource was present, it was very deep.

The third drill site was located approximately half-way between temperature gradient hole No. 1 and temperature gradient hole No. 2 (fig. 4) along the trend of the gravity anomaly and 1.3 miles to the north of temperature gradient hole No. 2. This location would confirm if the Bullion Mountain fault (gravity anomaly) was the controlling structure for the geothermal fluids.

Due to the disappointing results from temperature gradient holes 1 and 2, it was mutually agreed by all parties to drill to a depth greater than 1,000 feet at this location. The amount of drill rod immediately available was 1,220 feet. At a depth of 1,090 feet, the bearings on the drill bit seized and drilling slowed. The hole was completed to 1,100 feet and maximum mud return temperatures were 30°C. These data confirmed that the Bullion Mountain fault, in the vicinity of the Center's administrative area, was not the controlling structure for the migration of geothermal fluids.

After analyzing the results of drilling, it was decided by DES and Navy personnel to drill different structural blocks on the Center to determine which faults controlled the migration of geothermal fluids.

Temperature gradient hole No. 4 was located at original drill site 81-21, immediately east of the Bullion Mountains (east of the Bullion Mountain fault), to ascertain if the geothermal fluids reported south of the Center were controlled by faults on the east side of the Bullion Mountains. Bedrock was encountered at 890 feet and drilling was terminated at 920 feet. Maximum mud return temperature was 29°C at 920 feet which indicated that the geothermal fluids are not in this structural block.

At this point, DES and Navy personnel agreed to drop two remaining primary sites near the administrative area and focus on other secondary sites west of the Bullion Mountain fault. This was done in an effort to locate the

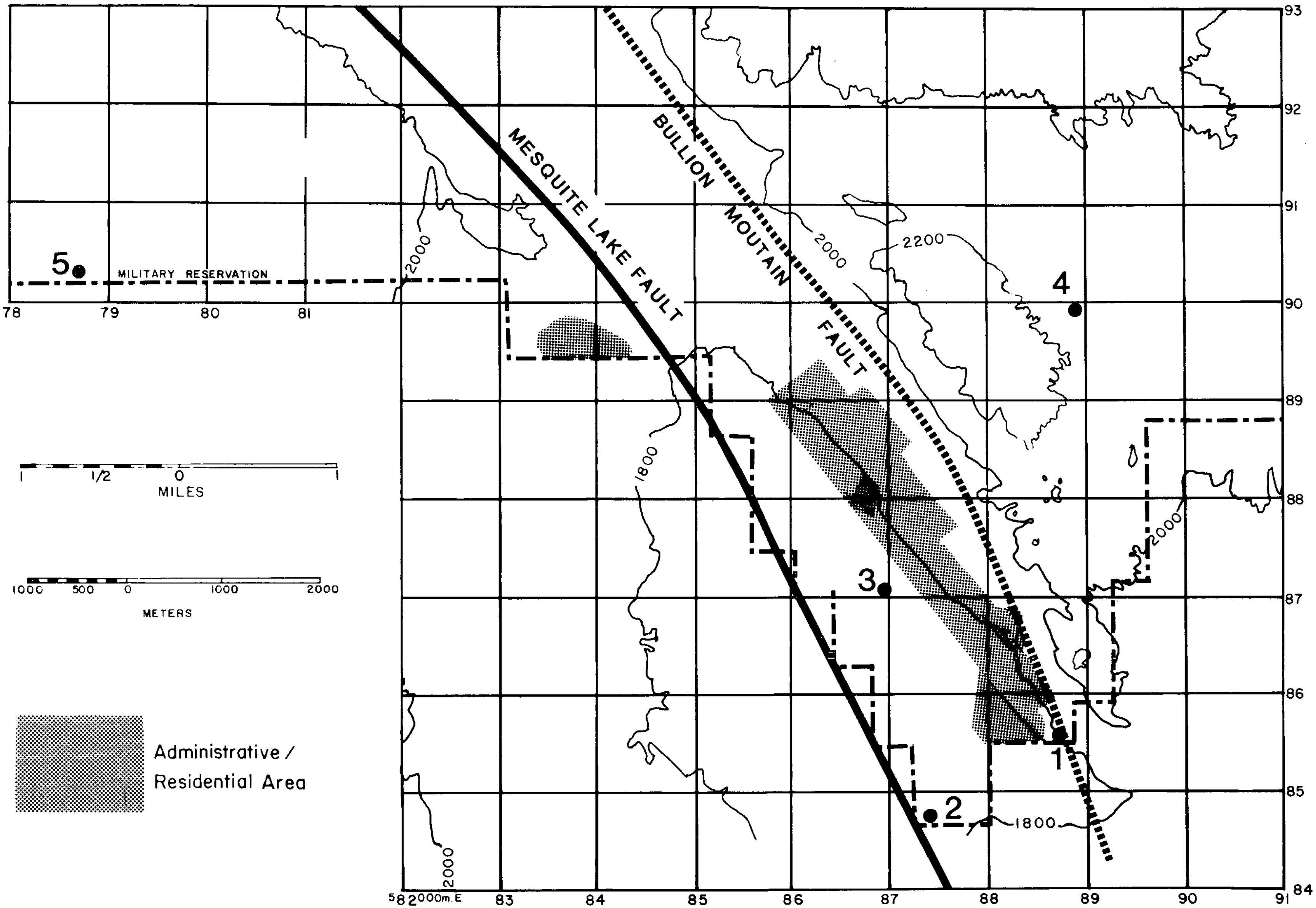


Figure 4. Location of temperature gradient holes 1 - 5.

controlling structures for the geothermal fluids. These two additional sites were chosen on opposite sides of the Surprise Spring fault. A major logistical problem surfaced because these sites are located on training ranges with restricted access. Temperature gradient hole No. 5 was drilled while permission to enter the training area was obtained.

Site 5, (site 78-16, fig. 3) is located 3 miles west-northwest of the Center's administrative area. It is situated between the Mesquite Lake fault on the east and Surprise Spring fault on the west. Maximum mud return temperatures were 34°C, indicating the presence of geothermal fluids. The hole was to be drilled to 1,100 feet, however, a bit change was required at 940 feet and, upon tripping back into the hole, circulation could not be recovered. Another pit of mud was prepared and pumped down the hole; circulation still was not regained. Further attempts to regain circulation would have resulted in wasted money and time. It was therefore decided, by DES personnel, to complete temperature gradient hole No. 5 to 940 feet.

Permission to enter the training area, where sites 6 and 7 are located (fig. 5) was obtained during drilling of temperature gradient hole No. 5. As mentioned previously, site 6 is located on the east side of the Surprise Spring fault. Based on the high mud return temperatures at site 5, site 6, which is located on the same side of the fault, looked promising.

Temperature gradient hole No. 6 was drilled to a depth of 1,100 feet. Maximum mud return temperatures were 39.4°C. The most interesting feature of the mud temperature monitoring was that, after termination of drilling, the mud return temperature increased 1.4°C in 20 minutes during circulation before trip out.

Temperature gradient hole No. 7 is located west of the Surprise Spring fault (fig. 5). Results from this site would indicate whether or not the fault

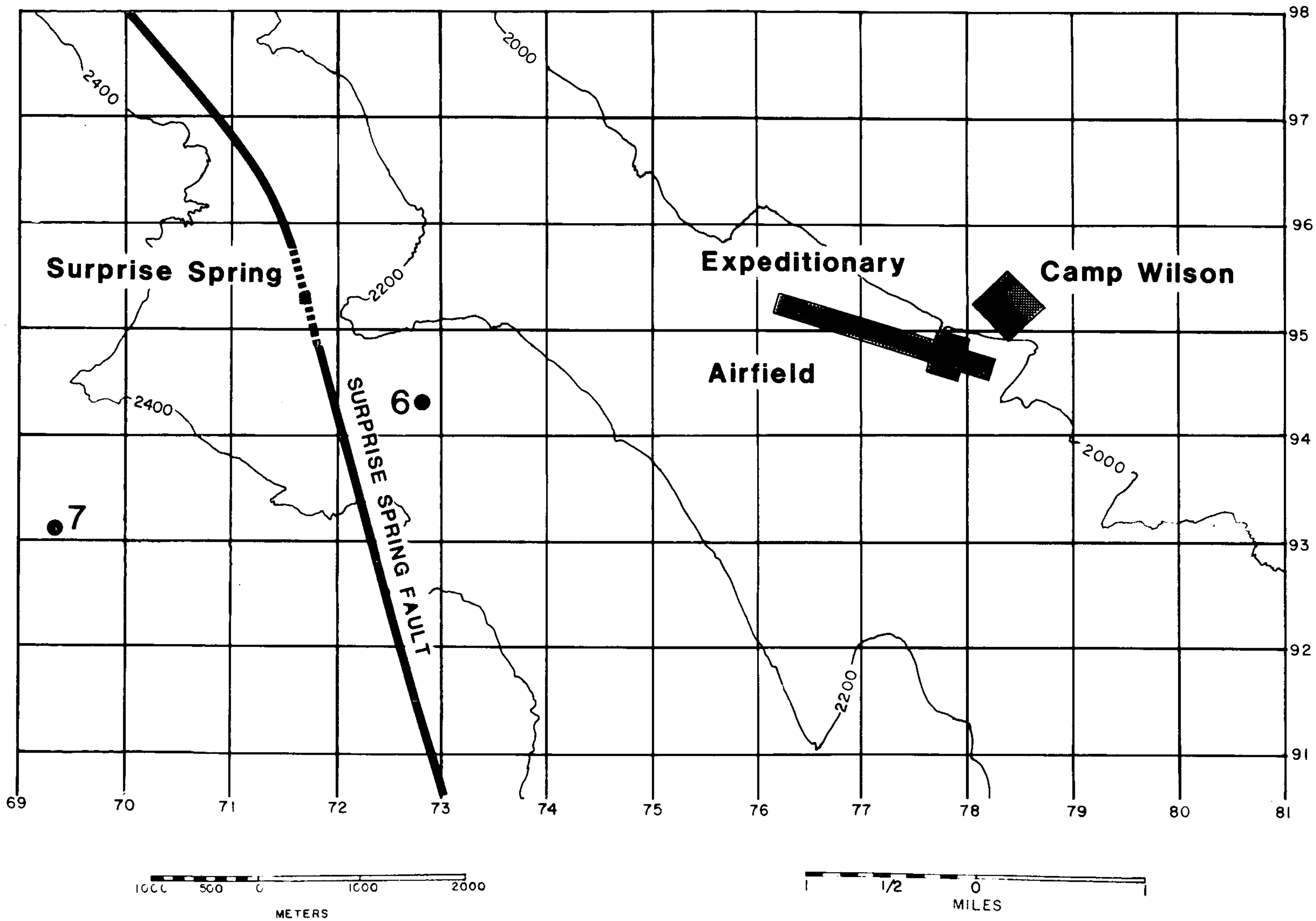


Figure 5. Location of temperature gradient holes 6 and 7.

is the controlling structure for the migration of geothermal fluids in the southern area of the Center. The hole was completed to 1,060 feet and the maximum mud return temperature was only 23°C. The low mud return temperatures tentatively indicated that geothermal fluids were migrating up the Surprise Spring fault and flowing east. A detailed summary of daily drilling activities and drilling progress charts for temperature gradient holes 1-7 are presented in Appendix B.

LITHOLOGIC LOGS AND TEMPERATURE GRADIENT PROFILES

Lithologic samples were collected at 20 foot intervals during drilling. Cursory examinations and identifications were made on-site. Laboratory analysis using a binocular microscope was performed to confirm field descriptions. Mud return temperatures were also monitored during drilling.

Lithologic logs and temperature profiles for each temperature gradient hole are presented in Figures 6 through 12. Temperature profiles developed during the second set of temperature measurements (February 27-28, 1984) are presented in Appendix C. Temperature gradient hole No. 1, (fig. 6), encounters sand and gravel to 70 feet. Clayey sand and clay are encountered from 70 to 93 feet. Samples from 100 to 160 feet consisted of coarse sand and gravel. A 40 foot section of sand, gravel and cobbles occurs between 160 and 200 feet. A thick sequence of alluvium consisting of coarse sand with clay and an occasional boulder occurs from 200 to 420 feet. From 420 to 480 feet, coarse sand and gravel with an occasional cobble occurs. A thin section of sandy clay occurs between an eighty foot thick sequence of boulders and cobbles to 600 feet. Coarse sandy clay was encountered to 660 feet at which point drilling slowed because a large boulder or dike of diabase was encountered. At 690 feet, quartz monzonite (bedrock) was encountered. Drilling continued to 880 feet.

Temperature gradient measurements performed on February 13, are shown graphically on Figure 6. The temperature gradient calculated over the interval from 200 feet to 820 feet indicates a gradient of 1.3°C/100 m (1°F/100 feet). A maximum temperature of 32.4°C was measured at 880 feet. Temperature measurements performed on February 28, show no appreciable change in temperature throughout the hole and the maximum bottom hole temperature was 32.6°C.

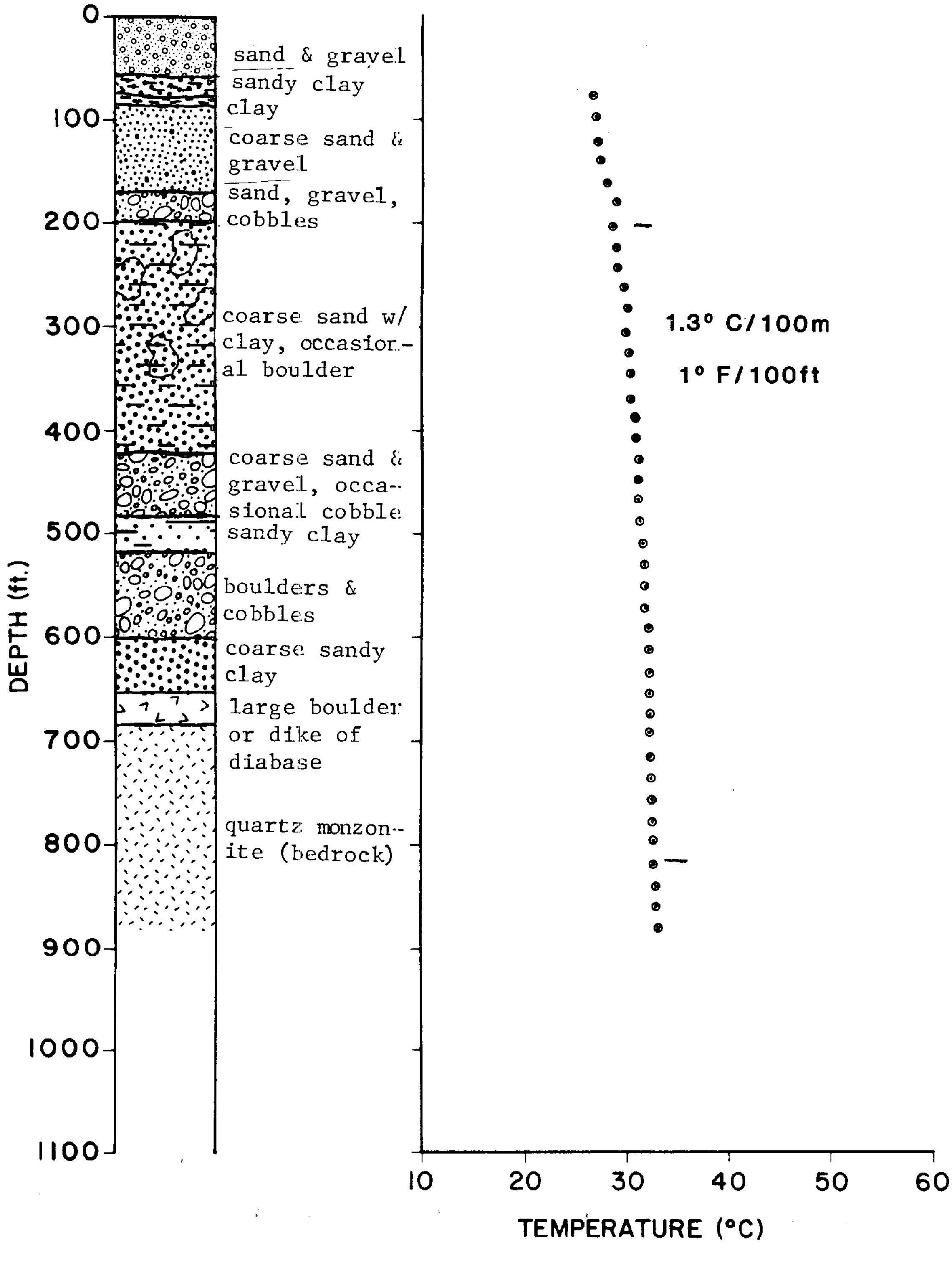


FIGURE 6. TEMPERATURE GRADIENT HOLE NO. 1 LITHOLOGIC LOG AND TEMPERATURE-DEPTH PROFILE.

The lithologic log from temperature gradient hole No. 2 shows that unconsolidated material was encountered to Total Depth (fig. 7). The upper 100 foot section of the hole contains coarse sand, gravel with minor clay, and sandy clay. A forty foot thick sequence of green clay beneath the clastic sediments probably represents playa deposits. From 160 to 320 feet, brown sandy clay with occasional gravel and boulders occurs. A 380 foot thick sequence of clayey sand and sandy clay with minor coarse sand (560-580 ft.) occurs to 700 feet. From 700 feet to Total Depth, sandy clay is the predominant lithology with minor intervals of coarse sand and gravel, and sandy gravel with boulders at 700 and 900 feet, respectively.

Temperature gradient measurements performed on February 14, are shown on Figure 7. The temperature gradient calculated in the interval from 200 to 1,000 feet indicates a gradient of 2.7°C/100 m (1.5°F/100 ft.). The maximum temperature of 29.7°C was measured at 1,000 feet. The second set of temperature measurements, taken on February 28, show no significant change in the thermal regime in temperature gradient hole No. 2, and the maximum bottom hole temperature was only 0.1°C higher than the previous measurement.

The lithologic log of temperature gradient hole No. 3 (fig. 8) indicates the presence of playa sediments beneath the upper 20 feet of sandy, gravelly clay. The playa clays continue to a depth of 120 feet; a 4 to 5 foot thick black organic clay layer is located at 116 feet. From 120 feet to a depth of 440 feet, the material encountered is principally sandy clay and clayey sand. Sand with only minor traces of clay occurs between 440 and 580 feet. Below 580 feet, sandy clay is the predominant lithology with minor occurrences of sand and gravel, cobble-gravel, and gravel at 640, 790 and 1,000 feet, respectively. The hole was completed to 1,100 feet, terminating in sandy clay.

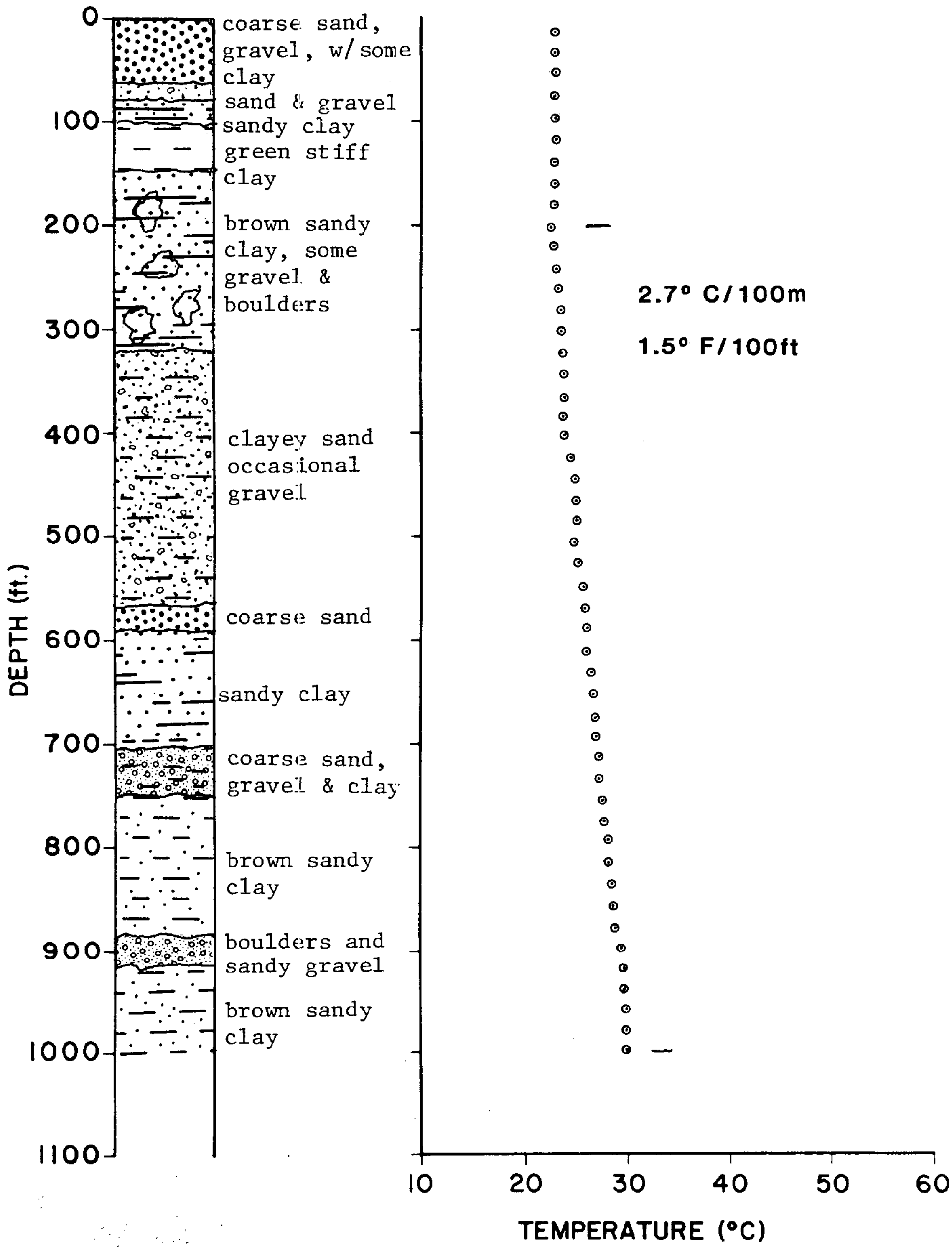


FIGURE 7. TEMPERATURE GRADIENT HOLE NO. 2 LITHOLOGIC LOG AND TEMPERATURE-DEPTH PROFILE.

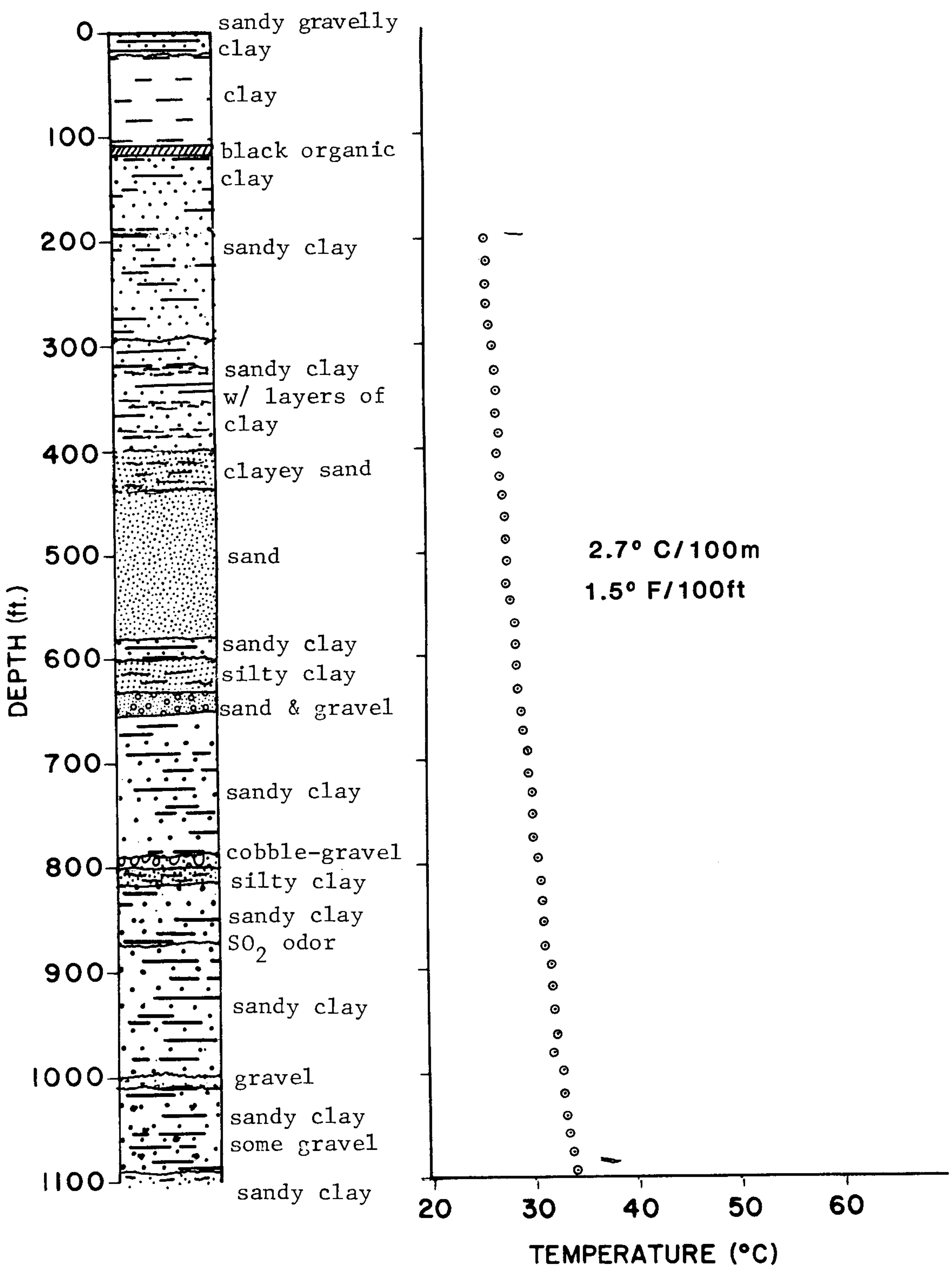


FIGURE 8. TEMPERATURE GRADIENT HOLE NO. 3 LITHOLOGIC LOG AND TEMPERATURE-DEPTH PROFILE.

The maximum temperature measured was 33.2°C at 1,100 feet on February 13, 1984. The temperature gradient calculated over the interval from 200 to 1,100 feet is 2.7°C/100 m (1.5°F/100 ft.). This is the same gradient as calculated for temperature gradient hole No. 2. No appreciable changes were noted in temperatures measured on February 28, 1984.

Temperature gradient hole No. 4 consists primarily of fine grained detrital material derived from weathered granitic rocks (fig. 9). The feldspars weathered to clay and the quartz grains were unaltered, producing sandy clay and clayey sand units. The transition from weathered alluvium and weathered bedrock is difficult to determine because of compositional similarities. The depth to weathered bedrock at this site is estimated at approximately 740 feet. Relatively unaltered quartz monzonite was encountered at 890 feet and the hole was completed to 920 feet.

The maximum temperature measured on February 14, 1984, was 32.1°C at 920 feet. A maximum temperature of 30.7°C was measured on February 28th. The difference in temperature probably reflects frictional-heat from drilling in the earlier measurement. The temperature gradient calculated over the interval from 100 to 900 feet is 2.6°C/100 m (1.4°F/100 ft.) which is comparable to temperature gradients calculated for temperature gradient holes 2 and 3.

The lithologic log for temperature gradient hole No. 5 (fig. 10) indicates a coarser-grained component in the unconsolidated material. Surficial material (upper 20 feet) consists of sandy gravel which is underlain by 120 feet of slightly clayey coarse sand. The interval from 140 to 200 feet consists of clayey sand, grading into coarse sand with gravel to 300 feet. Clayey coarse sand and sandy clay with gravel comprise the material encountered from 300 to 570 feet. A thin (5-10 feet) layer of gravel and cobbles occurs at 575 feet,

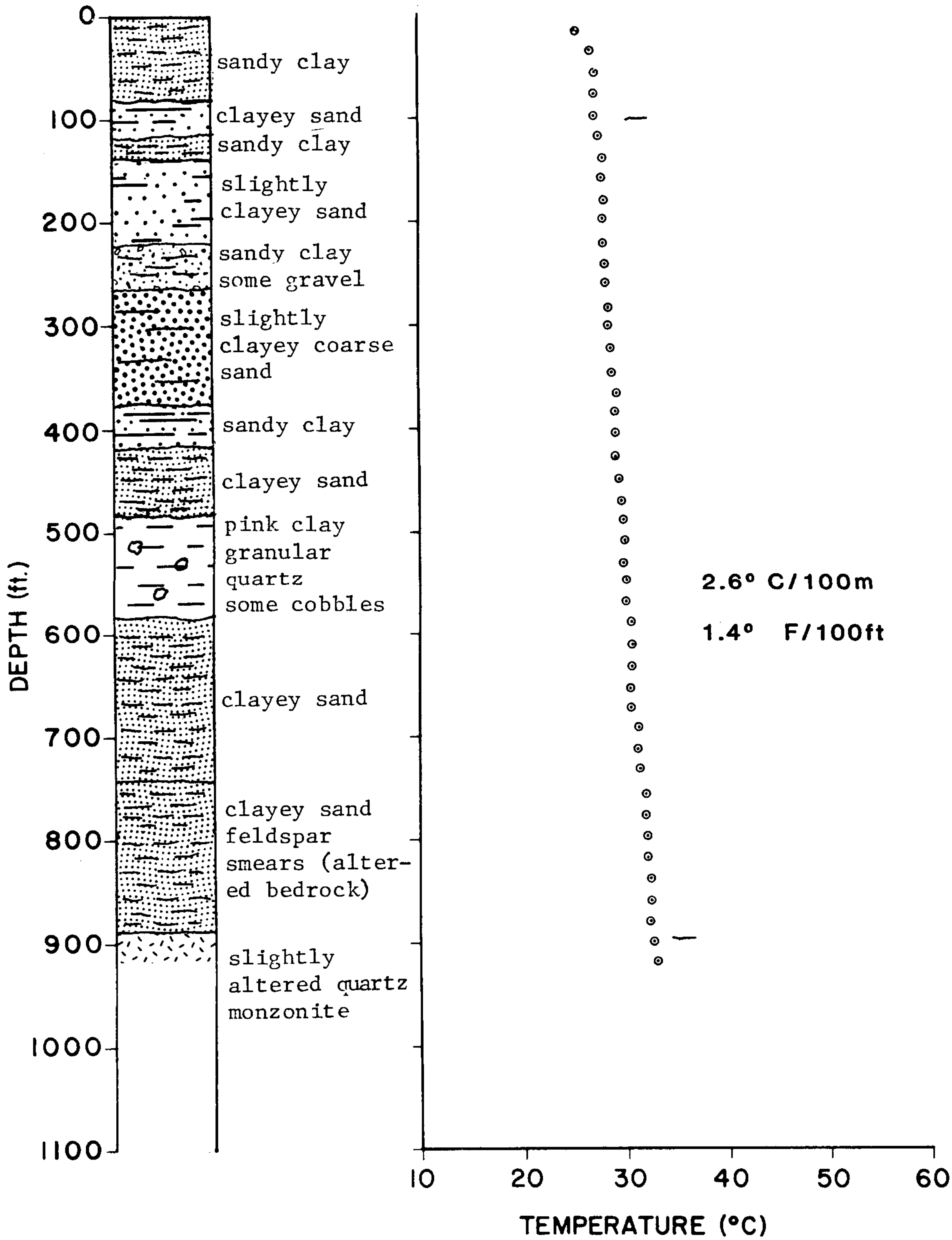


FIGURE 9. TEMPERATURE GRADIENT HOLE NO. 4
LITHOLOGIC LOG AND TEMPERATURE-DEPTH PROFILE.

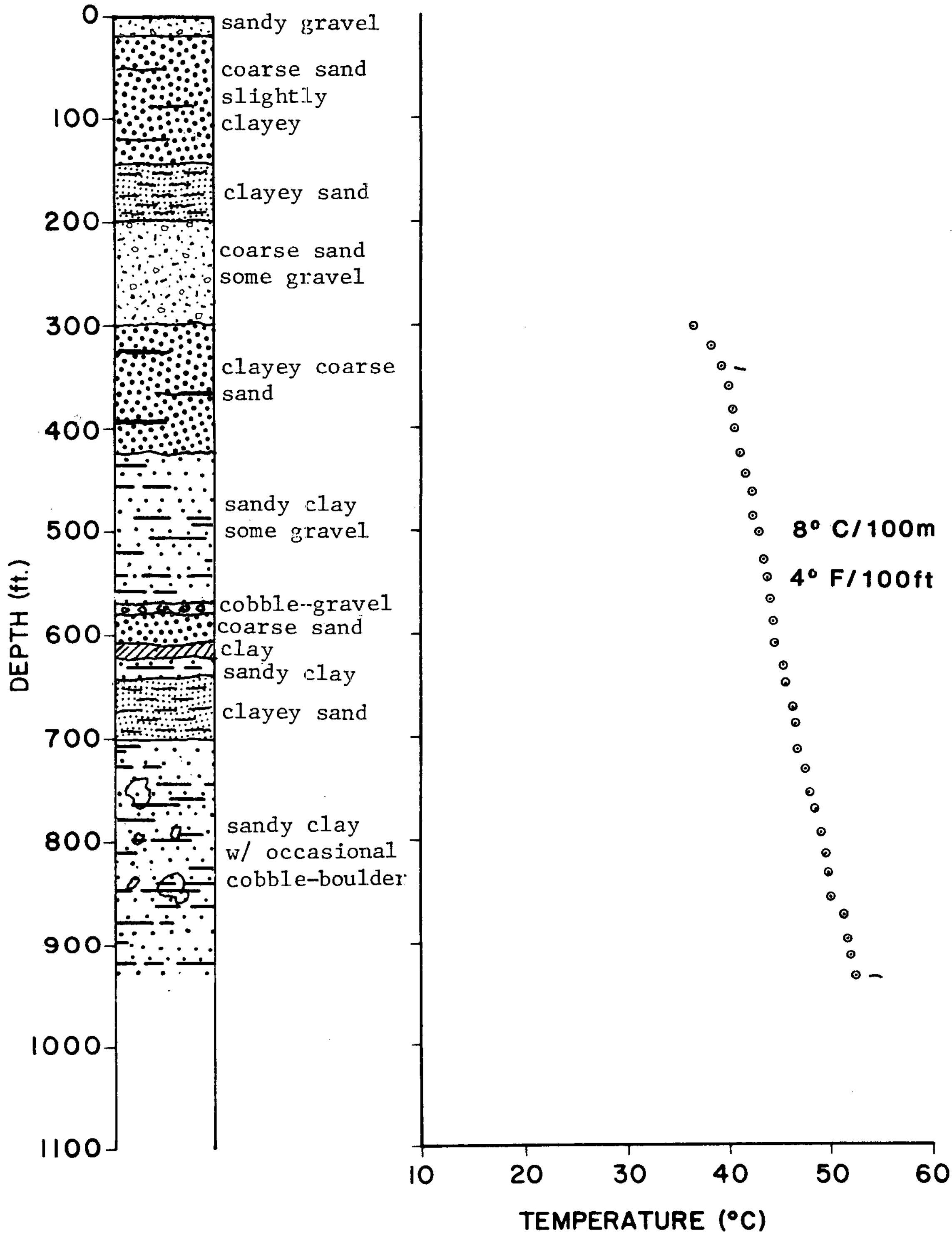


FIGURE 10. TEMPERATURE GRADIENT HOLE NO. 5 LITHOLOGIC LOG AND TEMPERATURE-DEPTH PROFILE.

this is underlain by a 40 foot section of coarse sand. This is probably the same producing zone for domestic wells one mile to the south. It is underlain by a clay layer which could act as an aquiclude. Below 640 feet, lithologies encountered consist of clayey sand and sandy clay with an increasing occurrence of cobbles and boulders near the bottom of the hole. A lost circulation zone occurred at 940 feet after drilling through a large boulder. Drilling was terminated after two attempts to regain circulation failed.

The temperature gradient calculated from the interval between 360 and 940 feet is 8°C/100 m (4°F/100 ft.). The gradient remains positive at the bottom of the hole (fig. 10). This would indicate that the maximum reservoir temperature has not been reached. The highest temperature measured was 51.6°C on February 15, 1984 at 940 feet. A temperature of 50.6°C was measured on February 28th. Increases in temperature of 0.5°C every 20 feet at the bottom of the hole were evident during both temperature profile measurements.

The lithologic log developed for temperature gradient hole No. 6 (fig. 11) indicates relatively unweathered coarse sand and gravel with occasional cobbles to 180 feet. Lithologic units below 180 feet are weathered and contain clay. Clayey coarse sand, sandy clay, and sandy clay with altered feldspar occurs to a depth of 1,060 feet. A thin gravel layer between 1,060 and 1,080 feet is underlain by more sandy clay. The hole was completed to 1,100 feet in a stiff red clay.

An inflection in the temperature gradient curve (fig. 11) at 900 feet required the calculation of two temperature gradients. The upper interval (160 to 900 feet) has a temperature gradient of 15.3°C/100 m (8.3°F/100 ft.). The temperature gradient calculated for the lower portion of the hole (900 to 1,100 feet) is less, but still positive at 3.3°C/100 m (1.7°F/100 ft.). A maximum temperature of 67.1°C was recorded on February 27, 1984. This is 1°C higher

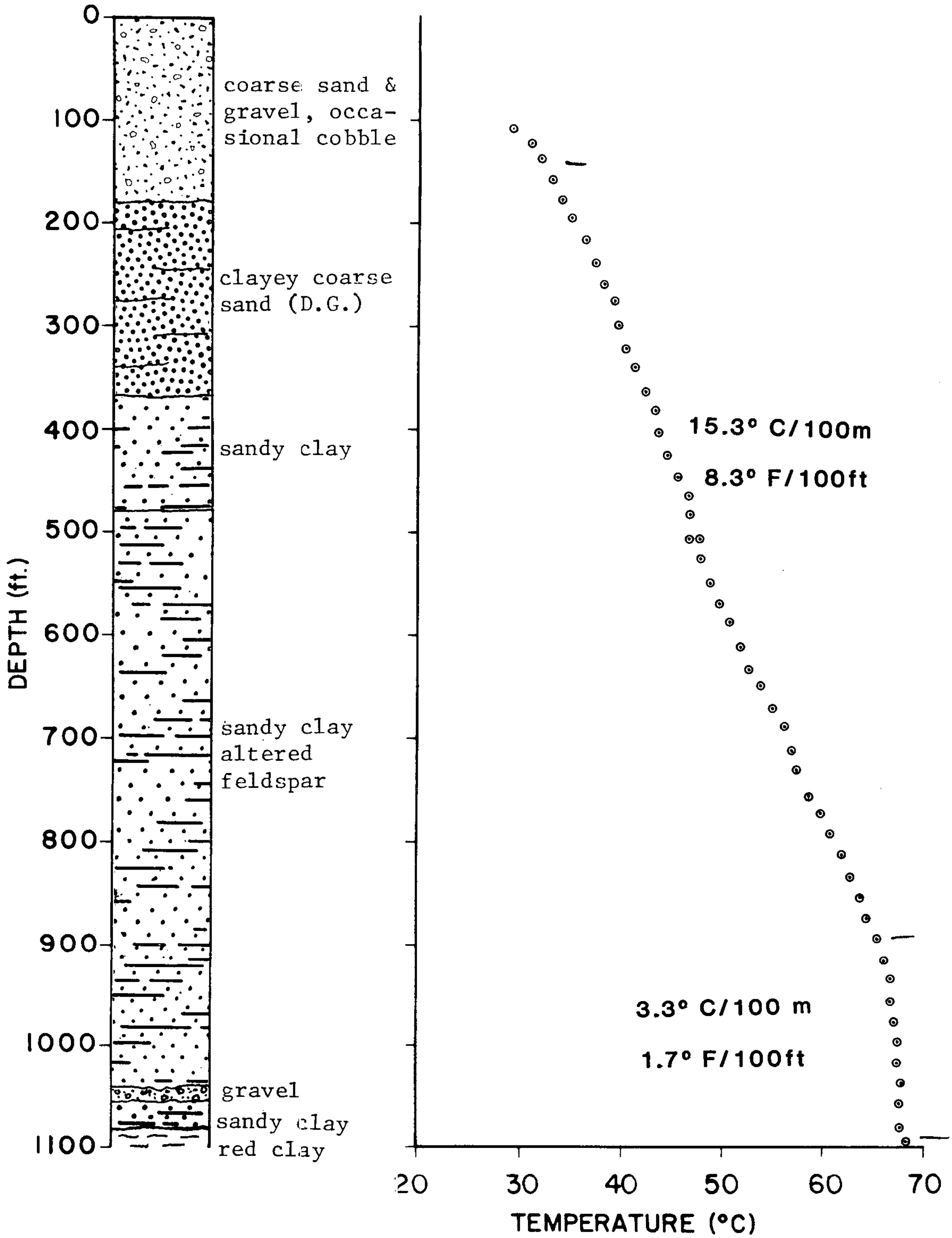


FIGURE 11. TEMPERATURE GRADIENT HOLE NO. 6 LITHOLOGIC LOG AND TEMPERATURE-DEPTH PROFILE.

than the maximum temperature measured on February 14, 1984.

The lithologic log for temperature gradient hole No. 7 (fig. 12) is similar to temperature gradient hole No. 6, although it is located on the opposite side of Surprise Spring fault. The upper 80 feet consists of coarse sand and sandy clay. The next 140 foot section contains sandy clay, coarse sand and gravel. Between 220 and 360 feet the clay content decreases. An 80-foot thick sequence of coarse sandy clay occurs between 360 and 440 feet. The remainder of the hole consists of coarse sand to 960 feet with a slightly more clayey interval between 660 and 720 feet. A layer of stiff red clay, similar to the red clay in the bottom of temperature gradient hole No. 6, occurs betwen 960 and 980 feet. The clay layer is underlain by clayey coarse sand to Total Depth (1,060 feet).

The temperature gradient calculated in the interval from 100 to 1,020 feet is 3.8 °C/100 m (2.1°F/100 ft.). A maximum temperature of 33.9°C was measured at 1,060 feet on February 14, 1984. Measurements made on February 27, 1984, showed no significant change. The bottom hole temperature was 33.7°C.

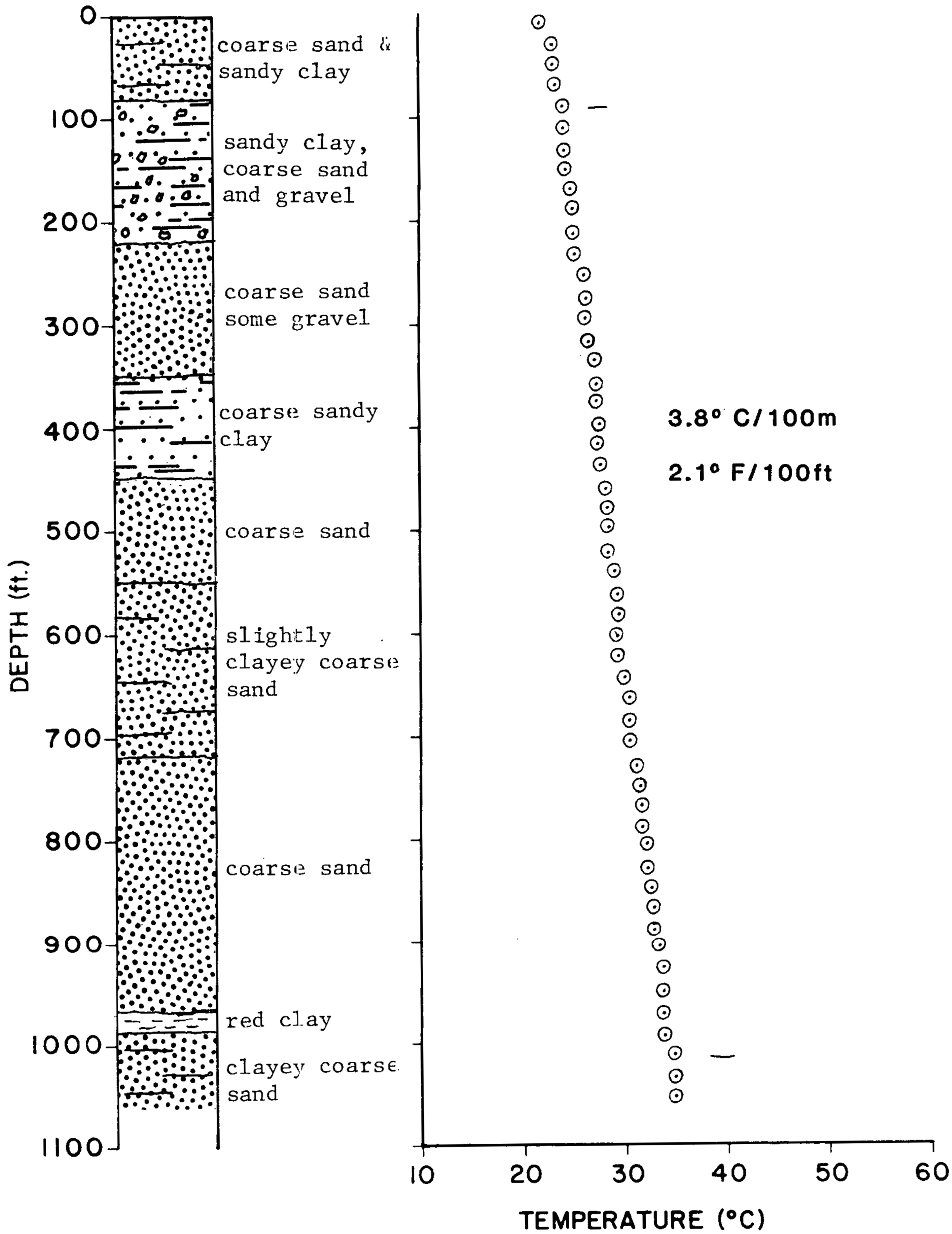


FIGURE 12. TEMPERATURE GRADIENT HOLE NO. 7 LITHOLOGIC LOG AND TEMPERATURE-DEPTH PROFILE.

DISCUSSION OF RESULTS

Temperature gradient holes drilled in the vicinity of the northwest trending gravity anomaly (17 mgals/mile), located along the east side of the Center's administrative area, represent near-normal temperature gradients for the Basin and Range Province. The temperature gradient measured in temperature gradient hole No. 1 of 1.3°C/m is below typical gradient values found in the Basin and Range Province. The reasons for this low temperature gradient are not readily apparent. Temperature gradients of 2.7, 2.7 and 2.6°C/m from drill temperature gradient holes 2 through 4, respectively, are considered to be representative of normal geothermal gradients for this portion of the southern Basin and Range Province.

The lithologies encountered in temperature gradient holes 2 through 4 indicate only a few zones of high permeability, which may be capable of transmitting large volumes of fluids. Temperature gradient hole No. 1 has numerous thick zones of coarse sand, coarse sand and gravel, and boulder-cobble layers which may form potentially productive horizons.

Although the bottom hole temperature in temperature gradient hole No. 1 is comparable to bottom hole temperatures in temperature gradient holes 2 and 4 (32°C), the gradient (1.3°C/100 m) is only half as much. The surface (20 ft.) temperature in temperature gradient hole No. 1 is 30°C as compared to 25°C in temperature gradient holes 3 and 4. It appears that abundant cool water is present in the near surface at temperature gradient hole No. 2 and a bottom hole temperature of only 30°C was recorded during both measurements. In all cases for temperature gradient holes 1 through 4, no zones of entry of hot water were noted based on the configuration of the temperature profiles. Zones of coarse sand and gravel did not influence the slight, but steady, increase in temperature as shown on the profiles (figs. 6-9).

Temperature gradients measured in temperature gradient hole No. 5 (fig. 10 and Appendix C) show a positive increase of 8°C/100 m from 320 to 940 feet. Slight perturbations in the temperature profile may result from inflows of warm water in zones of coarser materials.

In general, the clastic material in the lower portion of temperature gradient hole No. 5 is more coarse-grained than material in any of the other six holes drilled during the course of this study. The slight increase in temperature at 880 feet and the large gradient (0.5°C/20 ft.) at the bottom of the hole may be indicative of highly permeable units. It is also important to note that a lost circulation zone at 940 feet caused termination of drilling at this site. The positive gradient at the bottom of the holes indicates that the geothermal reservoir is below 940 feet.

The highest temperature (67.1°C) measured at any site was at 1,100 feet in temperature gradient hole No. 6. The temperature profile from 180 to 880 feet is relatively uniform at 15.3°C/100 m. Below 900 feet (fig. 11), the gradient remains positive but decreases to 3.3°C/100 m. This lower gradient represents the normal gradient for the northern Basin and Range Province in Nevada. The less positive aspect of the curve in the lower portion may reflect higher clay content and less conductive heat transfer. A dense stiff red clay was the last unit encountered in the hole.

The temperature gradient profile from temperature gradient hole No. 7 indicates a relatively uniform increase in temperature of 3.8°C/100 m. The maximum temperature recorded at this site was only 33.9°C. The slight temperature increase near the bottom of the hole (fig. 12), below the red clay, is not apparent in the listing of measured temperatures (Appendix D). Increases on the order of 0.3°C/20 ft. do not indicate a shift in the temperature gradient.

The lithologic log from this hole indicates the highest potential for transmissivity of fluids. The thick sections of coarse sand may provide good aquifers for ground water production.

CONCLUSIONS AND RECOMMENDATIONS

This temperature-gradient drilling program, combined with geophysical surveys completed by the Geothermal Utilization Division NWC, China Lake, has resulted in an increased understanding of the distribution of geothermal resources in the southern portion of the Marine Corps Air Ground Combat Center at Twentynine Palms. The geothermal resources reported 3.2 km (2 miles) southeast of the Center are not controlled by the intense northwest-southeast trending gravity and aeromagnetic anomaly (Bullion Mountain fault) identified near the Center's administrative area. Temperature gradients in this area (sites 1-4) are normal or below normal for the Basin and Range Province.

The controlling geologic structures appear to be the Mesquite Lake fault on the east and the Surprise Spring fault on the west. Conversations with local residents near temperature gradient hole No. 5 indicate a wide-spread, low-temperature geothermal resource in the area. Domestic wells within 2 miles of the Center's boundary, at this site, have water temperatures of 32-49°C (90-120°F). Depths of these domestic water wells are approximately 500 feet. These production temperatures correspond to measured temperatures in temperature gradient hole No. 5 at depths of 320 to 860 feet. The geophysical data in this area indicate that bedrock is nearer to the ground surface south of the Center's boundary. This thickening of alluvial fill may correspond with the positive temperature gradients at the bottom of temperature gradient hole No. 5, which indicate the presence of a geothermal resource greater than 50°C (122°F).

It is also apparent that a geothermal resource exists beneath temperature gradient hole No. 6 that has temperatures higher than the resource indicated in temperature gradient hole No. 5. Temperatures at a depth of 940 feet are 67.1

and 51.6°C, respectively. This may be the result of the bedrock high in the vicinity of temperature gradient hole No. 5 allowing mixing of deeper, hot geothermal fluids with cooler, near surface ground water.

Results of temperature gradient measurements in temperature gradient hole No. 7 indicate that no significant geothermal resources are located west of the Surprise Spring fault. Results of temperature gradient measurements from temperature gradient holes 5 and 6, and the existence of warm wells south of the Center's boundary (near temperature gradient hole No. 5), indicate an area of approximately 20 square miles which is underlain by a potential low- to moderate-temperature geothermal resource. If the distribution of the geothermal fluids can be confirmed east of temperature gradient hole No. 5, nearer potential users, the resource could be considered a viable source of alternative energy for space heating.

The results of the temperature gradient drilling have raised two important questions: 1) what is the maximum temperature of the geothermal resource in the southern portion of the Center, and 2) what is the maximum areal extent of the resource? To answer these questions, it is recommended that a temperature gradient hole be drilled at site 5 or 6, to a depth of 2,000 feet, to determine the maximum temperature of the resource, and that several 2,000 foot temperature gradient holes be drilled along the southern Center boundary east of site 5 to determine the lateral extent of the resource.

It is further recommended that an attempt be made to recover the 2.5 inch casing at the site selected for deeper drilling to save money by deepening an existing drill hole and by reusing the casing.

ANTICIPATED APPLICATIONS

Estimated temperatures at a depth of 2,000 feet, in the vicinity of Surprise Spring, are between 170° and 180°F based on observed temperature gradients in the 1,100 foot temperature gradient hole No. 6 and the 940 foot temperature gradient hole No. 5. Fluids with temperatures in this range may be used for space heating, domestic hot water heating, and air conditioning. All these uses employ existing technology and commercially available equipment which has been proven effective in many applications. Cost effectiveness is the primary consideration at the Center. Costs for a geothermal system include a production well, piping system, disposal system, and end-user heating/cooling retrofits. Each of these costs increase as the service area expands. The amount of fossil fuel, and hence money, saved also increases with service area, but not at the same rate as geothermal costs. An economic feasibility study would identify the optimum, cost effective geothermal system and service area to provide the greatest benefit at the least cost. The high potential for geothermal benefits at Twentynine Palms justifies a preliminary engineering feasibility study which would examine various installation options and costs.

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APPENDIX A

DRILLING SPECIFICATIONS

INVITATION TO BID
UNIVERSITY OF NEVADA, LAS VEGAS

Purchasing Department
Las Vegas, Nevada
(702) 739-3521

INTRODUCTION

The Division of Earth Sciences (DES), University of Nevada, Las Vegas, is conducting a geothermal temperature gradient survey at the Marine Corps Air Ground Combat Center, Twentynine Palms, California. This project is being funded by the U.S. Department of Energy in cooperation with the U.S. Navy, Geothermal Utilization Division, Naval Weapons Center, China Lake, California and administered through the University of Nevada, Las Vegas.

All holes drilled will be classed as temperature gradient wells. Diameter of the holes will be between five (5) and six (6) inches. The maximum depth of each hole is 1000 feet. This depth will be based on drilling mud return temperatures and depth to bedrock. Federal regulations specify that this kind of drilling must stop if return mud temperatures reach 175°F. Return mud temperatures will be monitored by DES personnel. If a total depth of 1000 feet cannot be attained due to the above stated regulations or bedrock is encountered at less than 1000 feet depth, the remaining footage from that hole will be allotted to additional holes. All holes will be cased with nominal 2.5 inch diameter threaded-and-coupled black iron pipe capped at the bottom of the casing string. Silicon-base cement/sealant will be applied to all T/C joints to prevent leaks.

The material to be drilled is valley fill and alluvium ranging from clay to cobble size. An occasional boulder may be encountered. Bedrock in the adjoining range consists of Mesozoic granitic rock and associated finer-grained dike rock. The holes will be drilled 20 feet into bedrock to ensure the encounter with hard drilling is not a boulder. At least one alternate site to be selected for additional footage, as necessary, may be totally in basaltic volcanic rock. For bidding purposes, assume 1000 feet of hardrock drilling.

The nearest geothermal occurrence is an artesian well 2 miles south-southeast of site 78-33 (fig. 1). Fluids from this well have a temperature of 164°F. The depth is 400 feet. Due to the lack of any higher temperatures or indicated excessive pressures in the area, the requirements for a BOP will be waived. However, drilling will cease if mud return temperatures exceed 175°F.

SPECIFICATIONS AND REQUIREMENTS

Section I: General Information

1. The project will follow the guidelines and requirements of all organizations and agencies involved who have jurisdiction over said project.
2. All of the drilling contractor's equipment will be in safe and sound operating condition and may undergo inspection by the client prior to approval for operation on this project. That equipment which does not meet the specifications of the client may be rejected as "Not as Specified" and the contractor will have to supply an acceptable replacement at no cost to the client.
3. Members of the Division of Earth Sciences (DES) will be on site during drilling operations. Overall project supervision will be the responsibility of the on-site DES representative and his decisions will take precedence.
4. The drilling contractor will supply all equipment, supplies, and services necessary for the proper completion of each hole. This equipment will include, but is not limited to, drill pipe, bits, subs, appropriate drilling fluids and any auxiliary equipment (e.g., backhoe) required to complete seven (7) holes, each 1000 feet total depth. Equipment to install 2.5 inch diameter black iron T & C pipe.
   - 4a. The drilling contractor will also supply all nominal 2.5 inch diameter T & C iron pipe couplings and caps for all drilled holes to the total depth. Casing will be capped on-the-bottom and filled with water. A threaded section will complete the casing string at or near ground surface and be capped.
5. Anticipated starting time is November 14, 1983. All drilling must be completed by January 9, 1984 . If conditions beyond the control of the

contractor interfere with this completion date, the client may extend the completion date.

Section II: Drill Site Requirements

A. The drill sites have been located by the client within the area shown on the location map (fig. 1).

B. The drill sites will contain all necessary equipment to complete the hole, located in secure and safe positions and will not extend beyond the perimeter established by the client.

C. The contractor will have on-site, during all drilling phases, the following items:

Drilling mud.

Mud additives to increase mud weight or viscosity.

NaCl and lost circulation material (LCM).

D. The drilling contractor will supply the following equipment:

1. Mud rotary drill rig capable of drilling a 5-6 inch hole to 1000 ft.
2. Mud pumps capable of maintaining circulation in a 5-6 inch hole to 1000 feet.
3. Backhoe for digging mud pits. Water truck with 4 wheel drive capability.
4. All necessary bits, subs, tools and supplies to complete 7, 1000 foot, 5-6 inch diameter holes.
5. Two and a half inch iron T & C pipe (7,000 feet) to be used to case all holes to total depth. Sealant for pipe threads. All threaded coupling to be sealed with silicon or other sealant.
6. Equipment to install casing to total depth.
7. Cement seal from surface to 3 m (10 feet).
8. Steel posts and fencing material to limit accidental access to mud pits.

E. The contractor will furnish all water required by the project. Water for drilling is available on the military base from hydrants.

F. The drill site will be restored to an environmentally and aesthetically acceptable condition by the contractor, including site clean-up, well pad completion and removal of any drilling fluids and cuttings.

G. Drilling operations will be restricted to between the hours of 8:00 a.m. to 6:00 p.m. at site No. 1 (78-33). No other time restrictions will be enforced on the remaining 6 sites.

Section III: Safety and Drilling Personnel

A. The Contractor shall take all reasonable precautions in the performance of the work under this contract to protect the safety and health of employees and of members of the public and shall comply with all applicable safety and health regulations. The Contractor shall immediately take such corrective action to comply with the provisions of this clause. In the event that the Contractor fails to comply with said regulations, the client may, without prejudice to any other legal or contractual rights, issue an order stopping all or any part of the work; thereafter, a start order for resumption of the work may be issued at the discretion of the client. The Contractor shall make no claim for an extension of time or for compensation or damages by reason of, or in connection with, such work stoppage.

B. A first aid kit will be on-site during all operations, and if an injury should occur, immediate first aid will be administered and appropriate personnel and authorities notified immediately.

C. A licensed California water well driller or geothermal driller will be on-site during all phases of drilling.

D. The client will have the option to request removal of any contractor personnel from the project, with justifiable cause.

Section IV: Drilling Requirements

A. The client's on-site representative will have authority to cease all drilling operations and recommend corrective action if any monitored parameter, such as return temperature, return flow and mud properties reach a critical state.

B. Cuttings samples will be collected by the client at 10 foot intervals as determined by the client, for each individual hole.

C. Maximum depth of any hole will be 1000 feet or when return temperatures exceed 175°F or when bedrock is encountered. When maximum depth is reached, the hole will be completed as stated previously.

Section V: Pricing and Specification Changes

A. Pricing. The price quoted by the contractor must be made on a per foot basis.

   1. Cost of seven (7) holes, each 1000 feet (total of 7,000 feet), cased and completed with one string of 2.5" diameter iron T & C pipe.

B. Changes to any of the above specifications, requirements or methods should be discussed with appropriate DES personnel. Any amendments must be made in writing, before the contract is completed, through the University of Nevada, Las Vegas, Purchasing Department, 4505 Maryland Parkway, Las Vegas, Nevada 89154 (702) 739-3521.

CERTIFICATION OF NONSEGREGATED FACILITIES

(Applicable to (1) contracts, (2) subcontracts, and (3) agreements with applicants who are themselves performing federally assisted contraction contracts, exceeding $10,000 which are not exempt from the provisions of the Equal Opportunity Clause.)

By the submission of this bid, the bidder, offeror, applicant, or subcontractor certifies that he does not maintain or provide for his employees any segregated facilities at any of his establishments, or that he does not permit his employees to perform their services at any location, under his contract, where segregated facilities are maintained. He certifies further that he will not maintain or provide for his employees any segregated facilities at any of his establishments, and that he will not permit his employees to perform their services at any location, under his control, where segregated facilities are maintained. The bidder, offeror, applicant, or subcontractor agrees that a breach of this certification is a violation of the Equal Opportunity clause in this contract. As used in this certification, the term "segregated facilities" means any waiting rooms, work areas, rest rooms and wash rooms, restaurants and other eating areas, time clocks, locker rooms and other storage or dressing areas, parking lots, drinking fountains, recreation or entertainment areas, transportation, and housing facilities provided for employees which are segregated by explicit directive or are in fact segregated on the basis of race, creed, color, or national origin, because of habit, local custom, or otherwise. He further agrees that (except where he has obtained identical certifications from proposed subcontractors for specific time periods) he will obtain identical certifications from proposed subcontractors prior to the award of subcontractors exceeding $10,000 which are not exempt from the provisions of the Equal Opportunity clause; that he will retain such certifications in this files; and that he will forward the following notice to such proposed subcontractors (except where the proposed subcontractors have submitted identical certifications for specific time periods).

FIRM ______________________________

BY ______________________________

TITLE ______________________________

NONDISCRIMINATION IN EMPLOYMENT BY GOVERNMENT CONTRACTORS AND SUBCONTRACTORS

During the performance of this contract, the contractor agrees as follows:

(1) The contractor will not discriminate against any employee or applicant for employment because of race, creed, color, or national origin. The contractor will take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, creed, color, or national origin. Such action shall include, but not be limited to the following: Employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. The contractor agrees to post in conspicuous places, available to employees and applicants for employment, notices to be provided by the contracting officer setting forth the provisions of this nondiscrimination clause.

(2) The contractor will, in all solicitations or advertisements for employees placed by or on behalf of the contractor, state that all qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

(3) The contractor will send to each labor union or representative of workers under which he has a collective bargaining agreement or other contract of understanding, a notice to be provided by the agency contracting officer, advising the labor union or workers' representative of the contractor's commitments under Section 202 of Executive Order No. 11246 of September 24, 1965, and shall post copies of the notice in conspicuous places available to employees and applicants for employment.

(4) The contractor will comply with all provisions of Executive Order No. 11246 of September 24, 1965, and of the rules, regulations, and relevant orders of the Secretary of Labor.

(5) The contractor will furnish all information and reports required by Executive Order No. 11246 of September 24, 1965, and by the rules, regulations and orders of the Secretary of Labor, or pursuant thereto, and will permit access to his books, records, and accounts by the contracting agency and the Secretary of Labor for purposes of investigation to ascertain compliance with such rules, regulations and orders.

(6) In the event of the contractor's noncompliance with the nondiscrimination clauses of this contract or with any of such rules, regulations, or orders, this contract may be cancelled, terminated or suspended in whole or in part and the contractor may be declared ineligible for further Government contracts in accordance with procedures authorized in Executive Order No. 11246 of September 24, 1965, and such other sanctions may be imposed and remedies involved

as provided in Executive Order No. 11246 of September 24, 1965, or by rules, regulations, or order of the Secretary of Labor, or as otherwise provided by law.

(7) The contractor will include the provisions of Paragraphs (1) through (7) in every subcontract or purchase order unless exempted by rules, regulations or orders of the Secretary of Labor issued pursuant to Section 204 of Executive Order No. 11246 of September 24, 1965, as that such provisions will be binding upon each subcontractor or vendor. The contractor will take such action with respect to any subcontract or purchase order as the contracting agency may direct as a means of enforcing such provisions including sanctions for noncompliance: Provided, however, that in the event the contractor becomes involved in, or is threatened with, litigation with a subcontractor or vendor as a result of such direction by the contracting agency, the contractor may request the United States to enter into such litigation to protect the interests of the Unites States.

FIRM ______________________________

BY ______________________________

TITLE ______________________________

APPENDIX B

SUMMARY OF DRILLING ACTIVITIES

AND DRILLING PROGRESS CHARTS FOR TEMPERATURE GRADIENT HOLES 1-7

SUMMARY OF DRILLING ACTIVITIES

December 17, 1983

Begin drilling pilot hole at drill site #1 (78-33) in preparation for installation of BOP equipment. Complete pilot hole to 60 feet.

December 18, 1983

#1 (78-33), Continue drilling pilot hole. Drilling through sand, gravel and clay. Complete hole to 100 feet. Trip-out. Begin to ream-out hole to 12 inches diameter.

December 19, 1983

#1 (78-33), Complete reaming hole to 100 feet.

December 20, 1983

Maintenance Day

December 21, 1983

#1 (78-33), Set 8 5/8 inch casing to 100 feet. Cement casing in place.

December 22, 1983 to January 2, 1984

Shut down for holidays.

January 3, 1984

Drill site #1 (78-33) using 6 1/4 inch long tooth mill bit. Drill out 20 feet of cement in 100 foot 8 5/8 inch casing. BOPE in place. Pressure test BOPE, 300 PSI - no leaks after 2 hours. Release pressure on BOPE. Drill out cement, trip-out of hole.

January 4, 1984

#1 (78-33), Complete mud pits with backhoe. Trip into hole, begin drilling at 120 feet. Drill to 300 feet, encounter sand, gravels and clays. Maximum return temperature is 24.1°C.

January 5, 1984

#1 (78-33), Begin drilling at 300 feet, adding phosphates to thin the mud. Sand, clay and cobbles at top of hole - boulders near bottom. Maximum return mud temperature is 24.1°C. Stop drilling at 518 feet, trip-out.

January 6, 1984

#1 (78-33), Replace mill tooth bit with 6 inch bottom bit, trip into hole, begin drilling at 518 feet. Encounter granitic and basaltic boulders throughout the hole. Drill to 645 feet. Maximum return temperature is 27.5°C. Trip-out.

January 7, 1984

#1 (78-33), Replace wire rope on hoist. Begin drilling at 645 feet. All bedrock granitic and basaltic drill chips. Drill to 720 feet. Maximum return temperature is 28.3°C. Trip-out.

January 8, 1984

#1 (78-33), Begin drilling at 720 feet. Hit zone of apparent hydrothermal alteration at 720 feet. Abundant clays, kaolin? Drill to 840 feet. Maximum return temperature is 29°C. Trip-out.

January 9, 1984

#1 (78-33), Mix phosphate to thin-out mud. Begin drilling at 840 feet. Drilling in granitic bedrock - drill to 880 feet. Maximum return temperature is 26.6°C. Trip-out.

January 10, 1984

#1 (78-33), Circulate mud at 880 feet. Prior to casing, remove BOPE; set 2 1/2 inch black iron T/C pipe to 880 feet. Fill casing with water. Rig down.

January 11, 1984

Rig up at drill site #2 (13-4). Drilling with portable mud tank. Drill to 320 feet. Drilling through sand, gravels, clays. Maximum return mud temperature is 22.5°C. Trip-out.

January 12, 1984

#2 (13-4), Trip into hole, begin drilling at 320 feet. Drilling through sands, gravels, clays to 620 feet. Maximum return temperature is 25.5°C. Trip-out.

January 13, 1984

#2 (13-4), Begin drilling at 620 feet, some reaming at 320 feet. Complete hole to 1,000 feet at 11:50 a.m. on 1/14/84. Circulate, trip-out, set 2/1/2 inch pipe to T.D. Fill pipe with water.

January 14, 15, 1984

Equipment maintenance - day off.

January 16, 1984

Begin drilling hole #3 (78-29). Drill through sands, gravels and tight clays to 400 feet. Maximum return temperature is 24°C. Drilling on 24 hour, round-the-clock shifts now.

January 17, 1984

#3 (78-29), Continue drilling from 400 feet using desander off-and-on. Change bits at 460 feet. Drill to 860 feet - same sandy, clay-rich material as above. Maximum return temperature is 27.4°C.

January 18, 1984

#3 (78-29), Continue drilling at 860 feet. Foul smell reported from samples taken at 880 feet. Drilling through sandy clay - reach T.D. of 1,100 feet. Maximum return temperature is 34.2°C (at 980 feet). Trip-out to set casing.

January 19, 1984

Rig down at site #3 (78-29), repairing mud pump. Begin move and rig-up to site #4 (81-21). Begin drilling site #4. Material is coarse, sandy clay; drill to 240 feet. Maximum return temperature is 20.7°C.

January 20, 1984

#4 (81-21), Continue drilling at 240 feet with new bit. Drilling through sands, clays, gravels. Adding phosphate to thin mud - some altered feldspars in samples from 520 to 560 feet. Replace fuel filter. Drill to 700 feet. Maximum return temperature is 25.6°C.

January 21, 1984

#4 (81-21), Continue drilling at 700 feet. Drilling through altered feldspars, pink clay, some diorite. Drill to 920 feet. Last rod very slow drilling, probably bedrock, cease drilling at 920 feet. Maximum return temperature is 29.4°C at 920 feet. Trip-out, set casing. Rig down.

January 22, 1984

Move equipment to drill site #5 (78-16). Drill to 160 feet. Maximum return temperature is 19.4°C.

January 23, 1984

#5 (78-16), Continue drilling through sands and clays, with some cobbles (160 feet). Change bits at 180 feet. Drilling through sand and cobbles, some clay - change bits again at 410 feet. Some altered material found in sample at 520 feet. Drill to 740 feet. Maximum return temperature is 29.5°C at 740 feet.

<u>January 24, 1984</u>

#5 (78-16), Continue drilling at 740 feet. Encounter boulder layer at 820 feet. Return temperature is 30.3°C. Drill to 940 feet. Return temperature is 34.1°C. Trip-out to check bit. Bit OK, trip back into hole. Can't regain circulation, mix mud, still no circulation. Trip-out, set 2 1/2 inch pipe to 940 feet.

<u>January 25, 1984</u>

Arrive at drill site #6, rig-up. Begin drilling with mill tooth bit. Pull maintenance on mud pump. Drilling through clay, sand, and gravel. Drill to 300 feet. Maximum return temperature is 23.9°C at 300 feet.

<u>January 26, 1984</u>

#6, Continue drilling at 300 feet in sand and decomposed granite, some clay. Change bit at 450 feet. Drilling through coarse sand and clay, occassional altered feldspar. Change bit at 620 feet. Resume drilling in sandy clay. Reach 800 feet. Return temperature is 30°C.

<u>January 27, 1984</u>

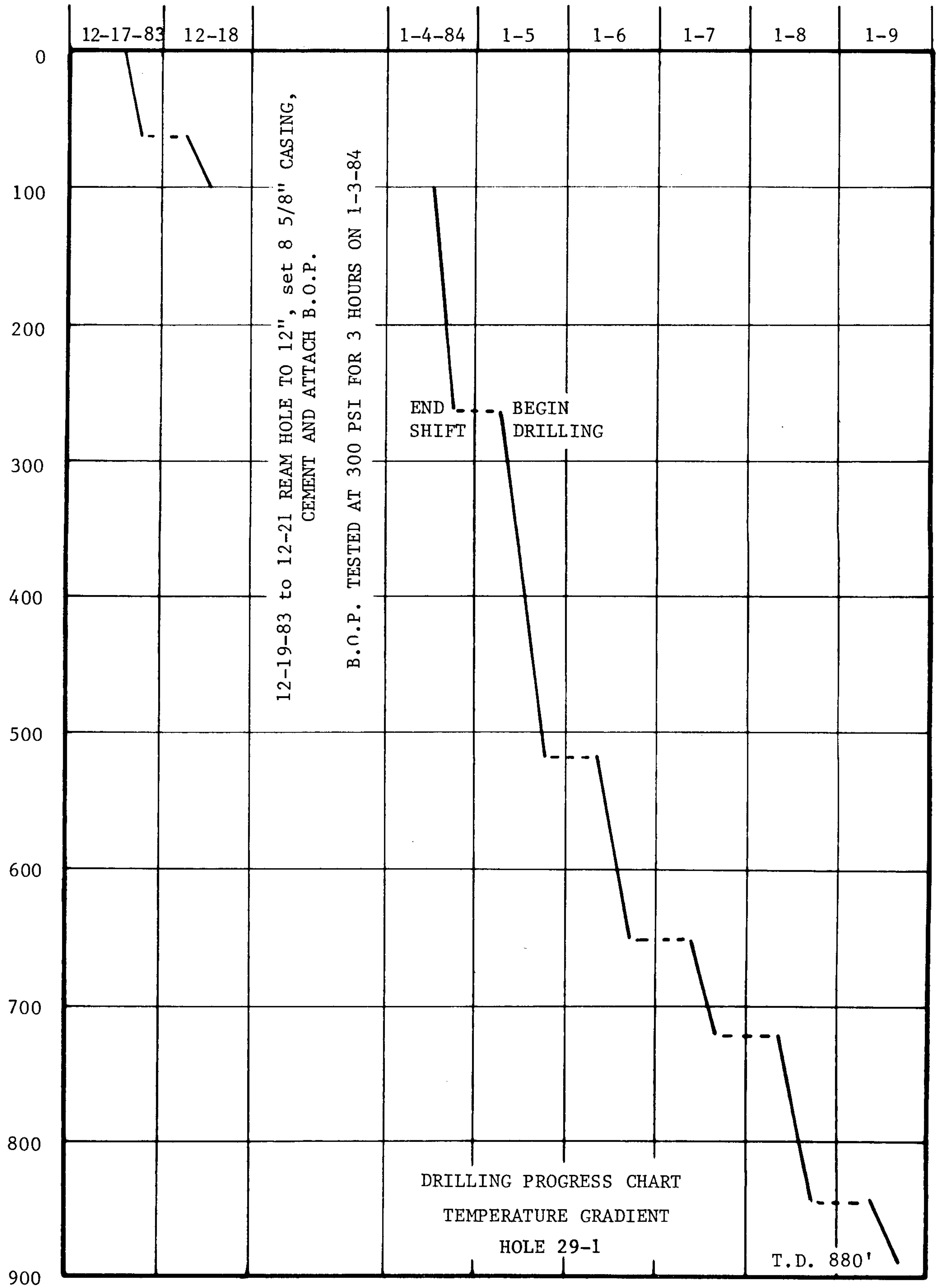
#6, Continue drilling at 800 feet in sandy clay. Reach T.D. of 1,100 feet at 12:30 p.m. Return temperature is 38°C. Circulate mud for 20 minutes, return temperature is 39.4°C. Trip-out, set casing, rig down and move to drill site #7. Rig up at site #7, begin drilling. Drill to 40 feet. Return temperature is 20.4°C - in coarse sand and sandy clay.

<u>January 28, 1984</u>

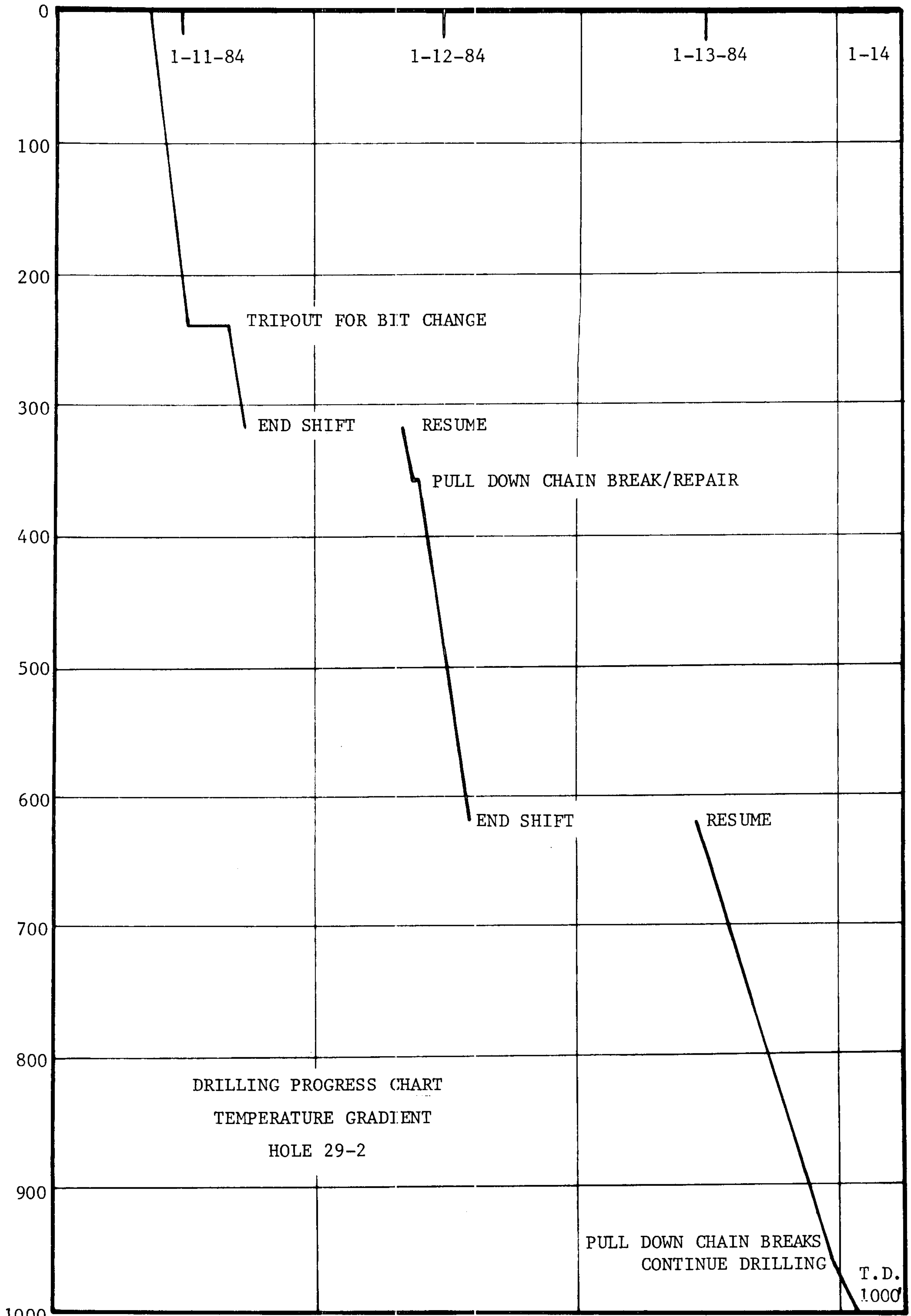
#7, Continue drilling at 40 feet. All coarse sand. Drill to 740 feet and stop drilling to repair mud pump. Resume drilling. Drilling off and on due to mud pump problems.

<u>January 29, 1984</u>

#7, Continue with mud pump problems. Slow drilling at 780 feet. Return temperature is 21.4°C. Replace top-side gasket in mud pump. Drilling picks up. Continue drilling in coarse sand. Encounter red clay layer at 960 feet. Return temperature is 21.6°C. Trip-out to change bit. Engine on rig overheating - stop drilling to replace water pump. Resume drilling at 960 feet in coarse sand and sandy clay. Drill to T.D. of 1,060 feet. Return temperature is 22.8°C. Trip-out to set 2 1/2 inch pipe. End of drilling.



DRILLING PROGRESS CHART
TEMPERATURE GRADIENT
HOLE 29-1



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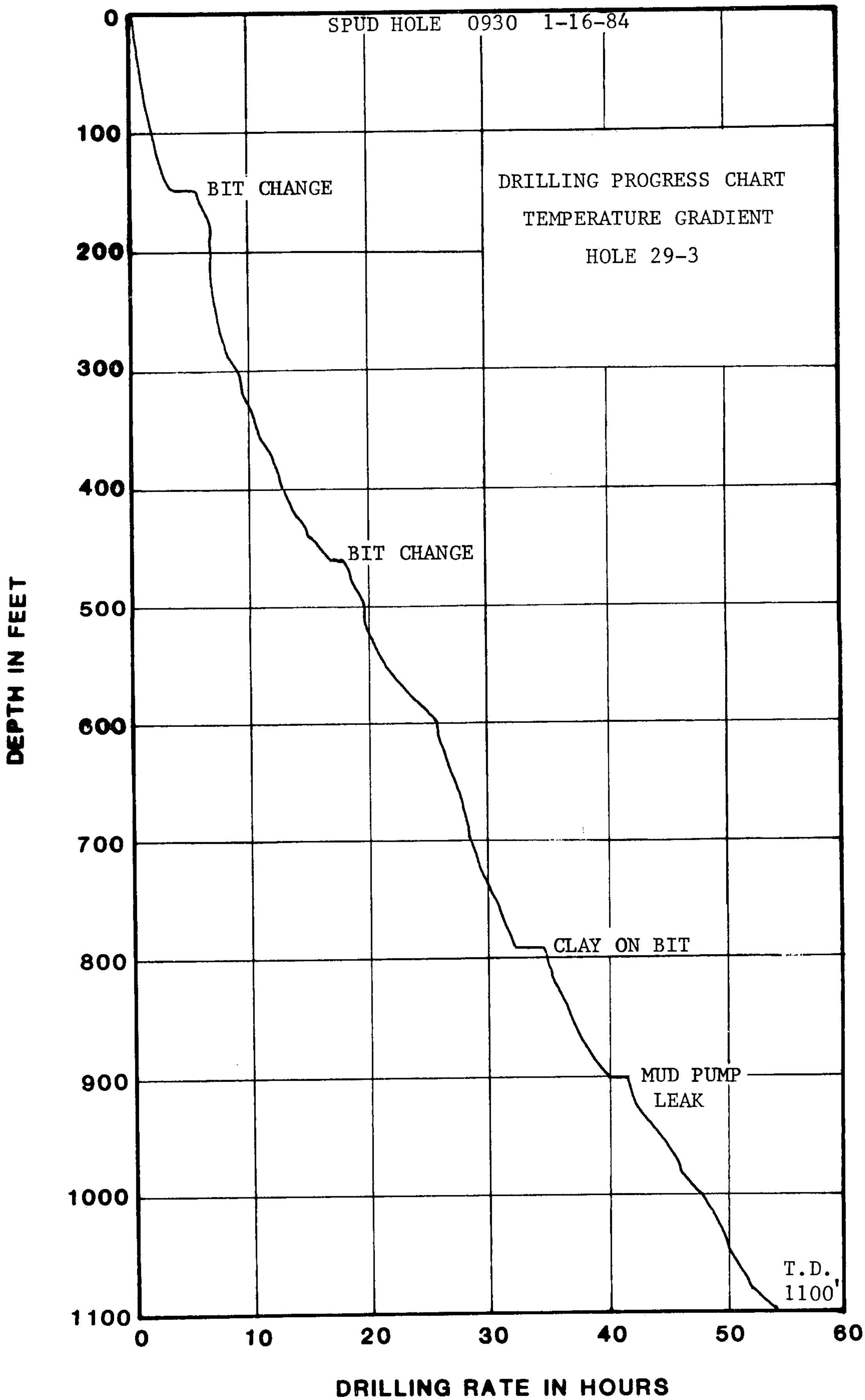
TRIPOUT FOR BIT CHANGE
END SHIFT
RESUME
PULL DOWN CHAIN BREAK/REPAIR
END SHIFT
RESUME
DRILLING PROGRESS CHART
TEMPERATURE GRADIENT
HOLE 29-2
PULL DOWN CHAIN BREAKS
CONTINUE DRILLING
T.D.
1000'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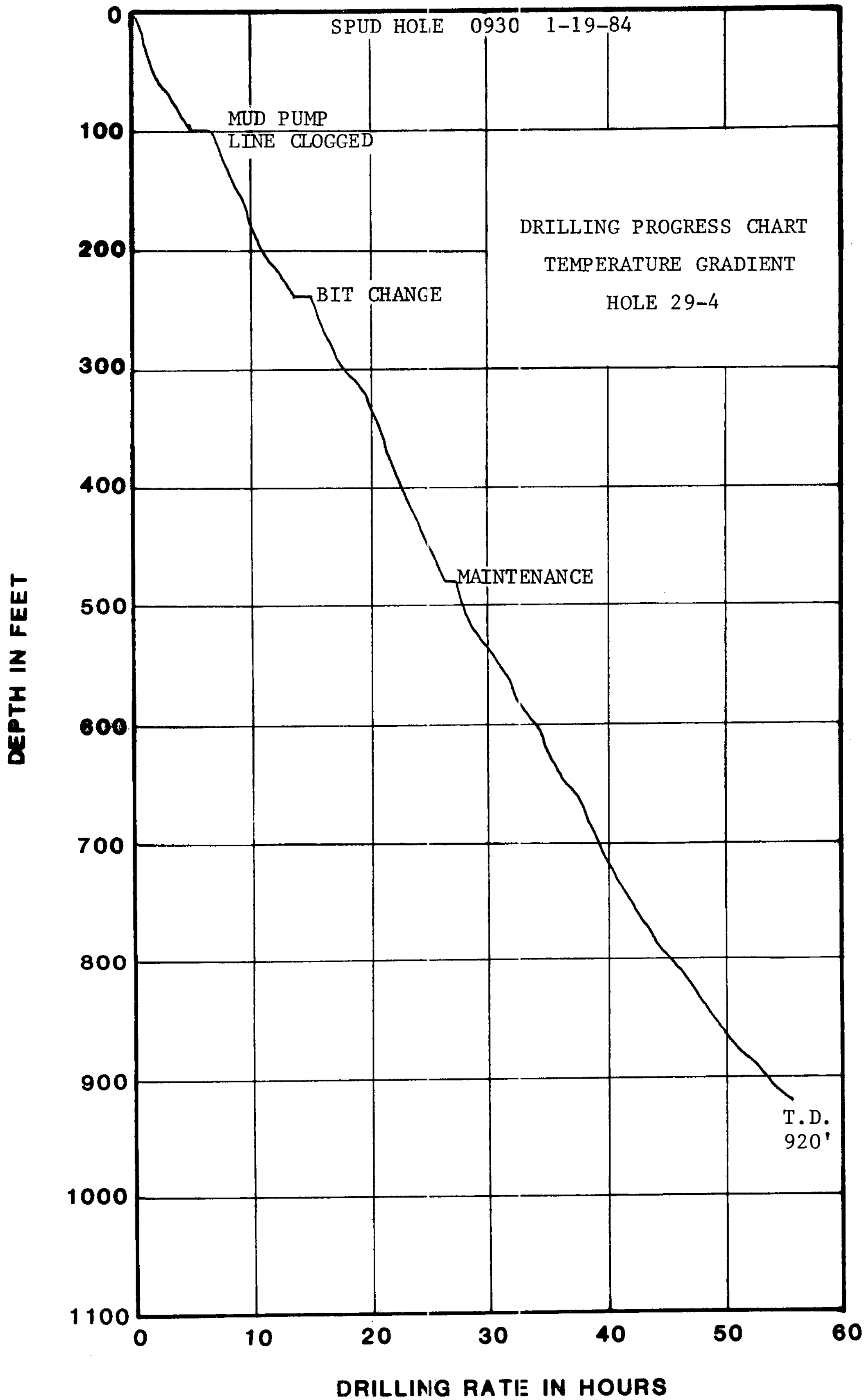
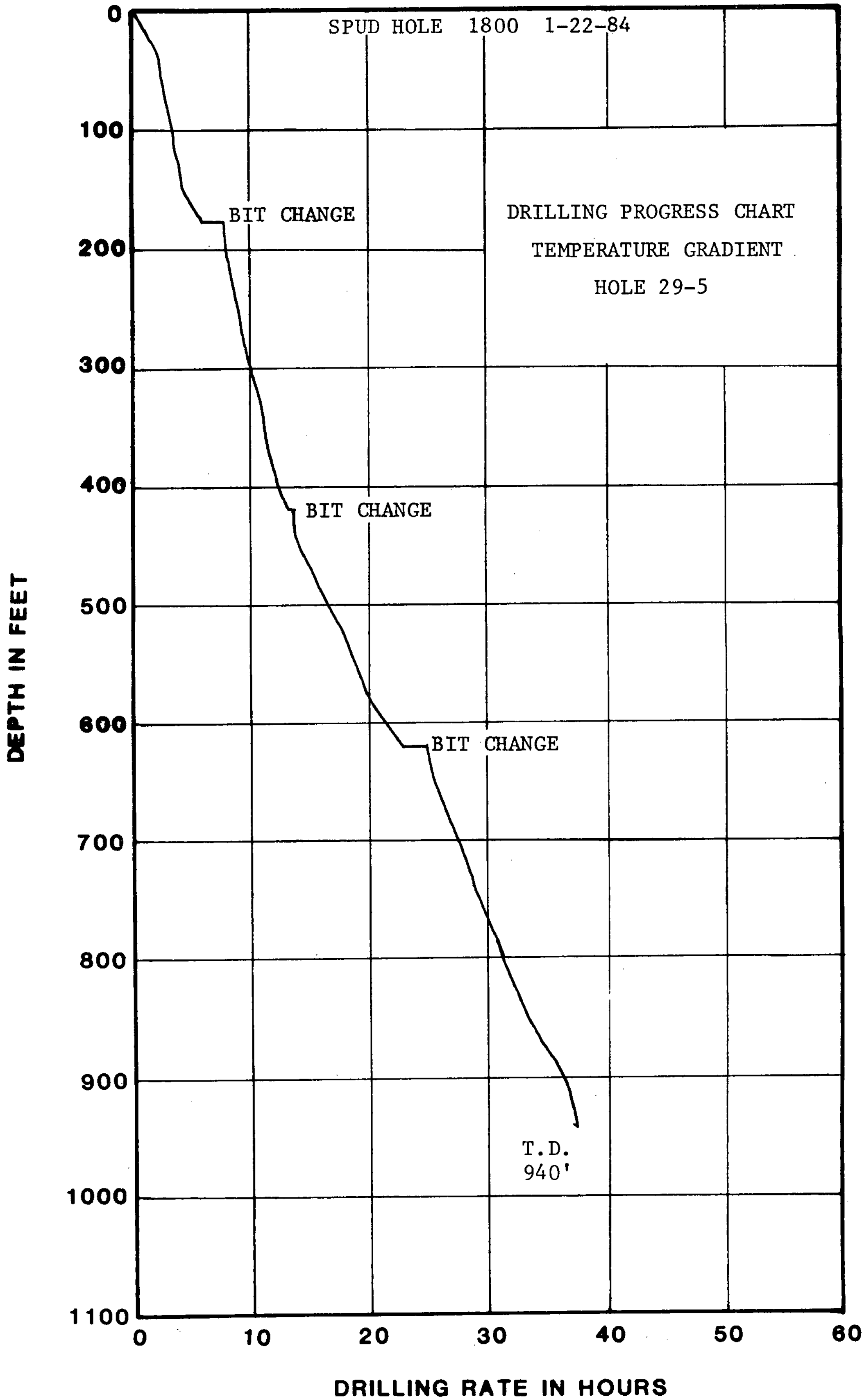
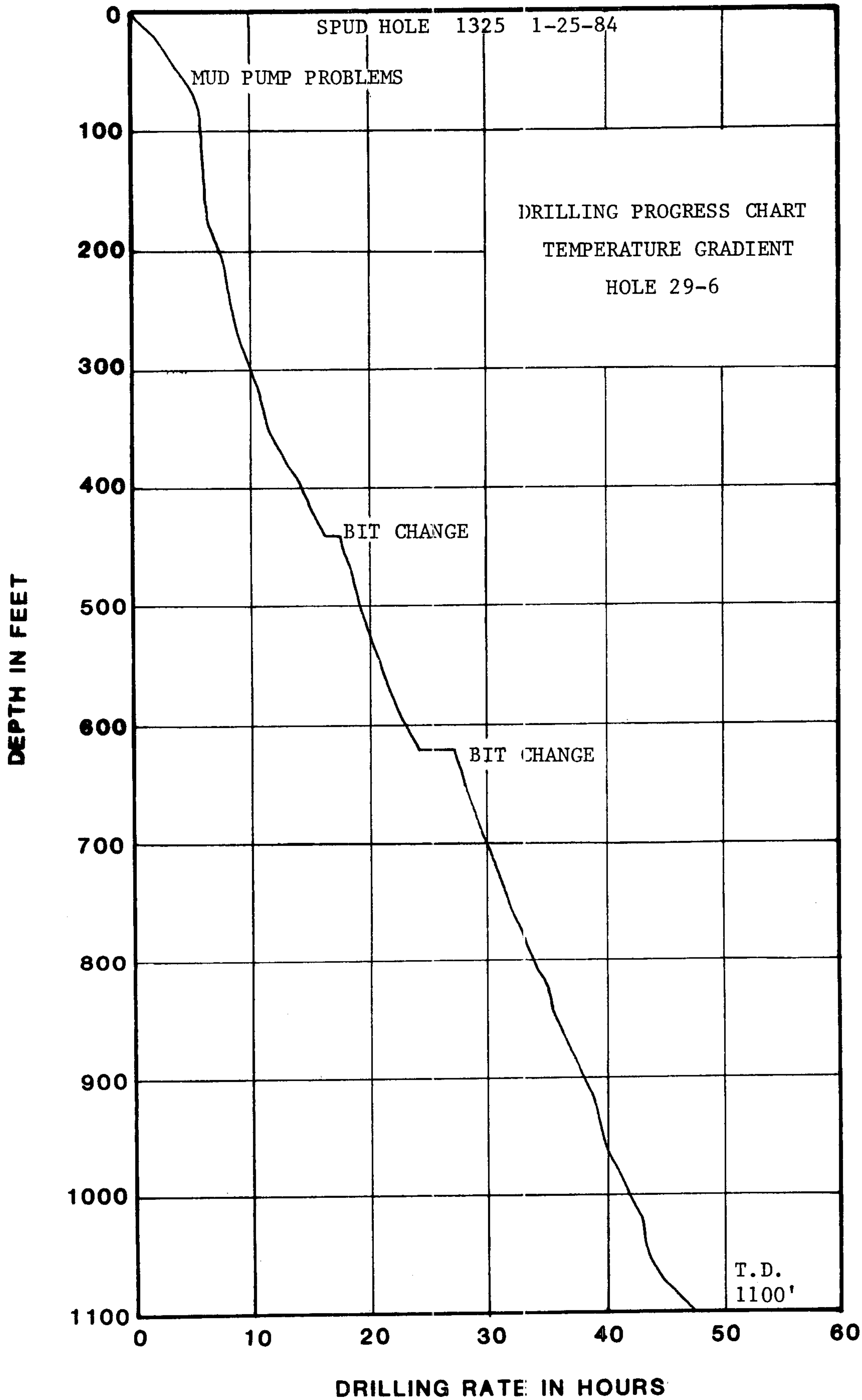
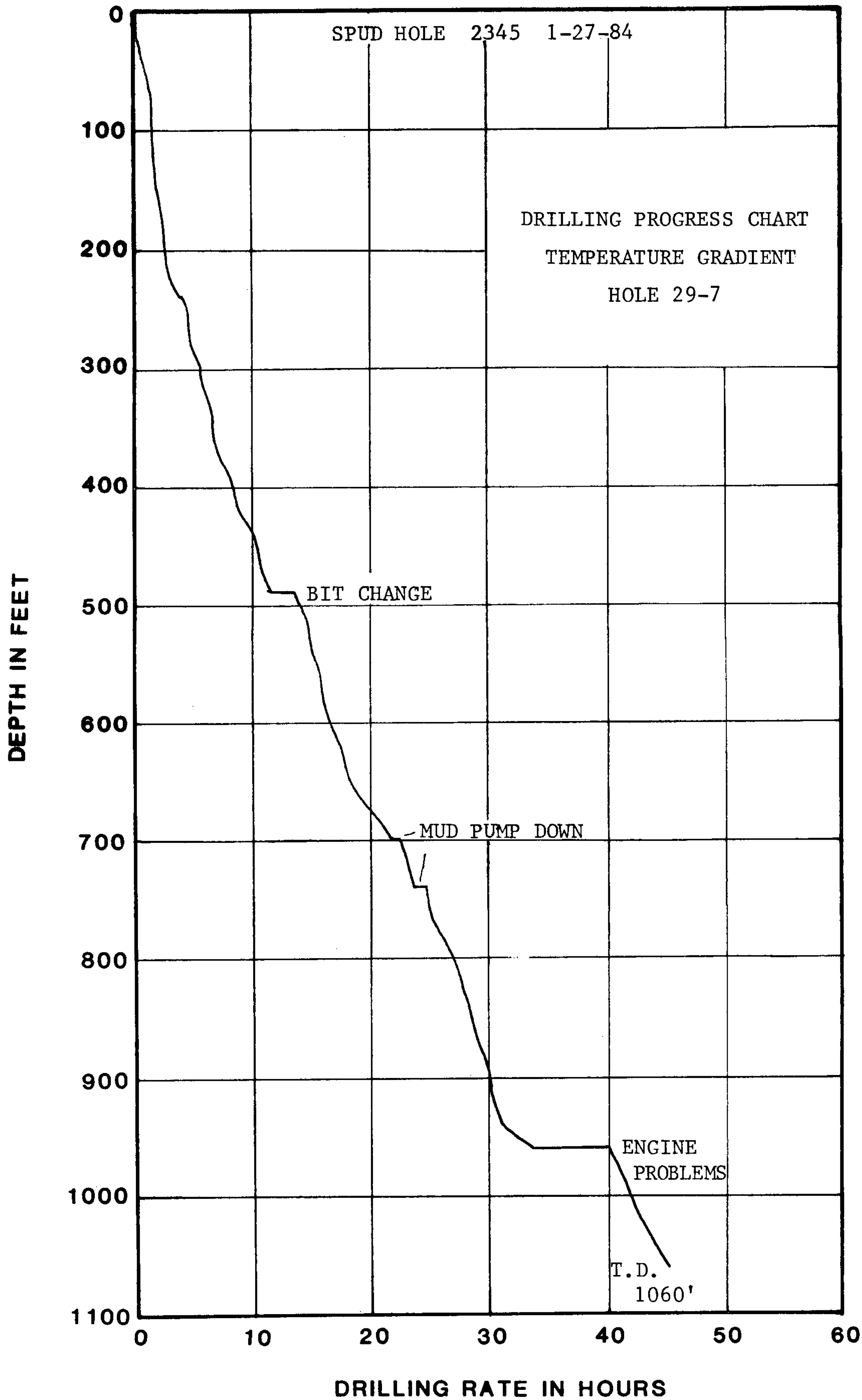
HOLE 29-3
BIT CHANGE
BIT CHANGE
CLAY ON BIT
MUD PUMP LEAK
T.D. 1100'
DEPTH IN FEET
0
100
200
300
400
500
600
700
800
900
1000
1100
0
10
20
30
40
50
60
DRILLING RATE IN HOURS


SPUD HOLE 0930 1-19-84
MUD PUMP
LINE CLOGGED
BIT CHANGE
MAINTENANCE
T.D.
920'
DRILLING PROGRESS CHART
TEMPERATURE GRADIENT
HOLE 29-4
DEPTH IN FEET
0
100
200
300
400
500
600
700
800
900
1000
1100
0
10
20
30
40
50
60
DRILLING RATE IN HOURS


SPUD HOLE 1800 1-22-84
DRILLING PROGRESS CHART
TEMPERATURE GRADIENT
HOLE 29-5
BIT CHANGE
BIT CHANGE
BIT CHANGE
T.D.
940'
DEPTH IN FEET
0
100
200
300
400
500
600
700
800
900
1000
1100
0
10
20
30
40
50
60
DRILLING RATE IN HOURS



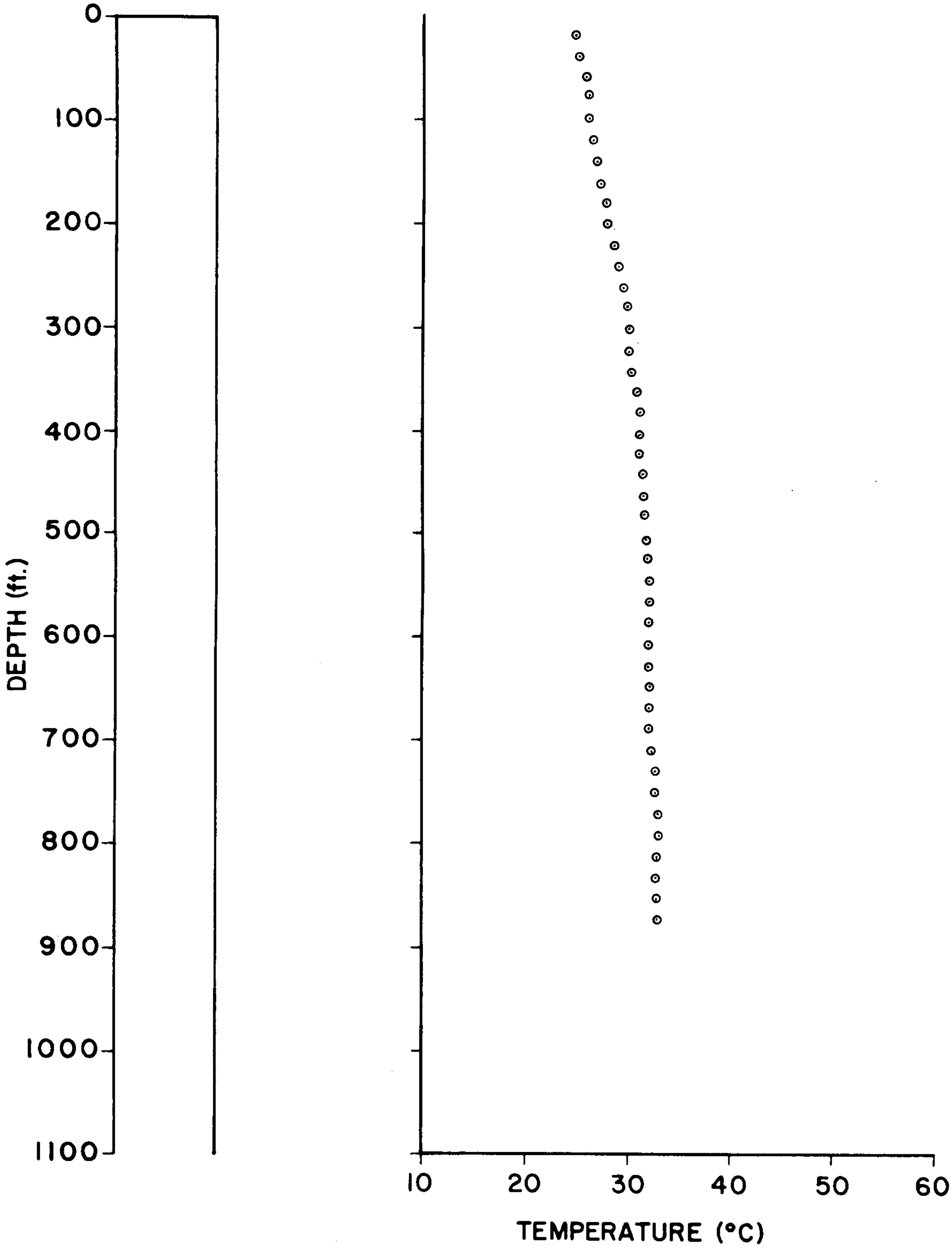
SPUD HOLE 1325 1-25-84
MUD PUMP PROBLEMS
DRILLING PROGRESS CHART
TEMPERATURE GRADIENT
HOLE 29-6
BIT CHANGE
BIT CHANGE
T.D.
1100'
0
100
200
300
400
500
600
700
800
900
1000
1100
DEPTH IN FEET
0
10
20
30
40
50
60
DRILLING RATE IN HOURS


SPUD HOLE 2345 1-27-84
DRILLING PROGRESS CHART
TEMPERATURE GRADIENT
HOLE 29-7
BIT CHANGE
MUD PUMP DOWN
ENGINE PROBLEMS
T.D. 1060'
DEPTH IN FEET
0
100
200
300
400
500
600
700
800
900
1000
1100
0
10
20
30
40
50
60
DRILLING RATE IN HOURS

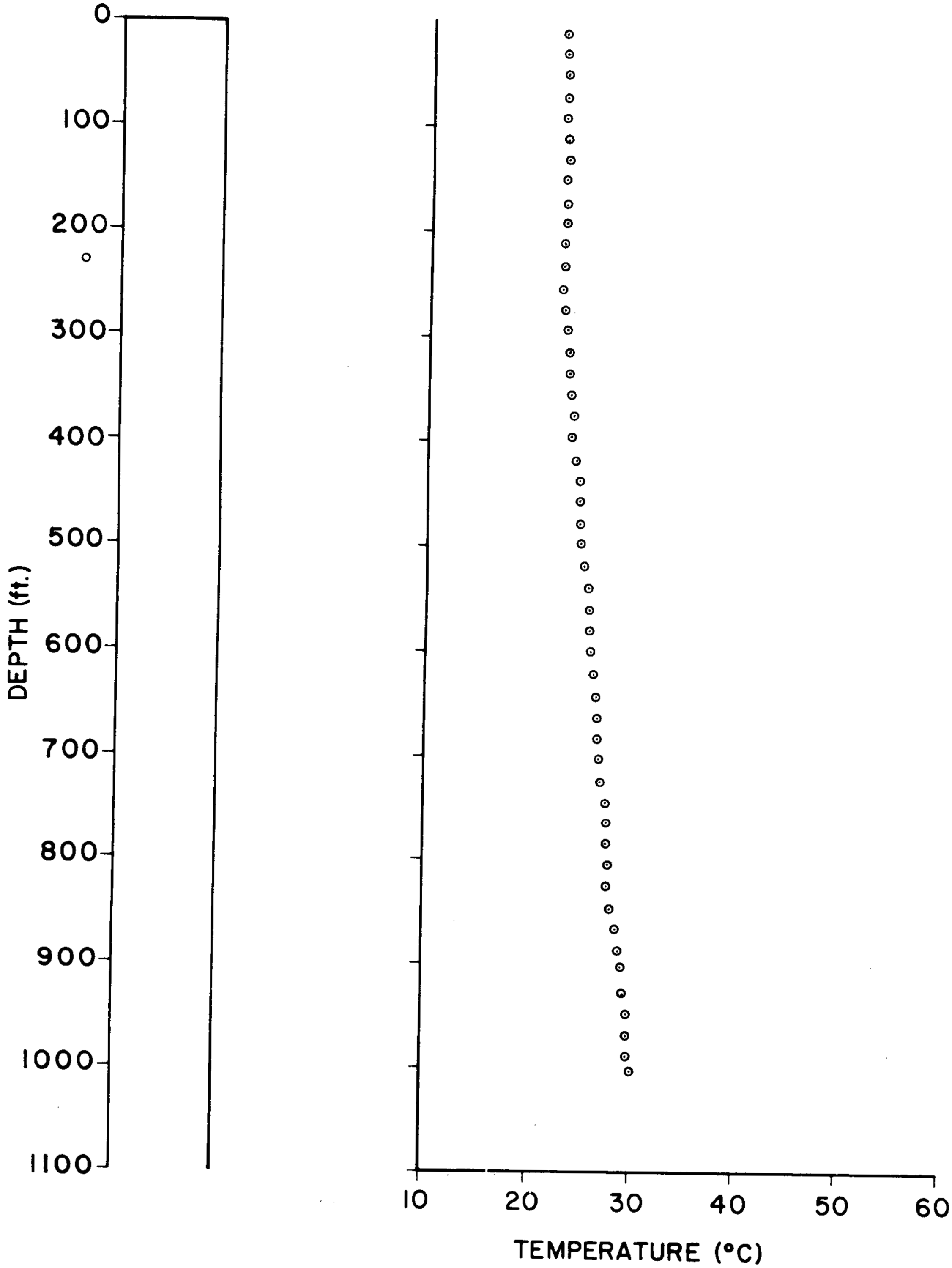
APPENDIX C

TEMPERATURE GRADIENT PROFILES FOR T.G. HOLES 1-7

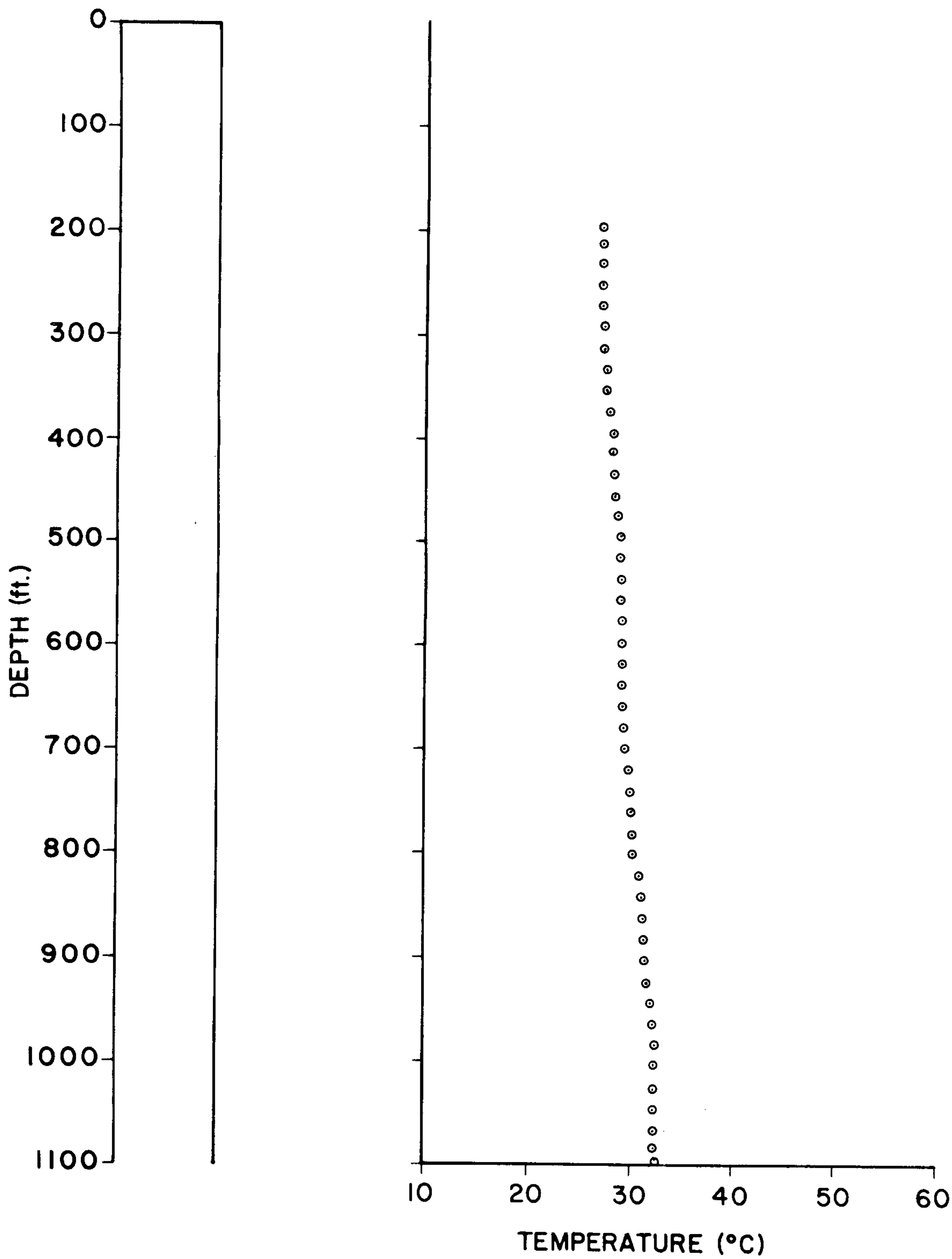
FROM TEMPERATURES MEASURED ON FEBRUARY 27 and 28, 1984



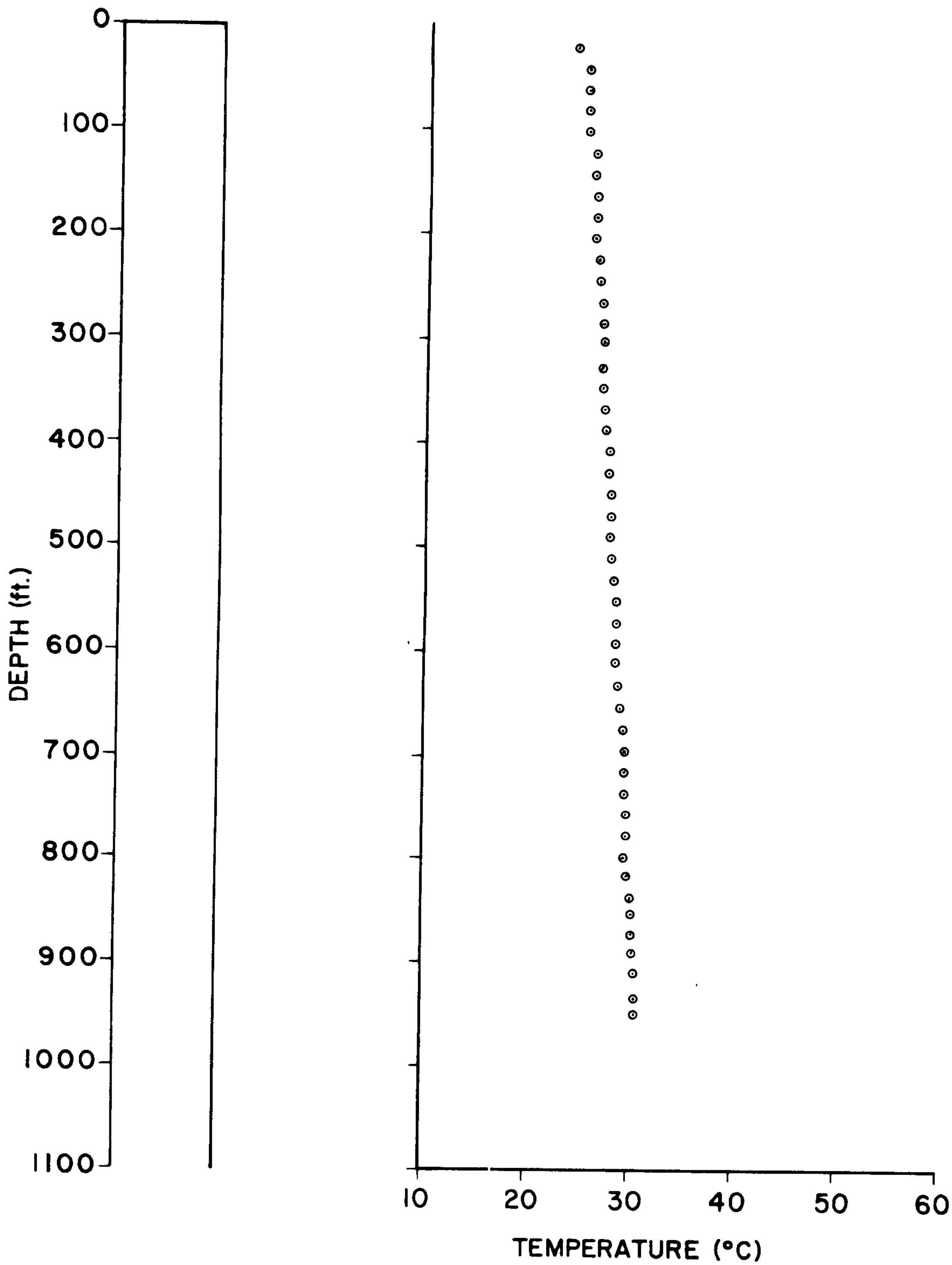
TEMPERATURE GRADIENT HOLE NO. 1



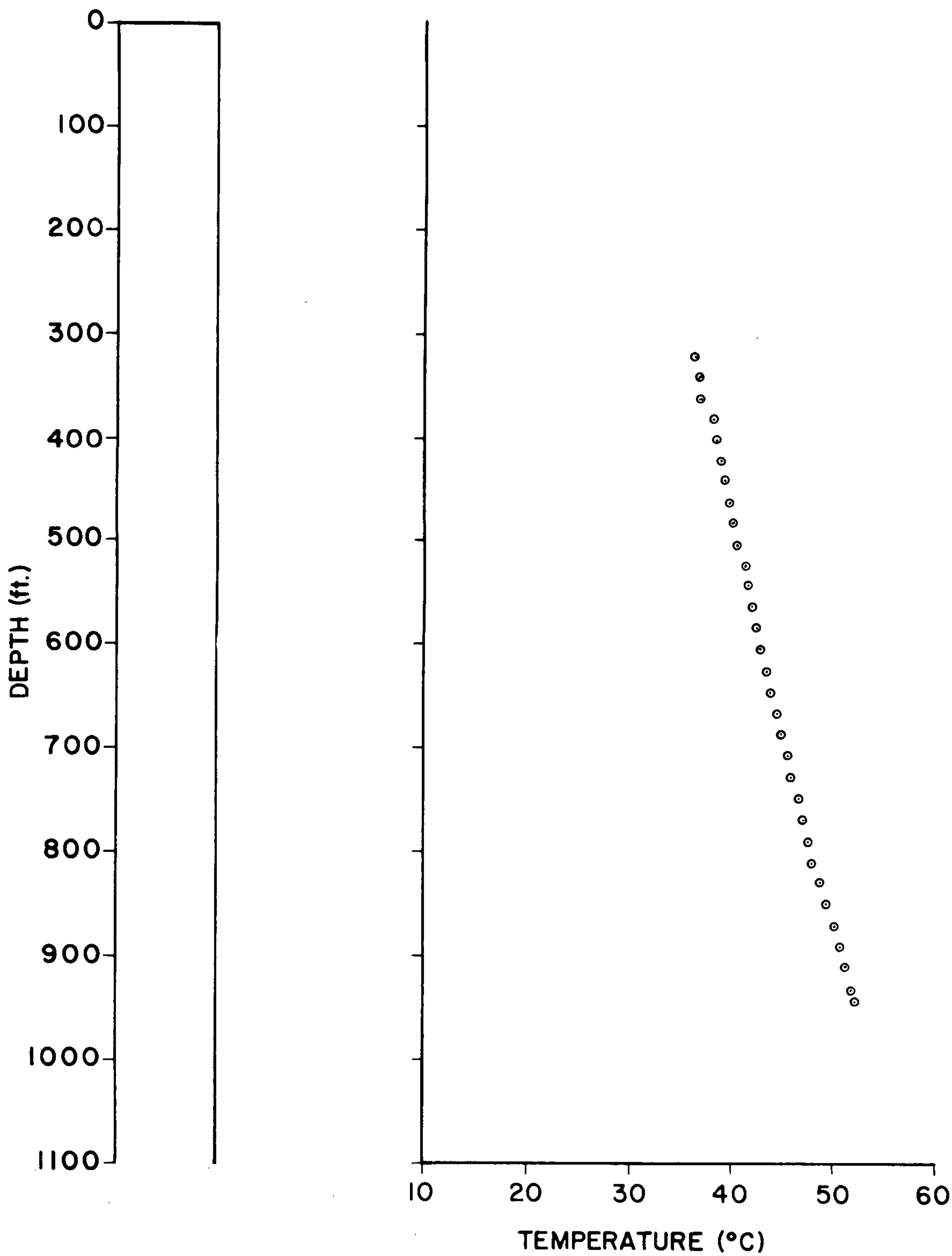
TEMPERATURE GRADIENT HOLE NO. 2



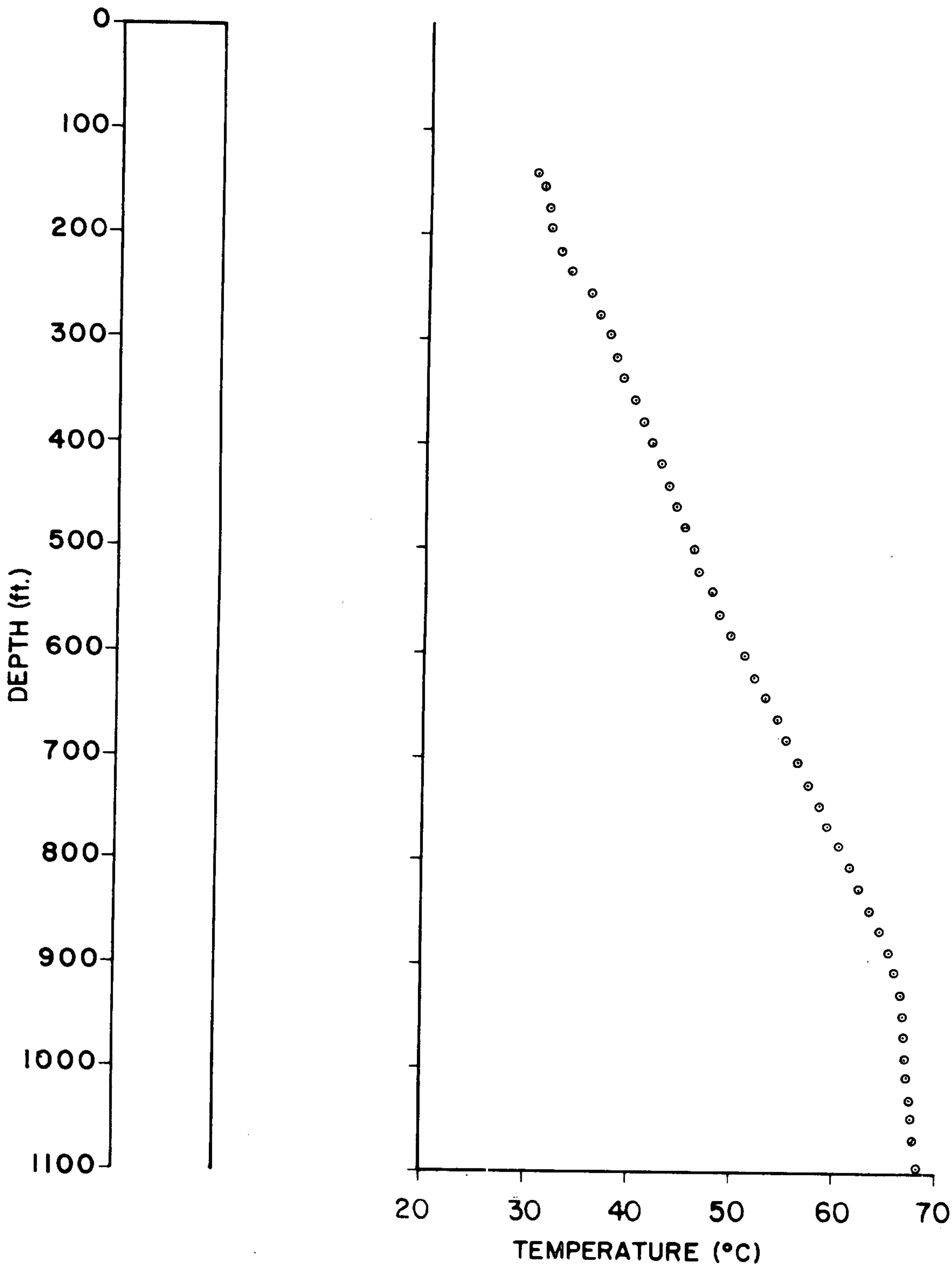
TEMPERATURE GRADIENT HOLE NO. 3



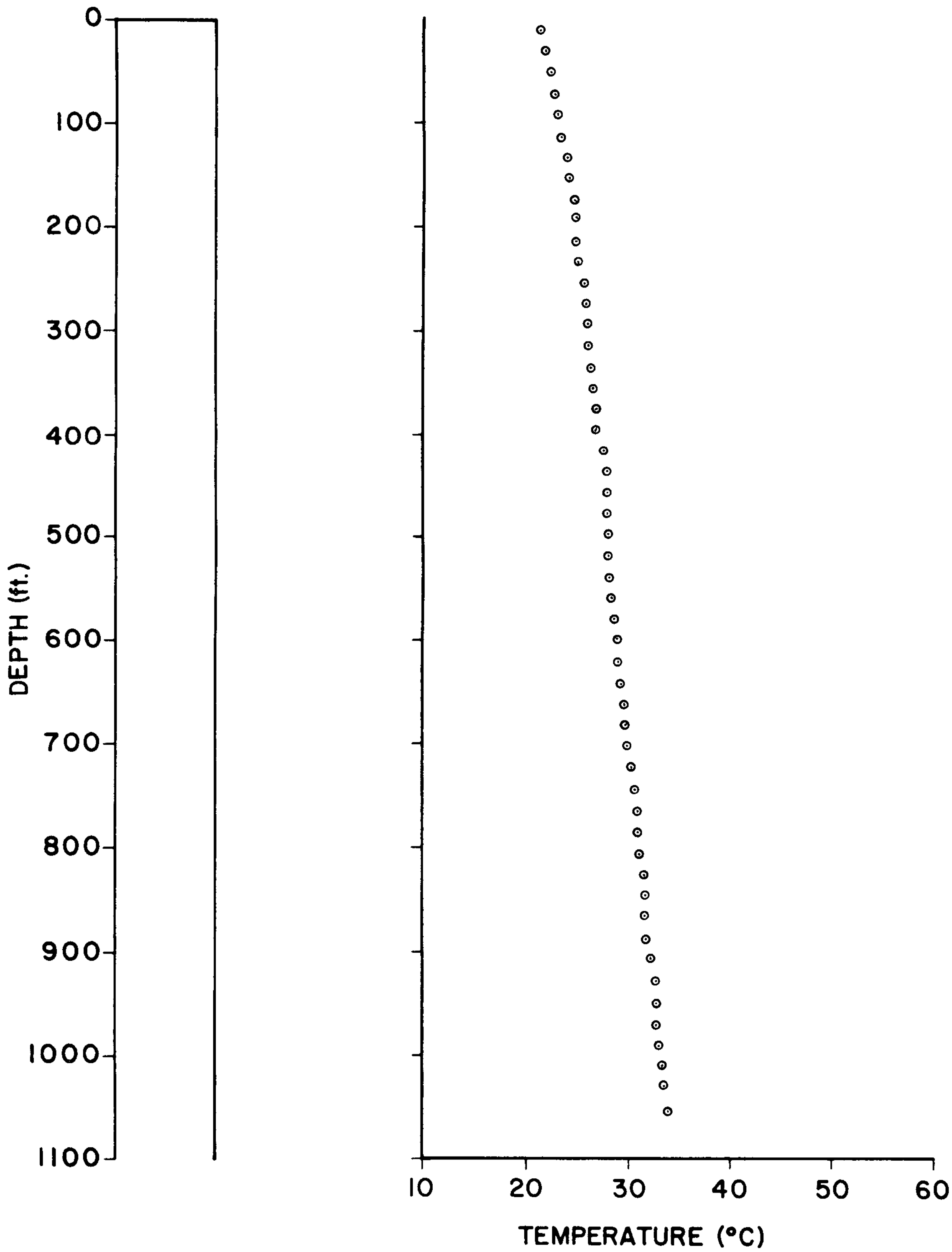
TEMPERATURE GRADIENT HOLE NO. 4



TEMPERATURE GRADIENT HOLE NO. 5



TEMPERATURE GRADIENT HOLE NO. 6



TEMPERATURE GRADIENT HOLE NO. 7

APPENDIX D

MEASURED TEMPERATURES FROM T.G. HOLES 1-7

(FEBRUARY 13-15, 1984 and FEBRUARY 27 & 28, 1984)

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 1

DATE: February 13, 1984

TIME: **Start** – 1341 hours
End – 1435 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	29.9	520	31.0
40	27.0	540	31.1
60	28.7	560	31.2
80	31.8	580	31.3
100	26.0	600	31.4
120	26.5	620	31.5
140	26.4	640	31.5
160	26.8	660	31.6
180	27.3	680	31.6
200	28.9	700	31.7
220	28.0	720	31.8
240	28.4	740	31.9
260	28.7	760	32.0
280	29.0	780	32.0
300	29.3	800	32.1
320	29.5	820	32.2
340	29.7	840	32.2
360	29.9	860	32.3
380	30.0	880	32.4
400	30.2		
420	30.3		
440	30.5		
460	30.6		
480	30.7		
500	30.8		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 2

DATE: February 14, 1984

TIME: **Start** - 1321 hours
End - 1411 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	22.2	520	24.8
40	22.6	540	25.1
60	22.4	560	25.2
80	22.2	580	25.6
100	22.2	600	25.7
120	22.3	620	25.8
140	22.2	640	26.0
160	22.3	660	26.3
180	22.3	680	26.3
200	22.6	700	26.6
220	22.5	720	26.8
240	22.7	740	26.9
260	27.8	760	27.1
280	22.9	780	27.3
300	23.2	800	27.5
320	23.2	820	27.8
340	23.3	840	28.0
360	23.6	860	28.1
380	23.7	880	28.4
400	23.9	900	28.7
420	23.9	920	29.0
440	24.2	940	29.3
460	24.4	960	29.3
480	24.5	980	29.5
500	24.9	1000	29.7

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 3

DATE: February 13, 1984

TIME: **Start** - 1542 hours
End - 1629 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C
200	25.3
220	25.4
240	25.6
260	25.7
280	25.9
300	26.0
320	26.2
340	26.3
360	26.5
380	26.6
400	26.8
420	26.9
440	27.1
460	27.2
480	27.4
500	27.6
520	27.7
540	27.9
560	28.1
580	28.3
600	28.6
620	28.8
640	28.9
660	29.1
680	29.2
700	29.4

DEPTH IN FEET	TEMPERATURE °C	
720	29.5	
740	29.7	
760	29.9	
780	30.0	
800	30.2	
820	30.4	
840	30.7	
860	30.8	
880	31.0	
900	31.2	31.8
920	31.4	31.9
940	31.5	32.0
960	31.7	32.2
980		32.3
1000		32.4
1020		32.6
1040		32.8
1060		32.9
1080		33.1
1100		33.2

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 4

DATE: February 14, 1984

TIME: **Start** – 1503 hours
End – 1549 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	24.9	520	29.5
40	26.1	540	29.7
60	26.4	560	29.6
80	26.7	580	30.0
100	26.8	600	30.0
120	27.0	620	30.2
140	27.1	640	30.3
160	27.3	660	30.6
180	27.3	680	30.6
200	27.4	700	30.8
220	27.5	720	30.9
240	27.8	740	31.1
260	27.9	760	31.1
280	28.0	780	31.2
300	28.0	800	31.5
320	28.2	820	31.6
340	28.3	840	31.8
360	28.5	860	31.8
380	28.6	880	31.9
400	28.7	900	32.1
420	28.9	920	32.1
440	29.1		
460	29.3		
480	29.3		
500	29.4		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 5

DATE: February 15, 1984

TIME: **Start** - 0826 hours
End - 0858 hours

WATER LEVEL: 312'

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
320	35.9	700	45.5
340	37.6	720	45.9
360	38.4	740	46.4
380	39.1	760	47.0
400	39.6	780	47.5
420	39.9	800	48.0
440	40.2	820	48.5
460	40.7	840	48.8
480	41.2	860	49.2
500	41.6	880	50.0
520	41.9	900	50.6
540	42.3	920	51.0
560	42.7	940	51.6
580	43.0		
600	43.4		
620	43.8		
640	44.3		
660	44.7		
680	45.1		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 6

DATE: February 14, 1984

TIME: **Start** - 0855 hours
End - 1100 hours

WATER LEVEL: 107' 8"

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
120	28.6	620	50.5
140	30.3	640	51.2
160	31.4	660	52.3
180	32.3	680	53.3
200	33.2	700	54.2
220	34.3	720	55.2
240	35.4	740	56.1
260	36.3	760	57.1
280	37.3	780	58.0
300	38.1	800	59.0
320	38.8	820	60.0
340	39.7	840	60.8
360	40.6	860	61.9
380	41.3	880	62.7
400	42.1	900	63.6
420	42.8	920	64.3
440	43.7	940	64.6
460	44.4	960	64.8
480	45.1	980	65.1
500	45.8	1000	65.2
520	46.6 45.6	1020	65.4
540	46.4	1040	65.5
560	47.3	1060	65.5
580	48.4	1080	65.8
600	49.4	1100	66.1

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 7

DATE: February 14, 1984

TIME: **Start** - 1032 hours
End - 1125 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	21.6	560	28.2
40	22.2	580	28.4
60	22.6	600	28.4
80	22.9	620	28.6
100	23.2	640	29.0
120	23.3	660	29.3
140	23.6	680	29.5
160	23.9	700	29.7
180	24.0	720	30.0
200	24.3	740	30.3
220	24.7	760	30.5
240	24.8	780	30.7
260	25.1	800	31.0
280	25.5	820	31.2
300	25.6	840	31.5
320	25.9	860	31.7
340	26.1	880	31.9
360	26.3	900	32.1
380	26.5	920	32.2
400	26.7	940	32.5
420	26.8	960	32.7
440	27.0	980	32.9
460	27.2	1000	33.3
480	27.4	1020	33.6
500	27.6	1040	33.6
520	27.8	1060	33.9
540	28.1		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 1

DATE: February 28, 1984

TIME: **Start** - 0930 hours
End - 1013 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	22.6	520	31.1
40	24.3	540	31.2
60	24.8	560	31.3
80	25.2	580	31.4
100	25.5	600	31.5
120	25.7	620	31.6
140	26.0	640	31.7
160	26.5	660	31.7
180	27.0	680	31.8
200	27.4	700	31.9
220	27.8	720	32.0
240	28.2	740	32.1
260	28.6	760	32.2
280	29.0	780	32.2
300	29.2	800	32.3
320	29.5	820	32.4
340	29.7	840	32.5
360	29.9	860	32.6
380	30.1	880	32.6
400	30.3		
420	30.4		
440	30.5		
460	30.7		
480	30.8		
500	31.0		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 2

DATE: February 28, 1984

TIME: **Start** - 1115 hours
End - 1227 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	22.1	520	25.0
40	22.2	540	25.2
60	22.2	560	25.4
80	22.2	580	25.6
100	22.2	600	25.8
120	22.3	620	26.0
140	22.4	640	26.1
160	22.4	660	26.3
180	22.5	680	26.5
200	22.6	700	26.7
220	22.6	720	26.9
240	22.7	740	27.1
260	22.8	760	27.3
280	22.9	780	27.5
300	23.1	800	27.7
320	23.2	820	28.0
340	23.4	840	28.2
360	23.5	860	28.4
380	23.6	880	28.7
400	23.8	900	28.9
420	24.0	920	29.1
440	24.2	940	29.3
460	24.4	960	29.5
480	24.6	980	29.7
500	24.8	1000	29.8

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 3

DATE: February 18, 1984

TIME: **Start** – 1048 hours
End – hours

WATER LEVEL: 192 feet

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
200	25.5	720	29.2
220	25.4	740	29.3
240	25.5	760	29.5
260	25.6	780	29.7
280	25.7	800	29.8
300	25.9	820	30.1
320	25.9	840	30.3
340	26.0	860	30.5
360	26.2	880	30.7
380	26.3	900	30.8
400	26.5	920	31.0
420	26.7	940	31.2
440	26.8	960	31.4
460	26.9	980	31.5
480	27.0	1000	31.7
500	27.2	1020	31.8
520	27.4	1040	32.0
540	27.5	1060	32.2
560	27.7	1080	32.3
580	28.0	1100	32.5
600	28.2		
620	28.4		
640	28.6		
660	28.7		
680	28.9		
700	29.1		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 4

DATE: February 28, 1984

TIME: **Start** - 0937 hours
End - 1005 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	23.2	520	28.0
40	24.5	540	28.1
60	24.6	560	28.3
80	24.8	580	28.4
100	24.9	600	28.6
120	25.1	620	28.7
140	25.2	640	28.8
160	25.4	660	29.0
180	25.5	680	29.1
200	25.7	700	29.2
220	25.8	720	29.3
240	26.0	740	29.5
260	26.1	760	29.6
280	26.2	780	29.7
300	26.3	800	29.9
320	26.5	820	30.0
340	26.7	840	30.2
360	26.8	860	30.3
380	27.0	880	30.4
400	27.1	900	30.6
420	27.3	920	30.7
440	27.4		
460	27.6		
480	27.8		
500	27.9		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 5

DATE: February 28, 1984

TIME: **Start** – 0757 hours
End – 0845 hours

WATER LEVEL: 305 feet

DEPTH IN FEET	TEMPERATURE °C
320	35.5
340	36.0
360	36.0
380	37.2
400	37.7
420	38.0
440	38.5
460	39.0
480	39.4
500	39.7
520	40.2
540	40.6
560	41.0
580	41.3
600	41.8
620	42.3
640	42.8
660	43.3
680	43.7

DEPTH IN FEET	TEMPERATURE °C
700	44.1
720	44.8
740	45.2
760	46.0
780	46.5
800	47.0
820	47.4
840	48.0
860	48.9
880	49.4
900	50.0
920	50.5
930	50.6

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 6

DATE: February 27, 1984

TIME: **Start** - 1428 hours
End - 1543 hours

WATER LEVEL: 140.2'

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
150	30.2	640	52.3
160	30.8	660	53.3
180	31.6	680	54.4
200	32.7	700	55.5
220	33.8	720	56.5
240	34.7	740	57.5
260	35.5	760	58.5
280	36.4	780	59.5
300	37.2	800	60.6
320	38.0	820	61.6
340	38.8	840	62.5
360	39.8	860	63.5
380	40.6	880	64.2
400	41.4	900	64.9
420	42.2	920	65.2
440	43.0	940	65.5
460	43.7	960	65.7
480	44.6	980	65.9
500	45.3	1000	66.0
520	46.0	1020	66.2
540	47.1	1040	66.4
560	48.0	1060	66.7
580	49.1	1080	67.0
600	50.1	1095	67.1
620	51.3		

TEMPERATURE GRADIENT DATA

HOLE NUMBER: 7

DATE: February 27, 1984

TIME: **Start** – 1607 hours
End – 1702 hours

WATER LEVEL: Surface

DEPTH IN FEET	TEMPERATURE °C	DEPTH IN FEET	TEMPERATURE °C
20	21.0	560	28.1
40	21.6	580	28.3
60	22.0	600	28.5
80	22.3	620	28.7
100	22.6	640	29.0
120	23.0	660	29.3
140	23.3	680	29.6
160	23.5	700	29.8
180	23.9	720	30.0
200	24.3	740	30.2
220	24.5	760	30.5
240	24.7	780	30.7
260	25.1	800	30.9
280	25.3	820	31.2
300	25.5	840	31.4
320	25.7	860	31.6
340	26.0	880	31.8
360	26.2	900	32.0
380	26.3	920	32.2
400	26.5	940	32.5
420	26.6	960	32.7
440	26.8	980	33.0
460	27.0	1000	33.2
480	27.3	1020	33.4
500	27.5	1040	33.6
520	27.7	1050	33.7
540	27.9		

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