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EVALUATION OF COSO GEOTHERMAL EXPLORATORY HOLE NO. 1 CGEH-1 COSO HOT SPRINGS: KGRA, CHINA LAKE, CA.

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EVALUATION OF COSO GEOTHERMAL EXPLORATORY
HOLE No. 1 (CGEH-1)
COSO HOT SPRINGS: KGRA, CHINA LAKE, CA

C. Goranson, R. Schroeder, and J. Haney

January 1979

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LAWRENCE BERKELEY LABORATORY
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INTRODUCTION

The well, Coso Geothermal Exploratory Hole No. 1 (CGEH-1), was drilled at the China Lake Naval Weapons Center under the supervision of DOE/NVO and CER Corporation by Big O Drilling Company. They started drilling on 2 September 1977, and completed the well on 1 December 1977 to 4845 ft. The well is an exploratory hole to determine geological and hydrothermal characteristics of the Coso Hot Springs KGRA (Known Geothermal Resource Area). During drilling, numerous geophysical and temperature surveys were performed to evaluate the geological characteristics of CGEH-1. LBL performed eight temperature surveys after completion of the well to estimate equilibrium reservoir temperatures. Downhole fluid samples were obtained by the U.S. Geological Survey (USGS) and Lawrence Berkeley Laboratory (LBL), and a static pressure profile was obtained.

Two flow tests were attempted in 1978. The first test began September 5, 1978 using nitrogen stimulation to initiate flow; this procedure resulted in small flow and subsequent filling of the bottom hole with drill cuttings. The second test, on November 2, 1978, utilized a nitrogen-foam-water mixture to clean residual particles from bottom hole, following which nitrogen was again used to stimulate the well. The well remained dry after stimulation. Water influx was calculated at 4-5 gal/min as the well filled after unloading of the wellbore.

Figure 1 shows the location of Coso Hot Springs. Figure 2 illustrates the location of CGEH-1 relative to heat flow contours obtained by ARPA (Advanced Research Projects Agency) and DOE heat flow holes. Numerous geological and geophysical studies were performed (1-18) prior to the drilling of CGEH-1. However, the geological characteristics of the Coso area are rather complex. This is illustrated in the aforementioned references. The area consists essentially of a ring fracture zone located in the basin and range province east of the Sierra Nevada range (19). Figure 3 illustrates generalized alteration, geophysical characteristics, and active thermal areas in the Coso Hot Springs area.

WELL COMPLETION--CGEH-1

The drill site is on rhyolite pyroclastic debris covering a granite complex. Rhyolite dikes intrude and are probably contemporaneous with the extruded rhyolite domes in the vicinity. Faults and fracture zones had a strong influence in hole direction and penetration rates. Figure 4 shows the surface projected horizontal deviation of the well.

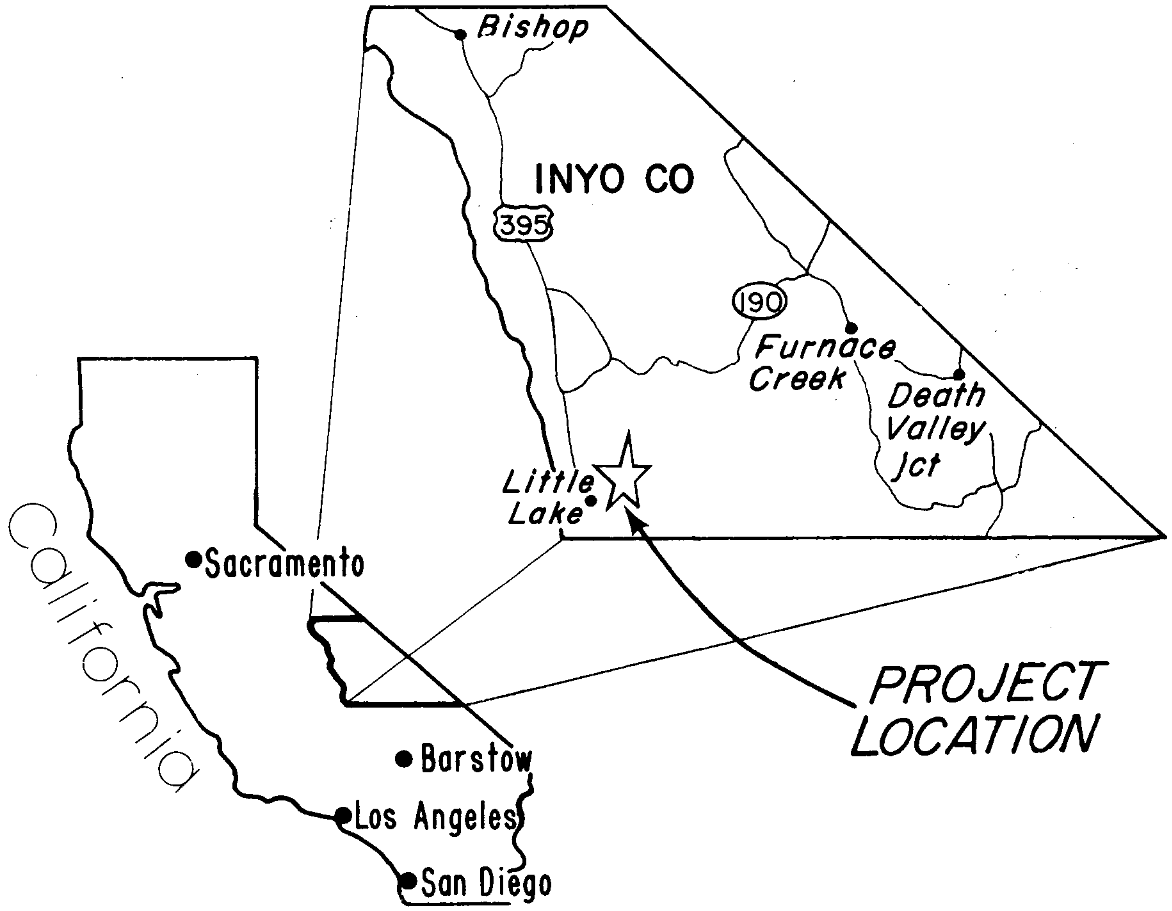

Fig. 1. Location of the China Lake Naval Weapons Center. (XBL 786-997)

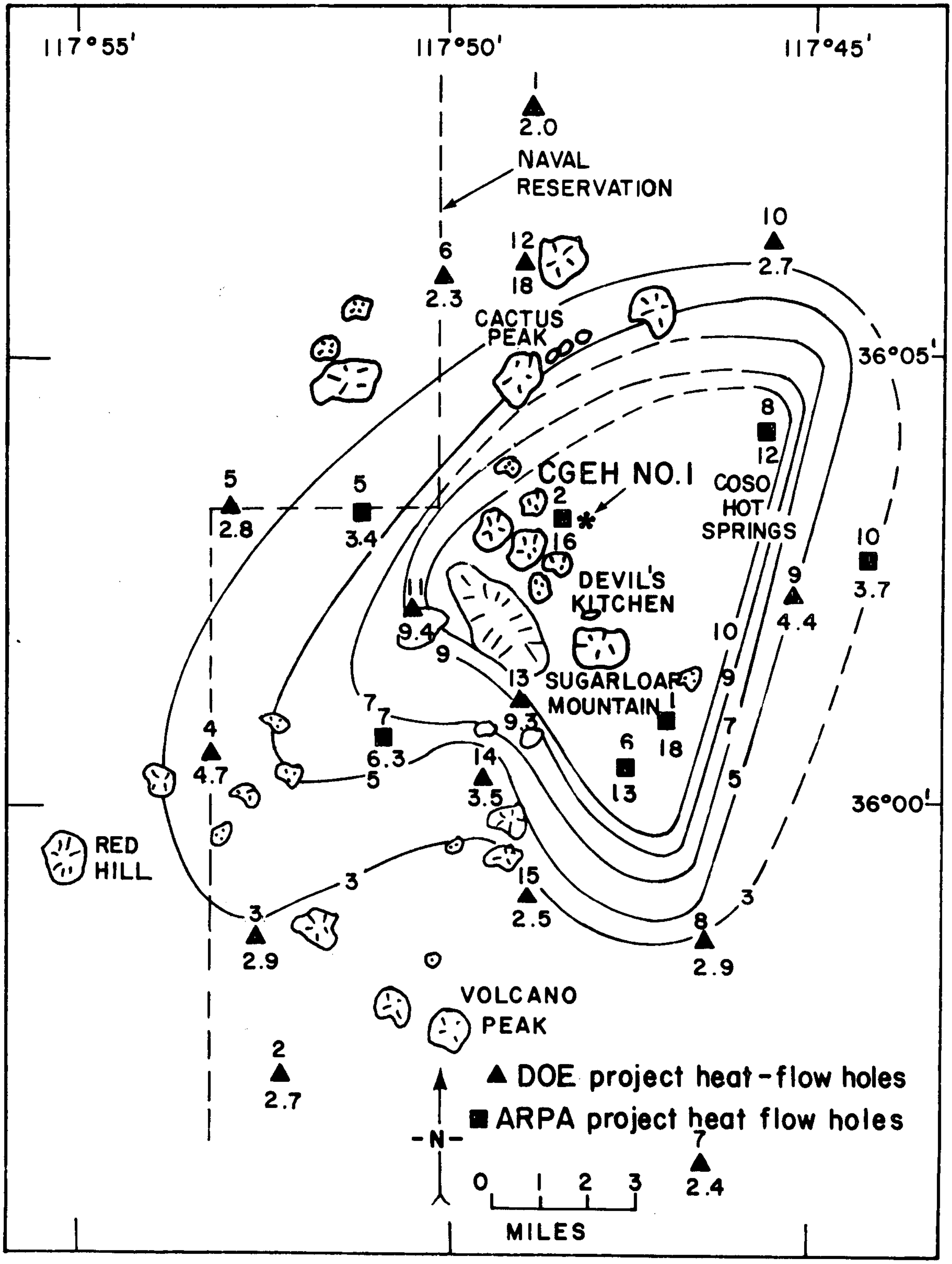

Fig. 2. Generalized map of thermal anomalous region and the CGEH No. 1 well location. The numbers above the symbols identify the holes, and those below the symbols give heat flow in HFU.(XBL 786-998)

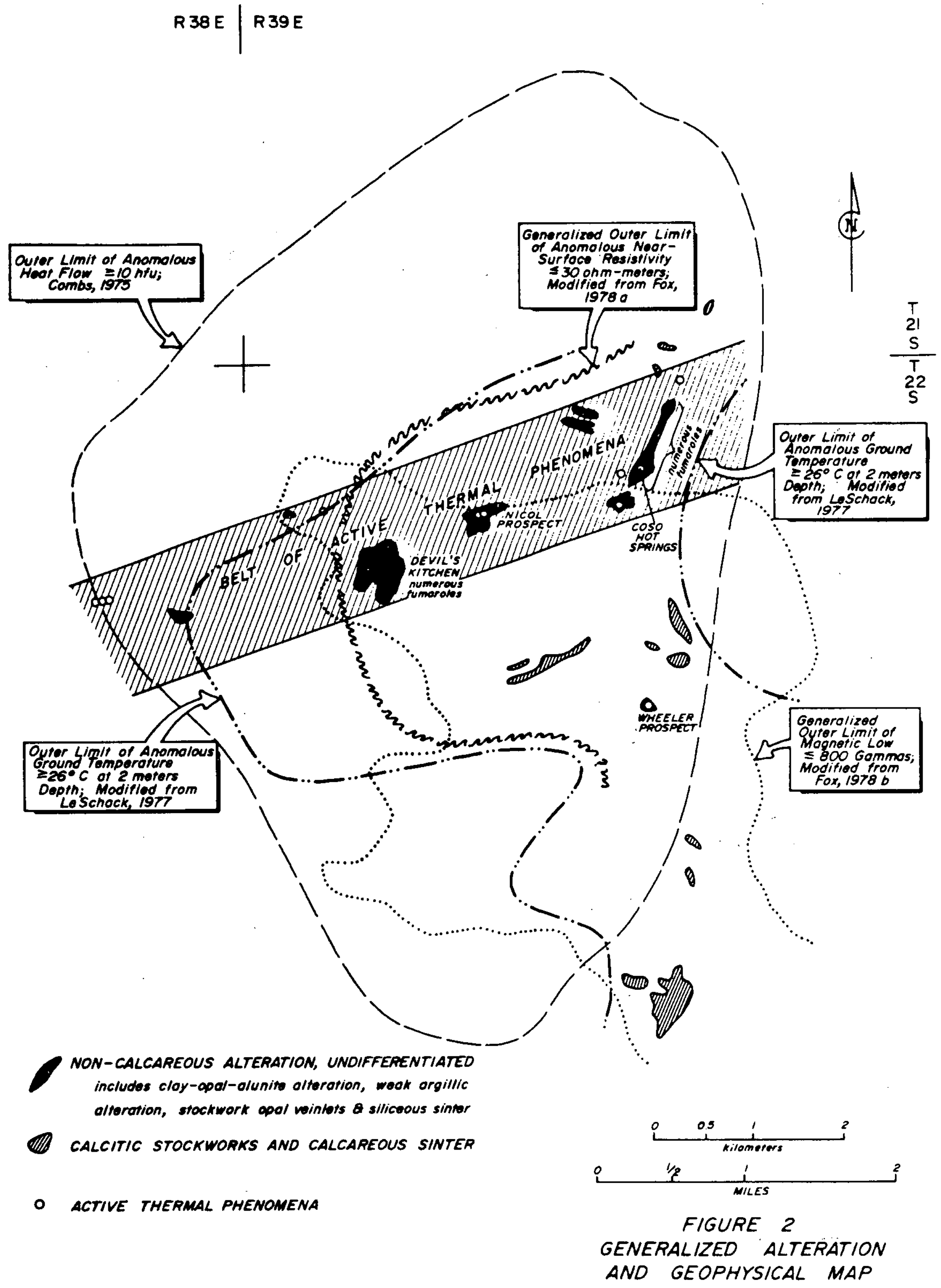

Fig. 3. Generalized alteration and geophysical map. (From Hulen, 1978.)

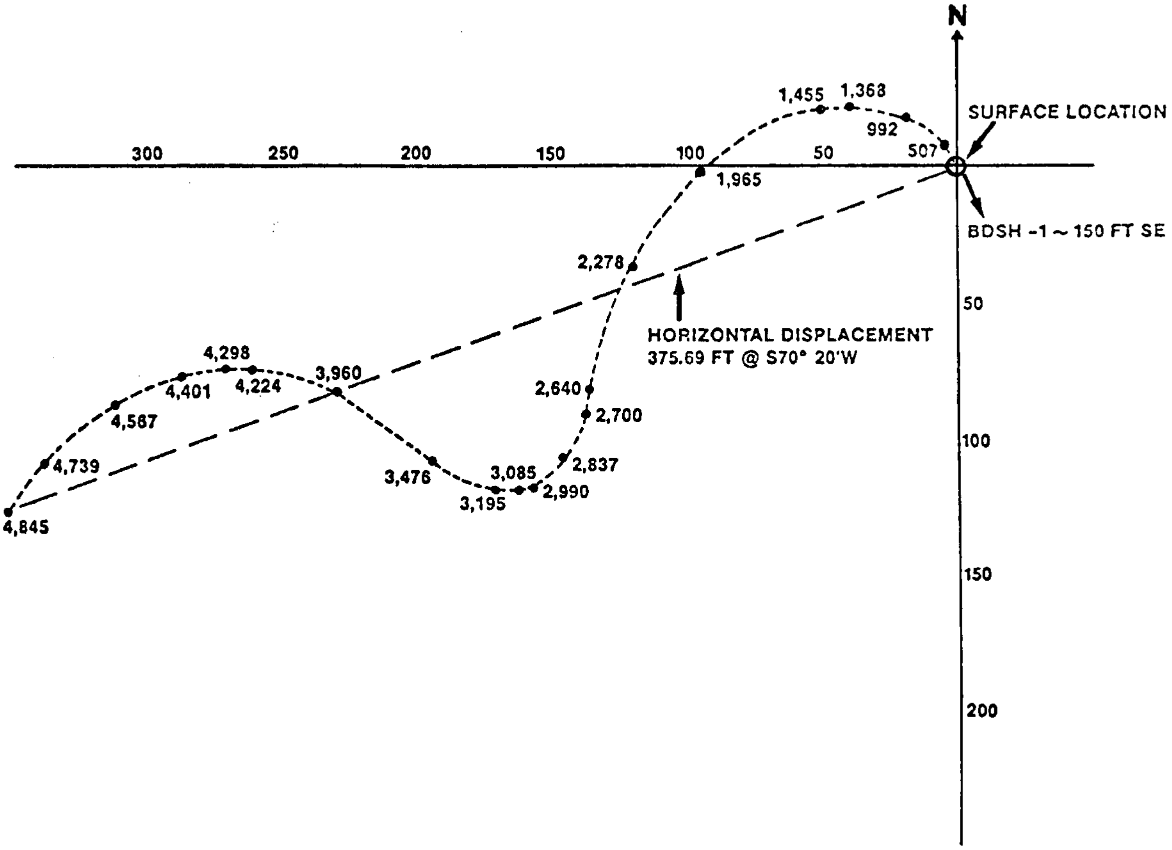

Fig. 4. Horizontal projection in feet plotted as a function of measured depth.

Maximum horizontal displacement was calculated to be 375 ft at S70° 20'W. As shown in the figure, three large meanders in the wellbore occurred during drilling. Final bottom hole vertical depth is approximately 4815 ft (total drilled depth, 4845 ft).

Figure 5 is a synopsis of the completion record. Three large mud losses occurred along the cased portion of the well (CGEH-1 is cased to 3488 ft). An influx of water at a rate of 90 BPH was observed at about 1900 ft. Above this zone, at about 1660 ft running clay and gravel entered the wellbore. The gravel was subangular and the clay is actually powdered granite with clay-sized particles. Numerous mud losses occurred below 3500 ft. However, it is not known whether this mud went into the fractured zone near 3500 ft or if other fractures intersect the well below this point.

THERMAL EQUILIBRIUM PERIOD December 1977--September 1978

LBL performed eight temperature surveys (21) before the first flow test. The final recorded maximum temperature was 194°C (382°F) at 1900 ft. The water level varied, but was found at approximately 890 ft. Figure 6 shows five of eight temperature surveys. The figure illustrates that zones above 3500 ft (1900, 2700, 3500 ft), where large mud losses occurred during drilling, show atypical temperature distribution indicating that the formation was cooled from mud entry. However, zones below 3500 ft where numerous mud losses are observed do not illustrate this abnormal behavior. This seems to indicate that the mud losses below 3500 ft probably entered the large fracture zone above 3500 ft and not into fractures below the portion of the well that was subsequently cased. However, there was a large mud loss at Total Depth (TD).

Downhole chemical samples (21) of wellbore fluid were also obtained during this initial equilibrium period. Dissolved silica concentrations from bottom hole samples indicate a temperature of 170°C (338°F) (201 mg/l). Silica temperatures at 2740 ft were calculated to be 90°C (194°F) (40 mg/l). The causes of these discrepancies are unknown. However, the drill pipe was stuck at 3488 ft for a short period. Pipe release and diesel fuel were added to free the drill bit. The presence of residual organics in the wellbore might explain low silica concentrations observed at the 2700 ft depth. (23)

FLOW TEST 1

The first extended flow test was carried out September 5 to 8, 1978. During the well stimulation and subsequent flow the wellhead temperature was 128°C (262.5°F) and the discharge tube temperature was 121°C (250°F). This occurred during the nitrogen lift at 300 ft^3/min of heated N_2 with the tube at 2060 ft. Nitrogen flow rates were varied as

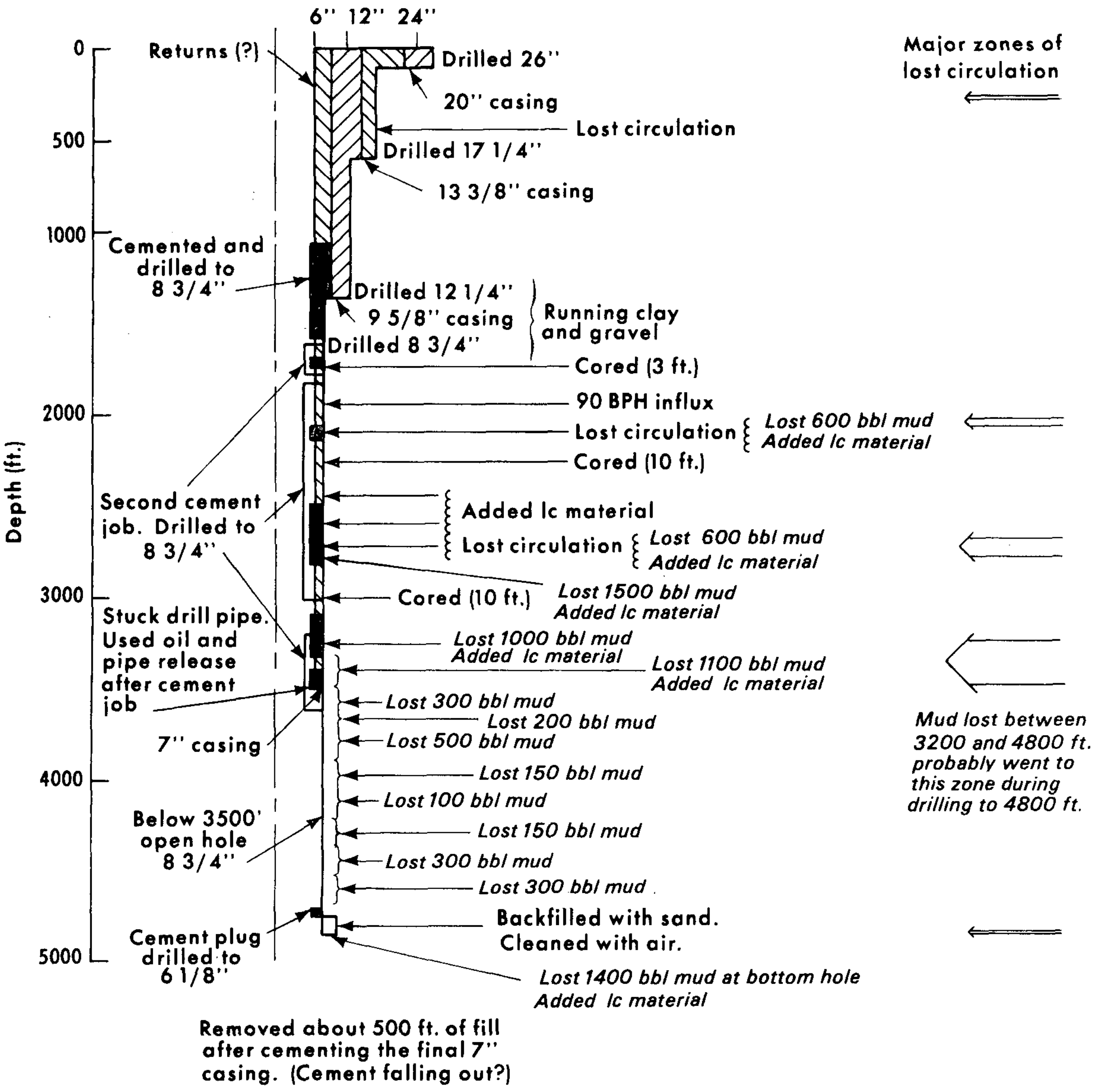

Fig. 5. Synopsis of well completion record. (XBL 7812-13390)

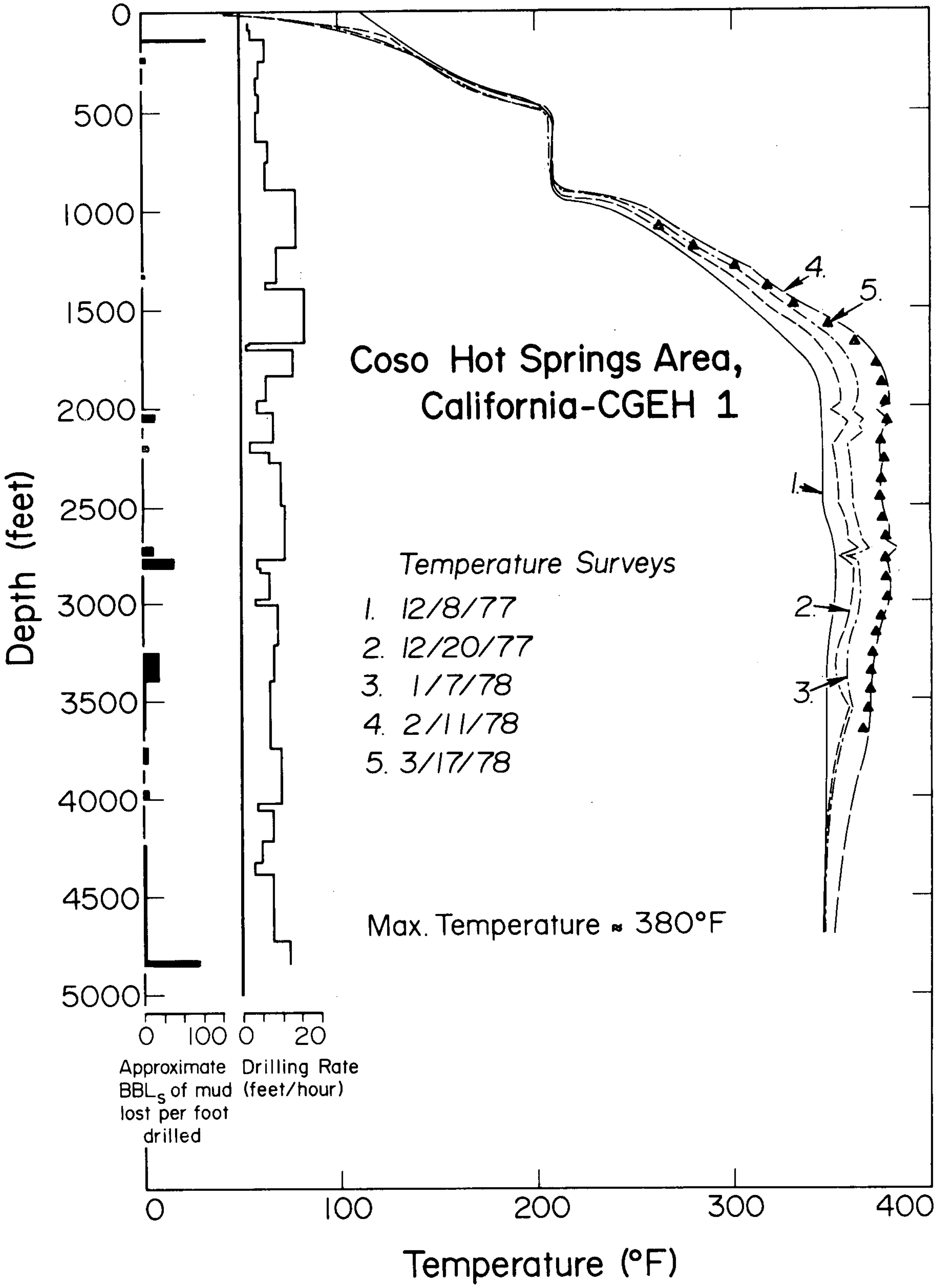

Fig. 6. Temperature surveys in the static steam and water column at Coso Hot Springs. (XBL 784-7951)

the tube was lowered to the final depth, 4590 ft. When the nitrogen was shut off, the flow decreased to nearly atmospheric pressure at the discharge tube within 30 min. The wellhead temperature dropped to 95°C (203°F) at this point. Within five minutes of shutting off the nitrogen, the flow had decreased appreciably. The well was then pressured with 2000 psi pressure at the nitrogen truck for 30 min. At this time, the tubing was terminated at 4590 ft downhole. The wellhead pressure at this time was 370 psi and nitrogen was pumped at 200 ft^3/min. The well was opened and unloaded an unknown quantity of water, then died. An attempt was made to find a liquid level with the N_2, but the attempt was unsuccessful. The N_2 tubing was then lowered to 4700 ft but no nitrogen returns were observed and the nitrogen pressure reached 3000 psi. When the tubing was removed, the lower 250 ft of tubing was plugged with sand and clay. At this point the flow testing was terminated.

FLOW TEST 2

The second flow test utilized a nitrogen-foam-water mixture to clean the bottom portion of the well below 4700 ft. The well cleanup and stimulation began on November 5, 1978 by injecting foam at 1000 ft and slowly lowering the injection tube while continuing to pump foam. Good returns were obtained during the descent. A wellhead sample of the foam was taken for analysis. The sample showed a large amount of grey clay-like material entrained in the foam. Subsequent analysis by R. Clark (DOE/NVO) indicated that the material was fine powdered granite, not clay. At this point over 100 ft of material was being circulated out of the well, but further progress was not possible due to an obstruction at 4695 ft. An attempt was made to withdraw the tubing, but it could only move a maximum of about 60 ft upward. The tubing moved freely downward, but could not be withdrawn more than about 60 ft upward. The tubing was worked up and down a few times and finally came free. However, when the end came to the surface about 145 ft of the tubing had been left in the well.

During the cleanout procedure, fluid samples were taken from a tube at the wellhead using a high-pressure needle valve for metering. This valve was subsequently plugged with sand grains brought up with the foam. The sand was retained as a sample of the material removed from the well. Before removing the nitrogen injection tube, the well was cleaned to 4695 ft by circulating a water-foam mixture for four hours. After four hours, the well was cleaned by pumping clean water for one hour followed by nitrogen until the well reached its maximum flowing temperature and pressure at the critical discharge tube. The nitrogen was shut in and the well flowed for less than five minutes, after which the temperature and flow decreased rapidly. The wellhead temperature was 95°C (203°F) and flow was essentially pure steam.

After the nitrogen tube was brought to the surface, a different end was made up to try to pass the blockage at 4695 ft. The well was again foamed (this time at 3500 ft) and the tubing was lowered after returns were obtained. The tubing encountered a block at 4490 ft. The well was again cleaned and stimulated with nitrogen. The well again died in less than five minutes after stimulation. The nitrogen was then pumped at 3000 psi with the wellhead shut in for about 15 min. The 2 in. and 4 in. discharge tubes were then opened. No show of water was seen, only nitrogen. No subsequent show of water was found with the well open for 12 hours.

A water-level tool was then used to monitor the position of the water level in the well. The water level was first found at 3645 ft. This was about 23 hours after the final pressurization and flow of the well, and 12 hours after shutting in the well. This is an average increase in water level of about 1.3 ft/min $\approx$ 4 gal/min. The water level was subsequently monitored closely and it was seen that the time required for the water level to rise 1 ft was decreasing slightly as the height of the water column increased. This continued up to 3460 ft, at which time the rate of filling began to decrease. Since the latter depth is approximately the depth to which the well is cased, we conclude that the well was not filling from the bottom, but instead the water was coming from the well annulus at the bottom of the casing. Following the well fill-up measurements, the testing was terminated.

CONCLUSIONS

The well was drilled in very hard rock. It was extremely difficult to prevent drill bit wandering, and the final bottomhole location is $\sim$ 374 ft (horizontal) from the wellhead location with three serious meanders (see Figure 1). During the monitoring of the thermal equilibration, at least 15 downhole surveys were run over a period of about 10 months. Our final surveys, before the workover began, indicated considerable friction below the casing. During the cleanout the nitrogen tubing was broken with a piece apparently lodged between 4490 and 4635 ft. This suggests that the well is currently unuseable at the present time below about 4000 ft due to either cable and wireline cuts in the uncased curved well, fractures which have been opened during the downhole activity, or opening of a fracture during drilling. (The drill bit was stuck temporarily at 4771 ft.)[20] Since the well had about 200 ft of fill, and since the flow seems to come down the wellbore, the tension could also have been due to a sticky layer of clay (powdered granite) in the well. It is not likely that there are serious cable grooves below 4500 ft, and the origin of the fill is unknown, hence it is likely that the tubing was stuck in a fracture.

During drilling there were several circulation losses while using mud. The deepest circulation loss occurred at bottomhole, where more than $\sim$ 1400 bbl ($\sim$ 59,000 gal) of mud was lost, as shown in Figure 5. This large quantity of mud, plus the material added to the mud to prevent further losses to the fracture, make production from this zone questionable.

The apparent lack of significant influx from the lower zone (recall that the maximum influx during well fill-up after cleanout was about 5 gal/min) leads us to conclude that the lower zone is not of significant interest for production of geothermal fluids at this time. When the temperature log is examined, the bottomhole can be seen to be about 22.2°C (40°F) cooler than the zones which are about half as deep.

The well was cased to about 3500 ft. The largest mud losses during drilling occurred in the zone adjacent to the casing shoe, i.e., in the zone from 3260 to 3500 ft, as shown in Figure 2.(20) In this zone, up to 4000 bbls (168,000 gal) of drilling mud and circulation material was consumed (note that this follows only if the mud losses while drilling from 3600 to ∿ 4500 ft are all assumed lost in this interval). This zone shows up as a broad temperature depression in the temperature logs taken during thermal equilibration of the well as shown in Figures 5 and 6. It is likely that this zone is contributing the 3-6 gpm of influx that fills the well when the latter is emptied during the flow tests. The mud lost in this zone has a volume equal to about 20,000 ft^3. Assuming an effective porosity of 10% we have a damage radius which is at least 17 ft. If this zone contributes all of the flow to the well, the head is 3260-900 = 2360 ft = 1015 psi. At ∿ 196°C (385°F) this is well above the saturation curve for pure water, and implies that the fluid source is liquid, not steam. The chloride content of the well was the same as that at Coso Hot Springs.[14] The pieziometric head at both Coso Hot Springs and CGEH-1 is approximately 3500 ft above sea level.

While the mud losses are not quite so enormous in the two zones above 3200 ft they are still appreciable. One fracture was encountered at ∿ 2750 feet where more than 2100 bbl (∿ 88,000 gal) of mud and various materials were lost during drilling. The shallowest and hottest zone was at 2060 ft, where more than 900 bbl (37,800 gal) were lost. It is also noteworthy that at 1900 ft a water influx of at least 60 gal/min occurred while drilling under pressure with air. A switch to mud was made at that point, hence there is no indication of how much the formation could flow from that zone.

Several water samples have been taken during the course of the well equilibration and during the well tests. These water samples probably came from the zone near the bottom of the casing. It is also likely that there has been contamination of the fluid samples by drilling mud and other foreign material. It is unlikely that we have sampled the uncontaminated reservoir fluid. On the other hand, it is equally unlikely that the source of fluid near CGEH-1 is at an appreciably higher temperature than observed in this well [<199°C (390°F)]. All of the sand, clay, and fluid samples that were taken during the recent work are being held at LBL.

Although numerous problems were encountered during the drilling of CGEH-1, it has proved valuable in the initial hydrogeological evaluation of the Coso Hot Springs area. Further drilling in the area is necessary to provide a more complete evaluation, and the Coso Hot Springs KGRA shows promise for development of power production or direct heat utilization.

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