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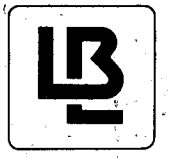
Earth Sciences Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California

June 1978



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STATIC DOWNHOLE CHARACTERISTICS OF WELL CGEH-1 AT COSO HOT SPRINGS, CHINA LAKE, CALIFORNIA*

by

C. Goranson

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ABSTRACT

A series of measurements has been made in the exploratory well CGEH-1 at Coso Hot Springs. The temperature measurements provide estimates for the thermal equilibration of the well and indicate that the fractures intersecting the well have different temperatures. The hottest fractures are in the upper-cased portion of the well. Downhole chemical sampling suggests that the borehole still contains remnants of drilling materials. The well has never been extensively flowed at this time.

The China Lake Naval Weapons Center is located in southeastern California as shown by the star in Figure 1. The Coso Hot Springs KGRA is located within the Naval Weapons Center (NWC). The KGRA is part of a large volcanically active region associated with a ring-fracture zone.(1) To the west of Coso Hot Springs is a line of rhyolite domes, and near these domes the exploratory well CGEH-1 was drilled. The well was completed on December 2, 1977 at the location indicated in Figure 2. The total depth is 4845 ft., and the hole is cased to a depth of 3488 ft. with 7 in. diameter pipe.(2) The geological formation is primarily granitic rock with many fractures intersecting the well bore. The gological summary shown in Table 1 was provided by Galbraith.(3)

One pressure and six temperature profiles have been measured since the well was drilled. In addition, fluid sampling has been done by both Lawrence Berkeley Laboratory (LBL) and United States Geological Survey (USGS). One of the temperature profiles was obtained in cooperation with the Sandia Laboratory Albuquerque (SLA). Figure 3 shows the LBL temperature profiles obtained with both a Gearhart-Owens (GO) continuous surface readout tool and a Kuster clock-driven downhole recorder.(4) The Sandia profile is very similar to survey #5. The temperature surveys that were made using the GO tool represent temperatures obtained after a five-minute wait at each recording stop. Although this procedure was time consuming, it ensured that the tool was in equilibrium when the reading was taken. Since the Kuster tool is operated by a downhole clock drive with limited operating time, the stops could not be made as often or for as long an interval as the continuous recording tool from Gearhart-Owens.

Figure 3 also shows the drilling rate and amount of mud lost during drilling. The regions of highest mud loss are interpreted as major fracture zones intersecting the well bore. The dip of the fractures is not known at

this time. The nonuniform heating in some portions of the well bore are interpreted as being due to the lower thermal conductivity of the drilling materials and material used to prevent caving during drilling. The latter materials included cement, mica, etc. The constant temperature portion of the profile (about 280°F) is a steam column above the water level. The latter increased during the measurements from ∿ 905 ft. below the Kelly bushing to about 895 ft. due to the thermal expansion of the water column as it heated up. The complete data for the static temperature and pressure profiles are given in the appendix.

Three samples of well bore fluid were obtained using a Kuster 1000 cc sampling tool. Two samples were taken at the 2740 ft. depth. A twenty-four hour period occurred between these two samples. The samples obtained at different depths show somewhat different chemical properties. Field pH was obtained by calibrating the pH meter with buffers at the site. The tool was cooled to ambient temperature in an ice bath, and the samples were then removed to plastic bottles where the pH was measured. The chemical analyses, using the atomic absorption method, were performed by GHT Laboratories in Brawley, California. The results are given in Table 2.

It can be noted that there are large discrepancies in concentration of several components (HCO_3, SO_4, Ca, SiO_2) between the two elevations. The Ca and SO_4 concentrations at 4800 ft. are 57% and 55%, respectively, of those at 2740 ft. However, from the inverted solubility of $CaSo_4$ it would be expected that the concentration of these ions would be greater, rather than smaller, at the cooler bottom-hole temperature.

Another discrepancy appears in the SiO_2 inferred temperatures. The bottom-hole concentration of 201 mg/l of SiO_2 yields a temperature of 338°F, in fair agreement with measured bottom-hole temperature of 345°F. The concentration at 2740 ft. yields a SiO_2 temperature of 194°F.[5]

Since the well has not been flowed for any significant length of time (it was airlifted for about two hours after completion), it is reasonable to assume the silica numbers reflect possible residual drilling materials in the well. A well test is planned for this well and additional wellhead and downhole chemical sampling will be carried out at that time.

Summary

Temperature and pressure profiles were obtained in the Coso exploration well CGEH-1 after the well was completed. The temperature profiles show anomalous zones of heating during the thermal equilibrium process. The anomalous zones coincide with locations of large losses of drilling materials. The temperature in the region from 2000 to 3500 ft. is at the highest temperature to date, $\approx$ 380°F.[6] The bottom-hole temperature is lower, $\approx$ 345°F, indicating that the fractures at the bottom of the well have cooler, not hotter, water in them. The well has not yet been tested, but the downhole temperature has not increased during the thermal equilibration of the upper zone. The chemical samples suggest that the wellbore is not yet free of drilling materials, hence the SiO_2 inferred temperature is still uncertain.

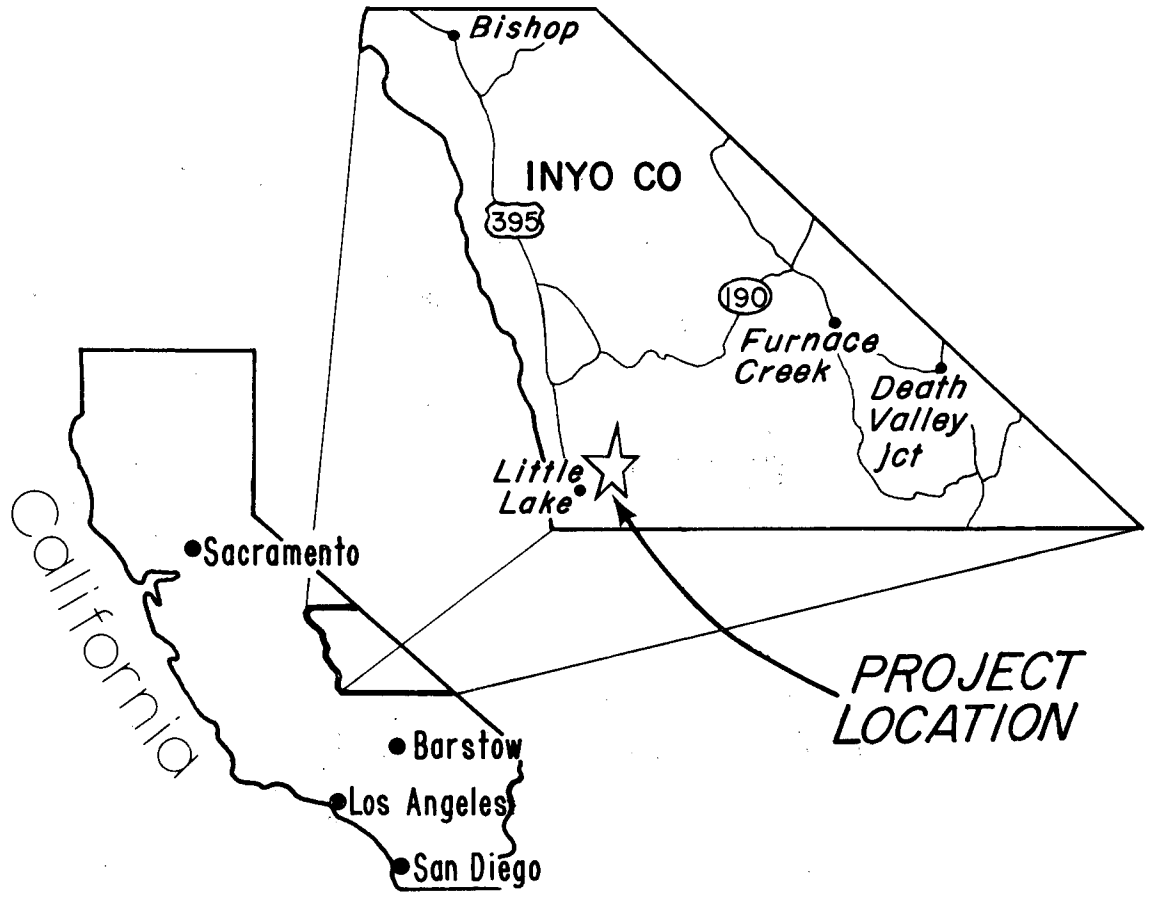

Figure 1. The location of the China Lake Naval Weapons Center.

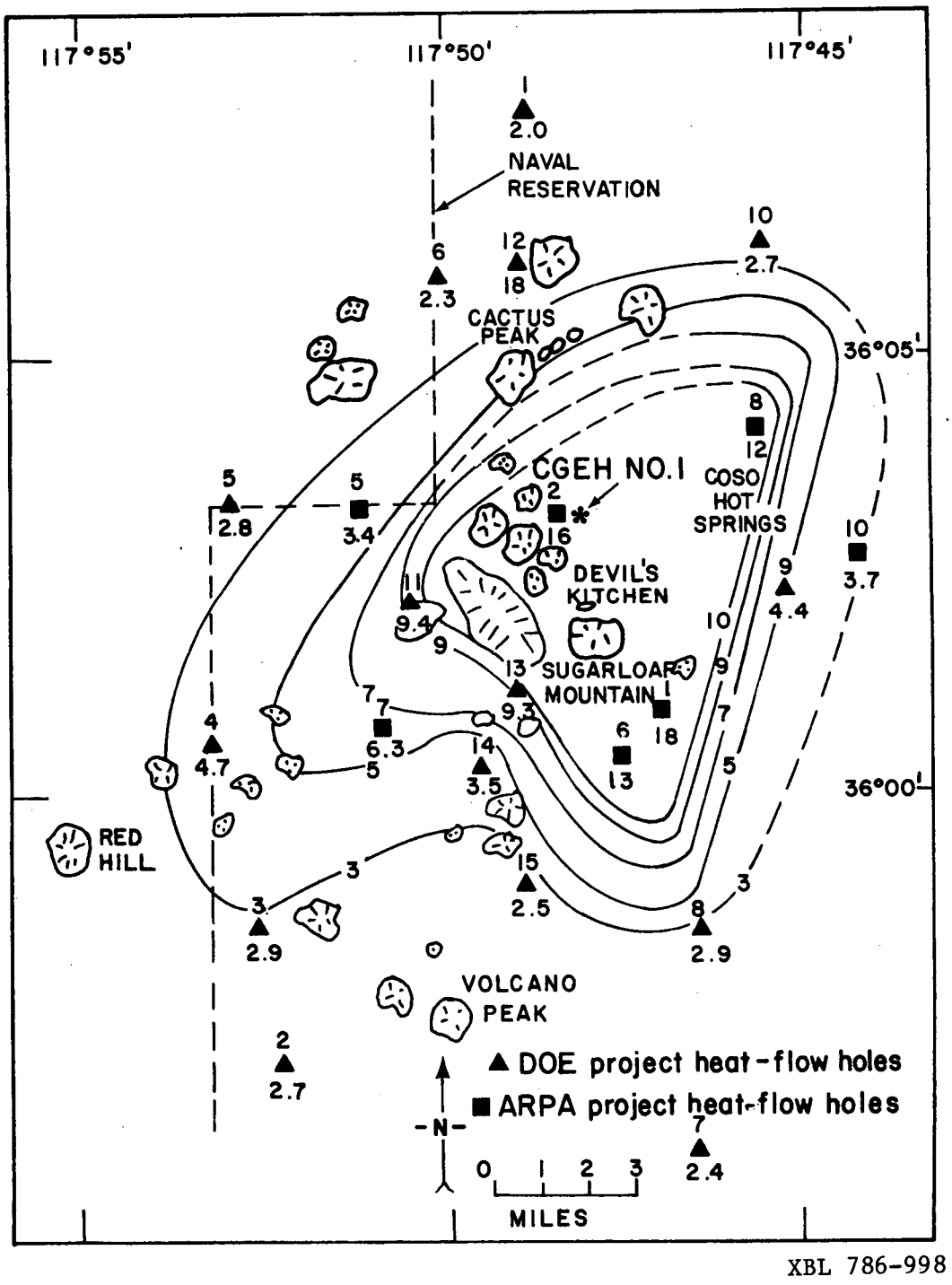

Figure 2. Generalized map of thermal anomalous region and CGEH No. 1 well location. The numbers in the figure identify the hole and (below) give the heat flow in HFU.

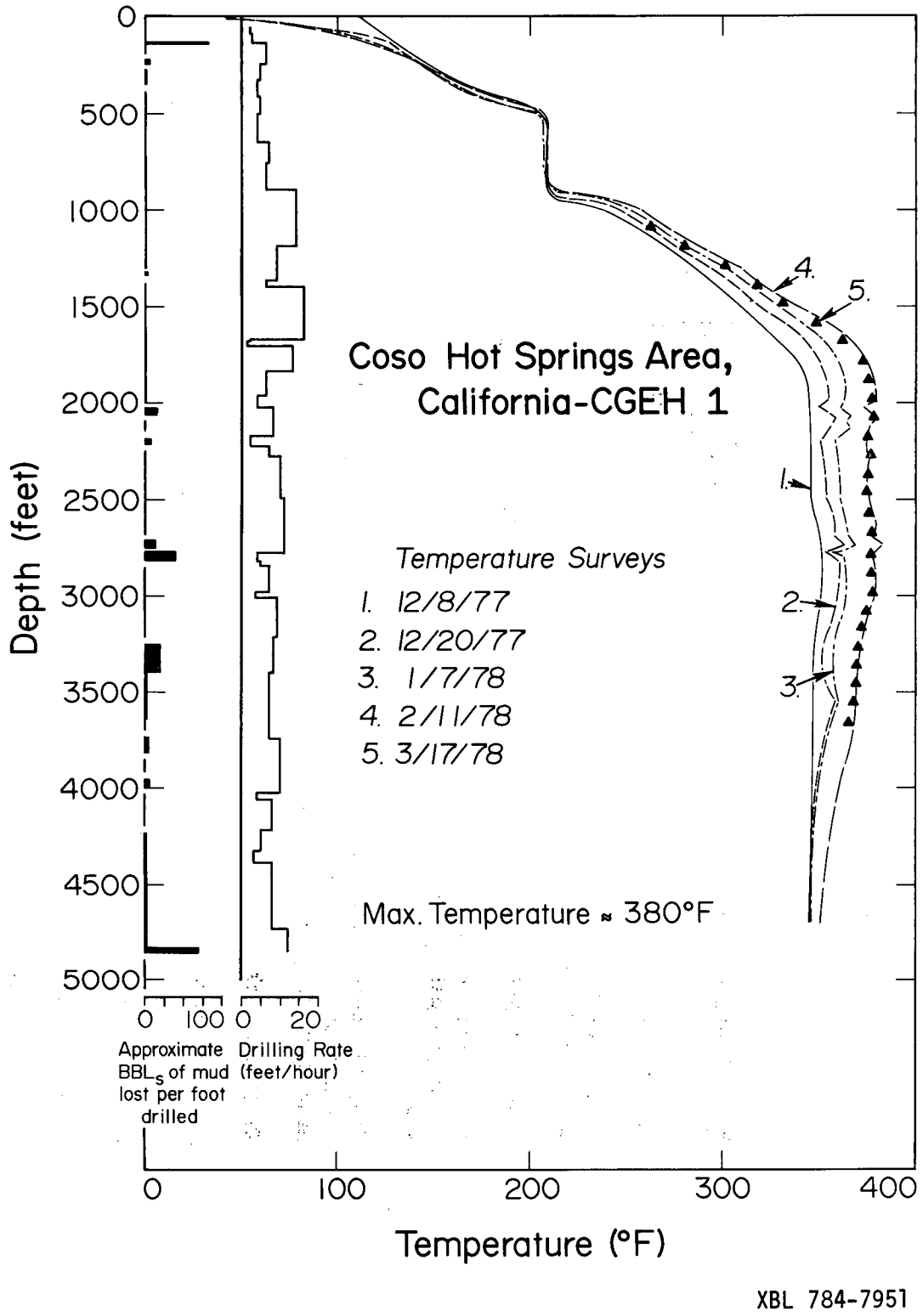

Figure 3. Temperature surveys in the static steam and water column at Coso Hot Springs.

Table 1. The geological summary obtained from cores and cuttings during the drilling of CGEH-1.

(All measured from G.L. Coso Geothermal Exploratory Hole #1)

(CGEH-1)

DEPTH	ROCK TYPE	REMARKS
Btm Conductor Pipe (47')		
47-400'	Hard granitic rock	Lost 250 bbl mud 114-117 ft. Lost circulation 224-239 ft.
400-410'	Igneous dike	Lost mud 401-404'
410-583'	Hard granitic rock Set surface pipe (13 3/8")	
583-600'	Hard granitic rock	No lost circulation
969-1229'	Fault zone containing igneous dikes and metasediments, some clay	
1229-1347'	Granitic rocks with some alteration (clay) set Intermediate pipe (9 5/8")	Lost some mud
1347-1378'	Granitic rocks	Changed to air @ 1378'
1378-1479'	Granitic rocks, fractured	Water production increased from 2 bbls/hr to 20 bbls/hr
1479-1539'	Metasediments	
1539-1549'	Gouge zone with clay	
1549-1589'	Metasediments	
1589-1619'	Gouge zone with clay	

(continued)

Table 1
(continued)

DEPTH	ROCK TYPE	REMARKS
1619-1660'	Fractured granites Switched to mud	Hole Making 1520 bbls wtr/hr hole caving; clay & gravel running into hole
1660-1686'	Granitic rock Switched to air	Squeezed hole 1686 to casing
1686-1854'	Granitic rocks	
1854-1893'	Clay & fine grain sand Switched to mud	Making 80-90 bbls wtr/hr Previous cement plug caved in.
1893-1969'	Fractured granitic rocks	1900-1950 lost 150 bbls/mud
1969-2049'	Shearing, fractured granitic Rock with quartz veining	Lost circulation Lost 600 bbls mud at 2039
2049-2100'	Fractured granitic rocks	Lost about 300 bbls/day
2100-2746'	Fractured white granite Layered with zones of granodiorite	2100-2208 lost 300 to 400 bbls mud while drilling.
2746-2801'	Metasediments and highly fractured granite	2746 lost circulation. Lost about 1500 bbls fluid. Unable to gain full returns. Had to run cmt. plugs.
2801-4450'	Fractured white granite with some granodiorite Set 7 in. casing at 3488	3240-3367 lost 2000 bbls mud 3367-3532 lost about 300 bbls mud 3532-4022 losing mud during drilling 4022-4450 lost about 300 bbls mud/day
4450-4530'	Pink granite	
4530-4824'	Fractured white granite	Lost complete returns at 4821' drilled to 4824' without returns. Lost 1400 bbls fluid.

Table 2. The chemical analysis for the downhole samples from Coso CGEH-1.

IDENTIFICATION:	3/17 COSO #1 #569 2740 ft. 3/18 COSO #2 #570 2740 ft. 3/18 COSO #3 #571 4800 ft.		
	Results of Analysis		
	#1	#2	#3
Bicarbonates (HCO_3)	64 Mg/L	62 Mg/L	168 Mg/L
Sulfate (SO_4)	172 Mg/L	150 Mg/L	89 Mg/L
Chloride (Cl)	2470 Mg/L	2550 Mg/L	2300 Mg/L
Sodium (Na)	1460 Mg/L	1500 Mg/L	1420 Mg/L
Potassium (K)	145 Mg/L	139 Mg/L	154 Mg/L
Calcium (Ca)	131 Mg/L	114 Mg/L	70 Mg/L
Boron (B)	54 Mg/L	66 Mg/L	65 Mg/L
Magnesium (Mg)	2.6 Mg/L	2.3 Mg/L	1.7 Mg/L
Silica (SiO_2)	37 Mg/L	41 Mg/L	201 Mg/L
Lithium (Li)	9.1 Mg/L	9.6 Mg/L	10.2 Mg/L
pH	5.3	5.2	5.6
Total Volume	585 Ml	875 Ml	910 Ml
Σions $\equiv$ TDS	4545	4644	4479
Field pH	5.7	5.7	5.4

REFERENCES

1. Geothermal Exploration Techniques: A Case Study. Joint authors: The Center for Energy Studies, UTD. EPRI Research Report ER-680, (February 1978), p. 32.

2. COSO Geothermal Exploratory Hole No. 1, CGEH #1 Completion Report, NV/0655-04, U.S.D.O.E./NVO, in print.

3. R. Galbraith, private communication.

4. A. Graf, Lawrence Berkeley Laboratory, prepared the data for this figure.

5. Harold Papazian, Lawrence Berkeley Laboratory, interpreted the chemical data.

6. J. Wang, Lawrence Berkeley Laboratory, has calculated the final equilibrium temperature to be about 390°F based on line-source heat flow model.

APPENDIX:

TEMPERATURE AND PRESSURE PROFILE DATA FOR COSO CGEH-1

COSO HOT SPRINGS

CGEH #1

TEMPERATURE SURVEYS*

SURVEY #	DATE	COMMENT
1	12/ 8/77	= 250 foot incremental survey
2	12/20/77	100 foot steps maximum temp. = 360.9° F
3A	1/ 6/78	Tool failed 3,820 feet
3B	1/ 7/78	Maximum temp. = 368° F
4A	1/19/78	Tool failure 2,000 feet
4B	1/19/78	LBL tool failed 2,000 feet
		Sandia tool failed 4,700 feet
5	2/11/78	Maximum temp. 382° F but tool essentially failed - somewhat questionable temperatures.
6	3/16/78	Kuster tool maximum temperature 192.55° C = 378.6° F
7	3/17/78	Pressure Survey - Kuster tool

* All depths measured from 6 feet above ground level.

CGEH #1 SURVEY #1

12/8/77

DEPTH (ft.)	TEMPERATURE (^{o}F)
0	112
250	147.5
340	-
350	160.1
360	-
500	207.6
750	208.6
920	210
935	214.6
1000	239.5
1250	278.8
1410	300
1500	309
1600	320
1680	330
1800	340
2000	345
2100	-
2500	345
2660	350
2830	352
3000	351
3500	348
4000	345
4405	347

CGEH #1 SURVEY #2

12/20/77

DEPTH (ft.)	TEMPERATURE (^{o}F)
0	42.6
100	119.1
200	137.8
300	153.4
400	169.1
500	203.9
540	209.0
600	209.5
700	209.5
800	209.5
900	209.5
910	212.3
950	230.2
1000	246.5
1100	264.1
1200	278.0
1300	296.0
1400	309.2
1500	319.0
1600	333.6
1700	344.7
1800	352.0
1900	353.7
1950	356.0
2000	355.0
2025	350.0
2100	358.0
2200	351.4
2300	353.6
2400	354.0
2500	354.1
2600	357.6
2640	359.9
2700	358.4

CGEH #1 SURVEY #2 (Cont'd)

12/20/77

	DEPTH (ft.)	TEMPERATURE (^{o}F)
	2730	360.9
	2739	362.0
	2751	360.0
	2780	350.0
	2800	356.2
	2823	360.1
	2838	360.9
	2900	359.6
	3000	358.7
	3100	357.5
	3200	354.1
	3300	352.0
	3400	352.1
	3500	353.9
	3570	357.9
	3600	356.3
	3700	353.3
	3800	351.6
	3900	350.3
	4000	348.9
	4100	348.3
	4200	347.7
	4300	347.3
	4400	347.1
	4500	346.6
	4600	346.2
	4700	345.7
	4800	345.8
T.D.	4850	345.5

CGEH #1 SURVEY #3A

1/6/78

DEPTH (ft.)	TEMPERATURE (^{o}F)
100	109.6
200	132.6
400	167.3
500	208.3
600	208.5
700	208.6
800	208.7
880	208.9
885	208.9
890	208.9
892	209.6
895	210.1
900	213.9
950	239.2
1000	251.2
1100	268.8
1200	283.3
1300	301.4
1400	315.6
1500	326.6
1600	342.1
1700	353.6
1800	361.2
1900	363.3
2000	364.2
2100	366.5
2200	360.1
2300	362.2
2400	362.2
2500	362.2
2600	365.6

CGEH #1 SURVEY #3A (Cont'd)

1/6/78

DEPTH (ft.)	TEMPERATURE (^{o}F)
2690	368.0
2700	366.4
2736	370.0
2800	364.7
2878	368.3
2900	366.7
3000	365.9
3100	364.4
3200	361.2
3300	358.8
3400	358.9
3500	359.1
3600	360.1
3700	357.4
3800	355.5
3820	Tool Failed

CGEH #1 SURVEY #3B

1/7/78

DEPTH (ft.)	TEMPERATURE (^{o}F)
100	111.8
200	133.3
300	150.3
400	166.4
450	187.3
500	207.6
600	207.8
700	207.9
800	208.0
880	208.1
885	208.0
890	208.0
892	208.8
893	209.1
900	214.3
950	238.1
1000	250.0
1100	267.6
1200	282.0
1300	300.5
1400	314.4
1500	325.9
1600	340.7
1700	352.2
1800	359.8
1900	361.7
2000	362.6
2030	360.9
2075	365.6
2080	365.3
2100	364.6
2135	365.0
2200	358.1
2300	360.1

CGEH #1 SURVEY #3B (Cont'd)

1/7/78

DEPTH (ft.)	TEMPERATURE (^{o}F)
2400	360.2
2500	360.4
2600	363.5
2690	365.8
2700	364.3
2735	368.0
2745	367.5
2750	365.4
2770	356.5
2800	362.5
2340	366.5
2860	365.3
2900	364.7
2950	364.7
3000	363.7
3100	362.1
3200	359.0
3300	356.7
3400	356.4
3500	357.1
3560-3580	359.4
3600	358.1
3700	355.4
3800	353.6
3900	352.0
4000	350.5
4100	349.6
4200	348.9
4300	348.1
4400	347.6
4500	346.8
4600	346.2
4700	345.6
4800	345.4
4850	345.1

CGEH #1 SURVEY #4A

1/19/78

DEPTH (ft.)	TEMPERATURE (^{O}F)
100	109.8
200	131.0
300	148.7
400	166.3
450	203.4
500	206.8
600	206.9
700	207.0
800	207.1
890	207.1
900	216.2
950	239.5
1000	251.5
1100	268.7
1200	283.5
1300	301.7
1400	316.4
1500	328.5
1600	343.5
1700	355.0
1800	362.9
1900	364.7
2000	Tool Failed

1/19/78

DEPTH (ft.)	FREQUENCY (KHz)	TEMPERATURE (^{O}F)
1000	24.354	247.0
1100	25.125	264.5
1200	25.825	280.0
1300	26.700	299.0
1400	27.400	314.0
1500	27.960	326.0
1600	28.690	341.5
1700	29.235	353.5
1800	29.610	363.0
1900	29.720	364.0
1985	29.835	368.5
2000	29.760	365.5
2060	29.855	
2080	29.877	
2100	29.853	
2200	29.580	
2300	29.650	
2400	29.654	
2500	29.665	
2600	29.802	
2680	29.910	
2690	29.865	
2700	29.850	
2720	29.925	
2730	29.977	
2735	30.000	
2800	29.786	
2900	29.858	
3000	29.812	
3100	29.734	
3200	29.597	
3300	29.487	
3400	29.470	
3500	29.472	
3600	29.498	

CGEH #1 SURVEY #4B (Cont'd)

1/19/78

DEPTH (ft.)	FREQUENCY (KHz)	TEMPERATURE (°F)
3700	29.379	
3800	29.297	
3900	29.221	
4000	29.150	
4100	29.100	
4200	29.058	
4300	29.018	
4400	28.990	
4500	28.948	
4600	28.911	347.0
4700		Tool Failed

CGEH #1 SURVEY #5

2/11/78

DEPTH (ft.)	TEMPERATURE (^{o}F)
0	48.8
100	104.8
200	130.5
300	150.8
400	166.8
500	207.1
600	207.4
700	207.4
800	207.6
882	210.3
900	224.2
950	244.3
1000	255.6
1100	273.3
1200	289.4
1300	308.7
1400	324.7
1500	338.0
1600	354.5
1700	367.1
1800	375.6
1900	378.0
1990	380.0
2000	378.4
2100	379.5
2200	373.1
2300	374.9
2400	374.7
2500	375.1
2600	378.3
2680	380.5
2700	379.2
2740	382.3
2800	377.0

CGEH #1 SURVEY #5 (Cont'd)

2/11/78

DEPTH (ft.)	TEMPERATURE (^{o}F)
2847	380.7
2890	380.3
2900	379.5
3000	377.6
3100	375.4
3200	372.1
3300	369.3
3400	368.9
3500	368.4
3600	368.5
3700	365.6
3800	363.6
3900	361.6
4000	359.8
4100	358.5
4200	357.5
4300	356.4

Tool failure, but was able to get further somewhat questionable temperatures.

4650	352.6
4700	352.3
4800	351.9
4835	351.7

CGEH #1 SURVEY #6

KUSTER TOOL S/N KT-B 10279

3/17/78

DEPTH (ft.)	TEMPERATURE (^{o}F)
900	214.0
1000	244.0
1100	264.3
1200	281.4
1300	301.2
1400	317.4
1500	332.8
1600	349.2
1700	363.1
1800	373.7
1900	376.4
2000	378.1
2100	378.6
2200	375.6
2300	374.3
2400	374.0
2500	374.0
2600	375.4
2700	378.6
2800	378.3
2900	377.0
3000	378.3
3100	375.6
3200	373.2
3300	370.5
3400	368.9
3500	368.0
3600	366.9
3700	366.1

COSO HOT SPRINGS

PRESSURE SURVEY SURVEY #7

3/17/78

KUSTER PRESSURE TOOL
S/N KPG 15859 0-6100 psig

DEPTH (ft.)	PRESSURE (psig)
1000	66.3
1200	143.7
1400	223.2
1600	299.7
1800	382.3
2000	455.65
2200	529.05
2400	602.4
2600	678.9
2800	755.4
3000	828.7
3200	905.2
3400	981.7
3600	1064.2
3800	1134.6
4000	1211.0
4200	1287.5

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