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THE HONEY LAKE GEOTHERMAL PROJECT
Lassen County, California

FINAL TECHNICAL REPORT

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by
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1. INTRODUCTION

This report is the final technical report on the Honey Lake (California) Geothermal Project. It encompasses the drilling, completion and testing of deep well WEN-2, the second of two wells drilled by GeoProducts Corporation under the U.S. Department of Energy's (DOE) User Coupled Confirmation Drilling Program (Contract #DE-FC07-81ID12262). The report covers the period March 1 to August 31, 1984. A previous Interim Progress Report (August 1982) submitted to DOE covered the drilling and testing of WEN-1.

The Honey Lake Geothermal Project is a hybrid electric power project being developed by GeoProducts Corporation of Oakland, California. DOE, through its Idaho Operations Office is providing cost share assistance on both wells in an amount determined by the success of the wells.

The power generation facilities portion of the project is being engineered by the Dow Engineering Company (Houston). The plant will utilize the area's moderate temperature geothermal fluids confirmed by the two wells drilled under this contract, and wood fuel, procured from nearby private and national forestlands, in a hybrid power cycle to generate electric power. The complete project will require a minimum three production wells and an injection well.

The project is being developed within the Wendel-Amedee Known Geothermal Resource Area about 25 miles east of Susanville, California on County Highway 320 (See Figures 1 and 2). The project is located within a leasehold of some 10,000 acres of property owned and leased by GeoProducts. The deep exploration program conducted on the prospect was premised on the existence of a fault which crosses part of the leasehold and gives rise to surface features including hot springs and tufa linears. The drilling of WEN-1 in 1982 confirmed the existence of this fault at depth and that it had a northwesterly dip in the range of 65-75°. The fault was encountered at a depth of 5,304 feet, about 300 feet below the top of a highly fractured granite formation.

The drilling strategy adopted for WEN-2 was to step out about 0.8 miles from WEN-1 in a southwesterly direction and about 0.5 miles west of Wendel Hot Springs (Figure 3). The drilling target was the same or related fault structures encountered previously in the drilling of WEN-1, and it was expected that the target horizon might be slightly deeper than in WEN-1.

Figure 1. Project Location

Figure 3. WEN-2 Site Location

2. PERMITS AND APPROVALS

WEN-2 was drilled on a 320 acre BLM split estate lease held by GeoProducts. Leasehold boundaries are shown in Figure 2. WEN-2 was drilled at the location designated as Site A in Figure 2.* Well drilling and test permits were obtained for both drill sites shown on the BLM lease and for three additional well sites (not shown) located on GeoProducts fee property in adjacent Sections 14 and 15. The third production well and the project injection well will be sited at two of these remaining four permitted well locations.

Permits were obtained from the Lahonton Regional Water Quality Control Board (fluid disposal), the Lassen County Planning Commission (land use), and the California Division of Oil and Gas and the BLM (drilling permits for private and BLM mineral reserved lands, respectively).

* The permitted designation of the Well is #24-23 but "WEN-2" will be used throughout this report.

3. SITE DEVELOPMENT

The drill site for WEN-2 was located immediately off Antola Road (Figures 2 and 3) in Section 23 about 1.75 miles west of Wendel. The drilling pad was about 275 feet square and, because of the very high water table, was constructed about 30-36 inches high with coarse aggregate capped with finer material. The unlined sump, initially measuring approximately 200' x 20' x 4', had to be doubled in size later because of the limited capacity due to the high water table. Later when the well was lifted an auxiliary sump and connecting channel to the north of the pad also had to be constructed.

A highly productive water well was drilled on the northeast corner of the pad to a depth of 230 feet and an 8 inch plastic slotted liner and gravel pack was run back to the surface. The water quality was less than 100 ppm TDS. Three inch PVC pipe was run from the water well to the rig water storage tank. The water well contractor also drilled a 26 inch conductor hole to a depth of 320 feet. A 20 inch conductor pipe was set to 309 feet.*

Site electric power was obtained from the rig diesel electric system. A telephone line was run in a covered trench about 600 feet from the main cable along Antola Road.

* Unless otherwise noted, all depth measurements used herein will be from ground surface which was 20 feet below KB.

4. DRILLING HISTORY

The drilling on WEN-2 started in the evening of April 9, 1984 and proceeded for the next 35 days, to May 14, according to the drilling time profile shown in Figure 4.

Separate sections of this report cover the mud program, the geologic formations encountered, and geophysical log interpretations. The bit record is shown in Appendix A. A general overview of the drilling period is presented here.

The 20 inch conductor casing in WEN-2 was set to 309 feet compared to 95 feet in WEN-1. A casing split had occurred in WEN-1 at depth 235 arousing widespread, but unfounded concern about contamination of nearby fresh water drinking and recreational supplies. To alleviate similar concern about WEN-2, the conductor casing was run about 70 feet below the fresh water zone which, together with the surface casing, would provide a double wall protection through the fresh water aquifer zone which is in the approximate interval 150-240 feet. During the drilling of the WEN-2 conductor hole, the troublesome lost circulation zone which on WEN-1 had caused a 3-day down time at depth 209 was not encountered.

Throughout the drilling operation, directional surveys and bottom hole temperatures were taken at nominal 150 foot intervals. Due

FIGURE 4
DRILLING TIME PROFILE

to the proximity of the well location to the east and south boundary of the BLM lease, it was important to insure that the hole did not encroach beyond the lease boundaries.

At depth 1510, drilling was halted, and preparations were made for logging and running casing. Dual induction and temperature logs were run by Schlumberger and the 17½ inch hole further conditioned for running the casing. The 13 3/8 inch surface casing (61 ppf, K-55, BT&C) was set to 1499 feet and cemented with complete returns and no problems. The BOP stack was changed in preparation for drilling the 12½ inch hole below the surface casing (Figure 5).

Because the hole was drifting constantly towards the southeast and the lease boundaries, at depth 1604 a Dyna Drill was used to bring the hole back around to the northwest. At depth 1777 drilling resumed with the conventional bottom hole assembly.

Good progress was made through the next several days with time diverted from the drilling only for bit changes, surveys, hole conditioning, and rig servicing. At depth 3810, approximately 150 bbls. of mud volume was lost. The lost circulation conditions were quickly cured with an LCM pill and drilling resumed. The geology through this interval consisted of clay rich tuff and volcanic mudflow. Subsequent lost circulation zones occurred at

Figure 5. BOP Stack

depth 4388 when 200 bbls. were lost, depth 4541 (250 bbls.), and depth 4602 (75 bbls). These lost circulation zones in the conglomerate above granitic basement had not been encountered in the drilling of WEN-1 and, using that experience as a guide, had not been expected this high up in WEN-2. The possibility was then entertained that the hole may be encountering the periphery of the same general fault system associated with WEN-1, but WEN-2's location was such that the fault system was possibly being penetrated at a shallower depth in the conglomerate above the granite. The bottom hole temperature recorded with a maximum reading thermometer during a survey at depth 4457 was 152°F. Given the possibility of being in or near the drilling target, the decision was made to conduct a temperature buildup for several hours and to try to establish an equilibrated bottom hole temperature at depth 4630 as a basis for deciding to run the 9-5/8 inch casing string. Temperatures recorded during the buildup on May 3 were as follows:

8:15 a.m.	172°F
9:00	175°F
10:15	177°F
12:15 p.m.	180°F
1:30	181°F
2:35	185°F
4:30	188°F
6:00	191°F

The projected equilibrated temperature from these readings lay in the 240° - 250° range, near the BHT from WEN-1. The decision was made, therefore, to set the 9 5/8 inch casing string while trying to preserve that part of the hole below 4350 feet where the lost circulation zones were encountered. If even more promising resource data were encountered deeper, presumably in granitic basement, a liner could be set through this part of the hole, but the resource data in hand for this section of the hole appeared similar to that encountered in WEN-1.

The following logging sequence was run by Schlumberger at depth 4630 and the results are discussed in Section 8:

Sonic with gamma ray

Dual Induction

Compensated Neutron

Bulk Density with gamma ray

Temperature

A sand plug was ordered to protect approximately 300 feet in the bottom part of the hole. With the drill pipe initially set at 4578 feet, three stages of sand (totaling 293 CF) were pumped in the hole, each time displaced with about 360 CF of mud. After waiting on the sand, the run back in the hole went clear to bottom. With the drill pipe again set to 4540 feet the remaining 110 CF of sand was pumped in, displaced, and just as rapidly as

before disappeared. An LCM pill was placed in the hole and circulation was partially regained while new sand was ordered. With the drill string set at 4545 feet two 73 CF sand plugs were pumped in, displaced with water, and in each instance also disappeared. A 110 CF sand plug was mixed in a thick slurry with 77 bbls of water and pumped in. After three hours it appeared that this plug may have partially held at 4530 feet. An additional 40 CF of sand was pumped in in a thick slurry and tagged at 4499 feet. Another 80 CF plug was pumped in and tagged at 4327 feet, indicating a set plug of about 300 feet. The hole was circulated 100 feet above the top of the plug, bottoms up with a 70 bbl gel sweep, and preparations made to run casing.

The 9 5/8 inch casing (2320 feet of N-80, 40 ppf, BTC and 703 feet of K-55, 36 ppf, BTC) was hung inside the surface string at depth 1295, providing a 204 foot overlap, and set to depth 4318. The final well construction profile is shown in Figure 6.

Considerable difficulty was encountered in cementing the 9 5/8 inch casing string. Two cement baskets were placed near the bottom of the string, a DV collar was set at depth 3804, and later an R.T.T.S. tool was also used. Three cementing operations, consuming about 46 hours of time, were required before returns were established and the system successfully pressure tested at 1250 psi. Subsequent pressure tests were made successfully at

Figure 6. Well Construction Profile

the lap joint, the DV collar and at the float collar (depth 4265). The sand was again tagged, this time at depth 4407 indicating the loss of at least 80 feet of plug during the casing/cementing operations.

During the casing and cementing operations, an air compressor was brought in and was used to provide an aereated water drilling system for the remainder of the hole. As the well was blown, the hole was making several hundred gpm and posed a continuing water management problem. The intent was to continue drilling with the aereated water system, at least to the 5200-5500 foot depth where, using WEN-1 as a guide, the fracture system could be extended into solid granite.

Over the next two days after drilling resumed, the hole was deepened about 400 feet to depth 5030. Obtaining cutting samples became both difficult and hazardous because of the steam and hot water, but increasing granite cuttings, as expected, became evident at about 4860 feet suggesting the possibility of being able to extend the production zone of the well into the granite formation.

During the pumping of a gel sweep pill at depth 5030, the drill pipe became stuck. No circulation could be achieved and no movement in the drill pipe, either vertically or rotationally, could be induced.

A manual back-off became the only alternative and during the pull out, the well had to be periodically killed with cold water indicating that wherever the pack off was located, considerable fluid production existed above it. At complete pull out, it was found that part of the bottom hole assembly (8 3/4 in bit, near bit reamer, bit sub and float, stabilizer, and 4 drill collars) had been left in the hole, and that 5 drill collars had been recovered. The top of the "fish" was at depth 4890.

The decision was made to test the well's performance at that point with an 8-hour flow test. A blooie line was rigged up to the banjo box and the well opened.

During the flow test, the well heated up faster than had WEN-1 during a similar flow period, reaching 239°F after approximately two hours. A specific capacity of 9.6 gpm/psi was calculated for a flow rate of 480 gpm.

Given the options of conducting a problematic fishing operation in a producing zone, sidetracking the well and drilling deeper, or accepting the resource data in hand, it seemed prudent to terminate the drilling operation. A run back in the hole with a new bit went to depth 4871, which was 19 feet above the fish. The hole was open throughout and so rig down operations commenced. The rig was released at 6 p.m., May 14th.

5. MUD PROGRAM

A Gel-lime system was used through the first 1,525 feet of the hole. Viscosity was maintained throughout at 36-40 (sec./qt.). The mud weight was 8.8-9.0 (lb./gal.) to about 1,000 feet and kept at 8.8 or less to 1,530 feet. One sack of caustic per tour was also used for pH control. Bicarbonate and soda ash was used to treat out the cement for the surface string.

To depth 4,630 a basically Gel-lignite caustic system was used. Multiplex was used (one bucket per tour) below 2,525 ft. to reduce gel strength and to lower fluid loss. Viscosity was maintained at 40-45 through this section of the hole and mud weight held at 8.8 or less. Nutshell, sawdust, and kwikseal was used to cure lost circulation zones at 3,810, 4,388, 4,541 and 4,602 ft.

To total depth the drilling medium was changed to an aereated water system. Corrosion inhibitors (Hib A) were added regularly. Caustic and lime was used to raise the pH (maintain 11-12) and gel-lime sweeps were run on every third connection to keep the hole clean. For most of this interval the hole was producing about 600 bbl/hr.

A mud engineer was provided by the service company (PROFCO) and was on site throughout the drilling operation.

6. GEOLOGY

A sequence of volcanic rocks were penetrated in WEN-2 from approximately 300 - 4395 feet which included flows, tuffs, tuffaceous sediments, volcanic mudflows and conglomerates. Flows were relatively sparse in the section occurring almost exclusively above 2460 feet as discrete, less than 150 feet thick, variously altered and fractured units of andesitic-basaltic composition. Altered tuff and dominantly monolithologic volcanic mudflow/conglomerate comprise the majority of the sequence drilled in WEN-2.

The tuffs penetrated in WEN-2 were highly variable in type including pumiceous, lithic and crystal rich varieties, both layered and massive and ranging in color from white to red. Important accessory minerals included pyrite and euhedral zeolite, probably stilbite or laumontite.

The mudflows in WEN-2 are primarily comprised of fresh to highly altered, aphanitic andesite - basalt in a matrix of smaller fragments and clay (probably altered ash).

An excellent sample (approximately 6 x 4 x 2 inches) of a portion of the mudflow section around 4300 feet was obtained from one of the reamers during a trip out at 4362 feet. This rock consisted of well rounded to sub-angular black basalt (some vesicular) fragments from 1/4 to 2 inches across in a matrix of greenish

(chloritic) sand, silt and clay. The sample was well indurated and cut by very distinctive euhedral zeolite veins up to 1/8 inch which, when viewed under the microscope, revealed open spaces of up to 1/16 inch. This type of veinning (partial fracture filling) probably accounted for the lost circulation experienced around 3800 feet.

Below the volcanic rocks a conglomerate of sedimentary origin was drilled from 4395 - 4860 feet. This unit is a multilithologic well rounded, moderately sorted, probably alluvial sediment comprised of white quartzite, black aphanitic volcanic, chert, acidic intrusive and siliceous metasediment clasts in a finer grained matrix. Pyrite in blebs and cubes and to a lesser extent zeolite(s) and calcite are found throughout this section which has been extensively fractured and faulted. This unit serves as the production zone in WEN-2.

The top of the granite basement in WEN-2 lies at 4860. At least the first 70 feet of granite are highly weathered and generally iron stained to a reddish color. The rock is a fine grained granite-quartz monzonite which is quite friable, possibly due to microfracturing. Below 4930 feet samples were unobtainable due to flashing around the shaker screen; however, the penetration rate suggests the weathered zone did not extend below 4950 feet.

In general drilling rates ran 10 - 15 feet/hour with breaks occurring in several zones which were characterized by faulting/

fracturing and lost circulation. Of particular importance is a zone of very fast drilling between 4540 and 4780 feet where the bit was virtually free-falling although the rate was held back to around 15 feet/hour to prevent an excessive buildup of cuttings up the hole. This zone also exhibited several lost circulation zones and the cuttings show indications of faulting (slicks and gouge) throughout. Subsequent testing and logging show this zone (which correlates with WEN-1) to be the main production zone in WEN-2 and probably related to the Wendel Fault.

Slickensides, fault gouge and fracture indications occur at a number of other depths in WEN-2 and probably represent minor faults. Other than one zone around 3800 feet, none had any indications of permeability.

The lithologic log for WEN-2 is shown in Figure 7.

Figure 7
LITHOLOGY COLUMN

7. FLUID CHEMISTRY

Water samples from WEN-2 were taken during both phases of flow testing. Each sample was filtered in the field (.45 micron pore size) and the appropriate splits placed in laboratory prepared and acidified bottles. Analysis was performed by the Earth Science Lab, University of Utah Research Institute. The quality of the analytical work is good with anion-cation imbalance of only .42 epm. Lab reports for each sample are contained in Appendix B.

The samples are chemically similar to each other as well as to analyses of WEN-1 and the Wendel Hot Springs. Generally the WEN-2 samples are closer in chemistry to the Hot Springs but differ from both the Hot Springs and WEN-1 in silica content. The lower SiO_2 values relative to the other two sample points may be related to an equilibrium process involving the extensive deposition of zeolite within the production zone; however, this is speculative. Although the conglomerate unit which produces in WEN-2 is comprised of very siliceous constituent rock types, no abundant chalcedony or hydrothermal quartz was observed.

The geothermometry results from WEN-2 suggest a reservoir temperature that is slightly higher than the measured bottom hole temperature (251°F). The predicted temperatures from the cation (sodium - potassium - calcium) geothermometer are in the range

259-266°F, chalcedony indicates 230-239°F and quartz gives 279-286°F. The fact that the chalcedony temperature is lower than the observed lends support to the hypothesis that some other phase (zeolite) is controlling silica solubility in the WEN-2 water.

8. GEOPHYSICAL LOGGING PROGRAM

A. Scope

The geophysical logging of WEN-2 was designed as a three step program with logging runs to be conducted prior to setting surface and intermediate casing and at total depth. Additionally a spinner survey was planned as part of the production testing program. Certain modifications to these initial plans were required due to hole conditions and other factors considered at the time of logging. All logging was conducted by Schlumberger, Inc. out of the Sacramento and Bakersfield (caliper only) offices, with the exception of the spinner survey which was run by COGCO, Inc. of Woodland, California.

The first phase of the logging program was conducted on April 17, in the interval from 300 ft. (conductor casing) to 1490 ft. A dual induction-spherically focused log and temperature log were run in open hole filled with fresh mud.

The second phase of the program was conducted on May 5 across the interval from surface casing to 4630 ft. in open hole filled with fresh mud. The following suite of logs were run over the intermediate sections: dual induction, compensated density log, compensated neutron log with gamma ray and caliper, borehole compensated sonic log with gamma ray, SP and integrated travel time,

and a temperature log as the final pass. Two maximum reading thermometers, one jacketed and one open to borehole pressures were run with each tool.

Upon reaching TD at 5030 ft. the same suite of logs run at 4630 ft. were scheduled. However, the drill string became stuck and the crew had to back off. Schlumberger was on location at this time, and due to concerns over the possibility of hanging one of the geophysical tools, particularly a nuclear instrument, no logs were run at TD.

The final phase of geophysical logging consisted of a spinner survey and a caliper log performed at the conclusion of the first flow testing in July.

The geophysical logging program was designed to serve two major objectives: (1) evaluation of lithology and formation fluid, and (2) correlation with past and future wells drilled in the area. Within the first objective are included:

- (a) evaluation of primary and secondary porosity
- (b) determination of general formation fluid quality and temperature (equilibrium)
- (c) detection of zones of hydrothermal alteration

The second objective encompasses the use of well logs to pick formation tops, identify correlatable sequences and detect faults and other structural features.

B. Log Quality

The quality of geophysical logs can be judged by various criteria including: repeatability during the same or overlapping runs, depth agreement between logs, proper calibration, hole conditions, wireline tension curve, and certain on-site operational practices such as logging speed, matrix selection, drilling fluid resistivity measurements, etc.

Overall the quality of logs run at WEN-2 is good. Where problems were encountered it was generally due to hole washouts which makes the data from several sections of the logs suspect. Generally these zones can be detected by the caliper along with the complete attenuation of the first sonic arrival which causes cycle skipping.

The repeatability, depth agreement and internal calibration of the logs and logging tools were all satisfactory with the exception of the gamma ray on the second logging run.* Although certain equipment and operational difficulties including a missing three arm caliper log were encountered during logging, these problems are generally not reflected in the final set of logs. The lack of the three arm caliper normally obtained with a sonic

* The curve on this run was recorded too high due, according to the site engineer, due to the computer confusing the placement of the tool in the string.

log was due to the running of the dual induction log in tandem which did not allow an additional cable conductor for the caliper signal. This problem unfortunately was not foreseen by the logging engineer until the tool string was on bottom.

C. Log Types/Tool Responses

Resistivity Log: The formation parameter of resistivity is obtained directly from the log and can be useful for lithology determinations, well to well correlations, evaluation of the invasion (drilling mud) profile and approximation of formation fluid quality. Additionally, an electric log is required by the Division of Oil and Gas for all wells drilled in California. The resistivity tool run in WEN-2 (DIL) included a deep reading induction device, a medium induction device, a spherically focused log for shallow investigation and a spontaneous potential (SP) electrode. The resistivity curves were printed in the log-linear format with the detail log (5"/100') on a split 4 decade logarithmic scale and the correlation log (2'/100') on a linear scale.

The SP curve was recorded with the formation resistivity and displayed on a -50 +50 millivolt linear scale in the first log track. The SP curve is a recording versus depth of the difference between the potential of a moveable electrode in the borehole and the fixed potential of a surface electrode. Deflections in the SP curve result from electric currents flowing

in the mud column. These currents can arise in several ways and can be related to formation permeability and formation fluid resistivity; however, in WEN-2 as in WEN-1 the SP is a featureless curve of little value. SP was run in WEN-2 only because it is a standard component on other more useful tools and is provided at no charge.

Sonic Log: The sonic log is a recording, versus depth, of the time (t) required for a compressional sound wave to traverse one foot of formation. The interval transit time (ITT) is the reciprocal of the wave velocity and depends on both lithology and porosity. The sonic log run at WEN-2 was borehole compensated (BHC) which substantially reduces tool effects due to borehole rugosity and sonde tilt. The ITT is recorded in micro-seconds/ft and presented on a 40-140 linear scale. A gamma ray, spontaneous potential and integrated travel time were also recorded simultaneously.

The integrated travel time is given by a series of ticks recorded on the left edge of the first track of the log. Each tick indicates an increase of one millisecond of the total travel time so that the travel time between two depths is obtained by counting the intervening squares. The feature is useful for correlation with seismic data.

Compensated Density - Neutron Log: The neutron log is primarily a porosity log which responds to the amount of hydrogen, usually

in the form of water or oil which is present in a formation. The CNL was recorded in linear porosity units (0-60%) for a sandstone lithology (2.65 g/cc) and run in combination with a gamma ray and caliper. Because the neutron log sees all hydrogen in a formation, including that bound in mineral phases, clay rich units or other formations containing hydrated minerals will show a neutron porosity greater than the actual effective porosity.

The compensated density log is also a porosity tool which is very useful for lithology determinations. CDL measures the electron density which is related to the bulk formation density which is in turn dependent on rock matrix density, formation fluid density and porosity. The CDL porosity curve is recorded in the same tracks as the CNL. A delta rho curve which indicates how much density compensation has been applied to correct for mud cake and hole rugosity is also shown.

Schlumberger also provides a log tracking bulk density and the photoelectric effect of the formations (Pe). The Pe is related to lithology and, like the density detector is compensated for mudcake and hole shape.

Gamma Ray Log: The gamma ray log is a measurement of the natural radioactivity of the formation almost entirely due to the presence of potassium 40 and the radioactive elements of the uranium and thorium series. Because the radioactive elements tend to

concentrate in clays, the GR log normally reflects the clay content of the formation; however alkali rock types such as granites not uncommonly register "hot" due to the presence of K in feldspars and micas.

The gamma ray curve is recorded in the first log track on a 0-300 API unit linear scale.

Spinner (flowmeter) Log: The spinner tool measures the fluid velocity within the wellbore and, when the hole diameter is known, (from caliper) provides the flow rate at that point.

By continuous logging, the various fluid entry points within the production zone can be identified along with their relative contribution to the total flow. Additionally, wellbore flow between different zones can be detected (above a threshold flow depending on hole size) when the well is shut in.

Caliper Log: The caliper log measures either the average or maximum borehole diameter depending on the caliper type. A caliper log was recorded on a 10-20 inch linear scale in the first track of the CNL-CDL. On the neutron-density tool the distance between the face of the detector skid and the centering arm is recorded as a caliper log (one arm). A second caliper was later run with the spinner to facilitate interpretation. This tool was a three arm type capable of reading to 20".

Temperature Log: The temperature log provides continuous measurement of absolute borehole fluid temperature and differential temperature. The differential data is obtained by comparing a particular absolute temperature value with one obtained at a preceeding time. Since the differential curve is more sensitive to small temperature changes, it is useful in the interpretation of fractures or water entrys which may cause small perturbations in the gradient. Absolute temperature can be recorded versus depth or with the tool stationary versus time.

D. Lithology/Formation Fluid

1. Analytical Methods: The first objective of the geophysical log analysis was to characterize the very complex section penetrated in WEN-2 in terms of lithology, porosity/permeability and formation fluid. The section can be roughly delineated on the basis of cuttings sample descriptions; there are, however, several drawbacks to relying on these samples alone including:

- Sample intervals ranged from 10-30 ft in rapidly changing lithology,
- representative samples are impossible to assure,
- samples were frequently contaminated by caving or mixing due to differential settling,

The lithologic descriptions from cuttings, although sometimes problematic, serve as the basis, supported with the geophysical

logs and other data such as the penetration rate, to effectively define the subsurface stratigraphy and to refine the existing exploration model.

The log analysis focused on the interval 1485-4340 ft. where a more complete log suite was available.

Lithologic Geophysical Responses

Basalt/Andesite flows: Units defined by cuttings examination as volcanic flows are characterized by their high gamma ray, high resistivity, high density, short interval travel time and low apparent neutron porosity. Resistivities for this unit are generally above 70 ohm-meters, except where fractured. This log value is relatively low compared to the true resistivity of unfractured basaltic rock (usually over 800 ohm/m) and is due in part to the geometrical factor of the deep induction tool.

Neutron response of the basalt was generally around 15 porosity units and apparent bulk density ranged from 2.60 to 2.85 gr/cc. Sonic travel time was generally around 55-60 microseconds/ft or 16,600 ft/sec to 18,000 ft/sec. The gamma ray response, unlike that observed in WEN-1 was high, often over 300 API units.

Tuff/Tuff Breccia: Log responses in these units was somewhat more varied than for basalt/andesite flows although generally characteristic. Tuffs penetrated in WEN-2 were mostly altered to clay typically illite and often ferruginous. Chlorite is also

common. Tuffs are indicated by low resistivities, low bulk densities, low sonic travel times and high apparent neutron porosities as should be expected from clay rich materials.

Resistivities in the tuff/tuff breccias averaged between one and ten ohm meters. Sonic travel times ranged from approximately 170 to 110 microseconds/ft or 6,000 to 9,000 ft/sec.

Apparent bulk densities and neutron porosity of tuff units also varied widely ranging from 1.75 to 2.2 gr/cc and from 20 to 40 porosity units, respectively. No characteristic gamma ray response was noted. The Pe curve (index of photoelectric cross section) provided by Schlumberger is strongly correlated to the matrix mineralogy and, in conjunction with the bulk density curve, suggests the dominant clay mineral in the tuffaceous units is an illite (non-expanding) type, although several discrete zones of montmorillinite rich tuff were penetrated and, not unexpectedly (due to swelling), showed some associated washout.

The relatively wide range of log response for the tuff units is due to both their heterogeneous makeup (ranging from crystal and lithic rich types to nearly pure ash) and their varying degrees and types of alteration.

Alluvium/Conglomerate/Volcanic Mudflow: Rocks assigned to these units on the lithologic log are the most varied in both rock type and geophysical response. Included, though largely undifferen-

tiabale within the cuttings samples are: alluvial fan deposits, volcanic mudflows (both volcanoclastic and epiclastic), flow breccias, fluvial sediments, lacustrine deposits and probably some weathered lava flows and flow breccias. Additionally much of the sediment probably received volcanoclastic input which has subsequently altered.

Materials of these units exhibit log responses which generally vary between the average values for the preceding two units. Where deposits have received substantial amounts of ash or detrital clay they respond similar to the tuff units; where cleaner coarse grained and well consolidated they resemble the basalt. The logs very clearly delineate the siliceous conglomerate penetrated at 4395 ft. from other conglomerate and coarse mudflow units cut by WEN-2. Higher and more consistent values for bulk density, formation resistivity and sonic velocity are characteristic of this unit which serves as the production zone in WEN-2.

The resistivity curves provided an enhanced interpretation of the siliceous conglomerate than was obtained from the cuttings. Microscopic examination of the drill chips suggest a relatively clean, well rounded and sorted sediment with good intergranular porosity. The induction log, however, shows only discrete zones of porosity where mud invasion has occurred. These zones correlate with fractures indicated on other logs and are indicated by

a curve separation due to the invasion of the formation by the very high resistivity drilling fluid. The resistivity contrast is further emphasized by temperature differences between drilling fluid and formation fluid.

Granite-Qtz Monzanite: The basement unit in WEN-2 was not logged due to cancellation of the final logging run.

Porosity/Permeability Evaluation

An important objective of the log analysis is the evaluation of formation porosity and permeability for the various units particularly where it may correlate to temperature. No significant permeability was encountered in WEN-2 above 3800 ft. and only the section from 4500 to 4800 ft. has demonstrated production, hence the discussion will focus on that 1000 ft. interval. At the time completion decisions were being made, only the section to 4630 feet had been logged and a buildup at 4630 had indicated temperatures around 250°F, the target level. In order to delineate fractured and potentially productive zones a number of diagnostic criteria were used:

- a. drilling rate - faster drilling rates typically accompany permeable or fractured zones;
- b. hole size - caving and hole enlargement are common in fractured zones and is indicated by caliper and other logs or by tightness on tool runs;

- c. three arm vs. one arm caliper - the one arm caliper on the CDL-CNL generally reads the maximum hole diameter, the three arm sonic caliper is an average; therefore in elliptical holes created by inclined fractures the one arm caliper should indicate a large diameter. This evidence should not be too strongly argued however, due to the frequently elliptical shape in nonfractured boreholes;
- d. differential temperature curve - gradient fluctuations typically occur in fractured and/or productive sections;
- e. resistivity curve separation - indications of formation invasion typically signify permeability, either primary (intergranular) or secondary;
- f. Density-neutron porosities - these curves typically record porosity which implies permeability in clean formations;
- g. Sonic travel time - this parameter is related to porosity (a "sonic porosity" is calculable) and also implies permeability in clean formations.

The first indications of permeability were encountered while drilling at 3800 ft. when several small circulation losses were noted (100-130 barrels in 30 minutes). None of the subsequent geophysical logs, nor the lithologic log indicated any permeability and the problem was easily cured with LCM.

Later lost circulation zones were encountered at 4388, 4541 and 4602 ft. all in or near zones which the logs indicated were fractured and permeable. Below 4630 feet drilling began with aerated water and no circulation losses could be discerned, however, the spinner/caliper survey run later while testing shows the production to be coming largely from discrete zones (fractures) between 4500 and 4800 feet. The zone between 4500 and 4600 ft. which appears most fractured on the geophysical logs also corresponds to the main production interval on the spinner survey and, based on the abundance of slickensides and vein material (xeolite, calcite pyrite) in the drill chips, is interpreted as representing the Wendel Fault.

E. Reservoir Temperature

Temperatures were monitored throughout the drilling process in order to establish the local gradient, assist in the selection of casing points and other drilling decisions, and in order to estimate equilibrium temperatures at various depths. Temperatures were recorded regularly at the mud return line, two maximum reading thermometers were run with every directional survey and a bottomhole temperature buildup was taken at 4630 feet.

Additionally, tools were run at casing points as part of the geophysical logging program.

Mud return temperatures are shown in Appendix C. Below 4630 feet drilling with aerated water began and return line temperatures increased drastically due to the production of formation fluids. The trends indicated by the return mud temperatures are similar to the bottom hole temperatures recorded during deviation surveys (Appendix D).

In order to determine the equilibrium bottom hole temperature before committing intermediate casing at 4630 feet a temperature buildup was recorded and used for projection. Because the conventional Horner plot typically underestimates true equilibrium temperature the method of Roux, Sanyal and Brown (1980) was utilized. This predicted a stabilized temperature of 240-250°F at 4630 feet which was later confirmed during flow testing.

9.0 WELL TESTING

A. Initial Flow Testing

WEN-2 flowed continuously for 3½ days while drilling with aerated water prior to an 8 hour test on May 13. The well was produced during drilling from a 10" flow line attached to the rotating head which ran to an "air buster" on the shaker. The "air buster" separated the steam and allowed the produced water to recirculate through the mud tanks. Prior to the short term test the well was killed for safety reasons several times during the trip out by injecting cold water.

The wellhead and flowline configuration used for the short term test consisted of a 12 inch blooie line bolted to the banjo box and flanged to a 6 inch line outfitted with orifice plate and a butterfly valve.

A step test indicated the well would not sustain more than 500 gpm without flashing across the orifice plate and so a 4 hour constant rate test was performed at 480 gpm. A drawdown of 50 psi was observed at the wellhead at the conclusion of the testing period.

Although the capacity determined from the initial test indicated substantially lower productivity than WEN-1, some improvement as the well developed was anticipated and, due to the more rapid temperature increase at the wellhead, a slightly higher production temperature was considered likely.

B. Sustained Artesian Flow Test

A two-phase test format consisting of three short term pulse/recovery tests followed by a longer term constant flow test was submitted to DOE on April 17, 1984. Testing was conducted by GeoProducts' technical staff with assistance from scientists and technical personnel from EGG Idaho, who also supplied much of the wellhead instrumentation.

The wellhead assembly for the test consisted of a 12" 3000 API production "T" with a 6" 300 ANSI flowline connected to the master valve through a 12" adaptor flange. The master valve is a 400 ANSI WKM power seal gate valve. The flowline and down hole instrumentation system is shown in Figure 8. The flowline was fitted with a 3" orifice plate and continuous recording digital differential pressure meter for measuring the discharge rate. Pressures were monitored by mechanical gauges and a continuous recording digital quartz meter on the flowline and by a wireline quartz pressure gauge (Hewlett-Packard) downhole. Temperatures were monitored by a mercury thermometer on the flowline and a digital thermocouple downhole. Additionally WEN-1 was fitted with a Stevens water level recorder (sensitivity of 1/10 inch) throughout the flow period on WEN-2.

Testing began on July 3, 1984 with initial temperature logging of the hole while running in with the Hewlett-Packard tool. The temperature profile is shown in Figure 9.

Figure 8. Flow Testing Assembly

Figure 9

On July 4-5 three pulse tests were performed at 155, 275 and 400 gpm in order to establish a productivity curve. From the results of the pulse testing a rate deemed sustainable was selected for the long term constant discharge test (370 gpm).

The two main objectives of the test program were to provide information on the productivity of WEN-2 (gpm per psi drop) and to characterize the geothermal reservoir in terms of transmissivity, storativity and boundary conditions.

The first objective is served by recording the transient pressure behavior, both at the wellhead and downhole, over a range of production rates. For the four rates monitored in the WEN-2 test it was observed that the pressure drawdown did not vary linearly with flow rate. The decline in capacity (downhole pressure) from 12 gpm/psi at a flow rate of 155 gpm to 6.7 gpm/psi at 400 gpm can be attributed to complex hydrologic conditions at depth, particularly the likelihood of non-Darcy (turbulent) flow within fractures feeding the well bore. Wellhead pressures showed a similar non-linearity with flow rate; however, the wellhead values also include an increment of pressure loss due to friction in the wellbore ("well losses") which are not observed in the downhole readings since the T-P tool is placed just above the producing zone. Under the above conditions a quadratic or higher order polynomial is required to describe reservoir pressure drop; however, no theoretical basis exists for terms of cubic and higher.

The complex hydrologic conditions near the wellbore on WEN-2 which account for the productivity variations are indicated in several ways. The geophysical and lithologic logs, as previously discussed, showed the interval between the intermediate casing shoe and 4820 ft. to be variously fractured and washed out. These effects were indicated on the subsequent spinner/caliper runs by considerable fluid velocity fluctuations which correlated with hole size variations through much of the interval. Although the spinner was difficult to interpret due to the washouts and a bridge at 4810 ft. the producing zone appears to extend from approximately 4500 to 4800 ft. (KB).

Complications such as fracture flow in the well-reservoir system penetrated in WEN-2 make the application of theoretical methods to calculate formation hydrologic parameters, which is the second main objective of testing, of uncertain value. Several methods including both semilog plots (Horner, Miller-Cyes-Hutchison) and type curve matching (McKinley, Ramey) have been applied to the drawdown and recovery data. Based on the WEN-2 pressure response a transmissivity on the order of 10,000 - 35,000 gallons per day per foot is indicated. This is approximately 10-30% of the value calculated during the WEN-1 testing in 1982.

Normally more reliable interpretations could be expected from the response data of WEN-1 (outfitted with Stevens water level recorder) during WEN-2 testing; however, the drawdown curve exhi-

bits a complicating diurnal fluctuation. A manual "best fit" line of the semilog plot from WEN-1 during the long term (370 gpm) test indicates a transmissivity of approximately 50,000 gallons per day per foot and a storativity of 6.5×10^4 .

During the testing no boundary effects were observed in WEN-2 as was also the case during the test of WEN-1. Although this does not allow for any determination of reservoir size, intuitively it must be large.

At the conclusion of the flow testing the spinner/caliper combination was run. The results showed a bridge at 4810 ft. which corresponded to the cut off in production. Based on drilling rate and lithology it was believed that some additional production could be obtained by cleaning out the bridge and any associated fill between 4810 and the top of the fish at 4890 feet.

10. WORKOVER OPERATIONS

WEN-2 was re-entered on July 25, 1984 with two objectives in mind. First the hole was to be cleaned of the fill which had accumulated from the top of the fish to approximately 4820, as the spinner had suggested some additional production might be obtainable from that zone. The second, and lesser priority objective was to make an attempt at recovering the four collars previously left in the hole. It was hoped that recovery of the fish might also improve productivity as well as possibly help defray the cost of the workover if the tools were still in good condition and saleable.

The entire operation was conducted using water as the drilling fluid, aerated by a single compressor. The crews tripped in on July 25 and after an additional trip for a plugged bit, were able to clean the hole to the top of the fish with no problems. After a 6 hour development period a trip was made for washover pipe in preparation for the fishing operations. On July 27 two passes were made, the first with an overshot produced nothing and suggested the collars were leaning to one side of the hole. A second pass with open ended pipe succeeded in screwing into the top collar and it was believed the entire lost string was recoverable. Unfortunately, upon coming out of the hole only one of the collars had been picked up and a decision was made to terminate the operation. Rig down began and preparations were begun for a rerun of the previous testing program.

11. FINAL WELL TESTING

At the conclusion of the workover operation a retest plan for WEN-2 was submitted to DOE and the test conducted during the period August 8-21, 1984. The plan called for three short term pulse tests followed by a longer constant rate test at the maximum flow deemed sustainable. The wellhead assembly and instrumentation for these tests was the same as used during the testing in July.

The test format followed in the field was the same as that of the earlier testing in terms of rates and duration. It appeared from the step test results that not only hadn't the well improved from the workover but had possibly lost some productivity. However, it was later observed that the differential pressure meter had drifted and that the actual flow rates during the second test were slightly higher which accounted for the increased pressure drawdowns. When this effect was accounted for the results of the first and second testing were identical, indicating the workover operation had not provided any additional production. The production zone in WEN-2 occurs from the Wendel Fault, primarily between 4500 and 4600 feet with some minor additional flow from subsidiary fractures across the zone from 4400-4800 feet.

12. WENDEL GEOTHERMAL SYSTEM

Correlations between WEN-1 and WEN-2 suggest a complex, structurally controlled, perhaps multi-level geothermal system at Wendel.

The fault dip calculations used in siting WEN-2 were calculated from the WEN-1 data which was hindered to some extent by uncertainties regarding the normal distance between WEN-1 and the surface trace of the Wendel Fault. This uncertainty is due to the anomalous bend the fault makes just north of the Wendel Hot Springs. It appears this bend which lies between WEN-1 and WEN-2 may have some structural significance as the WEN-2 section is consistently 150-170 feet higher than WEN-1. This implies possible faulting (minor) or northward tilting between the two wells. Interestingly, this structural trend (dipping to north) was indicated on resistivity profiles run by GeoProducts in 1978. Additionally, a thermal gradient hole drilled near the bend has a substantially higher temperature at 1300 feet than either WEN-1 or WEN-2.

The basic components of the Wendel system can only be speculated upon at present.

The recharge area is still unknown although isotope sampling would be useful in delineating the source although volcanic high-

lands to the north are possible sources they do not receive extensive precipitation. The Diamond Mountains and the Sierra Nevada block to the west is also a potential source and has substantially greater recharge potential due to the large snowpack.

The system flowpath(s) at Wendel are likewise highly speculative. Small structures such as the Wendel or Amedee Faults are undoubtedly important in localizing the near surface occurrences; however, larger regional features such as the Walker Lane or Honey Lake Faults are probably the main conduits for deep circulation of recharging waters. Given the documented propagation depths of faults in the earth's crust, deep circulation coupled with the high regional heat flow (over two heat flow units) in the Honey Lake Basin is the most likely mechanism for driving the system.

The discharge area is clearly the best understood part of the geothermal system and is comprised largely of the Wendel Fault and Springs. The direct link between the spring discharge and the production zones in the two deep wells is strongly indicated by the fluid chemistry data. Additionally mercury sampling across both production zones and the Hot Springs show anomalous values associated with fractures and producing zones.

In summary, the Wendel geothermal area appears to be a typical Basin and Range system where meteoric waters recharging in moun-

tain highlands percolate through faults and fractures and are heated by a high regional flow. The discharge zone is controlled by subsidiary faulting and other local features which are critical to siting wells.

APPENDIX A

<u>Bit No.</u>	<u>Size</u>	<u>Make</u>	<u>Type</u>	<u>Depth Out (KB)</u>	<u>Feet</u>	<u>Hours</u>	<u>Feet/Hour</u>
1	17 1/2	Sec.	M4MJ	827	498	29.5	16.8
2	17 1/2	Sec.	S-88	1095	268	38.5	6.9
3	17 1/2	Smith	DGJ	1530	435	57	7.6
4	12 1/4	Smith	F-3CB	1624	94	11	8.5
5	12 1/4	Smith	F-3G	1690	66	7	9.4
5RR	12 1/4	Smith	F-3G	1797	173	12	14.4
4RR	12 1/4	Smith	F3CB	2761	964	97	9.9
6	12 1/4	Smith	F-3G	4382	1633	123	13.2
7	12 1/4	CB-STC	F-4	4650	168	17	15.7
8	12 1/4	CB-HTC	J-33	1315	160	4	40.0
9	8 3/4	Sec.	M-84F	4427	0 Cement, DV Collar, Shoe		
10	8 3/4	Sec.	M-84F	4967	540	39	13.8
11	8 3/4	Sec.	H-88F	5050 (left in Hole)	83	12	6.9
9RR	8 3/4	Sec.	M-84F	Clean Out	----	----	----

Sample Number (Company): WEN-2A

Sample Number (ESL): 16

Company: UNCAL

Analytic Date: 8/84

	Concentration (ppm)	Analytic Method	Detection Limits	Concentration (Moles/Liter)
Na	298.00	1	0.61	0.130E-01
K	8.00	1	1.22	0.205E-03
Ca	23.00	1	0.24	0.574E-03
Mg	< 0.49	1	0.49	< 0.201E-04
Fe	0.06	1	0.02	0.107E-05
Al	< 0.61	1	0.61	< 0.226E-04
Si02	107.00	1	0.52	0.178E-02
B	3.60	1	0.12	0.333E-03
Li	0.16	1	0.05	0.231E-04
Sr	0.26	1	0.01	0.297E-05
Zn	< 0.12	1	0.12	< 0.187E-05
Ag	< 0.05	1	0.05	< 0.452E-06
As	< 0.61	1	0.61	< 0.814E-05
Au	< 0.10	1	0.10	< 0.496E-06
Ba	< 0.61	1	0.61	< 0.444E-05
Be	< 0.00	1	0.00	< 0.541E-06
Bi	< 2.44	1	2.44	< 0.117E-04
Cd	< 0.06	1	0.06	< 0.543E-06
Ce	< 0.24	1	0.24	< 0.174E-05
Co	< 0.02	1	0.02	< 0.514E-06
Cr	< 0.05	1	0.05	< 0.939E-06
Cu	0.40	1	0.06	0.630E-05
La	< 0.12	1	0.12	< 0.878E-06
Mn	< 0.24	1	0.24	< 0.444E-05
Mo	< 1.22	1	1.22	< 0.127E-04
Ni	< 0.12	1	0.12	< 0.208E-05
Pb	< 0.24	1	0.24	< 0.118E-05
Sn	< 0.12	1	0.12	< 0.103E-05
Sb	< 0.73	1	0.73	< 0.601E-05
Te	< 1.22	1	1.22	< 0.956E-05
Th	< 2.44	1	2.44	< 0.105E-04
Ti	< 0.12	1	0.12	< 0.255E-05
U	< 6.10	1	6.10	< 0.256E-04
V	< 1.22	1	1.22	< 0.239E-04
W	< 0.12	1	0.12	< 0.664E-06
Zr	< 0.12	1	0.12	< 0.134E-05
Total Alkalinity as HCO3	55.00	2	10.00	0.901E-03
SO4	364.00	4	2.00	0.379E-02
Cl	204.00	2	2.00	0.575E-02
PO4	< 1.84	1	1.84	< 0.194E-04
F	4.00	5	0.10	0.211E-03

Total Dissolved
Solids

Measured	1042.00	4	4.00
Calculated	1039.52	6	
100xMeas/Calc	100.24		

pH 8.5 7

Analytical Methods:

1. Inductively Coupled Plasma Spectrometer
2. Titration (in Laboratory)
3. Titration (in the field)
4. Gravimetric
5. Specific Ion Electrode
6. Method of Hem (1970) Water supply paper (1473)
7. pH meter (laboratory)
8. pH meter (field)
9. Colorimetric
10. Atomic Adsorption

Sample Number (Company): WEN-2

Sample Number (ESL): 2

Company: JUNCAL

Analytic Date: 5/84

	Concentration (ppm)	Analytic Method	Detection Limits	Concentration (Moles/Liter)
Na	301.00	1	0.61	0.151E-01
K	9.00	1	1.22	0.230E-03
Ca	23.00	1	0.24	0.574E-03
Mg	< 0.49	1	0.49	< 0.201E-04
Fe	< 0.02	1	0.02	< 0.437E-06
Al	< 0.61	1	0.61	< 0.226E-04
SiO2	100.00	1	0.52	0.166E+02
B	4.20	1	0.12	0.388E-03
Li	0.19	1	0.05	0.216E-04
Sr	0.32	1	0.01	0.365E-05
Zn	< 0.12	1	0.12	< 0.187E-05
Ag	< 0.05	1	0.05	< 0.453E-06
As	< 0.61	1	0.61	< 0.334E-05
Au	< 0.10	1	0.10	< 0.496E-06
Ba	< 0.61	1	0.61	< 0.444E-05
Ge	< 0.00	1	0.00	< 0.541E-06
EI	< 2.44	1	2.44	< 0.117E-04
Cd	< 0.06	1	0.06	< 0.543E-06
Ce	< 0.24	1	0.24	< 0.174E-05
Co	< 0.02	1	0.02	< 0.414E-06
Cr	< 0.05	1	0.05	< 0.330E-06
Cu	< 0.06	1	0.06	< 0.960E-06
La	< 0.12	1	0.12	< 0.878E-06
Mn	< 0.24	1	0.24	< 0.444E-05
Mo	< 1.22	1	1.22	< 0.127E-04
Ni	< 0.12	1	0.12	< 0.208E-05
Pb	< 0.24	1	0.24	< 0.118E-05
Sn	< 0.12	1	0.12	< 0.103E-05
Sb	< 0.73	1	0.73	< 0.601E-05
Te	< 1.22	1	1.22	< 0.956E-05
Th	< 2.44	1	2.44	< 0.105E-04
Ti	< 0.12	1	0.12	< 0.255E-05
U	< 6.10	1	6.10	< 0.256E-04
V	< 1.22	1	1.22	< 0.239E-04
W	< 0.12	1	0.12	< 0.664E-06
Zr	< 0.12	1	0.12	< 0.134E-05
HCO3	50.00	2	10.00	0.819E-03
CO3	2.00	0	10.00	0.333E-04
SO4	370.00	4	2.00	0.385E-02
CL	216.00	2	2.00	0.609E-02
PO4	< 1.84	1	1.84	< 0.194E-04
F	4.60	5	0.10	0.242E-03

Total Dissolved Solids

Measured	1042.00	4	4.00
Calculated	1052.85	6	
100xMeas/Calc	98.97		

pH	8.7	7
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Analytical Methods:

1. Inductively Coupled Plasma Spectrometer
2. Titration (in laboratory)
3. Titration (in the field)
4. Gravimetric
5. Specific Ion Electrode
6. Method of Hem (1970, USGS water supply paper 1473)
7. pH meter (laboratory)
8. pH meter (field)
9. Colorimetric
10. Atomic Absorption

APPENDIX C

MUD RETURN TEMPERATURES

<u>Depth</u>	<u>Temperature (°F)</u>	<u>Depth</u>	<u>Temperature (°F)</u>
400	82	2800	119
500	84	2900	120
600	88	3000	121
700	79	3000	124
800	95	3200	125
900	86	3300	127.5
1000	96	3400	127
1100	100	3500	127
1200	100	3600	128
1300	113	3700	131
1400	115	3800	131
1500	112	3900	130
1600	84	4000	133
1700	100	4100	138
1800	105	4200	147
1900	106	4300	145
2000	106	4400	144
2100	108	4500	144
2200	111	4600	142
2300	113	4700	200+
2400	117	4800	200+
2500	117	4900	200+
2600	117		
2700	117		

APPENDIX D

BOTTOM HOLE TEMPERATURES

(Taken with maximum reading thermometer during deviation surveys)

<u>Depth</u>	<u>Temperature (°F)</u>
1512	118
1719	106
1963	111
2026	112
2086	112
2240	112
2396	122
2549	122
2705	125
2861	138
3015	139
3170	142
3328	142
3482	142
3637	142
3794	149
3919	150
4070	162
4259	167
4477	167
4650	167

below 4650: not recorded