769
4/13/81
T-5
21160
(2)

DL 2191

MASTER

LBL-11187
UC-66a

EVALUATION OF THE SUSANVILLE, CALIFORNIA GEOTHERMAL RESOURCE

S. Benson, C. Goranson, J. Noble, R. Schroeder,
D. Corrigan, and H. Wollenberg

June 1980

Prepared for the U.S. Department of Energy
under Contract W-7405-ENG-48

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price Code: A06

EVALUATION OF THE SUSANVILLE, CALIFORNIA GEOTHERMAL RESOURCE

S. Benson, C. Goranson*, J. Noble**, R. Schroeder*,
D. Corrigan, and H. Wollenberg

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

June 1980

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Prepared for the U. S. Water and Power Resources Service under contract #14-06-200-8612A and the U.S. Department of Energy under contract #W-7405-ENG-48.

* Presently with BGI, Berkeley, California

** Presently with Phillips Petroleum, Bartlesville, Oklahoma

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

TABLE OF CONTENTS

[illegible]

 

LIST OF FIGURES

1.	Location map of Susanville Geothermal Anomaly.	2
2.	Location map of wells drilled to date in Susanville	4
3.	Well completion data: Suzy 1-6, Pool, Church, Naef, Davis, LLB #2	9
4.	Well completion data: Suzy 7-11	9
5.	Division of the Susanville geothermal prospect into five structural units	10
6.	Cross sections showing relationships between various structural units (as indicated by the natural gamma logs)	12
7.	Cross sections showing relationships between various structural units (as indicated by the natural gamma logs)	12
8.	Thin section of the fracture-coating hydrothermal deposit under crossed nichols	14
9.	Temperature profiles from wells: (A) Suzy 1 through 7; (B) Suzy 8 and 9, the Davis, Naef, LLB#2 and Swimming Pool wells; and (C) Suzy 9a, 10 and 11.	16
10.	Cross sections of the thermal anomaly (see Figure 15 for lines A-A' and B-B')	17
11.	Subsurface temperature contours (A) at 1250 m elevation; (B) at 1200 m elevation; and (C) at 1150 m elevation	19
12.	Davis well pressure and flow rate data	22
13.	Suzy 4 interference test data	23
14.	Lassen Lumber and Box #2 interference test data	23
15.	Suzy 3 interference test data	24
16.	Naef well interference test data	24

17.	Naef well pre-test data	28
18.	Naef well pre-test data	28
19.	Match of calculated and observed values for pre-test drawdown at Naef due to production of the Church well . . .	29
20.	Semi-log plot of Davis well drawdown versus time	30
21.	Davis well-head temperature	31
22.	Match of calculated and observed values for the drawdown of the Naef well due to production of the Davis well . . .	32
23.	Match of calculated and observed values for the drawdown at the Naef well while pumping the Swimming Pool well . . .	33

LIST OF TABLES

1.	Well completion data.	7
2.	Instrumentation.	25
3.	Summary of well test values and indications of reservoir boundaries.	34

ABSTRACT

The Susanville geothermal anomaly, located in northeast California, has been identified as a resource with potential for the development of geothermal energy for direct use applications. As a result of the City of Susanville's interest in developing the resource for a city-wide space heating program, the Water and Power Resources Service (formerly the Bureau of Reclamation) and the Earth Sciences Division of Lawrence Berkeley Laboratory (LBL) have collaborated since 1978 on a geothermal resource evaluation project. As part of this project, twelve exploratory temperature gradient holes have been drilled (bringing the total number of old and new holes and wells to 23), subsurface geologic and geophysical data have been analyzed, and a well test has been conducted by Lawrence Berkeley Laboratory.

Interpretation of data obtained from well testing, drillers' and lithologic logs and geophysical surveys suggests the presence of a fault-related reservoir of high permeability, shallow depth, limited thickness and limited lateral extent.

Temperature contours and profiles suggest the upwelling of fluids on a northwest-trending fault, from where they are dispersed into the reservoir along a highly permeable, fractured agglomerate-basalt interface and fractured volcanic units. Well tests show a high lateral permeability associated with the fractured interface, and porosity values are low, supporting evidence for a fracture-dominated producing aquifer(s).

The areal confinement of the anomaly has been established on three sides (west, south, east) to a depth of 200 m. In the southern portion, temperature reversals below an agglomerate-basaltic interface suggest a vertically confined aquifer. Water samples and petrologic data indicate that in the past, fluids of temperatures between 70°C and 150°C flowed through the fracture system. Computer modeling indicates that a horizontal, regional flow of hot fluids is required to match the observed temperature distribution.

It is recommended that calculations for an estimation of resource life in terms of temperature and pressure decline be made. Before a confident estimate of total resource producibility is possible, the resource must be more completely identified, and the total depth, maximum fluid temperature and the extent of the northern portion of the resource must be established. The results of further testing, combined with previous test data, as well as all other available data, would yield a complete description of the reservoir, and define future drilling depths, expected temperatures, and sites for reinjection wells.

INTRODUCTION

The Susanville geothermal anomaly is located in northeast California, at the foot of the Sierra Nevada. The presence of several shallow hot water wells and a natural hot spring initially identified this area as a prospective candidate for the development of geothermal energy. More recently, increased fossil fuel costs and the high price of transporting liquified natural gas to Susanville and the surrounding area stimulated interest in developing the resource for a city-wide space heating program. Since late 1978, the Water and Power Resources Service and the Earth Sciences Division of Lawrence Berkeley Laboratory have collaborated on a geothermal resource evaluation project at Susanville. As part of this project, twelve deep and five shallow temperature gradient holes were drilled, sub-surface geologic and geophysical data were analyzed, and a well test was conducted.

GEOLOGIC SETTING

The city of Susanville is located at the intersection of three major physiographic provinces: the Modoc Plateau, the Sierra Nevada and the Basin and Range (see Figure 1). Plio-Pleistocene volcanic rocks form a dissected plateau north and west of the city. These volcanics have been identified¹ as members of the Warner Basalt, a collective unit of petrographically and structurally similar lavas found throughout the Modoc Plateau. South of Susanville lie the Jurassic-Cretaceous quartz monzonite and quartz diorite of the Sierran batholith. Extending east and southeast from Susanville is the graben-like structure of Honey Lake Valley, filled in part by Pleistocene sediments of extinct Lake Lahontan.

Fig. 1. Location map of Susanville Geothermal anomaly.

The Susanville geothermal exploratory wells penetrated Holocene alluvium and Pleistocene Lahontan Lake sediments, interbedded with Plio-Pleistocene basalts and andesites. These same lithologic units are penetrated by water wells in the Susanville-Johnsonville area and typically provide good yields of groundwater. The respective amounts of water produced from either the basalt or the sediments are not well understood.² Meteoric water permeates through fractures and joints in the basalt and along vesicular and scoriaceous zones at the top and bottom of the basalt units. The Lahontan Lake sediments thicken to the east of Susanville. To the south, they interface with coarser, near-shore Lahontan deposits. These near-shore deposits outcrop along the base of Diamond Ridge.

Hydrologically, the near-shore Lahontan deposits have a dual role. They are usually highly permeable and provide a path for groundwater recharge of interfingering Lahontan sediments and, in some cases, recharge to underlying basalt units. In saturated zones, such as along the base of Diamond Ridge, near-shore deposits are important shallow groundwater aquifers.

The geologic relationships formed between rock units of the three major intersecting provinces are too complex to be discussed in detail here. We can comment, though, on stratigraphic and structural characteristics of the potential Susanville geothermal area based on observations made from lithologic and geophysical well bore logs.

Fig. 2. Location map of wells drilled to date in Susanville. (XBL 801-6767)

Geothermal Wells in the City of Susanville

Twenty-three temperature gradient holes and wells have been drilled in the City of Susanville to date. Five temperature gradient holes, with a target depth of 40 m, were drilled for preliminary resource identification. Twelve exploratory wells, with depths of 135 m to 640 m, were then drilled in an attempt to outline the areal extent of the geothermal anomaly. Lithologic logs of these wells are included in Appendix B. Six older wells, five drilled in the 1920's and one drilled in the early 1960's, are also in the City of Susanville. Well locations are shown in Figure 2.

Five temperature gradient holes were drilled, and four (TG-1, TG-17, TG-18, TG-19) were completed to a target depth of 46 m. TG-2 only reached a depth of 15 m due to difficulties encountered during drilling. Temperature gradients of $0.12^{\circ}\text{C}/\text{m}$ to $0.21^{\circ}\text{C}/\text{m}$ were encountered in all of the TG holes except TG-17 (2.5 miles south of Susanville). TG-17 had a much lower temperature gradient of $0.04^{\circ}\text{C}/\text{m}$, with a bottom hole temperature of 12°C . All of the TG holes, except TG-17 and TG-2, penetrated interbedded volcanics and sediments. TG-17 penetrated mostly granitic sediments; TG-2, drilled to 15 m, penetrated alluvial fill.

During the period from 1977 to 1980, the Water and Power Resources Service drilled twelve exploratory holes (Suzy 1 through Suzy 11, and Suzy 9A) ranging in depth from 135 m to 640 m. Standard heat flow completions were used for most of the holes. Heat flow completions in this area consisted of drilling a 6-1/2 inch hole to the total depth (TD). A two-inch pipe (PVC or steel) was emplaced in the hole, capped at the bottom and filled with water. The remaining

holes were completed for possible use as observation wells in future reservoir tests. These holes were also drilled with a 6-1/2 inch diameter, and a 2-inch pipe with a screen and wellpoint was installed at the bottom of each one. The holes were gravel packed several hundred feet above the bottom, and then cemented to the top. One of the holes, Suzy 6, was completed with a 6-inch blank casing to 32 m. A 6-inch diameter slotted liner with gravel-pack to the TD was inserted so that the well could be used as a production, injection, or observation well during testing of the aquifers. Table 1 outlines detailed information of the well completions, locations, depths, elevations and static water levels.

During the drilling of each well, a geologic well log was compiled to record borehole cutting descriptions and drilling operations as described by a well site geologist. These well logs are found in Appendix B and offer more detailed descriptions of the information found in Table 1. Upon completion of drilling, geophysical well logs were run to investigate the petrophysical nature of the lithologic units penetrated by the wells. Examples of the geophysical logs are presented in Appendix C.

Wells Suzy 2 and Suzy 3 were logged by a commercial well logging company. In each well the following logs were recorded: self-potential (SP), resistivity, natural gamma ray, caliper, neutron and density porosity, sonic velocity, bulk density and temperature. Subsequent holes were logged by a government logging service. The standard suite recorded in some of these holes was as follows: SP, caliper, resistivity, neutron, gamma-gamma ray, natural gamma ray, and temperature (SP, caliper and resistivity were not run in the cased

Table 1. WELL COMPLETION DATA

Well	Location	Elevation (m)	Total Depth (m)	Cased Depth (m)	Casing Size (inches)	Open Interval (m)	Static Water Level (m)	Comments
Suzy 1	N393,794 E2,375,183	1273.4	271.0	266.0	2	61-90 (30.5) ⁽²⁾	2.3	Perforated 61-90 m Gravel pack 149-271 m Well point 266-271 m
Suzy 2	N394,304 E2,374,716	1276.0	512.0	512.0	2	114-129 (15.2) ⁽²⁾	5.8	Perforated 114-129 m
Suzy 3	N394,298 E2,372,571	1289.0	636.0	636.0	2	73-104 (30.5) ⁽²⁾	15.2	
Suzy 4	N393,964 E2,373,944	1279.0	234.0	232.0	4	232-234 (2) ⁽²⁾	4.6	Well point 2" Slotted liner 2.4 m
Suzy 5	N373,278 E2,376,886	1271.0	225.0	222.6	2	85-106 (21) ⁽²⁾	8.2	Well point 2.4 m Gravel pack 152-225 m
Suzy 6	N392,883 E2,375,452	1273.0	190.0	189.0	6	32-190 (158) ⁽²⁾		Slotted liner 32-190 m
Naef	--	1288.0	127.0	114.0	8 (0-74) ⁽¹⁾ 7 (74-114) ⁽¹⁾	--	14.0	Well drilled - 1930 ⁽³⁾
Davis	N393,113 E374,112	1276.0	192.0	--	--	--	4.4	Well drilled - 1929 ⁽³⁾
LLB #2	N392,029 E2,376,569	1273.0	152.0	--	--	--	4.0	Well drilled - 1930 ⁽³⁾
Swimming Pool	--	1295.0	335.0	--	--	--	8.5	Well drilled - 1930 ⁽³⁾
LDS Chuch	--	1268.0	175.0	--	12 (0-71) ⁽¹⁾ 10 (71-127) ⁽¹⁾ 8 (127-172) ⁽¹⁾	--	5.5	
Suzy 7	N392,359 E2,374,642	1275.3	224.0	223.1	12 (10.7- well point) ⁽¹⁾	152		
Suzy 8	N396,668 E2,373,994	1276.8	160.9	159.4	2 (159.4) ⁽¹⁾	none	--	Bottom of pipe sealed & filled with clear water
Suzy 9	N396,276	1283.2	135.6	135.6	2	none	--	Bottom of pipe sealed & filled with clear water
Suzy 9a	N396,288 E2,372,122	1283.2	249.3	249.3	2	none	--	Bottom of pipe sealed & filled with clear water
Suzy 10	N406,625 E2,372,595	1291.4	197.4	197.4	2	none	--	Bottom of pipe sealed & filled with clear water
Suzy 11	N397,306 E2,371,270	1305.8	243.2	243.0	2	none	--	Bottom of pipe sealed & filled with clear water

(1) cased interval in meters

(2) length of open interval in meters

(3) completion data not available

holes). Temperature surveys have been run periodically in each hole since completion.

In addition to the aforementioned wells, a private well, Naef, was cleaned out for use as an observation and test well. A suite of geophysical well logs was also run in the Naef well.

In 1978, four of the Suzy wells were perforated (Suzy 1, 2, 3, and 5) in order to use them as observation wells in an interference test. Selection of the perforation interval was based on the maximum measured temperatures and estimated porosities as determined from the well logs obtained during drilling and completion. Due to several complicating factors the perforation job was considered to be successful only in Suzy 3.

Six wells had been drilled prior to this investigation: the Naef Well, the Davis Well, the L.D.S. Church Well (the Church of Jesus Christ of Latter Day Saints), Swimming Pool Well, Lassen Lumber and Box #2 Well, and the Wirth Well. Some of these wells have been used intermittently since the 1920's for space heating, industrial processing, and for heating a swimming pool. Because these wells were drilled long ago, little detailed information on total depth and well completion is available. The information obtained is summarized in Figures 3 and 4, and Table 1.

Interpretation of Subsurface Logs

Two basalt beds were identified as marker units on the natural gamma ray logs. Correlations between wells drilled in these two units inferred the structural relationships of the lithologic units penetrated. One of the basalt

Fig. 3. Well completion data: Suzy 1-6, Pool, Church, Naef, Davis, LLB #2. (XBL 795-7442)

Fig. 4. Well completion data: Suzy 7-11. (XBL 7912-1348A)

beds is typically penetrated within the first 100 feet of drilling. The second bed is encountered between 300 and 500 feet. The basalt beds are absent or ill-defined on the Suzy 3 natural gamma well log; the upper basalt bed is not evident and there is a poorly-defined basalt bed between 140 and 230 feet. In Suzy 9, 9A, and 11, the upper basalt bed is present but the lower bed is andesite rather than basalt (Appendices B and C).

On the basis of the gamma ray log correlations, the Susanville geothermal prospect has been divided into five structural units (Figure 5). Cross sections have been constructed to illustrate the structural relationships between

Fig. 5. Division of the Susanville geothermal prospect into five structural units. (XBL 806-7210)

the various units (Figures 6 and 7). Except as noted in the text, the Susanville wells typically penetrate 10-15 feet of recent Holocene alluvial deposits, 20-70 feet of basalt, 300-400 feet of interbedded Lake Lahontan sediments and Pleistocene basalt lenses, and 100+ feet of Plio-Pleistocene basalt.

To the west, Suzy 3 in Block 1 penetrates 140 feet of clays, sand and gravels interbedded with thin basalt lenses, 90 feet of basalt with minor clay, and 1800 feet of sand and clay with minor gravel beds. Block 2, east of Block 1, is penetrated by wells Naef and Suzy 4 and is downfaulted by approximately 140 feet, assuming that the 90 foot thick basalt unit in Suzy 3 is the same unit as the lower basalt in Naef and Suzy 4. Block 3, south of Block 2, is downfaulted from Block 2 by at least 240 feet, based on offset of the lower basalt section. The upper basalt units indicate an offset of approximately 60 feet and could be indicative of Holocene faulting. Suzy 5, 6, and 7 penetrate Block 3. Block 4 is offset from Block 3 by relative upfaulting of Block 4 by approximately 180 feet and offset from Block 2 by downfaulting of Block 4 by approximately 100 feet. Cumulative offset between blocks may vary because of variations in basalt flow thicknesses, formation of uneven erosional surfaces and minor intra-block faulting.

Suzy 2 and Suzy 8 penetrate Block 4. From observations of the logs from these holes, it appears that the top of the lower basalt unit is offset by less than 25 feet between these wells, and there does not appear to be any offset of the bottom of the upper basalt unit. Such apparent offset of the lower unit can be explained by phenomena other than faulting; e.g., variations in the thickness of the basalt flow, differential topographic and erosional

Fig. 6. Cross sections showing relationships between various structural units (as indicated by the natural gamma logs). Each vertical division equals 100 ft. (XBL 806-72111)

Fig. 7. Cross sections showing relationships between various structural units (as indicated by the natural gamma logs). Each vertical division equals 100 ft. (XBL 806-7209)

patterns or jointing and erosion of the basalt. The lithologic units are inferred to be generally undisturbed between Suzy 2 and Suzy 8.

A fifth structural unit, Block 5, has been inferred by the lithologic change in the lower volcanic unit between Suzy 8 and Suzy 9 and 9A. The lower basalt unit evident in Suzy 8 is replaced by a thick andesite unit in Suzy 9. Based on this lithologic unconformity a fault or series of faults is inferred to separate a northerly block containing wells Suzy 9, 9A and 11 from Block 4 to the east and Blocks 1 and 2 to the south.

Petrologic Studies

The Water and Power Resources Service obtained core samples from several of the wells. Several of the cores from the basaltic units had fracture planes and vugs which were filled with hydrothermal mineral deposits. These deposits were primarily composed of zeolitic minerals and carbonates. Numerous authors have written articles^{3,4,5} on the temperature-depth relation associated with the formation and deposition of the various zeolites. The fracture plane mineral deposits from well Suzy 9A were analyzed to determine what type of hydrothermal mineralization had taken place and specifically, what type of zeolites were present. Correlation of zeolite species with different thermal regimes provides valuable information about the thermal history of the resource. Three distinct zones of mineralization were identified. Each of these indicates that the hydrothermal mineralization in this core took place in a temperature range of approximately 70°C to 150°C.

A core from a depth of 684 feet in Suzy 9A was examined in detail. The core matrix was determined to be a highly altered basalt or basaltic andesite.

Drs. H. Williams and A. Pabst (University of California, Berkeley) examined the core and concluded that it was andesitic. Thin section studies identified highly altered pyroxenes and some similarly altered olivines and feldspars. Some feldspars were relatively unaltered.

Figure 8 shows a thin section of the fracture-coating hydrothermal deposit of the Suzy 9 core. In the figure, three distinct zones can be seen. They are, from the outer surface to the rock substrate:

- (a) A buff-gray, fine-grained crystalline layer about 1.5 mm thick.
- (b) A translucent to white coarse grained crystalline layer with large crystals, approximately 3.5 mm thick.
- (c) A fine-grained, white to gray-white layer about 1 mm thick adjoining the rock surface.

XBB 800 11506

Fig. 8. Thin section of the fracture coating hydrothermal deposit under crossed nicols.

Petrographic examination and x-ray analyses indicated these deposits form a fracture-filling zeolite sequence. The analyses indicate the presence of at least two zeolites: stilbite and laumontite-leonhardite. Leonhardite is an altered laumontite formed by dehydration. This may have taken place in the core after recovery, because it was not sealed in wax and allowed to dry.

Kirstmannsdottir and Tomasson³ have identified temperature and depth zones for zeolites deposited in Icelandic basalts. The temperature zones (in order of increasing temperature) are: a chabazite zone, a mesolite/scolecite zone, a stilbite zone, and a laumontite zone. If the zeolite temperature sequence is applied to layers A, B, and C the following depositional temperature sequence can be implied:

layer A 70° - 150°C

layer B 70° - 110°C

layer C 70° - 150°C

The thickness and coarse crystalline form of layer B suggest that the producing solutions were probably present for a much longer period of time than those solutions producing layers A or C.

The lower temperature range shown for layer B is based on the ratio of stilbite to laumontite-leonhardite in the sample. The leonhardite is assumed to exist from drying of the core after its removal from the core barrel. None of the higher temperature minerals (wairakite, epidote, etc.) were noted in the sample. The thickness of the fracture plane (zeolite sequence) is quite large (5.5 mm). This suggests that warm solutions have been moving through the fracture plane for a considerable period of time.

A.

B.

C.

Fig. 9. Temperature profiles from wells (A) Suzy 1 through 7; (B) Suzy 8 and 9, the Davis, Naef, LLB #2, and Swimming Pool wells; and (C) Suzy 9A, 10, and 11 (XBL 8011-6422)

Although there are uncertainties in the relationship between temperature, solution, and zeolite deposition, the sample indicates that this geothermal system has long been in existence.

Temperature Distribution of the Anomaly

Temperature profiles obtained from the wells are shown in Figure 9.

Examination of the temperature logs indicate several trends:

1. The temperature profiles are characteristically similar for wells within each block outlined by the structural study (Figure 10).

Fig. 10. Cross sections of the thermal anomaly. See Fig. 15 for lines A-A' and B-B'. (XBL 796-7511)

2. In wells with temperature reversals, the maximum temperatures were recorded in a zone immediately above or below the contact between the Lahontan Lake sediments and the lower basalt or andesite unit.
3. Temperatures are generally warmest in Blocks 2, 4, and 5.

Maximum temperatures in the wells range from 35°C to 83°C. The hottest wells are Suzy 9, 9a and 11. Unlike the wells in the southern portion of Susanville, these three wells have no temperature reversals, indicating the possibility of higher temperatures with depth. The productivity of wells in this area is unknown, with the exception of well 9A. An air lift test in 9A, conducted by the Service, yielded results that will be released in another report.

Subsurface temperatures are contoured at three subsurface elevations (1250 m, 1200 m, and 1150 m) in Figure 11. As illustrated, at shallow depths (elev. 1300 m; 50 m below average ground surface), the anomaly is centered around the Davis and Naef wells. At greater depths the anomaly becomes asymmetrically shaped around a northwest trending axis. The anomaly deepens to the northwest.

The anomaly is sharply bounded to the west, indicating a hydrologic and/or geologic discontinuity; e.g., a fault, or a fracture zone. To the east and north, the thermal anomaly gradually abates, while it is more abruptly bounded to the south. Analyses of cores and geophysical data suggest cooler groundwater from shallow saturated strata may be mixing with geothermal fluids in these areas. The asymmetrically shaped thermal anomaly and the noticeable temperature reversals in the southern portion of the field suggest that heated fluids are upwelling along a northwest trending fault (or at the intersection of several faults). They are then dispersed into the reservoir, flowing through the most permeable strata. In the southern portion of the anomaly, the basalt-agglomerate interface appears to be the most permeable.

Fig. 11. Subsurface temperature contours: (A) at 1250 m elevation; (B) at 1200 m elevation; and (C) at 1150 m elevation. (XBL 8011-6423)

RESERVOIR TESTING

Well testing in geothermal reservoirs is used to determine the reservoir parameters which govern the flow of fluids through the reservoir. Factors which affect fluid flow are reservoir permeability, k , porosity, ϕ , fluid viscosity, μ , and production zone geometry. Two types of well tests can be used to determine the reservoir parameters. Production (injection) tests are those tests in which the transient downhole pressure is measured in the flowing well. This type of test is particularly useful for determining the condition of a well and obtaining values of the reservoir transmissivity, kH/μ , and storativity, ϕcH (where H is reservoir thickness and c reservoir compressibility) in the vicinity of the producing well. An interference test is one in which the pressure response at a well some distance from the production well is monitored. From this data we can obtain information about reservoir geometry (boundaries) and formation heterogeneity, as well as kH/μ and ϕcH . The data also offers information on the hydrologic continuity of the reservoir.

Susanville Well Tests

From December 10, 1978, to January 8, 1979, the reservoir engineering group at Lawrence Berkeley Laboratory conducted a well test in Susanville. Eight observation wells and one production well were monitored. The well test consisted of four segments. The first segment involved the measuring of background data prior to pumping the Davis well. However, due to the extremely cold weather, the L.D.S. Church well was being produced for space heating at the time. To avoid or minimize any transients associated with the Church well flow, the rate was held constant at approximately 90 gpm throughout both the

background data collection period and the subsequent pumping of the Davis well. The second segment of the test consisted of pumping the Davis well at a rate of 250 gpm for a period of 9 days. The well was then shut in and the pressure build-up was observed. Several days after the Davis well was shut in, the Church well was shut in for twelve hours, then pumped again for several days; shut in for twelve hours, and then pumped continuously for the duration of the test. During the last segment of the test the Roosevelt swimming pool well was pumped at a rate of 275 gpm for three days and then shut in.

The producing wells were flowed using existing (installed) pumps. Because the L.D.S. Church well had no flow measurement device, a five-gallon bucket and stop watch were used for estimating the mass flow rate. The elapsed time to fill the five-gallon bucket varied between 2.9 and 3.4 sec (110-90 gpm) with +10% accuracy on the time measurements. These measurements yielded maximum and minimum flow rates of 120 to 80 gpm. A 90 gpm flow rate was assumed for analysis.

The Swimming Pool well also had no flow measurement device, so flow rates were obtained from Reno Pump and Supply Company in Reno, Nevada. This company designed and installed a pump in 1975. At the time the pump was set the well was reportedly produced at 300 gpm with 75 feet of measured drawdown. This drawdown is inconsistent with measured drawdowns associated with the Davis and Church wells. The Swimming Pool well is estimated to be 1100 feet deep, and possibly produces from different zones since it is located in a different geological sequence than other wells in the area. A flow rate of 275 gpm, estimated without benefit of a flow measurement device, was used in the analysis.

Pressure data were recorded at eight observation wells and one production well (Davis well). The pressure data obtained from five of the wells are shown in Figures 12 through 16. Due to the small diameter of the casing (2"), pressure data in all but three of the observation wells were obtained by lowering a nitrogen-filled capillary tube into the wells. At the surface the tubing was connected to a wellhead pressure transducer. Downhole pressure transducers were used in the Suzy 4 and Lassen Lumber and Box wells (Paroscientific and Hewlett-Packard, respectively). The Naef well was instrumented for background data by the Service in July, 1978, with a continuously recording water level device. Pressure data obtained by the methods described above, especially those instrumented with nitrogen-filled tubing, are strongly affected (± 0.5 psi) by atmospheric temperature and pressure changes. Table 2 summarizes the instrumentation used for the well testing.

Fig. 12. Davis well pressure and flow rate data. (XBL 795-7439)

Fig. 13. Suzy 4 interference test data. (XBL 795-7436)

Fig. 14. Lassen Lumber and Box #2 interference test data. (XBL 795-7438)

Fig. 15. Suzy 3 interference test data. (XBL 795-7438)

Fig. 16. Naef well interference test data (XBL 795-7441)

Table 2. INSTRUMENTATION

Well	Test Classification	Measurement Parameter	Instrumentation	Resolution
Naef	observation	water level	Leupold-Stevens Type A water level recorder owned by Burec	0.1 ft
<i>Comments: Clear evidence of communication between Davis well, Church well, and the Swimming Pool well. Accuracy of data uncertain between 12/16/78 and 12/20/79 due to sticking of water level recorder.</i>				
Davis	production-observation	pressure	40 ft of tubing in pipe-pump annulus, connected to Paroscientific pressure transducer	0.01 psi
		wellhead temperature	platinum RTD	0.1°F
		flow	orifice and pitot tube	20%
<i>Comments: After 12/19/79 probable nitrogen leak in tubing which caused subsequent pressure change. Clear evidence of communication with the Church well.</i>				
LDS Church	production	flow	flow measured using container and stopwatch	20%
LLB #2	observation	pressure	Hewlett-Packard pressure probe and	0.01 psi
		temperature	Gearhart-Owen temperature tool set at 425 ft	0.1°F
Suzy 1	observation	pressure	50 ft tubing connected to Paroscientific pressure transducer	0.01 psi
<i>Comments: The perforation job was not successful. No pressure change due to flowing wells was recorded.</i>				
Suzy 3	observation	pressure	250 ft tubing and chamber connected to Paroscientific pressure transducer	0.01 psi
Suzy 4	observation	pressure	down-hole Paroscientific transducer set at 500 ft	0.01 psi
Suzy 5	observation	pressure	200 ft tubing and chamber connected to Paroscientific pressure transducer	0.01 psi
<i>Comments: Did not respond to the reservoir pressure due to unsuccessful perforation job.</i>				
Roosevelt Swimming Pool	production	flow	private communication	20%

The magnitude of drawdowns at the observation wells in this test ranged from 0.3 m to 1.5 m (0.4 to 2.5 psi). Readings from the wells instrumented with nitrogen-filled tubing (Suzy 1, Suzy 2, Suzy 3 and Suzy 5) were strongly affected by daily temperature and atmospheric pressure changes. The background noise obscured both the initial pressure and the drawdown caused by the production well(s), and rendered the data unsuitable for analysis.

The data obtained from Suzy 4 and the Lassen Lumber and Box well had drawdowns of 2.0 psi and 0.5 psi, respectively. Both of these wells show two peculiar features as compared to other wells (see Figures 13 and 14). They both showed a gradual pressure decrease several days prior to the time the Davis well was turned on; and they both began to build up several days prior to the time the Davis well was shut in. Because the reason for this behavior is not known, the data from these wells were not suitable for a complete analysis.

Since both the Lassen Lumber and Box and Suzy 4 wells experienced drawdown due to the Davis well production, it can be inferred that the pressure is affected by the Davis well production and by an external source; e.g., atmospheric pressure, ambient temperature, or an influx of fluids to the reservoir from some unknown source(s).

Well Test Data Analysis

Pressure data obtained from an observation well which is affected by the production of more than one well or by variable flow rates requires computer-assisted analysis methods. A nonlinear least squares computer matching program was used to analyze observation data from the Naef well.⁴ The program employs

the line source solution (Theis) which calculates pressure drawdowns assuming an isotropic, isothermal, homogeneous porous medium of constant thickness. The production well is modeled as a line source which fully penetrates the reservoir. The program can be used to search for vertical reservoir boundaries (impermeable or constant potential). Vertical boundaries are modeled using the method of images. These assumptions (isothermal, homogeneous, etc.) are far too simple to accurately model the Susanville reservoir; however, the program was employed for a preliminary analysis. Over short periods of time the reservoir behaves, in some average sense, as though the above assumptions are reasonable. Because of the lack of data on production zones, well completions and lithology in the older wells, a detailed model of the reservoir is not available. The application of analytic solutions that assume a more complex reservoir system is impractical. These same considerations require care in applying numerical simulators.

The Service obtained several months of background data at the Naef well prior to the well test. These data are shown in Figure 17. There are daily fluctuations of ± 0.1 ft superimposed on fluctuations of larger magnitude throughout the summer months. Particularly curious is the water level build-up that occurred over a period of several weeks in the early fall. At present the cause is unknown, although several possible explanations exist.

The sharp peaks and valleys in the data starting at the beginning of September are assumed to be caused by production at the L.D.S. Church well. An expanded section of this data is shown in Figure 18. The figure shows three build-ups and drawdowns corresponding to the Church well being shut in

Fig. 17. Naef well pre-test data. (XBL 795-7441)

Fig. 18. Naef well pre-test data. (XBL 795-7492)

for several hours and then pumped again. Analysis of this data returned a transmissivity value of 3.6×10^6 md-ft/cp (2.8×10^4 gal/day/foot) and a storativity value of 2.3×10^{-4} ft/psi. The best match of the data obtained indicated the pressure response was influenced by an impermeable vertical reservoir boundary. The best match obtained between calculated and observed pressures is shown in Figure 19.

Fig. 19. Match of calculated and observed values for pre-test drawdown at Naef due to production of the Church well. (XBL 796-7508)

Pressure data in the Davis well were obtained for the duration of the test. However, due to instrumentation problems, only data from the drawdown (12/10/78 to 12/19/78) are considered reliable. These data were analyzed by the Miller-Dyes-Hutchinson (semi-log) technique.⁵ The data are shown plotted on semi-log paper in Figure 20. After the first several hundred minutes the data fall on a single straight line indicating that no boundary is influencing the pressure

response. The calculated transmissivity is 7.3×10^5 md-ft/cp (3.4×10^3 gal/day/foot). This number is substantially lower than those obtained from the analysis of the interference data. Since the producing strata of the resource and the thickness of the producing interval(s) in this well are unknown, it is difficult to ascertain the meaning of the discrepancy. However, the low transmissivity indicates that the effective reservoir thickness sampled by the production well is less than that sampled by the observation wells. The value obtained for the transmissivity from this test is in close agreement with the value obtained from a similar test performed by the Bureau of Reclamation in 1976.⁶

Fig. 20. Semilog plot of Davis well drawdown versus time. (XBL 796-7507)

A plot of wellhead temperature versus time during production of the Davis well is shown in Figure 21. Temperatures decline from an initial value of 66°C

Fig. 21. Davis wellhead temperature. (XBL 795-7494)

to 59°C over several days of production. The discharge temperature appeared to stabilize at 59°C. The production temperatures may indicate the influx of cold water to the well (during production). The static temperature profile, shown in Figure 9, shows temperatures greater than 60°C. Flowing temperature and spinner surveys could provide information about how and where this temperature degradation is taking place.

The interference data from the Naef well were first analyzed using the production data from all three producing wells (the Church well, the Davis well and the Roosevelt Swimming Pool well). This analysis revealed that an acceptable match of the pressure data could not be obtained with one set of reservoir parameters (kH/μ , ϕcH , geometry). For this reason, the data were analyzed in

two parts. The drawdown at the Naef well caused by the Davis well was analyzed assuming that the production of the Church well had no pressure transients associated with it during the Davis well production. Analysis yields values for kH/μ of 2.3×10^6 md-ft/cp (1.8×10^4 gal/day/foot) and values for $\phi c h$ of 7.2×10^{-4} ft/psi. Figure 22 shows the best match obtained between the observed and calculated response. The best match of observed and calculated values indicates that the pressure response was influenced by an impermeable boundary. The low storativity values obtained may be an indication that secondary (fracture) permeability is controlling the fluid flow in these wells.

Fig. 22. Match of calculated and observed values for the drawdown of the Naef well due to production of the Davis well. (XBL 796-7507)

The drawdown at the Naef well caused by the Swimming Pool well was analyzed assuming that the pressure transients caused by the Davis and Church

wells were negligible compared to the drawdown caused by the Pool well. Analysis of drawdowns caused by the Swimming Pool well are complicated by several factors. The swimming pool well is thought to be 1100 feet deep. If the entire wellbore length or the lower zones are producing fluids, complications such as partial penetration and/or a multilayered system will affect the results of the analysis. If the lithology, open interval, and producing zones were known we could account for these in the analysis; however, this information is not available. Using standard techniques, a transmissivity value of 3.4×10^6 md-ft/cp (2.73×10^4 gal/day/foot) and a storativity of 4×10^{-3} ft/psi were obtained. The value of storativity obtained was substantially larger than that obtained from the analysis of drawdowns at the Naef well due to the production of Davis and Church wells. The physical meaning of this difference is difficult to infer due to the complications mentioned above. The best match obtained for the calculated and observed data is shown in Figure 23.

Fig. 23. Match of calculated and observed values for the drawdown at the Naef well while pumping the Swimming Pool well.
(XBL 796-7506)

The ultimate goal of any well test is to extract the reservoir permeability k , thickness, H , porosity, ϕ , and production zone geometry from the lumped parameters transmissivity (kH/μ) and storativity (ϕcH). Table 3 presents a summary of the values obtained from the well tests and possible indications of reservoir boundaries. Interpretation of the reservoir parameters obtained is complicated by several factors. First, no stabilized shutin pressure was obtained prior to production of the Church Well. Secondly, flow rates were low, resulting in small drawdowns that were subject both to the sensitivity of the instrumentation and to pressure transients caused by ambient temperature, atmospheric pressure, and precipitation. Interpretation of the analysis is

Table 3. Summary of well test values and indications of reservoir boundaries.

Observation Well	Pumped Well	KH/μ	ϕcH	Indication of Reservoir Boundaries
Naef	Church	$3.6 \times 10^6 \frac{\text{md-ft}}{\text{cp}}$ (2.8×10^4 gal/day/ft)	2.3×10^{-4} ft/psi	Barrier Boundary
Naef	Davis	$2.3 \times 10^6 \frac{\text{md-ft}}{\text{cp}}$ (1.8×10^4 gal/day/ft)	7.2×10^{-4} ft/psi	Barrier Boundary
Naef	Swimming Pool	$3.4 \times 10^6 \frac{\text{md-ft}}{\text{cp}}$ (2.7×10^4 gal/day/ft)	3.9×10^{-2} ft/psi	None
Davis	Davis	$7.3 \times 10^5 \frac{\text{md-ft}}{\text{cp}}$ (3.4×10^3 gal/day/ft)	Not obtained	None

ambiguous due to the lack of available data on the open intervals, well completions, well depths and well lithology of the older wells monitored in the area. Furthermore, we are not certain which of the reservoir strata are the producing zones. Average results, however, are still useful for an overall (average) estimation of resource producibility.

Pressure data indicate hydraulic continuity between all of the observation wells and production wells. Preliminary analysis indicates that the reservoir has a permeability on the order of several darcies. Porosity values extracted from the reservoir storativity, ϕcH , (where ϕ is porosity), are ambiguous; however, low storativity values obtained indicate secondary permeability (fracture permeability) may be playing a major role in fluid movement throughout this section of the reservoir.

INTERPRETATION

Information obtained from the well tests, drilling logs and geophysical surveys suggest a fault related reservoir of high permeability, shallow depth, limited thickness and limited lateral extent. The hydrothermal anomaly may be found to be more extensive and deeper toward the northwest. Surface geology indicates extensive block faulting in the area. Well testing, on the other hand, has not conclusively located any impermeable or constant potential boundaries. However, there are indications that pressure behavior may be influenced by impermeable reservoir boundaries and lateral discontinuities. Some of the pressure data behave as though the reservoir is affected by external sources, indicating that it may be unconfined in certain areas.

Temperature profiles from wells in the southern portion of the anomaly display a marked temperature reversal at relatively shallow depths. The modeling of these temperature profiles requires a substantial horizontal regional flow of heated fluids through the most permeable strata and a reservoir with very small vertical permeabilities. The high values of lateral permeability (fracture permeability?) obtained from well testing in the reservoir and the known lithology of cores from some of the wells indicate that relatively low vertical permeabilities are possible in certain layers. Temperature profiles from holes in the northern portion of the resource display no temperature reversal. Further drilling to greater depth is required to find the "bottom" of the thermal anomaly.

CONCLUSIONS

The occurrence of the Susanville geothermal anomaly appears to be related to a northwest trending fault. Temperature contours and temperature profiles suggest that heated fluids upwell along the fault and are then dispersed into the highly permeable agglomerate-basalt interface and/or permeable zones within the fractured volcanic sequence. Areal confinement of the shallow thermal anomaly has been established for three sides of the resource (west, east and south). The northwestern boundary of the thermal anomaly has not been completely defined. In the southern portion the thermal anomaly is vertically confined at or near the agglomerate-basalt interface as indicated by a temperature reversal. No temperature reversal occurs in the temperature gradient holes in the northern part of the anomaly. However, temperatures at depths below 300 m are not known. The maximum temperature measured, 84°C, was in

well Suzy 9A. Petrologic studies of a fracture coating from well Suzy 9 indicate fluids of temperatures between 70°C and 150°C have been flowing through the fracture system for some time. This temperature range agrees with the temperature regimes indicated from water samples.⁶

Analyses of interference and production test data from the southern portion of the anomaly give high permeability values. Storativity values are low, suggesting a low porosity of the producing strata. This information is consistent with geologic data indicating a fracture-dominated hydrologic system. Wells in the northern portion of the resource have not been sufficiently tested at this time to make estimates of the productivity of these higher-temperature fluids.

RECOMMENDATIONS

Successful development of the Susanville geothermal resource will depend heavily on obtaining fluid of sufficient heat content and volume, while maintaining the elevated fluid temperatures throughout the lifetime of the resource. Preliminary indications from drilling, temperature gradients, temperature contours and pumping tests indicate that the development of the system must be carefully engineered to prevent thermal degradation of the resource and to optimize usage of the "hot" fluid.

Prior to large scale development, a more complete knowledge and understanding of the resource must be obtained. Those strata which constitute the "hot" producing zones must be identified so wells can be completed in such a way as to avoid the influx of cold water. The existence (or lack) of confining strata

must be established. It must be known whether long term production will cause migration of cooler fluids through and from the confining strata into the producing aquifer. If the "hot" fluid formation is of limited lateral extent, it must be established when colder fluids will flow into the hotter areas due to the pressure decline in the area of the producing well(s). Regional flow patterns must be established to ascertain optimal locations for production and injection wells (if reinjection is chosen as the fluid disposal method). Well testing and perhaps drilling in the northern portion of the resource will be required to determine the productivity and size of that portion of the resource.

Long-term production tests (up to 1 month) at maximum flow rates should be conducted. The monitoring of pressures and temperatures in a number of suitable observation wells and in the producing well would be necessary. A high flow rate would insure drawdowns of sufficient magnitude to establish reservoir geometry, leakage, and heterogeneity. By monitoring temperatures at the observation wells, the movement of colder (or hotter) fluids into the production region could be detected. If both spinner and flowing temperature surveys were conducted in the production wells, the "hot" producing layers and presence of a cold water influx could be established. By correlation of these data with geophysical logs and lithologic logs a more coherent model of the reservoir can be obtained.

Calculations for an estimation of resource life in terms of temperature and pressure decline have not been performed. The resource has not been completely identified. Total depth of the resource, maximum fluid temperature and reservoir size have not been established for the northwestern portion of

the resource. Until these facts are known, a completely confident estimate of the total resource producibility is not possible.

The results of further reservoir testing in this area, combined with previous test data, should yield estimates of the resource size and producibility. The combination of all the available data will yield a more complete description of the resource. This information will define the depths that subsequent wells will penetrate, temperature estimates at depth, drilling problems and sites for reinjection wells.

ACKNOWLEDGEMENTS

We would like to thank W. Davis and D. Naef for the use of their wells during testing in the Susanville area. We also thank Lyle Tomlin and Dick Richardson from the U. S. Water and Power Resource Service, and the Mid-Pacific Region for their help in obtaining reservoir information at Susanville and allowing publication of their data. The information obtained from J. Jesky, C. Richardson, and others of the City of Susanville is also acknowledged.

REFERENCES

1. U. S. Bureau of Reclamation, 1976, Susanville Geothermal Investigations: Special Report 1976, and Susanville Geothermal Investigations: Supplemental Technical Data - Special Report 1976: Mid-Pacific Region, Sacramento, California.
2. Rudser, R., 1978, The Geology and Geothermal Potential of Susanville, Lassen County, California: Master's Thesis, University of California, Davis.
3. Hay, H. L., 1977, Geologic Occurrence of Zeolites: In Sant, L. B., and Mumpton, F. A., Eds., Natural Zeolites: Occurrence, Properties and Use: Pergamon Press, Elmsford, New York.
4. McEdwards, D., and Tsang, C. F., 1977, Variable Rate Multiple Well Testing Analysis in Invitational Well Testing Symposium, Lawrence Berkeley Laboratory, Berkeley, California, LBL-7027, October, 1977.
5. Earlougher, R., 1977, Advances in Well Test Analysis: SPE Monograph, v. 5.
6. U. S. Bureau of Reclamation, 1976, Water Quality Analysis, Inferred Geothermal Reservoir Temperatures and Reservoir Evaluation Test: Mid-Pacific Region, Sacramento, California.

APPENDIX A

TABLE OF SYMBOLS AND UNITS

<u>Symbol</u>	<u>Definition</u>
C	total compressibility = $\phi C_w + (1-\phi) C_r$
H	reservoir thickness
k	permeability
K	$\frac{k\rho g}{\mu}$
μ	fluid viscosity
ϕ	porosity

<u>symbol</u>	<u>definition</u>	<u>Units</u>	
		<u>petroleum</u>	<u>groundwater</u>
kH/μ	transmissivity	md-ft/cp	gallon/day/foot

Note: To convert md-ft/cp to gallons/day/foot for 70°C water:

$$KH_{(\text{gallons/day/foot})} = KH/\mu_{(\text{md-ft/cp})} \times 8.036 \times 10^{-3}$$

THE UNIVERSITY OF CHICAGO

 

LECTURE NOTES

BY J. H. KATZ

1954

1955

1956

 

LECTURE NOTES

APPENDIX B

LITHOLOGIC WELL LOGS

1000000000

1000000000

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly-- Susanville Geothermal
FEATURE Lassen County **PROJECT** Investigations **STATE** California
HOLE NO. SUZY-1 **LOCATION** See Notes **GROUND ELEVATION** 4178' **ANGLE FROM**
COORDINATES N. 393,794; E. 2,375,183 **TOTAL DEPTH** 890.0' **VERTICAL** Vertical
BEGUN 7-18-78 **FINISHED** 8-23-78 **GARY A. HOLLINGER**
DEPTH TO WATER 11.0' **T.O.C.** 8-24-78 **HOLE LOGGED BY** & Robert L. Turner **DRILLER** N. Tuggle; W. Skaggs

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
Purpose of Hole: (1) Temperature gradient; (2) geo- physical proper- ties; (3) geolog- ic evaluation.	13 3/4" RB	0	DAILY SUMMARY OF DRILLING OPERATIONS	NOTE: Log based on rockbit cuttings and limited core.
Landowner: D. G. Wood Pro- ducts; Susanville, CA.			7-18-78: Move Failing 1500 to site and rig up. One shift/day.	0-4.0': MODERN FILL.
Location: NE 1/4 NW 1/4 Sec. 5, T. 2° N., R. 12 E.			7-19-78: Complete rigging up. Drill to 13' with 6 1/2" rockbit and small portable mud pit.	Fine to coarse, predominantly angular sand with clay, silt and charcoal. On edge of old lumber mill pond.
Drill Rig: Failing 1500			7-20-78: Drill to 23'. Down 1 1/2 hours to mix new mud twice.	4.0-8.0': RECENT ALLUVIAL DEPOSITS.
Drilling Methods: Rockbit drilled using bentonite mud and additives as required. Two mud pits used.			7-21-78: Drill to 46'. Secure for weekend. Gravel caving prob- lems.	Sandy Silt and Clay. Brown, fine- grained.
0-60': 13-3/4" rockbit for per- manent installa- tion of 10" sur- face casing.			7-24-78: Drill to 56'. Down 1 1/2 hours for mud pump repair and mix- ing mud. Serious gravel caving problems.	8.0-500' (?) * PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS
60-890': 6 1/2" rockbit.			7-25-78: Drill to 73'. Down 1 1/2 hours for mud conditioning.	8-33': Basalt. Broken flow and/or cobbles and boulders, gray to black, hard, occasional thin smooth drilling zones less than 6" thick.
At 333': 4"x5' haystellite core run; recovered 3'.			7-26-78: Drill to 80'. Down 1 hour due to water pump failure on drawworks engine. Caving problems.	33-35': Sandy Clay. Reddish brown, fine-grained.
At 432': 4"x5' diamond core run. Core lost from barrel on up-hole trip.			7-27-78: Drill to 83'. Down 6 hours to replace water pump and clean mud pump.	35-40': Sandy Clay with Gravel. Vol- canic fragments probably from gra- vel; smooth layers less than 4" thick.
At 462': 4"x5' haystellite core run; recovered 3'.			7-28-78: No drilling. Rigged up for deep drilling. Dug two mud pits about 10"x5"x8'. Mix 3000 gal of mud. Secure for weekend.	40-46': Gravel and Sandy Clay. Gra- vel is fine to coarse, mostly sub- rounded, dark, volcanic; minor light colors; caves; contains warm water.
Drilling Condi- tions: 0-8': Fast & smooth 8-35': Hard & slow. 35-41': Medium smooth. 41-46': Hard and slow. 46-56': Caving. 56-65': Fast and smooth. 65-73': Medium smooth. 73-86': Slow, hard and rough.			7-31-78: Ream hole to 24' with 13-3/4" rockbit.	46-56': Sandy Clay. Reddish brown, mostly fine with medium grains, oc- casional gravel.
			8- 1-78: Ream hole to 35' using two shifts per day. Down 4 1/2 hrs to repair kelly swivel and break-out table.	56-63': Gravel & Clay. Fine, hard to slightly weathered, dark volcanic gravel in clay matrix; minor coarse grains. Some thin sandy clay zones especially at 58-59'. Red-brown with fine volcanic sand.
			8- 2-78: Ream hole to 60'. Caving problems. Installed 60' of 10" steel casing with 1 1/2" stickup. Cemented in with 25 sacks.	63-70': Sand and Gravel with Clay. Mostly highly weathered, fine to coarse, subangular sand and hard, fine gravel. Gravel is dark in color to black volcanic. Occasion- al gravel-free bed 16" thick. Gra- vel: highly weathered below 68'.
			8- 3-78: Drilled to 140' with 6 1/2" rockbit. Down 3 1/2 hours to build decking and mix mud.	70-75': Sand. Fine to medium, high- ly compacted, scattered coarse sand and gravel; dark volcanic, predominantly subangular, minor clay and silt. Occasional rough gravel zone less than 6" thick. Gradational contact with 63-70' zone.
			8- 4-78: No drilling. Condition hole and mud for weekend.	75-86': Basalt. Generally massive, black, angular fragments; very mi- nor blue clay.
			8- 7-78: Drilled to 143'. Down 12 1/2 hours to repair mud pump and kelly chuck.	
			8- 8-78: Drilled to 203'. Down 2 hrs to mix mud and repair mud pump and kelly chuck.	
			8- 9-78: Drilled to 262'. Down 2 1/2 hrs to repair carburetor and replace cable.	
			8-10-78: Drilled to 333'. Down 9 1/2 hrs for mud pump repair.	
			8-11-78: Drilled to 336'. Down 9 1/2 hrs to repair mud pump and clean pits. Made core run at 333'.	

EXPLANATION

* Contact between the Pleistocene and
Pliocene lake deposits cannot be deter-
mined from cuttings. The contact was
estimated from geophysical logs and
existing data.

Sheet 1 of 3

FEATURE: Susanville Anomaly--Lassen County **PROJECT:** Susanville Geothermal
Investigations **Hole No.** SUZY-1

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly-- Susanville Geothermal
FEATURE Lassen County **PROJECT** Investigations **STATE** California
LOCATION See Notes **GROUND ELEVATION** 4178' **ANGLE FROM**
HOLE NO. SUZY-1 **COORDINATES** N.393,794; E.2,375,183 **TOTAL DEPTH** 890.0' **VERTICAL** Vertical
BEGUN 7-18-78 **FINISHED** 8-23-78 **GARY A. HOLLINGER**
DEPTH TO WATER 11.0' **T.O.C.** 8-24-78 **HOLE LOGGED BY** & Robert L. Turner **DRILLER** N. Tuggle; W. Skaggs

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
DAILY SUMMARY OF DRILLING OPERATIONS:				
Drilling Condi- tions (Cont.):				86-96': Sandy Clay. Blue-gray, soft.
86-104': Fast and smooth.				96-104': Sand. Fine to coarse, pre- dominantly medium, subrounded.
104-140': Medium smooth.				104-140': Basalt with Sand and Clay. Weathered volcanic gravel and cob- bles with sand and clay in alter- nating layers; clay soft and squeezing.
140-176': Slow, smooth to rough.	550		550	140-157': Sand. Predominantly coarse, subangular, dark, volcanic and fine gravel; minor light- colored grains. Gradational con- tact from 104-140' zone.
176-203': Fast and smooth.	62" RB			157-165': Sandy Clay. Blue-gray; brown below 163'. Predominantly medium
203-252': Inter- mittent, slow and smooth to slow and rough.	600		600	165-176': Sand and Gravel. Fine to coarse, subangular to subrounded sand and fine gravel. Multicolor- ed, mostly dark weathered volcanic. Minor light colors. Common quartz in thin intervals with occasional decomposed granite; minor gray brown clay.
252-262': Smooth and fast.	650		650	176-500': Pebble Conglomerate. Mul- ticolored, fine to coarse gravel from many sources, predominantly volcanic, minor granitic, occasion- al cobbles, mostly subrounded to rounded, minor subangular, often weathered. Matrix is moderate to well-cemented sandy clay; light gray to gray brown and pinkish; predominantly fine-grained, appears altered or with a high percentage of ash and silt.
262-322': Inter- mittent, slow and smooth to slow and rough.	650			Cuttings recovered mostly as sandy clay and volcanic fragments. Drill action indicates weak bed- ding. Minor fluctuations in color and clay content throughout total interval. Clay content highest in 285-290', 305-322' and 352-357' zones.
322-336': Hard and slow.	700		700	500(?) - 890': PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS.
336-352': Medium speed, medium rough.	700			500-525': Basalt. Angular black fragments; very little clay.
352-357': Fast and smooth.	750		750	525-553': Basalt with Alternating Sand and Clay Layers. Clay soft, brown; sand is fine to coarse, subangular to subrounded, multi- colored; often highly weathered; variable amounts of light gray to white grains.
357-432': Medium speed, smooth.	750			551-553': Very soft clay or cavity.
432-462': Fast and smooth.	800		800	553-560': Basalt. Hard, black frag- ments.
462-465': Hard, slow and smooth.	62" RB			
465-500': Slow, medium speed and medium rough.	800		800	
500-512': Very slow and fairly smooth.	850		850	
512-550': Slow, smooth to very rough.	850			
550-599': Hard, slow, rough; oc- casional very soft zone.	900		900	
599-615': Very hard and very slow, rough.	900			
615-620': Very slow and hard.	950		950	
620-660': Medium smooth.	950			
660-726': Fast and smooth.	950			
726-760': Hard, slow, rough to smooth.				
760-840': Soft, smooth to medium rough, fast.				

EXPLANATION

Sheet 2 of 3

FEATURE: Susanville Anomaly--Lassen County **PROJECT:** Susanville Geothermal Investigations

Hole No. SUZY-1

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET

FEATURE: Susanville Anomaly-- PROJECT: Susanville Geothermal Investigations
 Lassen County

SHEET 3 OF 3

NOTES (Continued)	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (Cont.)
<p><u>Drilling Conditions (Continued):</u> 840-860': Fast and smooth. 860-890': Medium smooth.</p> <p><u>Estimated Drilling Fluid Return:</u> 0-890': 95% to 100%</p> <p><u>Representative Drilling Fluid Temperature (°F):</u> 98° at 25' 100° at 33' BHT 112° at 53' 102° at 53' after weekend 120° at 83' BHT 127° at 60' measured in hole after night. 127° inside 60' of surface. 118° at 30' measured in hole after night. 100° at 120' 100° at 180' 110° at 300' 108° at 340' 98° at 382' after mixing new mud. 105° at 412' 124° at 462' after night 110° at 485' 111° at 517' 125° at 517' after night 114° at 555' 111° at 575' 113° at 615' 118° at 675' 116° at 760' 118° at 820' 112° at 890' 126° at 890' after 20 hours.</p> <p><u>Caving Conditions:</u> 41-46': Serious caving 46-56': Caving from above hampers drilling. 73-80': Caving. 143-162': Raveling sand and gravel 162-176': Caving 176-203': Caving from above</p> <p><u>Casing Record:</u> 10" steel surface casing installed to 58.5'. Casing permanently cemented into hole.</p> <p><u>Geophysical Logging:</u> The following geophysical logs were run by the USGS, Denver Office: (1) Electric (4) Neutron (2) Natural Gamma (5) Temperature (3) Gamma Gamma (6) Caliper</p> <p><u>Hole Completion:</u> 2" steel pipe with 8' of 60 mesh well screen installed in hole. Screen about 10' off bottom. Bottom $\pm$ 390' of hole gravel-packed, top portion cemented in. Site protected with steel guard rail.</p>	<p>560-570': <u>Clay</u>. Grades from soft, red brown to hard, bluish clay with weathered volcanic sand.</p> <p>570-600': <u>Sandy Clay and Basalt Gravel and Cobbles</u>. Clay is hard, compact, gray. Sand mostly fine, basaltic fragments, medium to coarse, angular, black. 585-590': Especially hard. 590-600': Increase in sand.</p> <p>600-616': <u>Basalt Cobbles (?)</u>. Black to brown and gray-brown, hard.</p> <p>616-619': <u>Basalt and Clay</u>. Basalt similar to 600-616' interval; clay gray and soft.</p> <p>619-675': <u>Sandy Clay</u>. Medium gray, soft with fine to coarse, multicolored lithic fragments. Subangular, mostly volcanic, weathered.</p> <p>675-726': <u>Sandy Clay</u>. Medium brown, soft clay as in 619-675' interval.</p> <p>726-733': <u>Basalt</u>. Cobbles (?) black, hard; minor brown clay.</p> <p>733-760': <u>Clay and Sand</u>. Medium brown soft clay with multicolored fine to coarse, predominantly volcanic sand.</p> <p>760-815': <u>Sandy Clay</u>. Medium brown to gray. Soft with fine to medium sand as in 733-760' interval.</p> <p>815-860': <u>Sandy Clay</u>. Similar to 760-815' interval with common light pink and red clay.</p> <p>860-890': <u>Clayey Sand (?)</u>. Fine to very coarse, subangular to sub-rounded, multicolored sand with minor brown to gray clay.</p>

Sheet 3 of 3

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County		PROJECT Investigations	STATE California
HOLE NO. SUZY-2	LOCATION See Notes	GROUND ELEVATION 4185	ANGLE FROM
BEGUN 8-25-77	COORDINATES N.394,305; E.2,374,717	TOTAL DEPTH 1680.0'	VERTICAL Vertical
FINISHED 9-15-77		Robert L. Turner &	
DEPTH TO WATER Not Determined	HOLE LOGGED BY Gary A. Hollinger	DRILLER Taylor; Hutchins; &	Tuggle

DEFINITION OF NOTES			Type and Size of Hole	% Recovery	DEPTH	CLASSIFICATION AND PHYSICAL CONDITION
NOTES On water table levels, water return, character of drilling						
Purpose of Hole: (1) Temperature gradient. (2) Geophysical properties. (3) Geologic evaluation.			12 1/4" RB	0		Log based on rockbit cuttings. 0-9.8': <u>RECENT ALLUVIAL DEPOSITS</u> Fine to medium sand and clay. Increase in sand past 5 feet.
Land Owner: Lassen Molding Co.; 755 Alexander St.; Susanville, CA.						9.8-372'(?):*
Location: NW 1/4 NW 1/4 Section 5, T. 29 N., R. 12 E.			6 1/2" RB			<u>PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS.</u> 9.8-44': Basalt. Hard, black volcanic fragments, minor red, green and other volcanic fragments. Scattered rounded gravel and occasional brown sandy clay zones ± 1/2' thick. Minor red and gray clay.
Drill Rig: Failing 1500						44-65': Clay. Brown with fine sand. Fine gravel at 45'. 65-96': Basalt. Fine to coarse, hard, black fragments with sand.
Drilling Methods: Rockbit drilled using bentonite mud and barite weight material. Three mud pits and shaker used. 0-44.0': 12 1/4" rockbit for installation of 8" surface casing. 44.0-1680.0': 6 1/2" rockbit. 140': Attempted coring; hole caved; could not complete. 875.0-879.8': 3-7/8" Hayestellite bit. Recovered 2.4' (50%)						96-98': Clay. 98-107': Hard, volcanic rock fragments. 107-109': Clay. 109-180': Basalt and/or Volcanic Boulders and sand and clay in alternating layers. Volcanic material is black and hard. Occasional sand and clay layers usually less than 1' thick; layers increase below 140'; gray and brown; sand is fine, dark.
Drilling Conditions: 0-9.8': Smooth. 9.8-44.0': Slow and rough. 44.0-61.4': Smooth to slightly rough. 61.4-270.0': Slow and rough. 270.0-370.0': Medium smooth. 370.0-398.8': Slow and rough. 398.8-640.0': Fast and smooth, minor rough spots. 640.0-740.0': Medium fast and smooth. 740.0-785.0': Slow and rough. 785.0-860.0': Fast and smooth.						180-230': Clay and volcanic fragments similar to above. Marked increase in clay. Light gray to tan, soft. Minor decomposed ash. 230-290': Clay and Sand. Clay similar to above. Sand is fine to medium, angular, dark grained, derived mostly from volcanics. Percentage of light-colored grains increase after 270'. 290-310': Clay. Brown, with coarse dark volcanic fragments, sand and minor gravel. Decrease in clay and increase in gravel from 300-310'. 310-350': Clay with sand and gravel. Mostly dark-colored grains with minor light colors. Decrease in clay at about 330'; decrease in gravel at about 340'. 350-360': Gravel. Coarse, dark-colored fragments from many sources with brown clay. 360-372': Clay. Brown and sandy with minor gravel; mostly dark colored.
						372.0(?) - 1,680.0': <u>PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS</u> 372-398': Fine gravel and lava beds (?) with Sand. Medium to coarse, dark colored grains, minor quartz and light colored grains. Increase in clay below 380'. 400-420': Volcanic and dark-colored fragments. Medium sand sizes, minor white and brown grains.

EXPLANATION

Hole drilled by U. S. Bureau of Reclamation,
Mid-Pacific Region, Sacramento, California.

Contact between the Pleistocene and Pliocene Lake Deposits cannot be determined from cuttings. The contact was estimated from geophysical logs.

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal

FEATURE Susanville Anomaly--Lassen County **PROJECT** Investigations **STATE** California
LOCATION See Note, Sheet 1 **GROUND ELEVATION** 4185' **ANGLE FROM**
HOLE NO. SUZY-2 **COORDINATES** N.394,305; E.2,374,717 **TOTAL DEPTH** 1680' **VERTICAL** Vertical
BEGUN 8-25-77 **FINISHED** 9-15-77 **Robert L. Turner &** **Taylor; Hutchins;**
Not Determined **HOLE LOGGED BY** Gary A. Hollinger **DRILLER** & Tuggle

DEPTH TO WATER	NOTES On water table levels, water return, character of drilling	Type and Size of Hole	Recovery	DEPTH	CLASSIFICATION AND PHYSICAL CONDITION
	Representative Drilling Fluid Return Temperatures (°F) (Continued): 86° at 400' 92° at 430' 100° at 460' after trip. 95° at 470' 99° at 505' 100° at 570' 102° at 620' 108° at 640' after trip. 102° at 650' 104° at 720' 108° at 760' 106° at 785' 104° at 840' 104° at 850' after 1 hour downtime. 104° at 900' 108° at 940' 106° at 960' 109° at 1020' 113° at 1050' 117° at 1100' 115° at 1120' 118° at 1160' 113° at 1180' 115° at 1200' 109° at 1220' 108° at 1260' 113° at 1320' 130° at 1320' after 90 hours downtime. 108° at 1340' 106° at 1350' 110° at 1380' 107° at 1460' 113° at 1530' 113° at 1640' 111° at 1680'	6 1/2" RB			940-960' (Continued): multicolored grains, minor clay. 960-1010': <u>Sand with clay.</u> Fine to medium gray to brown grains, minor black; increase in dark grains and gray clay below 990'. 1010-1030': <u>Clay with Sand.</u> Clay is light brown with mostly fine to medium, dark-colored sand; minor light colors. 1030-1040': <u>Clay.</u> Blue-gray. 1040-1060': <u>Clay with Sand.</u> Clay is brown with fine black and dark brown sand. 1060-1150': <u>Sand and Clay.</u> Sand and clay variable in amounts; sand mostly fine, black and brown, volcanic and lithic fragments; clay is gray to pink. Slight decrease in clay from 1130-1140'. 1150-1260': <u>Sand.</u> Fine to medium, dark grains, minor multicolored lithic fragments. Minor light tan to pink clay. Slight increase in fines and clay below 1170'. 9- 2-77: Drilled to 1330'. Repaired break-out table and winch drum. New bit at 1280'. Mud pump and engine failed, pulled rods and secured equipment for long Labor Day weekend. 9- 6-77: Drilled to 1540'. Repaired mud pump and engine. 1260-1270': <u>Sand & Gravel.</u> Fine sand to fine gravel. Material mostly dark colored with minor light colors. 1270-1290': <u>Sand and Clay.</u> Predominantly fine, dark-colored sand with minor light colors; clay light brown to pinkish brown. Increase in brown sand below 1280'. 1290-1350': <u>Sand.</u> Fine to medium, subangular, dark volcanic sand with minor multicolored lithic fragments. Very minor quartz fragments. Minor light tan to light pink, soft clay. 1350-1370': <u>Sand and Clay.</u> Fine to medium, dark-colored sand, minor light colors. Clay is gray. Marked increase in coarse, multicolored and quartz grains and fragments and minor pink clay below 1360'. 1370-1430': <u>Sand and Clay.</u> Predominantly fine, brown sand and pinkish brown clay; minor black and light-colored grains and medium sand. Decrease in grain size below 1380'. Increase in weathered, medium sand-size lithic fragments at about 1400'. 1430-1450': <u>Sand and Granitic (?) Material.</u> Fine-grained, highly weathered. 1450-1490': <u>Sand.</u> Predominantly fine, black and brown sand with scattered light grains and minor light brown clay. Decrease in light-colored grains (granitic?) below 1480'.
	Caving and/or Squeezing Conditions: Caving caused difficulty in pulling rods mostly during first few days of drilling. Schlumberger logging tool stuck (caving in tight spot?) at 650' on 9-8-77. Conditions noted by driller (caving may be from higher formations):				

EXPLANATION

Sheet 3 of 4

Hole No. SUZY-2

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County		PROJECT Investigations	STATE California
HOLE NO. SUZY-2	LOCATION See Note Sheet 1	GROUND ELEVATION 4185	ANGLE FROM
	COORDINATES N.394,305; E.2,374,717	TOTAL DEPTH 1680'	VERTICAL Vertical
BEGUN 8-25-77	FINISHED 9-15-77	Robert L. Turner &	Taylor; Hutchins;
DEPTH TO WATER Not Determined	HOLE LOGGED BY Gary Hollinger	DRILLER	& Tuggle

NOTES	Type and Size of Hole	Recovery	DEPTH	CLASSIFICATION AND PHYSICAL CONDITION
Caving and/or Squeezing Conditions: (Cont.) 61.4-81.4: Caving 91.4-93.9': Rods stuck. 99.0-111.0': Rods stuck. 111.0-140.0': Caving 439.0-459.0': Caving 440.0-480.0': Rods stuck. A2-870.0': Rods stuck. 1250-1280': Caving.	1550 1600 6 1/2" RB	0		
Casing Record: 8" steel surface casing installed to 39.9'. Casing permanently cemented into hole with an 8" gate valve and two 2" bleed lines installed on top for blow-out protecting. Valves and lines removed after hole completion.	1650 1700			
Geophysical Logging: The following geophysical logs were run by Schlumberger: (1) Dual Induction Laterolog (2) Borehole Compensated Sonic (3) Compensated Neutron (4) Formation Density (5) Gamma Ray (6) High Resolution Temperature	1750 1900			
Hole Completion: 2" sealed, water-filled steel pipe installed and cemented into hole to 1659' for temperature gradient. Site protected with a steel guard rail.	1850 1900 1950			
DAILY SUMMARY OF DRILLING OPERATIONS (Cont.):				
9- 7-77: Drilled to 1680'. Total depth of rods available, condition hole for Schlumberger.			1550	1490-1560': Sand. Predominantly fine to minor coarse, black and brown grains. Coarse grains are mostly weathered light-colored material. Minor light brown clay. Slight decrease in coarse material at about 1500'. Sand grain size decreases about 1520' to predominantly fine to medium.
9- 8-77: Pulled rods from hole. Schlumberger geophysical logging started swing shift.			1550	
9- 9-77: Schlumberger logging tool stuck in hole at 650'. Circulating mud to clear hole. Fishing 2 shifts per day.			1600	1560-1630': Sand. Fine to coarse, sub-rounded grains. Minor light gray clay. Coarse material mostly weathered basaltic and granitic material and ash; increase in coarse grains and red clay (weathered ash?) below 1580'.
9-10-77: Fishing for tool with oil field rods supplied by Midway Fishing Tool Co. of Woodland.			1600	1630-1680': Sand. Fine to medium, dark gray with minor multicolored grains. Minor clay. Increase in light gray clay below 1660'.
9-11-77: Continued fishing.			1650	
9-12-77: Continued fishing. Work over fish but could not latch on.			1700	
9-13-77: Continued fishing with failing rods.			1700	
9-14-77: Latched fish at bottom of hole and recovered tool. Completed geophysical logging. Condition hole and mud for completion.			1750	
9-15-77: Set 1659' of 2" steel pipe, rig for cementing, pump in 10 cubic yards neat cement and chase cement with latch down plug and clear water.			1750	
9-16-77: Move rig from site.			1800	
			1850	
			1900	
			1950	

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

FEATURE <u>Susanville Anomaly--Lassen County</u>		PROJECT <u>Susanville Geothermal Investigations</u>		STATE <u>California</u>	
HOLE NO. <u>SUZY-3</u>		LOCATION <u>See Note</u>		GROUND ELEVATION <u>4,230</u>	
COORDINATES <u>N. 394,298; E. 2,372,571</u>		TOTAL DEPTH <u>2,088.0'</u>		ANGLE FROM VERTICAL <u>Vertical</u>	
BEGUN <u>9-19-77</u>		FINISHED <u>10-13-77</u>		G. A. Hollinger and Taylor, Tuggle, & R. L. Turner Hutchins	
DEPTH TO WATER <u>Not Determined</u>		HOLE LOGGED BY		DRILLER	

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION LOG BASED ON ROCKBIT CUTTINGS
Purpose of Hole: (1) Temperature gradient. (2) Geophysical properties. (3) Geologic evaluation.	12 3/4" RB	0		0-2,088': <u>PLEISTOCENE LAHONTAN LAKE (near shore) DEPOSITS WITH INTERBEDDED BASALTS AND PIOCENE LAKE DEPOSITS WITH INTERBEDDED BASALTS (?)</u> *
Land Owner: Lassen County.	6 1/2" RB	0		0-20.0': <u>Silt and Sand</u> . Predominantly fine-grained, brown.
Location: NW 1/4 NW 1/4 Section 5, T. 29 N., R. 12 E., near southeast corner of the Lassen County Maintenance Yard in the southern part of City of Susanville.	6 1/2" RB	0		20.0-40.0': <u>Silty Clay</u> . Minor sand, light brown to medium gray.
Drill Rig: Failing 1500	6 1/2" RB	0		40.0-50.0': <u>Sand</u> . Medium to coarse, volcanic, dark gray with coarse quartz fragments.
Drilling Methods: Rockbit drilled with bentonite mud, weight material, and lost circulation additives. 0-20': 12-3/4" rockbit for installation of 8" surface casing. 20-2088': 6 1/2" rockbit. 80-84': 3-7/8" Haystellite cor run; recovered 2.5' or 63%. 100': Attempted 3-7/8" Haystellite core run; destroyed bit; no recovery. 100-102': 2 1/4" diamond core run; recovered 2.0' or 100%. 2088': Attempted 3-7/8" diamond core run; blocked with clay, no recovery.	6 1/2" RB	0		50.0-68.0': <u>Sand and Clay</u> . Fine to medium volcanic sand, dark gray, common coarse quartz with dark gray clay. Increase in fine gravel from 60-68'.
Drilling Conditions: 0-60': Fast and smooth. 60-140': Slow and rough. 140-220': Hard and rough. 220-240': Slow and rough. 240-260': Medium speed and rough.	6 1/2" RB	0		68.0-73': <u>Gravel and Clay with Sand</u> . Fine to coarse, subrounded gravel, and gray clay. Sand is fine to coarse.
	6 1/2" RB	0		73.0-78.0': <u>Basalt</u> . Hard, dark colored, volcanic fragments.
	6 1/2" RB	0		78.0-94.0': <u>Sandy Clay with Gravel</u> . Sand mostly fine with medium and coarse, brown, scattered coarse to fine volcanic gravel, mostly subrounded. (Core 80-84' recovered 2.5' in pieces ±3" to 1", breaks along ±1" thick, fine to medium sand zones).
	6 1/2" RB	0		94-110': <u>Basalt and/or Cobbles and Gravel</u> . Dark gray to black volcanic fragments, minor dark sand. (Core 100-102': recovered 6" gray, black vesicular piece, vugs partially filled, and 5" gray nonvesicular piece). Gravel is rounded to subrounded volcanic, minor sand and gray clay interzones.
	6 1/2" RB	0		110-130': <u>Clay and Sand</u> . Light brown to red brown with minor greenish clay and fine to medium, multicolored sand. Marked decrease in dark-colored grains from above. Red-brown clay decreases below 115' and is absent below 120'. Scattered coarse zones less than 1 ft thick mostly below 115'.
	6 1/2" RB	0		130-140': <u>Sandy Clay</u> . Sand fine with minor medium grains, light yellow brown.
	6 1/2" RB	0		140-230': <u>Basalt with Interbedded Clay</u> . Basalt black to dark gray with red and tan common. Clay, brown, content increasing below 200', minor quartz and chalcedony.
	6 1/2" RB	0		230-260': <u>Sand and Clay</u> . Fine to coarse volcanic sand, light brown clay.
	6 1/2" RB	0		260-280': <u>Sand</u> . Fine to coarse, dark colored sand, minor light and brown colors.

Hole drilled by U. S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, California.

EXPLANATION

*Contact between Pleistocene and Pliocene rocks cannot be determined from cuttings.

Sheet 1 of 3

Hole No. SUZY-3

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal
 FEATURE Susanville Anomaly--Lassen County PROJECT Investigations STATE California
 LOCATION See Note, Sheet 1 GROUND ELEVATION 4,230 ANGLE FROM
 COORDINATES N. 394,298; E. 2,372,571 TOTAL DEPTH 2,088.0' VERTICAL Vertical
 BEGUN 9-19-77 FINISHED 10-13-77 G. A. Holinger and Taylor, Tuggle &
 DEPTH TO WATER Not Determined HOLE LOGGED BY R. L. Turner DRILLER Hutchins

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
Estimated Drilling Fluid Return (Con- tinued):			DAILY SUMMARY OF DRILLING OPERATIONS:	
830-880': Loss at intervals.				890-950' (Continued): sand below 930'.
880-940': 80%				950-1080': Sand with Clay. Fine to medium, minor coarse, black volcanic sand, some tan to red volcanics and quartz. Clay light gray to pink. Decrease in coarse grains and clay below 970'. Sand predomi- nantly fine below 1010'. Occasional rough zones below 1060'.
940-1000': Partial loss (?).			9-27-77: Drilled to 1175'. Mud loss prob- lems. Deck engine flywheel fail- ed. Pull rods.	1080-1120': Sand. Fine to coarse, minor gravel, subangular to subrounded black volcanic sand, common quartz and red to tan volcanics, some feldspars. Slight de- crease in coarse grains at approximately 1090'. Increase in pink clay below 1100'.
1000-1040': 70%			9-28-77: No drilling. Repairing deck en- gine. Replace all cables and ser- vice equipment.	1120-1130': Sand with Clay. Fine dark vol- canic sand and pink clay.
1040-1075': 90%				1130-1140': Sand. Fine to coarse, subangular to subrounded, dark gray to black, vol- canic, minor tan to red volcanics and quartz, minor tan to pink clay.
At 1075': Complete loss.			9-29-77: Drilled to 1200'. Completed re- pairs on deck engine. Replaced bit at 1175'.	1140-1200': Sand. Fine to medium, mostly dark gray to black volcanics with tan and red volcanics, minor clay.
1075-1090': Slow loss				1200-1230': Sand. Predominantly fine with medium, dark gray and tan, angular to sub- angular, minor clay. Increase in medium size grains and quartz below 1220'.
At 1090': Complete loss.				1230-1330': Sand. Fine to medium, dark gray to tan, angular to subrounded, minor clay. Decrease in grain size below 1250', slight increase in red and tan volcanic grains at approximately 1290', increase in medium grain size below 1310' (rough drilling 1290-1300').
1090-1120': Slow loss				1330-1380': Sand. Fine, dark gray to pink and tan, minor clay. Increase in grain size to fine to medium at approximately 1360-1370'.
At 1120': Complete loss.			9-30-77: Drilled to 1360'. Mud loss prob- lems continue. Additives being used to regain circulation. Pulled rods and replaced bit at 1360'. Secured for weekend.	1380-1640': Sand. Fine to medium, dark colored grains, minor red & light colors, and quartz, minor light brown to gray clay, occasional rough spots (gravel ?) less than 1' thick. Mostly fine sand be- low 1570'.
1120-1140': Slow loss				
1140-1175': 50%				
At 1175': Complete loss			10-3-77: Drilled to 1500'. Mud loss prob- lems continue. Additives being used. Replaced bit at 1480'. Re- paired mud line guide cable.	
1175-1180': 50%				
1180-1200': 95%				
1200-1220': Slow and continuous loss.				
At 1220': Complete loss.				
1220-1275': Slow and continuous loss.				
At 1275': Complete loss.				
1275-1300': Slow and continuous loss.				
1300-1360': 50% to complete loss.				
At 1360': Complete loss.				
1360-1420': Slow and continuous loss.				
1420-1460': 50% to complete loss.				
1460-1600': 90%				
1600-1690': 80%				
1690-2088': 90%				
Drilling Fluid Return Temperatures (°F):				
Normally 80-90° from 0-1570'.				
Normally 90-100° from 1570-2088'.				
Caving Conditions:				
No major caving problems were encoun- tered. Minor caving from 240-660' after trip.				

EXPLANATION

Sheet 3 of 5

Hole No. SUZY-3

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal STATE California
 HOLE NO. SUZY-3 LOCATION See Note, Sheet 1 GROUND ELEVATION 4,230 ANGLE FROM
 COORDINATES N.394,298; E.2,372,571 TOTAL DEPTH 2,088.0' VERTICAL Vertical
 BEGUN 9-19-77 FINISHED 10-13-77 G. A. Hollinger and Taylor, Tuggle, &
 DEPTH TO WATER Not Determined HOLE LOGGED BY R. L. Turner DRILLER Butchina

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
DAILY SUMMARY OF DRILLING OPERATIONS:				
<u>Casing Record:</u> Cemented 8" steel surface casing to 20.9'.			10- 4-77: Drilled to 1775'. Repaired mud line guide cable.	
<u>Geophysical Logging:</u> The following geo- physical logs were run by Schlumberger. (1) Dual Induction Laterolog. (2) Borehole Compensated Sonic (3) Compensated Neutron. (4) Formation Density. (5) Gamma Ray (6) High Resolution Temperature.	6 1/2" RB			1640-1760': <u>Clay and Sand</u> . Gray clay, fine to medium, dark volcanic sand, minor light colors and quartz. Sand grades to predominantly fine below 1740'.
<u>Hole Completion:</u> 2058' of two-inch sealed, water-filled steel pipe installed and cemented in hole for temperature gradients. Site pro- tected with a steel guard rail.		0	10- 5-77: Drilled to 1920'. New bit at 1900'.	1760-1810': <u>Sand</u> . Fine, gray with minor light-colored grains, minor clay.
	6 1/2" RB			1810-1830': <u>Sand with Gravel</u> . Predominant- ly fine-grained, dark volcanic sand with coarse rock fragments; red, white, green and brown (drillers report boulders).
			10- 6-77: Drilled to 2070'.	1830-1990': <u>Clay and Sand</u> . Gray clay, mostly fine, dark-colored sand, very mi- nor medium, very minor light colors. About 30% multicolored lithic fragments at approximately 1900'.
				1990-2088': <u>Sandy Clay</u> . Fine to medium, gray sand, common multicolored lithic

EXPLANATION

<h2 style="margin: 0;">GEOLOGIC LOG OF DRILL HOLE</h2>				
FEATURE Susanville Anomaly--Lassen County		PROJECT Susanville Geothermal Investigations		STATE California
HOLE NO. SUZY-3		LOCATION See Note, Sheet 1		GROUND ELEVATION 4,230
COORDINATES N. 394,298; E. 2,372,571		TOTAL DEPTH 2,088.0'		ANGLE FROM VERTICAL Vertical
BEGUN 9-19-77		FINISHED 10-13-77		DRILLER Taylor, Tuggle, & Hutchins
DEPTH TO WATER Not Determined		HOLE LOGGED BY G. A. Hollinger and R. L. Turner		
NOTES On water table levels, water return, character of drilling	Type and Size of Hole	Recovery	DAILY SUMMARY OF DRILLING OPERATIONS:	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	6 1/2" RB	0	<p>10- 7-77: Drilled to 2088' T.D. Schlumberger geophysical logged hole. Secured for 3-day holiday weekend.</p> <p>10-11-77: Assemble core barrel and service equipment. Two crews per day.</p> <p>10-12-77: Attempted core run at 2088'. No recovery. Start running 2" steel pipe.</p> <p>10-13-77: Cemented 2" steel pipe to 2058'. Pumped 15 cubic yards of cement into hole. Set locking plug at bottom with clear water.</p> <p>10-14-77: Move rig from site.</p>	<p>1990-2088' (Continued): fragments; clay light gray with minor gray-green. Increase in gray-green clay below 2030'.</p> <p>Formational clay increasingly hydrated by drill action below approximately 1400' preventing accurate evaluation of content. Clay content below 1400' may be higher than cuttings indicated.</p> <p>Drill action indicates formation may be increasingly indurated below approximately 1200' and may be predominantly fine-grained, weakly cemented sandstone and/or claystone increasing toward the total depth.</p>
	2450	2450		2450

EXPLANATION

Sheet 5 of 5
 Hole No. SUZY-3

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

SUSANVILLE GEOTHERMAL

FEATURE Susanville Anomaly--Lassen County PROJECT INVESTIGATIONS STATE CALIFORNIA
 HOLE NO. SUZY-4 LOCATION SEE NOTES GROUND ELEVATION 4196' ANGLE FROM VERTICAL VERTICAL
 COORDINATES N. 393,965; E. 2,373,944 TOTAL DEPTH 769'
 BEGUN 10-13-78 FINISHED 11-15-78
 DEPTH TO WATER NOT DETERMINED HOLE LOGGED BY G. HOLLINGER, R. TURNER DRILLER SKAGS, FERRELL, TUGGLE

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
PURPOSE OF HOLE: (1) TEMPERATURE GRADIENT. (2) GEOPHYSICAL PROPERTIES. (3) GEOLOGIC EVALUATION. (4) PIEZOMETRIC OBSERVATION.			DAILY SUMMARY OF DRILLING OPERATIONS	
LANDOWNER: CITY OF SUSANVILLE, CA LOCATION: NE $\frac{1}{4}$ NW $\frac{1}{4}$ SECTION 5, T. 29 N., R. 12 E. 20X20' PARCEL BETWEEN SHASTA AND SIERRA STREETS. DRILL RIG: FAILING 1500 DRILLING METHODS: ROCKBIT DRILLED USING BENTONITE MUD AND LOST CIRCULATION MATERIAL AS NEEDED. 0-63': 9-5/8" ROCKBIT FOR INSTALLATION OF 8" SURFACE CASING. 63-769': 6-1/2" ROCKBIT. DRILLING CONDITIONS: 0-16': FAST AND SMOOTH. 16-26': MEDIUM SPEED, SLIGHTLY ROUGH. 26-29': SLOW, ROUGH, CAVING IN. 29-32': HARD, SLOW, ROUGH. 32-39': MEDIUM SPEED AND ROUGHNESS. 39-52': MEDIUM SMOOTH. 52-58': SLOW, SMOOTH. 58-63': SLOW, ROUGH. 63-67': ROUGH TO SMOOTH. 67-170': FAST AND SMOOTH. 170-282': MEDIUM FAST AND SMOOTH. 282-304': No record. 304-367': MEDIUM FAST. 367-413': No record	9 5/8" RB 50 100 150 200 250 300 350 400 450	0 <		

EXPLANATION

*CONTACT BETWEEN THE PLEISTOCENE AND PLEISTOCENE LAKE DEPOSITS CANNOT BE DETERMINED FROM CUTTINGS. THE CONTACT WAS ESTIMATED FROM GEOPHYSICAL LOGS AND EXISTING DATA.

SHEET 1 OF 3

Hole No. SUZY-4

GEOLOGIC LOG OF DRILL HOLE

SUSANVILLE GEOTHERMAL
 FEATURE SUSANVILLE ANOMALY--LASSEN COUNTY PROJECT INVESTIGATIONS STATE CALIFORNIA
 HOLE NO. SUZY-4 LOCATION SEE NOTES, SHEET 1 GROUND ELEVATION 4196' ANGLE FROM VERTICAL VERTICAL
 BEGUN 10-13-78 FINISHED 11-15-78 TOTAL DEPTH 769'
 DEPTH TO WATER NOT DETERMINED HOLE LOGGED BY G. HOLLINGER, R. TURNER DRILLER SKAGGS, FERRELL, TUGGLE

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
DRILLING CONDITIONS (CONT.) 413-487': MEDIUM ROUGH AND SLOW 487-547': FAST, SMOOTH. 547-627': No record 627-667': MEDIUM FAST, SMOOTH. 667-693': SLOW, ROUGH. 693-740': No record 740-769': MEDIUM ROUGH AND SLOW.	550 600 6 1/2 RB 650 700 750 800 850 900 950 1000	0	130-150': GRAVEL AND SAND, SUBROUNDED TO ANGULAR, COARSE SAND AND FINE GRAVEL WITH MINOR MEDIUM GRAY CLAY. 150-225': SANDY CLAY, MEDIUM GRAY, SOFT CLAY WITH SAND AND GRAVEL OF SIMILAR COM- POSITION TO 130-150' INTERVAL. GRADUAL CHANGE TO BLUE-GRAY CLAY TOWARD BOTTOM OF INTERVAL. GRADUAL DECREASE IN CLAY AND INCREASE IN DARK VOLCANIC FRAGMENTS BELOW 215'. 225-255': CLAYEY SAND, FINE TO MEDIUM SAND WITH COARSE, PREDOMINANTLY VOLCANIC FRAG- MENTS. MINOR CLAY. TOTAL LOSS IN CIRCULA- TION AT 255'. 255-282': SAND AND GRAVEL, PREDOMINANTLY COARSE, BLACK VOLCANIC SAND AND FINE GRA- VEL. MINOR FINE TO MEDIUM SAND AND BLUE- GRAY CLAY. CUTTINGS HIGHLY CONTAMINATED BY EFFORTS TO REGAIN CIRCULATION. 282(?)' - 769': <u>PLIOCENE LAKE DEPOSITS AND</u> <u>INTERBEDDED BASALTS</u> 282-480': CUTTINGS AND DRILLING CONDITIONS NOT LOGGED BY GEOLOGIST. SAMPLE TAKEN BY DRILLER AT: 310': CLAY, POSSIBLE ASH, SOFT TO SLIGHTLY FIRM, MINOR MULTICOLORED SAND, FINE TO COARSE, PREDOMINANTLY SUBANGU- LAR VOLCANIC WITH MINOR QUARTZ. 360': SAND, MULTICOLORED, PREDOMINANTLY DARK, FINE TO COARSE, SUBANGULAR TO SUBROUNDED, PREDOMINANTLY VOLCANIC WITH MINOR QUARTZ, MINOR PINK SOFT CLAY. 400-487': SANDY CLAY, PINK, SOFT WITH SUB- ROUNDED, FINE TO MEDIUM MULTICOLORED SAND. 487-575': CLAY, PINK, SOFT, WITH MINOR FINE TO MEDIUM, PREDOMINANTLY SUBANGULAR MUL- TICOLORED, PREDOMINANTLY VOLCANIC SAND. GRADUAL INCREASE IN VOLCANIC SAND BELOW 540'. 575-612': SANDY CLAY, MEDIUM GRAY, SOFT, WITH FINE TO MEDIUM VOLCANIC, SUBANGULAR TO ROUNDED SAND. COLOR CHANGE TO PINK BE- LOW 587' AND WHITE PINK (TUFF?) BELOW 600'. SLIGHT INCREASING FIRMNESS TOWARDS BOTTOM OF INTERVAL. 612-675': CLAYEY SAND, MULTICOLORED, FINE TO COARSE, PREDOMINANTLY DARK VOLCANIC AND MINOR QUARTZ, SUBANGULAR TO SUBROUND- ED SAND WITH LIGHT PINK, SOFT TO MODERATE- LY FIRM CLAY (OR TUFF?). CLAY MOSTLY BROWN BELOW 665'. OCCASIONAL THIN BLACK VOLCANIC GRAVEL BEDS LESS THAN 1' THICK FROM APPROXIMATELY 625-640' AND BELOW 670'.	550 600 650 700 750 800 850 900 950 1000
ESTIMATED DRILLING FLUID RETURN: 0-255': 95-100% 255': TOTAL CIRCULA- TION LOSS, REQUIR- ED 4 SHIFTS TO RE- GAIN. 255-292': 10-60% 292-769': 90-95%				
REPRESENTATIVE DRILL- ING FLUID TEMPERA- TURE (° F): 59° AT 26' 61° AT 52' 63° AT 78' 67° AT 107' 67° AT 167' 88° AT 167' AFTER WEEKEND. 74° AT 220' Warm at 320' report- ed by Driller. 95° at 480' 104° AT 567' 100° AT 600' 106° AT 707' 107° AT 730'				
CAVING CONDITIONS: 26-29': CAVING.				
CASING RECORD: 8" STEEL SURFACE CASING CEMENTED IN- TO HOLE TO 62'.				
GEOPHYSICAL LOGGING: THE FOLLOWING GEOPHY- SICAL LOGS WERE RUN BY THE USGS DENVER OFFICE: (1) ELECTRIC (2) NATURAL GAMMA (3) GAMMA GAMMA (4) NEUTRON (5) TEMPERATURE (6) CALIPER				

EXPLANATION

SHEET 2 OF 3

Hole No. SUZY-4

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET

FEATURE, SUSANVILLE ANOMALY, PROJECT, SUSANVILLE GEOTHERMAL INVESTIGATIONS, LASSEN COUNTY, CALIFORNIA

HOLE NO. SUZY-4...

SHEET... 3 OF 3...

NOTES (CONTINUED)

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)

HOLE COMPLETION

6-3/4" HOLE REAMED TO 7-7/8". INSTALLED 735' OF 4" STEEL CASING WITH 21' OF 2" STEEL PIPE AND 8' OF 60 MESH WELL SCREEN ON BOTTOM TO 764'. GRAVEL PACKED TO 300'. CEMENTED UPPER PORTION OF HOLE. SITE PROTECTED WITH STEEL GUARD RAIL.

675-687': GRAVEL, SAND AND BASALT. FINE TO PREDOMINANTLY COARSE, BLACK VOLCANIC SAND AND GRAVEL FRAGMENTS. SAND ROUNDED TO PREDOMINANTLY SUB-ANGULAR, MINOR LIGHT COLORS AND GRAY CLAY. POSSIBLE BASALT FLOW AT LOWER, APPROXIMATELY 10'.

687-695': SANDY CLAY. BLACK VOLCANIC SAND SIMILAR TO 675-687' INTERVAL IN PINK GRAY CLAY.

695-726': GRAVEL AND SAND. SIMILAR TO BLACK VOLCANIC SAND AND GRAVEL IN 675-687' INTERVAL. INCREASE IN PINKISH GRAY CLAY BELOW 720'.

726-769': CLAYEY SAND AND GRAVEL. FINE TO COARSE, SUBANGULAR TO SUBROUND ED, PREDOMINANTLY DARK VOLCANIC SAND AND GRAVEL WITH VARYING AMOUNTS OF PINKISH GRAY SOFT CLAY.

Sheet 3 of 3

HOLE NO. SUZY-4....

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

SUSANVILLE ANOMALY-- LASSEN COUNTY		PROJECT		Susanville Geothermal Investi- gations		STATE		California	
FEATURE	LOCATION	See Notes	GROUND ELEVATION	4171'	ANGLE FROM				
HOLE NO.	SUZY-5	COORDINATES	N. 393,278; E. 2,376,886	TOTAL DEPTH	706.0'	VERTICAL	Vertical		
BEGUN	9-12-78	FINISHED	10-12-78	G. Hollinger;					
DEPTH TO WATER	4.0' (9-12-78)	HOLE LOGGED BY		R. Turner; J. Darling		DRILLER			
N. Tuggle; R. Swank									
NOTES	Type and Size of Hole	Recovery	DEPTH	FIELD CLASSIFICATION AND PHYSICAL CONDITION					
On water table levels, water return, character of drilling									
Purpose of Hole: (1) temperature gradient; (2) geo-physical properties; (3) geologic evaluation; (4) piezometric observation.	9 5/8" RB	0	50	NOTE: Log based on rockbit cuttings.					
Landowner: Sierra Pacific Industries; Eagle Lake Division; Susanville, CA			100	0-23.0': <u>RECENT ALLUVIAL DEPOSITS</u>					
Location: SE 1/4 NE 1/4 Section 5, T. 29 N., R. 12 E., on lumber mill property.			150	0-10': <u>Sandy Silt with Clay</u> . Fine-grained, brown, abundant mica and weathered granitic material.					
Drill Rig: Failing 1500			200	10-20': <u>Sand</u> . Fine to predominantly coarse, multicolored, derived from weathered granitic rocks, abundant quartz mica and feldspars, minor volcanics and dark brown clay. Grains angular to rounded, predominantly subrounded. Gradational contact with sandy silt above.					
Drilling Methods: Rockbit drilled using bentonite mud and additives, as required. Three mud pits used.	6 1/2" RB	0	250	20-23': <u>Clay and Sand</u> . Pinkish brown, soft, predominantly coarse with similar composition to weathered granitic material as above.					
0-80': 9-5/8" rockbit for installation of 8" surface casing.			300	23.0-512'(?)*: <u>PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS.</u>					
60-706': 6 1/2" rockbit.			350	23-29': <u>Basalt</u> . Black fragments from a flow or cobbles.					
Drilling Conditions: 0-15': Very fast and smooth.			400	29-35': <u>Sandy Clay</u> . Dark brown, soft, fine-grained.					
15-45': Fast and smooth, squeezing at 45'.			450	35-40': <u>Clay</u> . Light gray grading to brown near 40'; soft.					
23-30': Slow and rough.			500	40-48': <u>Sandy Clay</u> . Dark brown, hard, fine-grained; minor sand.					
45-91': Slow and rough to very rough.				48-58': <u>Basalt</u> . Black fragments, minor dark gray and brown clay.					
91-120': Intermittently slow to fast and smooth to rough.				58-60': <u>Clay</u> . Light brown, fat.					
120-160': Slow to medium speed, smooth to rough. Squeezing from 131-141'.				60-62': <u>Basalt</u> . Hard, with minor soft medium-brown clay.					
160-220': Hard, slow rough.				62-77': <u>Sand and Conglomerate</u> . Black and gray, firm with moderate-ly firm to soft clay. Occasional secondary white to yellow calcite (?) and quartz (?).					
220-271': Intermittently smooth and fast to slow and rough.				77-80': <u>Clay</u> . Red-brown, soft, with decomposed basalt (?)					
271-316': Medium				80-95': <u>Basalt and Clay</u> . Black volcanic fragments, minor red-brown clay beds less than 6 inches thick, minor quartz.					
				95-104': <u>Clayey Sand</u> . Dark gray to black, subangular to angular, fine to coarse volcanic sand with light gray, soft clay.					
				104-155': <u>Sand and Conglomerate</u> . Light to dark gray, fine to very coarse, angular to subrounded, mostly volcanic grains and fragments in a light gray clay matrix. Grain size decreases below 120'. Considerable increase in gray-brown clay below 136'. Drill action					

EXPLANATION

*Contact between the Pleistocene and Pliocene lake deposits cannot be determined from cuttings. The contact was estimated from geophysical logs and existing data.

Sheet 1 of 3

FEATURE: Susanville Anomaly--Lassen County

PROJECT: Susanville Geothermal Investi-
gations

Hole No. SUZY-5

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE SUSANVILLE ANOMALY--LASSEN COUNTY PROJECT Susanville Geothermal Investigations STATE California
 HOLE NO. SUZY-5 LOCATION See Note GROUND ELEVATION 4171' ANGLE FROM Vertical
 COORDINATES N. 393,278; E. 2,376,886 TOTAL DEPTH 706.0' VERTICAL
 BEGUN 9-12-78 FINISHED 10-12-78 G. Hollinger;
 R. Turner; J. Darling DRILLER N. Tuggle; R. Swank
 DEPTH TO WATER 4.0' (9-12-78) HOLE LOGGED BY

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	CLASSIFICATION AND PHYSICAL CONDITION
Drilling Conditions (Cont.)				104-155' (Continued): alternating between rough and smooth every few inches below 141'.
271-316' (Cont.): speed and smooth.				155-160': Sandy Clay with Volcanic Fragments. Brown to red brown, fine-grained, soft with increasing black volcanic fragments toward 160'.
316-327': Slow and rough.	550		550	160-179': Conglomerate and Clayey Sand. Rough and smooth alterna- ting layers, predominantly fine to coarse, black volcanic fragments with minor multicolored fragments, and angular to subangular with minor subrounded grains. Clay soft, brown to gray, increase in brown clay below 174'.
327-340': Slow to medium and smooth to slightly rough.	62 1/2" RB		600	179-182': Sandy Clay. Light medium brown, soft.
340-350': Squeezing, slow and smooth.			650	182-199': Pebble Conglomerate and Clayey Sand. Similar to 160-179' interval with common brown clay.
350-442': Medium fast to fast and smooth.	600		700	199-203': Sandy Clay. Fine to med- ium volcanic sand in medium brown soft clay.
442-482': Intermit- tently smooth to rough.				203-220': Pebble Conglomerate and Clayey Sand. Angular to subround- ed, fine to coarse, predominantly black basaltic with minor multicolored fragments in medium gray to brown clay. Gradual change from conglomerate to sand toward 220'.
482-512': Medium rough to rough, slow with some cav- ing.	650		750	220-230': Clayey Sand. Fine to coarse, angular to subrounded, pre- dominantly dark volcanic sand with medium gray soft clay, minor gra- vel.
512-542': Slow and smooth to rough.			800	230-261': Sand. Fine to coarse, angular to subrounded, predomi- nantly dark volcanic, minor clay.
542-609': Hard, slow and rough.	700		850	261-265': Sandy Clay. Fine to coarse volcanic sand with medium brown, soft clay.
609-612': Rough.				265-271': Sand. Fine to coarse, angular to subrounded, predomi- nantly dark volcanic, minor clay.
612-621': Smooth and fast.			900	271-295': Clayey Sand. Multicol- ored, fine to coarse, angular to subangular, predominantly volcanic in medium gray-brown to pink soft clay. Minor gravel.
621-646': Slow, hard and rough.	750		950	295-347': Gravel and Clay. Multi- colored, unconsolidated, fine sand to fine gravel; angular to sub- rounded. Clay is gray-green to light gray. Increase in gray- brown clay from 335-347'.
646-677': Medium speed to fast and smooth to slightly rough.				347-357': Clayey Sand. Multicolored
677-700': Rough and slow.	800			
700-706': Fast and smooth.				
Estimated Drilling Fluid Return:				
0-55': 95-100%	850			
55-639': 100%				
639-706': 90-100%				
Representative Drill- ing Fluid Tempera- tures (°F)				
64° at 12'	900			
68° at 55' after 60 hours downtime				
64° at 64'				
67° at 91' after 8 hours downtime.	950			
60° at 100'				
64° at 141' after 1 hour downtime				
70° at 170'				
75° at 215'				
80° at 270'				

EXPLANATION

Sheet 2 of 3

 FEATURE: Susanville Anomaly--Lassen County PROJECT: Susanville Geothermal
 INVESTIGATIONS

Hole No. SUZY-5

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET	
FEATURE: SUSANVILLE ANOMALY--..... PROJECT: Susanville Geothermal Investigations...	
HOLE NO. SUZY-5..... LASSEN COUNTY SHEET 3 OF 1.....	
NOTES (Continued)	FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Cont.)
<p><u>Representative Drilling Fluid Temperatures</u> (° F) (Continued)</p> <p>79° at 307' 81° at 357' 86° at 440' 98° at 512' after 8 hours downtime 95° at 562' after 8 hours downtime 96° at 602' after 8 hours downtime 96° at 632' 96° at 700'</p> <p><u>Casing Record:</u> 77' of 8" surface steel casing permanently installed in hole from 3-80'; 10" casing, surface to 5', cemented in around 8" casing.</p> <p><u>Geophysical Logging:</u> The following geophysical logs were run by the USGS, Denver Office:</p> <ol style="list-style-type: none"> (1) Electric (2) Natural Gamma (3) Gamma Gamma (4) Neutron (5) Temperature (6) Caliper <p><u>Hole Completion:</u> 2" steel pipe using centralizers with 8' of 60-mesh well screen on bottom installed to 699'. With the bottom, approximately 200' gravel-packed. Top portion cemented in. Site protected with steel guard rail.</p>	<p>347-357' (Continued): but predominantly dark volcanic, fine to coarse, angular to subrounded, clay. Medium gray-brown.</p> <p>357-481': <u>Sandy Clay</u>. Multicolored, fine to coarse, subangular to subrounded, abundant medium gray-brown soft clay. Increase in basalt fragments and decrease of light colors below about 462'.</p> <p>481-512': <u>Gravel</u>. Predominantly basaltic, subrounded to angular fragments, minor light colors decreasing toward 512'. Minor clay.</p> <p style="text-align: center;">512(?)* -706.0': <u>PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS.</u></p> <p>512-521': <u>Clayey Sand</u>. Angular to subrounded, predominantly dark volcanic sand with blue-gray clay increasing below 516'.</p> <p>521-609': <u>Basalt</u>. Black angular, hard fragments, minor sand and clay. Occasional thin light gray clay seams. Very minor light-colored fragments.</p> <p>609-642': <u>Clayey Sand</u>. Dark, mostly black, volcanic, angular to subrounded, predominantly angular to subangular. Fine to coarse. Some multicolored lithic fragments and quartz. Variable amounts of gray to gray-brown clay in thin layers.</p> <p>642-646': <u>Sandstone (?)</u>. Subangular to subrounded, light gray, fine to medium, silicic-cemented with common basaltic fragments, minor brown clay.</p> <p>646-675': <u>Sandy Clay</u>. Medium gray to chocolate brown, soft, minor multicolored, fine to medium, predominantly subangular sand.</p> <p>675-706': <u>Clayey Sand</u>. Multicolored, predominantly dark volcanic, fine to coarse, angular to subrounded, common quartz with gray-brown soft clay. Increase in coarse sand and fine gravel below about 682'.</p>

Sheet 3 of 3

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly-- Susanville Geothermal
 FEATURE Lassen County PROJECT Investigations STATE California
 HOLE NO. SUZY-6 LOCATION See Notes GROUND ELEVATION 4176' ANGLE FROM
 COORDINATES N. 392,883; E. 2,375,452 TOTAL DEPTH 624.0' VERTICAL Vertical
 BEGUN 11-16-78 FINISHED 1-26-79 G. Hollinger; Tuggle, Parrell,
 HOLE LOGGED BY R. Turner; L. Phillips DRILLER VanEtten, Skaggs,
 DEPTH TO WATER Not determined

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD CLASSIFICATION AND PHYSICAL CONDITION
Purpose of Hole: (1) Temperature gradient; (2) geo- physical proper- ties; (3) geolog- ic evaluation; (4) piezometric observation.			DAILY SUMMARY OF DRILLING OPERATIONS	
Landowner: Dr. Beams and Dr. Sturges; City of Susanville lease.	12 1/2" RB	0	11-16-78: Moving and set up, one shift per day.	NOTE: Log based on rockbit cuttings. 0-49': RECENT SOIL AND ALLUVIAL DEPOSITS. 0-12': Silty, Sandy Clay. Soil med- ium brown to yellow with thin sand-pebble beds of predominantly subangular to rounded, fine to very coarse, dark volcanics.
			11-17-78: Complete rigging up, se- cured for weekend.	
Location: SW 1/4 Sec. 5, T.29 N., R. 12 E.	50'		11-20-78: Drilled 12 1/2" rockbit hole to 22', two shifts per day, down 1 hour to re- pair light plant.	12-15': Clay. Red-brown, fat, with occasional fine to coarse, sub- rounded, multicolored lithic frag- ments.
			11-21-78: Drilled to 24', down 4 1/2 hours fishing for twisted off rods and to repair chuck.	
Drill Rig: Pilling 1500	100'		11-22/27-78: Rig down for repair.	15-21': Sand and Gravel. Predomi- nantly fine to very coarse, sub- rounded dark volcanics and red- brown, weathered volcanics. Com- mon quartz and multicolored lithic fragments.
			11-28-78: Drilled to 32'; down 1 1/2 hrs to repair chuck.	
Drilling Methods: Rockbit drilled using bentonite mud and additives as required. Three mud pits used.	150'		11-29-78: Drilled to 42'; down 5 hrs fishing and repairing rig.	21-40': Gravel and Cobbles. Angu- lar to subrounded, fine to very coarse, mostly dark gray to black volcanics. Minor red-brown silty clay, quartz and multicolored, fine to coarse, predominantly sub- angular sands.
			11-30-78: Drilled to 58'; installed 10-inch surface casing; down 1 hr to repair mud lines.	
0-58': 12 1/2" rockbit for per- manent installa- tion of 10" sur- face casing.	200'		12- 1-78: Cemented in surface cas- ing. Worked on equip- ment, secured for weekend.	40-49': Sand/Gravel. Fine to very coarse, angular to subrounded, predominantly medium-brown, sub- rounded, weathered volcanics with dark gray to black volcanics as in 21-40' interval. Common quartz, minor light gray, soft silty clay.
			12- 4-78: No drilling; down 8 1/2 hrs due to drill engine elec- trical problem.	
58-624': 8 1/2" rockbit.	250'		12- 5-78: Drilled to 80' with 8 1/2" rockbit, surface casing broken and loose.	49-589'(?)*: PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS. 49-83': Basalt. Black, hard, angu- lar cuttings with light gray to white soft clay, possibly ash in- terbeds.
			12- 6-78: Drilled to 93'; worked on surface casing.	
Drilling Condi- tions: 0-15': Fast. 15-20': Slow. 20-40': Very slow and very rough. 40-42': Smooth, hard and slow. 42-108': Slow to medium speed, rough, hard; smoother below 93'.	300'		12- 7-78: Drilled to 108', rods stuck in hole. Down 1 1/2 hrs to repair truck trans- mission.	83-98': Basalt. Similar to 49-83' interval except with increased light gray clay.
			12- 8-78: No drilling; surface cas- ing failed; secured for weekend.	
108-169': Slow to very slow, hard to very hard, rough. 169-193': Medium speed and rough- ness. 193-244': Slow, rough and hard. 244-295': Medium slow and rough.	350'		12-12-78: No crews on duty 12-11-78 Casing cemented into hole. Broke loose again on swing. Hole not ad- vanced.	98-120': Sandy Clay. Red-brown to gray-brown, soft, with fine to very coarse, subangular to round- ed, multicolored sands, predomi- nantly dark volcanics. Occasional thin, very coarse sands, possibly cobbles.
			12-13-78: Drilled to 158'; down 4 hrs to repair break-out table and truck water pump.	
	400'		12-14-78: No drilling. Down 7 1/2 hrs to repair break-out table.	120-145': Pebble Conglomerate (?) Fine to very coarse, angular to subangular, with some subrounded, multicolored but predominantly
			12-15-78: Drilled to 167'; down 3.5 hours due to transmission problem. Secured for weekend.	
	450'		12-18-78: No drilling. Down 4 hrs due to extreme weather conditions.	*Contact between the Pleistocene and Pliocene lake deposits cannot be de- termined from cuttings. The contact was estimated from geophysical logs and existing data.

EXPLANATION

*Contact between the Pleistocene and Pliocene lake deposits cannot be determined from cuttings. The contact was estimated from geophysical logs and existing data.

Sheet 1 of 3

Hole No. SUZY-6

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE					
Susanville Anomaly--		Susanville Geothermal			
FEATURE	Lassen County	PROJECT	Investigations	STATE California	
HOLE NO. SUZY-6	LOCATION See Notes	GROUND ELEVATION 4176'	ANGLE FROM		
BEGUN 11-16-78	COORDINATES N. 392,883; E. 2,375,452	TOTAL DEPTH 624.0'	VERTICAL		Vertical
FINISHED 1-26-79	G. Hollinger;		Tuggle, Farrell,		
DEPTH TO WATER Not determined	HOLE LOGGED BY R. Turner; L. Phillips		DRILLER VanEtten, Skaggs,		
				Warren	
NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD CLASSIFICATION AND PHYSICAL CONDITION	
Drilling Conditions (Cont.):				DAILY SUMMARY OF DRILLING OPERATIONS	
295-376': Slow, rough and hard.				(Continued)	
376-402': Medium slow and rough.				12-19-78: No drilling. Rig down for major repair.	
402-426': Medium smooth.				12-20-78: No drilling. Rig down.	
426-464': Fast and smooth.				12-21-78: Drilled to 193'. Down 5½ hrs finishing repairs.	
464-524': Slow, medium smooth to rough.				12-22-78: No drilling. Twisted off in hole. Secured for 3-day Christmas weekend.	
524-580': Fast and smooth.				12-26-78: Fishing, 3 shifts.	
580-590': Medium slow to very slow.				12-27-78: Recovered fish.	
590-624': Hard and rough, slow.				12-28-78: Drilled to 295'.	
				12-29-78: Drilled to 384'. Secured for 3-day New Year's weekend.	
Estimated Drilling Fluid Return				1- 2-79: Thawed out equipment; drilled to 464'.	
0-26': 90-95%				1- 3-79: Drilled to 564'; deck engine clutch failed.	
26-624': 95-100%				1- 4-79: Prepared for logging. Down for clutch repair.	
Representative Drilling Fluid Temperature (°F):				1- 5-79: Down due to clutch; hole logged by USGS. Secured for weekend.	
52°F at 22'				1- 8-79: No drilling; rig down.	
59°F at 33'				1- 9-79: No drilling; rig down.	
60°F at 49'				1-10-79: No drilling, rig repairs completed.	
59°F at 56'				1-11-79: Conditioned hole; drilled to 604'.	
77°F at 58'; bottoms up after approx. 80 hrs downtime.				1-12-79: Drilled to 624', total depth. Down 1½ hrs to re-rig cables, secured for weekend.	
71°F at 60'; bottoms up after 10 hrs downtime				1-15-79: Prepared to run casing.	
58°F at 117'				1-16-79: Started running casing, lost casing in hole.	
60°F at 135'				1-17-79: Fishing for casing.	
62°F at 150'				1-18-79: Fishing for casing.	
79°F at 158'; bottoms up after approx. 24 hrs downtime.				1-19-79: Casing installed, rigged for development; secured for weekend.	
63°F at 165'				1-22-79: Thawed out equipment, conditioned hole.	
59°F at 188'				1-23-79: Washed and air-jetted hole.	
60°F at 193'				1-24-79: Continued to develop hole.	
74°F at 193'; bottoms up after approx. 10 hrs downtime.				1-25-79: Repaired casing.	
63°F at 195'				1-26-79: Attempted to cement casing. Moved rig to SUZY-7	
68°F at 240'					
73°F at 260'					
73°F at 295'					
78°F at 320'					
				120-145' (Cont.): dark volcanic fragments with medium-gray brown to medium gray, occasionally light gray, soft to slightly firm clay. Clay content very variable.	
				145-158': <u>Pebble Conglomerate (?)</u> . Similar to 120-145' interval except with increase in medium gray, soft clay.	
				158-188': <u>Pebble Conglomerate (?)</u> . Fine to very coarse, predominantly angular, dark volcanics with common angular, multicolored lithic fragments. Locally common, white quartz, light green claystone and red-brown, weathered volcanics. Variable amounts of medium brown-gray soft clay.	
				188-193': <u>Sandy Claystone (?)</u> . Light blue-green, soft to slightly firm claystone with light-colored lithic fragments.	
				193-240': <u>Pebble Conglomerate (?)</u> . Geologist not present at site but drilling characteristics and one sample from 210' depth indicate same lithology as 158-188' interval.	
				240-284': <u>Pebble Conglomerate (?)</u> . Fine to very coarse, angular (some subrounded), predominantly dark volcanic fragments with some dark brown to red, weathered volcanic fragments, light green, moderately firm claystone, and white, soft, to moderately firm tuff. Locally common light gray to white, soft, partially hydrated clay, possibly ash.	
				284-290': <u>Sandy Clay (?)</u> Geologist not at site.	
				290-402': <u>Pebble Conglomerate (?)</u> . Similar to 240-284' interval with occasional light tan, soft clay.	
				402-420': <u>Pebble Conglomerate (?)</u> . Similar to 290-402' interval with increase in soft, brown clay.	
				420-430': <u>Sandy Clay</u> . Medium gray, soft clay with angular to sub-rounded, fine to coarse, multicolored sand.	
				430-517': <u>Sandy Clay</u> . Medium brown, soft clay with sands as in 420-430' interval. Occasional very	

EXPLANATION

Sheet 2 of 3

Hole No. SUZY-6

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET	
Susanville Anomaly-- Lassen County..... PROJECT Susanville Geothermal Investi- gations, California FEATURE..... HOLE NO. SUZY-6..... SHEET 3 OF 3...	
NOTES (Continued)	FIELD CLASSIFICATION AND PHYSICAL CONDITION (Continued)
<p><u>Representative Drilling Fluid Temperature (°F) (Continued):</u></p> <p>82°F at 325'; bottoms up after 2½ hrs downtime.</p> <p>79°F at 354'</p> <p>79°F at 370'</p> <p>100°F at 385'; bottoms up after 50 hrs downtime.</p> <p>82°F at 400'</p> <p>87°F at 455'</p> <p>108°F at 564'; bottoms up after 7½ days downtime.</p> <p>90°F at 589'</p> <p>93°F at 604'</p> <p><u>Caving Conditions:</u></p> <p>32-34': Minor caving.</p> <p>524-564': Hole squeezing.</p> <p><u>Casing Record:</u> 10" steel surface casing installed to 57' and permanently cemented into hole.</p> <p><u>Geophysical Logging:</u></p> <p>The following geophysical logs were run by the USGS, Denver Office:</p> <ol style="list-style-type: none"> (1) Electric (2) Natural Gamma (3) Gamma Gamma (4) Neutron (5) Temperature (6) Caliper <p><u>Hole Completion:</u> 6" steel casing was installed to the following approximate depths:</p> <p>0-103': 6" blank steel casing</p> <p>103-603': 6" factory-perforated steel casing.</p> <p>603-623': 6" torch-perforated steel casing.</p> <p>623-624': Solid well point.</p> <p>Attempt to cement in upper 103' unsuccessful. Site protected with guard rail.</p>	<p>430-517' (Continued): thin, very coarse, angular, multi-colored sands or conglomerate.</p> <p>517-524': <u>Sandy Clay</u>. Medium brown, soft, with fine to coarse, predominantly coarse, multicolored, angular to subrounded sands.</p> <p>524-530': <u>Clay</u>. Medium brown, soft, with minor multi-colored sands similar to 517-524' interval (possibly slough).</p> <p>530-564': <u>Clayey Sand</u>. Multicolored, fine to medium, subangular to subrounded, predominantly subangular, volcanic sand with medium brown, soft clay.</p> <p>564-589': <u>Sandy Clay</u>. Medium brown, soft clay with fine to medium, subangular to subrounded, multicolored sands. Minor gray-green claystone.</p> <p>589-599': <u>Sand</u>. Fine to coarse, predominantly medium, subangular to rounded, multicolored sand, predominantly black volcanics. Common tan to red, weathered volcanics, minor brown-gray, soft clay. (Geologist not at rig when drilled.)</p> <p>599' (T)*-624' T.D.: <u>PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS</u></p> <p>599-602': <u>Basalt</u>. Black, angular, fine to coarse cuttings with sand similar to 589-599' interval (sand possibly slough).</p> <p>602-624': <u>Basalt</u>. Similar to 589-602' interval but much harder drilling, probably less fractured and/or weathered.</p>

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

SUSANVILLE GEOTHERMAL

FEATURE SUSANVILLE ANOMALY--LASSEN COUNTY

PROJECT INVESTIGATIONS

STATE CALIFORNIA

HOLE NO. SUZY-7

LOCATION SEE NOTES, SHEET 1

GROUND ELEVATION 4,184

ANGLE FROM

VERTICAL

BEGUN 1-24-79

FINISHED 2-8-79

TOTAL DEPTH 735.0'

TUGGLE, WARREN;

SKAGGS, RABBITT

DEPTH TO WATER 6.0'

HOLE LOGGED BY R. TURNER, L. PHILLIPS

DRILLER

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
PURPOSE OF HOLE: (1) TEMPERATURE GRADIENT; (2) GEOPHY- SICAL PROPERTIES; (3) GEOLOGIC EVALUA- TION.	18"	0		NOTE: LOG BASED ON BUCKET-AUGER RETURN FROM 0-50' AND ON ROCKBIT CUTTINGS FROM 50-735'.
LANDOWNER: DR'S BEAMS AND STURGES				RECENT SOIL AND ALLUVIAL DEPOSITS
LOCATION: SE 1/4 of NW 1/4 SECTION 5, T. 29 N., R. 12 E.; NORTHEAST OF INTERSECTION OF SISKIYOU & EL DORADO STREETS.				0-49': SOIL. GRAY-BROWN, SILTY, CLAYEY, GRAD- ING TO YELLOW-BROWN SILTY FAT CLAY. MOIST AT 3'. SOME FINE TO MEDIUM, SUBANGULAR, PREDOMINANTLY VOLCANIC SAND.
DRILL RIGS: CALWELD BUCKET AUGER AND FAILING 1500 ROTARY.				6-7': SAND. MEDIUM GRAY, FINE TO MEDIUM, SUBANGULAR, PREDOMINANTLY DECOMPOSED VOL- CANICS. WATER AT 6'.
DRILLING METHODS: 18" BUCKET AUGER TO 50' FOR 12" SUR- FACE CASING; 6-1/2" ROCKBIT DRILLED US- ING BENTONITE DRILL MUD AND ADDITIVES AS REQUIRED FROM 50' TO 735' TOTAL DEPTH.	6 1/2"	0		6-15': SILTY CLAY. GRAY-BROWN, FAT, SANDY IN PART, SAND SIMILAR TO 6-7' INTERVAL. 15-39': CLAYEY SAND. GRAY-GREEN, FINE TO MEDIUM, PREDOMINANTLY FINE-GRAINED, DARK VOLCANIC SANDS; SILTY WITH MINOR QUARTZ AND MICA (GEOLOGIST NOT PRESENT DURING DRILLING.)
ESTIMATED DRILLING FLUID RETURN: 0-50': BUCKET AUGER 50-305': 90-100% 305-350': 100% 350-405': 90% 405-515': 100% 515-555': 90% 555-735': 100%				39-47': SILTY CLAY. GRAY-GREEN FAT CLAY WITH MINOR VOLCANIC SANDS SIMILAR TO 15- 39' INTERVAL.
DRILLING CONDITIONS: BUCKET AUGER: 0-49': MODERATELY FAST AND SMOOTH. 49-50': SLOW AND HARD; RESISTED FUR- THER DRILLING AT 50' ROTARY: 50-55': SLOW AND HARD 55-91': VERY SLOW AND VERY ROUGH. 91-95': SMOOTH. 95-155': VERY SLOW AND VERY ROUGH, OC- CASIONAL SMOOTH ZONE.				47-49': SAND/GRAVEL. FINE TO VERY COARSE SUBANGULAR, PREDOMINANTLY GRAY VOLCANIC SANDS WITH GRAY, ROUNDED PEBBLES, OCCA- SIONALLY COBBLES, PREDOMINANTLY VOLCAN- ICS. CONTINUED GRAY-GREEN SILTY CLAY.
				49-735' T.D.: PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS.*
				49-50': DECOMPOSED BASALT. BROWN TO RED- BROWN, GRITTY TO CLAYEY, HARD, WITH AL- TERED RED AND GREEN VOLCANIC PEBBLES. FINE TO MEDIUM CHALCEDONY, POSSIBLY VUG FILL- INGS.
				50-84': BASALT. BLACK, HARD, ANGULAR CUT- TINGS WITH OCCASIONAL THIN, MEDIUM GRAY CLAY BEDS.
				84-91': BASALT (?) AS IN 50-84' INTERVAL WITH LIGHT GRAY, SOFT CLAY. OCCASIONAL RED, SOFT TO SLIGHTLY FIRM CLAY.
				91-95': GEOLOGIST NOT PRESENT AT RIG; FAST- TER DRILLING.
				95-115': PEBBLE CONGLOMERATE (?) . FINE TO VERY COARSE, ANGULAR TO SUBROUNDED, MULTI- COLORED BUT PREDOMINANTLY ANGULAR, DARK GRAY VOLCANICS WITH VARIABLE AMOUNTS, BUT PREDOMINANTLY MINOR, LIGHT GRAY TO LIGHT TAN, SOFT TO SLIGHTLY FIRM CLAY.
				115-135': GEOLOGIST NOT PRESENT AT RIG; DRILLING CONDITIONS SIMILAR TO 95-115' IN- TERVAL.
				135-170': PEBBLE CONGLOMERATE (?) . FINE TO VERY COARSE, PREDOMINANTLY DARK, ANGULAR VOLCANICS WITH LESS MULTICOLORED LITHIC FRAGMENTS AS IN 95-115' INTERVAL.
				170-185': GEOLOGIST NOT PRESENT AT RIG; DRILLING CONDITIONS SIMILAR TO 135-170' INTERVAL.

EXPLANATION

*LOWER PORTION OF HOLE BELOW ±475' MAY BE
IN PLIOCENE DEPOSITS. CANNOT BE DETER-
MINED FROM CUTTINGS.

SHEET 1 OF 3

FEATURE SUSANVILLE ANOMALY--LASSEN COUNTY

PROJECT SUSANVILLE GEOTHERMAL INVESTI.

Hole No. SUZY-7

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE SUSANVILLE ANOMALY--LASSEN COUNTY PROJECT SUSANVILLE GEOTHERMAL INVESTIGATIONS STATE CALIFORNIA
 HOLE NO. SUZY-7 LOCATION SEE NOTES, SHEET 1 GROUND ELEVATION 4,184 ANGLE FROM
 COORDINATES N.392,359; E.2,374,642 TOTAL DEPTH 735.0' VERTICAL VERTICAL
 BEGUN 1-24-79 FINISHED 2-8-79 TUGGLE, WARREN;
 HOLE LOGGED BY R. TURNER; L. PHILLIPS DRILLER SKAGGS; BABBITT

DEPTH TO WATER	NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	HOLE LOGGED BY	DRILLER	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	DRILLING CONDITIONS (CONT.)					
	155-185': ALTERNATING HARD AND ROUGH TO SOFT AND SMOOTH.					185-188': <u>PEBBLE CONGLOMERATE</u> (?) FINE TO VERY COARSE, PREDOMINANTLY VERY COARSE, MULTICOLORED, SUBROUNDED TO ANGULAR. IN- CREASE IN SUBROUNDED FRAGMENTS. VERY MI- NOR, TAN, SOFT CLAY.
550	185-195': HARD AND SLOW.				550	188-195': <u>PEBBLE CONGLOMERATE</u> . SIMILAR TO 135-170' INTERVAL EXCEPT WITH MEDIUM GRAY, SOFT CLAY.
	195-285': FAST AND SMOOTH TO MEDIUM SMOOTH.					195-217': <u>SANDY CLAY</u> . LIGHT TO MEDIUM GRAY BROWN, SOFT CLAY WITH FINE TO MEDIUM SUBANGULAR TO SUBROUNDED, MULTICOLORED SAND.
600	285-305': HARD.				600	217-230': <u>SAND/CLAY</u> . LIGHT TO MEDIUM GRAY BROWN, SOFT CLAY WITH OCCASIONAL RED BROWN, SOFT CLAY. SAND IS FINE TO VERY COARSE, ANGULAR TO SUBROUNDED, MULTICOLO- RED BUT PREDOMINANTLY DARK VOLCANICS.
	305-335': INTERMIT- TENT SLOW AND HARD TO VERY HARD AND SMOOTH TO ROUGH.	6 1/2" RB	0			230-265': <u>SANDY CLAY</u> . MEDIUM GRAY-BROWN, SOFT CLAY WITH FINE TO MEDIUM, OCCASIONAL COARSE, ANGULAR TO SUBROUNDED, MULTICOL- ORED SAND.
650	335-397': SLOW AND INTERMITTENTLY SMOOTH TO ROUGH.				650	265-280': <u>SANDY CLAY</u> AS IN 230-265' INTER- VAL WITH INCREASE IN VERY COARSE, MULTI- COLORED BUT PREDOMINANTLY DARK, VOLCANIC LITHIC FRAGMENTS.
	397-402': MODERATELY FAST AND SMOOTH.					280-310': <u>CLAYEY SAND</u> . FINE TO COARSE, AN- GULAR TO SUBROUNDED, MULTICOLORED SAND WITH GRAY-BROWN TO RED, SOFT CLAY. (POS- SIBLY IN PEBBLE CONGLOMERATE AS ABOVE)
700	402-415': SLOW, HARD; INTERMITTENT- LY SMOOTH TO ROUGH.				700	310-335': GEOLOGIST NOT PRESENT AT RIG; NO SAMPLES TAKEN. DRILLING CONDITIONS SIMILAR TO 280-310' INTERVAL.
	415-475': ERRATIC, SLOW TO MEDIUM FAST, SMOOTH TO ROUGH.					335-350': <u>CLAYEY SAND</u> . SIMILAR TO 280-310' INTERVAL.
750	475-480': VERY SLOW, VERY ROUGH.				750	350-397': <u>SANDY CLAY</u> . LIGHT GRAY TO BROWN, SOFT CLAY WITH FINE TO MEDIUM, SUBANGULAR TO SUBROUNDED, MULTICOLORED BUT PREDOMINANTLY DARK VOLCANIC LITHIC FRAGMENTS.
	480-515': SLOW, MOD- ERATE TO VERY ROUGH.					397-402': <u>CLAY</u> . MEDIUM-GRAY BROWN, SOFT WITH MINOR SAND SIMILAR TO 350-397' IN- TERVAL.
800	515-555': SLOW TO MODERATELY SLOW; MODERATELY SMOOTH TO ROUGH.				800	402-415': <u>SANDY CLAY</u> . SIMILAR TO 350-397' INTERVAL.
	555-562': SLOW AND ROUGH-HARD.					415-455': <u>SAND</u> . ANGULAR TO SUBROUNDED, FINE TO MEDIUM, MULTICOLORED VOLCANIC FRAGMENTS WITH MINOR SUBANGULAR TO ROUND- ED QUARTZ AND FELDSPAR. VERY MINOR LIGHT BROWN SOFT CLAY.
850	562-575': MEDIUM FAST, SLIGHTLY ROUGH.				850	455-475': <u>SAND</u> . SIMILAR TO 415-455' INTER- VAL WITH INCREASE IN GRAIN SIZE; COARSE TO VERY COARSE.
	575-589': SLOW AND ROUGH.					475-485': <u>BASALT</u> . BLACK, HARD, ANGULAR CUTTINGS WITH MULTICOLORED SANDS AS A- BOVE; PROBABLY SLOUGHING OR RECIRCULATED CUTTINGS.
900	589-595': MEDIUM FAST, SLIGHTLY ROUGH.				900	485-562': <u>BASALT</u> . SIMILAR TO 475-485' INTERVAL EXCEPT WITH MINOR THIN INTER- BEDS OF LIGHT BROWN TO RED, SOFT CLAY.
	595-650': SLOW TO MEDIUM FAST, SMOOTH TO ROUGH.					
950	650-665': SLOW AND ROUGH.				950	
	665-735': MODERATELY FAST, SMOOTH WITH THIN, ROUGH SPOTS.					
	REPRESENTATIVE DRILL- ING FLUID TEMPERA- TURES (°F)					
	46° AT 70'					
	47° AT 75'					
	47° AT 100'					
	48° AT 135'					

EXPLANATION

SHEET 2 OF 3

FEATURE SUSANVILLE ANOMALY--LASSEN COUNTY PROJECT SUSANVILLE GEOTHERMAL INVESTIGATIONS HOLE NO. SUZY-7

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET	
FEATURE: SUSANVILLE ANOMALY--LASSEN COUNTY PROJECT: SUSANVILLE GEOTHERMAL INVESTIGATIONS, CALIFORNIA HOLE NO. SUZY-7 SHEET 3 OF 3	
NOTES (CONTINUED)	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)
<p><u>REPRESENTATIVE DRILLING FLUID TEMPERATURES (° F); (CONTINUED)</u></p> <p>49° AT 150' 50° AT 185' 54° AT 230' 57° AT 255' 55° AT 285' AFTER ADDING WATER TO MUD. 57° AT 305' 63° AT 340' 63° AT 350' 64° AT 360' 66° AT 395' 75° AT 485' 73° AT 495', AFTER ADDING WATER TO MUD. 73° AT 500' 77° AT 515' 73° AT 530' AFTER ADDING WATER TO MUD. 77° AT 552' 79° AT 665' 79° AT 710' 79° AT 735'.</p> <p><u>CAVING CONDITIONS:</u> AT 35': SQUEEZING WHEN RUNNING CASING. AT 135': CAVING FROM ABOVE. AT 150': HOLE SQUEEZING. 170-185': CAVING FROM ABOVE.</p> <p><u>CASING RECORD:</u> 12" STEEL SURFACE CASING INSTALLED TO 35' (COULD NOT ADVANCE TO 50' BECAUSE OF HOLE SQUEEZING), AND PERMANENTLY CEMENTED INTO HOLE.</p> <p><u>GEOPHYSICAL LOGGING</u> THE FOLLOWING GEOPHYSICAL LOGS WERE RUN BY THE USGS, DENVER OFFICE. LOGS WERE RUN IN 2" STEEL PIPE; NO OPEN HOLE LOGS WERE RUN. (1) NATURAL GAMMA (2) GAMMA GAMMA (3) NEUTRON (4) TEMPERATURE</p> <p><u>HOLE COMPLETION:</u> INSTALLED 733' OF 2" STEEL PIPE (2' STICKUP) WITH A SEALED 18" WELL POINT AT BOTTOM. PIPE FILLED WITH CLEAR WATER AND CAPPED. UPPER ±20' CEMENTED IN ON 3-22-79. SITE PROTECTED WITH STEEL GUARD RAIL.</p>	<p>*562-575': <u>SAND/GRAVEL</u>. FINE TO MEDIUM, ANGULAR TO SUBROUNDED, PREDOMINANTLY BLACK, ANGULAR VOLCANIC FRAGMENTS WITH INCREASE IN MULTICOLORED LITHIC FRAGMENTS AND RED-BROWN, SOFT CLAY.</p> <p>575- *635': <u>SAND/GRAVEL</u>. SIMILAR TO 562-575' INTERVAL EXCEPT WITH SLIGHT INCREASE IN SUBROUNDED, MULTICOLORED LITHIC FRAGMENTS.</p> <p>*635-665': <u>SAND/CLAY</u>. FINE TO COARSE, ANGULAR TO SUBROUNDED, BLACK TO BROWN VOLCANIC FRAGMENTS WITH MINOR MULTICOLORED LITHIC FRAGMENTS. COMMON GRAY-BROWN SOFT CLAY IN VARYING AMOUNTS.</p> <p>665-690': <u>SANDY CLAY</u>. MEDIUM GRAY-BROWN, SOFT CLAY WITH FINE TO MEDIUM, OCCASIONALLY COARSE, SUBANGULAR TO SUBROUNDED, MULTICOLORED SAND. OCCASIONAL THIN INTERVALS OF HARD DRILLING BUT NO CHANGE IN SAMPLE.</p> <p>690-735': <u>SANDY CLAY</u>. SIMILAR TO 665-690' INTERVAL BUT WITH DECREASE IN SAND CONTENT. OCCASIONAL MEDIUM TO DARK GRAY, SOFT CLAY BUT PREDOMINANTLY MEDIUM GRAY BROWN, SOFT CLAY.</p> <p>NOTE: GEOLOGIST NOT PRESENT AT DRILLING SITE WHILE 555-665' INTERVAL WAS BEING DRILLED.</p>

SHEET 3 OF 3

FEATURE: SUSANVILLE ANOMALY--LASSEN COUNTY

PROJECT: SUSANVILLE GEOTHERMAL INVESTIGATIONS

HOLE NO. SUZY-7

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly - Susanville
 Lassen County PROJECT Geothermal Investigations STATE California
 HOLE NO. SUZY-8 LOCATION See Notes GROUND ELEVATION 4189.89 ANGLE FROM
 COORDINATES N. 396,668; E. 2,373,994 TOTAL DEPTH 528.0' VERTICAL Vertical
 BEGUN 2-13-79 FINISHED 3-23-79
 DEPTH TO WATER 14.0' HOLE LOGGED BY Robert L. Turner DRILLER D. Warren; R. Babbitt
 N. Tuggle;

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION NOTE: Log based on rockbit cuttings.
Purpose of Hole: (1) temperature gradient; (2) geo- physical proper- ties; (3) geolog- ic evaluation.				
Landowner: City of Susanville.				
Location: NE 1/4 SW 1/4 Section 32, T.29 N., R. 12 E., MDB&M.; on south bank of the Susan- ville River.				
Drill Rig: Failing 1500				
Drilling Methods: Drilled with bentonite mud and additives as re- quired. Used 3 mud pits. 0-90': 6-3/4" rockbit. 90-92': 4-1/2" diamond bit & core barrel. 90-528': 6-1/2" rockbit. 193-198': 4-1/2" diamond bit & core barrel				
Drilling Condi- tions: 0-8': Erratic; slow to fast, smooth to rough. 8-27': Slow to medium, smooth to rough. 27-31': Slow; rough to very rough. 31-33': Very fast; smooth. 33-54': Slow; rough. 54-69': Slow to medium slow; rough. 69-75': Medium, smooth. 75-85': Erratic; very slow, very				
DAILY SUMMARY OF DRILLING OPERATIONS: 2-13/16-79: Failing 1500 moved to site and rigged up. 2-20-79: Delayed arrival due to bad road conditions. Mixed mud; pits losing water. 2-21-79: Drilled to 39' with major mud loss at 32'. 2-22-79: Drilled to 56' with major mud loss at 41'. 2-23-79: Drilled to 60' with occa- sional lost circulation. 2-26-79: Drilled to 90'. 2-27-79: Rig down for repairs to pump engine. 2-28-79: Reamed to 90'; repaired ro- tary transmission. 3- 1-79: Cored from 90-92'; repaired rotary transmission. 3- 2-79: Rig down for repairs to ro- tary transmission. 3- 5-79: Drilled to 113'. Hole cav- ing. 3- 6-79: Drilled to 141'. Hole cav- ing to 125'. 3- 7-79: Rig down for repairs to Kelly Chuck. 3- 8-79: Complete repairs. Drilled to 152'. 3- 9-79: Drilled to 193'. Cored from 193-198'. 3-12-79: Repaired mud pump, drilled to 237'. 3-13-79: Drilled to 433'. 3-14-79: Drilled to 461'. 3-15-79: Drilled to 523'. 3-16-79: Drilled to 528'. Lost cir- culation and stuck rods in hole. 3-17/20-79: Attempted to pull out of hole. 3-21-79: Pulled loose, pulled out of hole. 3-22-79: Attempted to run 2" pipe in hole; lower stabilizer broke off. 3-23-79: Chased junk to bottom; ran 2" pipe to 523'. Tore down and moved off site.				
0-27.0': FILL, RECENT SOIL, AND ALLUVIAL DEPOSITS. 0-4': <u>Compacted Man-Made Fill and Soil.</u> Medium to dark brown clay- ey sand with fine to coarse, mul- ticolored, subangular to subround- ed sands. 4-11': <u>Clayey Sand.</u> Medium brown, fine to medium, predominantly sub- angular volcanic sands with medium brown soft to slightly firm, silty clay. Occasional coarse to very coarse, subrounded volcanic sands. 11-13': <u>Clayey Sand.</u> Dark choco- late brown; sand as in 4-11' in- terval with dark chocolate brown decomposed, volcanic sand/clay. 13-16': <u>Sand/Pebbles/Cobbles.</u> Dark gray, fine to very coarse cuttings, angular to subrounded, predomi- nantly dark volcanics. Minor med- ium gray, soft clay. 16-17': <u>Clayey Sand.</u> Dark choco- late brown as in 11-13' interval. 17-27': <u>Sand/Pebbles/Cobbles.</u> Thinly interbedded. Pebbles and cobbles are dark gray to black, angular to subrounded cuttings, predominantly volcanic; sands are fine to very coarse, brown to gray, subangular to rounded, pre- dominantly volcanics and decom- posed volcanics. Occasional flood of chocolate brown decom- posed volcanic sands/clay. 27-528' (T.D.): PLEISTOCENE BASALT AND LAHONTAN (near shore) LAKE DEPOSITS 27-31': <u>Basalt.</u> Light gray to black, hard, angular cuttings. Minor light gray clay. 31-33': <u>Fractured & Weathered Ba- salt (?)</u> . Lost circulation but mud turned red just before loss. 33-54': <u>Basalt (?)</u> Samples con- taminated by LCM; drilling, and scattered cuttings similar to 27- 31' interval. 54-69'(?): Samples very contamina- ted by LCM and bulk bentonite mud poured down hole. 69-75': <u>Sand.</u> Dark gray, fine to medium, angular to subangular, predominantly dark gray volcan- ics with minor light gray clay. Samples still contaminated with LCM. 75-90': <u>Pebbles/Cobbles.</u> Fine to				

EXPLANATION

Sheet 1 of 3

FEATURE: Susanville Anomaly--Lassen County PROJECT: Susanville Geothermal Investigations HOLE NO. SUZY-8

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly-- Susanville Geothermal
 FEATURE Lassen County PROJECT Investigations STATE California
 HOLE NO. SUZY-8 LOCATION See Notes, Sheet 1 GROUND ELEVATION 4189.89 ANGLE FROM
 COORDINATES N. 396,668; E. 2,373,994 TOTAL DEPTH 528.0' VERTICAL Vertical
 BEGUN 2-13-79 FINISHED 3-23-79 N. Tuggle;
 DEPTH TO WATER 14.0' HOLE LOGGED BY Robert L. Turner DRILLER D. Warren; R. Babbitt

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
Drilling Condi- tions (Cont.): 75-85' (Cont.): rough. 85-86': Slow, smooth. 86-90': Erratic, very slow, very rough. 90-92': (Core) very slow, very rough. 92-103': Very slow, very rough. 103-109': Slow, rough. 109-113': Slow to medium, rough. 113-193': Erratic, slow to medium slow, rough to very rough. 193-198' (Core): Very slow, very rough. 198-237': Erratic; slow to medium fast, moderately rough to rough. 237-343': Medium fast, intermittent. 343-346': Erratic, slow, rough. 346-373': Medium fast, intermittent. 373-411': Fast, moderately smooth. 411-433': Slow, moderately smooth. 433-453': Slow, medium rough. 453-473': Slow, smooth. 473-478' (Core): Slow, smooth to medium, rough. 478-490': Slow, smooth. 490-500': Very slow, medium rough. 500-528': Slow, smooth.	6 1/2" RB	0	550	75-90' (Continued): very coarse cuttings; angular (minor subangu- lar), predominantly dark volcan- ics. Occasional medium brown, weathered volcanics. No clay. 90-92' (CORE): Pebbles/Cobbles. Unconsolidated, poorly sorted, subrounded to well rounded; size range from 3/4" to greater than 4"; predominantly medium gray to black, fine-grained basalt with surfaces commonly weathered to light gray. One basalt cobble is vesicular with opaline, secondary mineralization in vugs. No sand or clay present but may have been washed away during coring. 92-98': Pebbles/Cobbles. Similar to 90-92' interval. Very minor, fine to medium, subangular, dark volcanic sand, possibly sloughing from above. 98-132': Pebbles/Sand. Fine to very coarse, angular to subrounded, multicolored but predominantly dark vol- canics. 132-144': Cobbles/Pebbles/Sand. Pebbles and sand simi- lar to 98-132' interval. Cobbles black, hard, angular basalt cuttings and, inferred from very slow, very rough drilling. 144-155': Clayey Sand. Fine to coarse, subangular to subrounded, multicolored sands with light to medium, brown soft clay. 155-170': Clayey Sand. Similar to 144-155' interval but with light gray, soft clay and minor light to medium brown soft clay. 170-173': Clayey Sand. Fine to very coarse, angular to subrounded, multicolored sands with light gray, soft clay. Minor medium brown, soft clay. 173-193': Clayey Sand. Fine to medium, some coarse, subangular to subrounded, multicolored sands with light gray, soft clay. 193-198' (CORE): Pebble Conglomerate. Very poorly to moderately cemented. Sands fine to very coarse, angu- lar to subrounded, multicolored but predominantly dark volcanics. Pebbles subangular to rounded, predomi- nantly dark volcanics with common light gray to tan, weathered surfaces. Occasionally subrounded, red to black volcanic cobbles. All above loosely cemented by medium brown to medium gray, locally medium green, moderately soft to moderately firm silty clay. 198-215': Pebble Conglomerate. Similar to 193-198' in- terval with locally common light gray to white, soft clay. 215-232': Pebble Conglomerate. Similar to 193-198' in- terval with minor light brown soft clay. 232-238': Pebbles/Sand (Pebble Conglomerate ?) Fine to very coarse, angular to subrounded, mostly dark vol- canic fragments and sand with minor multicolored, lithic fragments. Minor light gray to white soft clay. 238-260': Pebbles/Sand/Clay. Fine to coarse, angular to subrounded, predominantly multicolored lithic

Estimated Drilling Fluid Return:

0-8': 100%
 8-27': 90%
 27-31': 90%
 31-32': 0%; lost circulation
 32-39': 70%
 39-42': 0%; lost circulation
 42-56': 70%
 56-60': 0%; lost circulation
 60-527': 85-95%
 527-528': 0%; lost circulation.

Representative Drilling Fluid Tempera-
 tures
 48° at 25'

EXPLANATION

Sheet 2 of 3

FEATURE: Susanville Anomaly--Lassen County PROJECT: Susanville Geothermal Investigations HOLE NO. SUZY-8

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET	
Susanville Anomaly-- FEATURE: Lassen County PROJECT: Susanville Geothermal Investigations, California HOLE NO. SUZY-8 SHEET 3 OF 3	
NOTES (Continued)	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (Continued)
<p><u>Representative Drilling Fluid Temperatures (° F): (Cont.)</u></p> <p>48° at 56' 54° at 76' 54° at 85' 60° at 92' after ± 90 hours downtime. 57° at 113' 57° at 125' 59° at 135' 64° at 141' after ±40 hours downtime. 59° at 148' 64° at 153' after ±10 hours downtime. 59° at 185' 68° at 198' after ±80 hours downtime. 57° at 215' 68° at 237' after ±9 hours downtime. 61° at 260' 63° at 273' 64° at 293' 68° at 333' 68° at 360' 70° at 373' 72° at 413' 73° at 433' 82° at 461' after ±10 hours downtime 72° at 473' 77° at 490' 77° at 518' 86° at 528' after ±24 hours downtime.</p> <p><u>Caving Conditions:</u> 86-125': Caving sands and gravel.</p> <p><u>Casing Record:</u> No casing used.</p> <p><u>Geophysical Logging</u> The following geophysical logs were run by the USBR, Denver Office on 4-23-79. Logs were run in 2" steel pipe; no open hole logs run. (1) Natural Gamma (4-23-79) (2) Neutron (4-23-79) (3) Temperature (6-29-79)</p> <p><u>Hole Completion:</u> Ran 525' of 2" steel pipe to 523' with 2' stick-up. Bottom of pipe sealed and pipe filled with clear water. Pipe protected with steel guard rail.</p>	<p>238-260': (Continued): fragments with common light gray to white, soft clay. Minor medium brown soft clay.</p> <p>260-293': <u>Clayey Sand</u>. Fine to coarse, angular to subrounded, multicolored but predominantly dark volcanic fragments. Occasionally weathered red-brown. Light gray to white soft clay. Minor white quartz, white tuff (moderately firm), and light to medium brown soft clay. Occasionally very thin, soft red clay beds.</p> <p>293-315': <u>Sand</u>. Fine to coarse, angular to subrounded, dark volcanic fragments with minor multicolored lithic fragments. Minor light gray to white soft clay.</p> <p>315-355': <u>Clayey Sand</u>. Fine to coarse, some very coarse, angular to subrounded, medium gray to black volcanics and common multicolored lithic fragments. Variable amounts of light gray and white soft clay.</p> <p>355-360': <u>Clayey Sand</u>. Fine to medium, some coarse, angular to subrounded, predominantly dark volcanics with some multicolored lithic fragments. Variable amounts of light to medium gray soft clay.</p> <p>360-363': <u>Pebbles/Sand</u>. Fine to very coarse, angular to subrounded, but predominantly angular, dark volcanics with minor light gray soft clay.</p> <p>363-411': <u>Clayey Sand</u>. Fine to coarse, angular to subrounded, mostly dark gray to black volcanics with minor multicolored lithic fragments. Common but variable amounts of light gray, locally light brown, soft clay. Occasional very thin beds of very coarse sand as above, possibly pebbles.</p> <p>411 - 415': <u>Pebbles/Sand</u>. Fine to very coarse, angular to subrounded, predominantly dark volcanic fragments with minor multicolored lithic fragments. Minor light gray clay.</p> <p>415- 4435': <u>Sandy Clay</u>. Medium red-brown soft clay with multicolored, angular to subrounded, fine to medium sand (not at site at lithologic change).</p> <p>4435- 4443': <u>Clayey Sand</u>. Fine to coarse, angular to subrounded but predominantly angular, dark volcanics with common multicolored lithic fragments. Common flesh-colored, moderately soft to moderately firm claystone (not at site at lithologic change).</p> <p>4443-450': <u>Basalt (?) (Possibly basaltic sand)</u>. Fine to coarse, angular (very minor subrounded) black basalt with very minor flesh-colored claystone as above (gradual lithology change).</p> <p>450-453': <u>Basalt (?) (Possibly Clayey Sand)</u>. Basalt similar to above interval with red, soft clay (possibly weathered volcanics or ash).</p> <p>453-473': <u>Basalt</u>. Fine to coarse, angular, black with very minor red-brown to medium brown clay. Some multicolored sands, probably slough from above.</p> <p>473-478' (CORE) <u>Basalt</u>. Black, locally red-brown, vesicular in part, vugs filled or partially filled with flesh-colored opal and white to clear crystalline quartz. Fractures healed with flesh-colored moderately firm opal.</p> <p>478-483': <u>Basalt</u>. Similar to 473-478' interval.</p> <p>483-500': <u>Basalt</u>. Similar to 473-478' interval but harder; i.e., less fractured and vesicular. No change in samples.</p> <p>500-528': <u>Basalt</u>. Fine to coarse, angular, hard cuttings with slight increase in red-brown, slightly firm clay (opal?). Less dense than 483-500' interval.</p>

Sheet 3 of 3

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly--		Susanville Geothermal	
FEATURE Lassen County		PROJECT Investigations	
HOLE NO. SUZY-9		STATE California	
LOCATION See Notes		GROUND ELEVATION 4210'	
COORDINATES N. 396,276; E. 2,372,187		ANGLE FROM VERTICAL	
BEGUN 3-27-79		TOTAL DEPTH 445.0'	
FINISHED 4-12-79		VERTICAL	
DEPTH TO WATER Not Determined		HOLE LOGGED BY G. Hollinger, R. Turner	
		DRILLER N. Taggle, D. Warren	

NOTES	Type and Size of Hole	% Core Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
On water table levels, water return, character of drilling				
NOTE: Log based on rockbit cuttings.				
Purpose of Hole: (1) Temperature gradient; (2) geophysical properties; (3) geologic evaluation.				
Landowner: City of Susanville.				
Location: SE 1/4 SE 1/4 Section 31, T. 30 N., R. 12 E.; near intersection of S. Lassen Street and S. P. Railroad.				
Drill Rig: Falling 1500				
Drilling Methods: Rockbit drilled using bentonite drilling mud and shaker, 0-443'. 443-445': 4x5 1/2" diamond bit with split-tube inner barrel.				
Estimated Drilling Fluid Return: 0-445': 90-100%				
Drilling Conditions: 0-70': Fast to slow. 70-96': Medium speed; smooth to erratic (84-88': Hard, slow, smooth) 96-221': Slow to medium, smooth. 221-316': Medium to fast. 316-333': Fast. 333-356': Medium 356-393': Slow. 393-443': Very slow and very hard, slightly rough.				
Representative Drilling Fluid Temperatures (°F) 53° at 22' 53° at 42' 61° at 66' 61° at 90' 68° at 141'; bottom up after 12 hours				
DAILY SUMMARY OF DRILLING OPERATIONS: 3-27-79: Started rigging up; two shifts. 3-28-79: Drilled 6-3/4" rockbit hole to 141' 3-29-79: Drilled to 316' 3-30-79: Rig down for 16 hours for tower and cable repair, secured for weekend. 4- 2-79: Drilled to 413'; down 4 hours to repair Kelley. 4- 3-79: Twisted off at 443', fishing. 4- 4-79: Fishing 4- 5-79: Fishing 4- 6-79: Recovered most of fish; secured for weekend. 4- 9-79: Fish for bit cones; dug mud pits; one shift. 4-10-79: Fishing 4-11-79: Fishing 4-12-79: Hole Completed with 2" steel pipe 4-13-79: Rig moved off hole.				
SOIL & RECENT ALLUVIAL DEPOSITS. 0-6.0': Soil. Dark brown to black, sandy, silty, with fine to coarse, subangular to rounded, predominantly dark, partially weathered volcanic sand and subrounded to rounded, black to red-brown, fine to coarse gravel and cobbles. Common fine to medium, white quartz. 6.0-10.0': Cobbles/Gravel/Sand/Clay. As in 0-6' interval with red-brown soft clay. 10-445.0': PLEISTOCENE LAHONTAN LAKE (Near-Shore DEPOSITS). 10.0-17.0': Sandy Clay. Dark blue-gray, soft with volcanic sands and gravel as in 0-6' interval. 17.0-19.0': Clayey Sand. Fine to medium, some coarse, subangular to rounded, black to red-brown volcanic sand with medium gray soft clay. 19.0-27.0': Sandy Clay. Dark blue-gray, soft clay with angular to subrounded, fine to coarse, black to medium-brown volcanic sands and gravel, occasional black volcanic cobble. 27.0-43.0': Silty Clay. Dark gray, soft, silty, slightly sandy, with occasional very thin beds of fine to coarse quartz and volcanic gravel as in 19.0-27.0' interval. 43.0-55.0': Sand/Pebbles/Cobbles. All multicolored but predominantly dark volcanics; fine to very coarse, angular to rounded, with brown-red weathered volcanics and angular, white quartz. Continued dark gray clay as in 27-43' interval, decreasing in quantity. 55.0-57.0': Gravel/Cobbles. Similar to 43.0-55.0' interval but mostly dark volcanics, angular cuttings. 57.0-68.0': Sand/Gravel. Angular to subrounded, fine to very coarse, multicolored but predominantly dark volcanics; common green and red weathered volcanics and white quartz. 68.0-72.0': Sand/Gravel. Similar to 57.0-68.0' interval but with white to light gray soft clay.				

EXPLANATION

Sheet 1 of 2

FEATURE: Susanville Anomaly--Lassen County

PROJECT: Susanville Geothermal Investigations

Hole No. SUZY-9

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET

FEATURE: Susanville Anomaly--Lassen
County

PROJECT: Susanville Geothermal Investigations, California

HOLE NO. SUZY-9

SHEET 2 OF 2

NOTES (Continued)	FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Cont.)
<p><u>Representative Drilling Fluid Temperatures (°F)</u> (Continued)</p> <p>64° at 156' 76° at 170' 77° at 216' 72° at 262' 77° at 290' 86° at 316'; bottoms up after 82 hours 86° at 353' 88° at 390' 95° at 410' 95° at 424' 100° at 440' 106° at 444'; bottoms up after 15 hours</p> <p><u>Squeezing Conditions:</u> 0-141': Some squeezing required reaming to keep hole open.</p> <p><u>Geophysical Logging:</u> The following geophysical logs were run 4-23-79 by the USBR, E&R Center. Logs were run in 2" steel pipe; no open hole logs were run. (1) Natural Gamma (2) Neutron (3) Temperature</p> <p><u>Hole Completion:</u> Installed 445' of sealed water filled steel pipe in hole with 1' stickup, cemented in at surface. Site protected with steel guard rail. After logs run, 2" pipe pulled on 6-26-79 and steel plate placed over hole.</p>	<p>72.0-82.0': <u>Clayey Sand/Gravel</u>. Fine to coarse, angular to subrounded, red to red-brown decomposed volcanics and black volcanic lithic fragments. Common red-brown soft clay.</p> <p>82.0-110.0': <u>Sandy Clay</u>. Gray-brown to red-brown soft clay with fine to coarse, angular to subrounded, multicolored sands, locally red-brown decomposed volcanics.</p> <p>110.0-138.0': <u>Clay</u>. Light to medium gray, occasionally with a brown cast, locally white, soft silty clay with minor very fine to medium, subangular dark sands.</p> <p>138.0-185.1': <u>Sandy Clay</u>. White to light gray, soft clay; silty with very fine to medium, subangular to subrounded, multicolored sands.</p> <p>185.1'-206.0': <u>Sandy Clay</u>. Light to medium gray-green, soft with minor multicolored sands. Gradual change in color.</p> <p>206.0'-270.0': <u>Sandy Clay</u>. Light red-brown; soft with minor fine to medium, multicolored sands. Occasional thin, light to medium gray, soft clay.</p> <p>270.1'-333': <u>Sandy Clay</u>. Medium gray; soft with slight increase in dark, angular, fine volcanic sands.</p> <p>333-365': <u>Volcanics (Andesite?)</u>. Medium gray-green, soft to slightly firm, fine-grained volcanics with fine to medium, subangular, dark volcanic sands. Minor quartz.</p> <p>NOTE: Top of volcanics inferred from slightly slower drilling and slight increase in volcanic fragments.</p> <p>365-380': <u>Volcanics (Andesite?)</u>. Medium gray-green; soft to slightly firm, fine-grained, with marked increase in multicolored angular to subrounded, fine to medium with some coarse sands, possibly slough. Common quartz, occasional red-brown decomposed volcanics, fine to medium, angular to subround. Occasional light to medium gray, occasionally white soft clay. Minor white calcite.</p> <p>NOTE: Probable much recirculation of cuttings.</p> <p>380-420': <u>Volcanics (Andesite?)</u>. Medium-gray-green, moderate soft to firm, with minor multicolored sands as in 365-380' interval. Minor calcite.</p> <p>420-443': <u>Volcanics (Andesite?)</u>. Similar to 380-420' interval but with increased multicolored, fine to coarse, subangular to subrounded sands.</p> <p>443-445': (core) <u>Andesite Agglomerate</u>. Medium gray-green, hard, massive, but locally fractured (no particular direction), fractures healed with white calcite and clear quartz. Groundmass very fine to medium-grained with common secondary calcite (white). Clasts angular to round, dark gray green to black, mostly aphanitic, fine to up to 1", some with altered surfaces. Common hornblende.</p>

Sheet 2 of 2

FEATURE: Susanville Anomaly--Lassen County

PROJECT: Susanville Geothermal Investigations

HOLE NO. SUZY-9.

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE		PROJECT		STATE	
Susanville Anomaly-- Lassen County		Susanville Geothermal Investigations		California	
HOLE NO. SUZY-9A	LOCATION See Note	GROUND ELEVATION 1210'	ANGLE FROM VERTICAL Vertical		
BEGUN 7-17-79	FINISHED 9-7-79	TOTAL DEPTH 618'	VERTICAL Vertical		
DEPTH TO WATER ±15'		HOLE LOGGED BY G. Hollinger; R. Turner		DRILLER N. Tuggle; R. Swank; A. Velarde	
NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION	
Purpose of Hole: (1) Temperature gradient; (2) geo- physical proper- ties; (3) geologic evaluation.	13 7/8" RB	0	0-60':	NOTE: Log based on rockbit cuttings. Litho- logic descriptions often differ from SUZY-9 due to surface casings preventing contaminat- ion and larger tooth bits producing better cuttings on SUZY-9A.	
Landowner: City of Susanville.	50" 10 5/8" RB	0	60-61':	RECENT SOIL AND STREAM CHANNEL DEPOSITS	
Location: SE 1/4 SE 1/4 Sec. 31, T. 30 N. R. 12 E., near intersection of S. Lassen St. and S. P. Railroad, approx. 68' W-SW of SUZY-9.	100" 150" 180" 200" 250" 300" 350" 400" 450" 500"	0	0-6':	Soil/Sand/Gravel/Cobbles. Med- ium brown silty, clayey soil with fine to very coarse, angular to rounded, dark volcanics and clear to milky quartz sands and subangu- lar to rounded dark volcanic gra- vel and cobbles.	
Drill Rig: Failing 1500	6 1/2" RB	0	6-34':	Silty Clay. Dark gray, soft with very fine to fine, angular to subrounded dark sand. Occasional thin beds of volcanic gravels as in 0-6' interval, common milky quartz. (Very poor returns due to large hole and low mud viscosity)	
Drilling Methods: Drilled with bentonite mud and additives as re- quired. Used three mudpits.	200" 250" 300" 350" 400" 450" 500"	0	34-40':	Sand. Fine to coarse, some very coarse, angular to subrounded, multicolored but common dark vol- canics, white quartz and red weath- ered volcanics.	
0-32': 13-7/8" rockbit.	250"	0	40-55':	Sand/Gravel. Fine to coarse, angular to subrounded, mul- ticolored gravels with sand as in 34-40' interval.	
32-76': 10-5/8" rockbit.	300"	0	55-60':	Sand/Gravel. As in 40-55' interval with occasional dark, subrounded cobble and increased fine to coarse gravel.	
76-818': 6 1/2" rockbit.	350" 400" 450" 500"	0	60'-818':	PLEISTOCENE VOLCANICS	
380-394.3') 4x5 1/2" 507-511.5') diamond	350"	0	60-74':	Basalt (?). Black, angular, hard basalt cuttings with very large amounts of sand and gravel as in 34-60' intervals, probably sloughing from above. Drilling much too slow for abundance of cut- tings.	
682.5-687') bit with split tube in- ner barrel.	400"	0	74-78':	Volcanics (Ash or mudflow). White to light pink, soft, partial- ly hydrated clay to moderately firm and brittle with fine grained, angular to subrounded, multicolor- ed lithic fragments. Continued fine to coarse sands and gravels, probably slough.	
Drilling Condi- tions:	450"	0	78-89':	Volcanics (Ash or mudflow). Medium brown with pink cast, mod- erately firm, brittle, predominant- ly fine grained, angular to	
0-6.5': Very slow, very rough.	500"	0	8- 1-79:	Drilled to 390'. Cored from 390- 395'. Drilled to 410'.	
6.5-22': Medium fast, smooth to slightly rough.	550"	0	8- 2-79:	Drilled to 454' and lost circula- tion.	
22-32': Slow, smooth to occasionally rough.	600"	0	8- 3-79:	No drilling due to no bentonite at site.	
32-40': Fast, smooth.	650"	0	8- 6-79:	Drilled to 460' and twisted off. Recovered fish.	
40-55': Slow, rough, erratic.	700"	0	8- 7-79:	Drilled to 477'. Rig mud pump un- able to start.	
55-75': Very slow, very rough.	750"	0	8- 8-79:	Replaced rig starter motor. Drill- ed to 507'. Cored to 511.5'. Drilled to 527'.	
75-78': Slow, smooth.	800"	0			
78-190': Medium to medium fast, smooth to occasionally rough.	850"	0			
190-230': Intermittent	900"	0			

EXPLANATION

Sheet 1 of 4

Hole No. SUZY-9A

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly-- Susanville Geothermal
 Lassen County Investigations STATE California
 FEATURE HOLE NO. SUZY-9A LOCATION See Notes, Sheet 1 GROUND ELEVATION 4210' ANGLE FROM
 COORDINATES N. 396,288; E. 2,372,122 TOTAL DEPTH 818' VERTICAL Vertical
 BEGUN 7-17-79 FINISHED 9-7-79 N. Tuggle; R. Swank;
 DEPTH TO WATER -15' HOLE LOGGED BY G. Hallinger; R. Turner, DRILLER A. Velarde

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Recovery %	DEPTH	CLASSIFICATION AND PHYSICAL CONDITION
190-230' (Cont.): slow to fast, smooth to moderately rough. 230-295': Fast, smooth. 295-395': Slow, smooth. 395-410': Slow, med- ium smooth. 410-465': Slow, smooth. 465-467': Medium, smooth. 467-477': Slow, rough 477-527': Medium to medium fast, smooth 527-584': Slow, smooth, occasionally rough. 584-630': Slow, rough 630-690': Medium, smooth. 690-692': Slow, rough 692-707': Medium, medium smooth. 707-790': Medium; smooth to occasional- ly rough. 790-807': Slow, med- ium rough. 807-818': Slow to medium, medium smooth.	1 1/2 RB	0	575 600 650 700 750 800 850 900 950 1000	78-89' (Cont.): subrounded, multi- colored lithic fragments. 89-90': <u>Volcanics</u> . Medium-gray, aphanitic, moderately firm, brit- tle. 90-91': <u>Clayey Sand (?)</u> Fine to very coarse, gray-green, predomi- nantly angular, some subrounded volcanic sand and common pink, soft clay, probably hydrated ash. 91-112': <u>Volcanics (ash or mudflow)</u> Medium-gray brown to pink, slight- ly soft to moderately firm, brit- tle, very fine to fine-grained ma- trix with angular to subrounded, multicolored lithic fragments. 112-125': <u>Volcanics</u> . As in 91-112' interval, predominantly brown-pink. 125-160': <u>Volcanics (ash or mudflow)</u> Light to medium gray, moderately firm, brittle, very fine to fine grain matrix with angular to sub- rounded, multicolored lithic frag- ments. Some primary hornblende. 160-175': <u>Volcanics</u> . As in 125- 160' interval; predominantly med- ium gray-green to gray color. Some medium-grained lithic fragments. 175-182': <u>Volcanics (ash or mudflow)</u> Medium pink, soft and hydrated to moderately firm and brittle, very fine-grained matrix with fine to medium-grained, angular to sub- rounded, multicolored lithic frag- ments. 182-190': <u>Volcanics</u> as in 175-182' interval with alternating gray- green, medium pink, red, medium brown colors. 190-220': <u>Volcanics (ash or mud- flow)</u> . Medium to dark red, moder- ately firm, brittle, very fine grained with multicolored lithic fragments as in 175-182' interval. 220-228': <u>Volcanics (Ash or mud- flow)</u> , as in 190-220' interval with medium red, very fine grained, slightly soft to moderately firm volcanics with few multicolored lithic fragments. 228-240': <u>Volcanics</u> . Medium gray, firm to moderately soft, slightly hydrated, aphanitic, with some dark, fine-grained, predominantly angular lithic fragments.
ESTIMATED DRILLING FLUID RETURNS: 0-390': 100% 390-454': 90-95% @ 454': Lost circu- lation. 454-467': 95-100% @ 468': Lost circu- lation. 469-477': 80-90% 477-602': 90-100% 602-694': 80-90% 694-747': 100% 747-818': 95% NOTE: Hole making some water, 600-818'.				
Representative Drill- ing Fluid Tempera- tures (°F) 79°F at 60' 79°F at 160' 81°F at 190' 84°F at 240' 88°F at 290' 93°F at 340'				

EXPLANATION

Sheet 2 of 4

Hole No. SUZY-9A

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET	
FEATURE, Susanville Anomaly-... PROJECT, Susanville Geothermal Investigations... HOLE NO. SUZY-9A Lassen County SHEET 3 OF 4	
NOTES (Continued)	FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Continued)
Representative Drilling Fluid Temperatures (°F) (Cont.) 99° at 380' 104° at 390' 120° at 410' after ±10 hours downtime 105° at 418' 109° at 447' 140° at 450' after ±90 hours downtime 105° at 520' after adding water to mud. 111° at 550' 115° at 576' 130° at 584' after ±110 hours downtime 112° at 612' 109° at 680' 112° at 747' 115° at 787' 118° at 805'	228-240' (Cont.): Calcareous in part. ±240-252': <u>Clay</u> . Medium gray, soft to slightly firm with minor lithic fragments as in 228-240' interval. Probably volcanic. 252-295': <u>Volcanics</u> . Medium gray to medium brown, to gray-green. Slightly firm to firm and brittle, aphanitic to medium grained. Occasional thin, soft red clay beds; locally common clear quartz and white calcite. Some coarse, angular and subrounded, dark lithic fragments, possibly slough. 295-332': <u>Volcanics</u> . Medium gray to gray-green, firm, brittle, aphanitic; calcareous in part. Occasional white, soft clay; trace of white calcite. 332-350': <u>Volcanics</u> . As in 295-332' interval with minor red-brown to pink, aphanitic volcanics. Slight increase in white, soft clay. 350-362': <u>Volcanics</u> . As in 332-350' interval with increased red-brown, soft to slightly firm, aphanitic volcanics; probably ash. 362-390': <u>Volcanics</u> . Medium gray to gray-green, soft to moderately firm; aphanitic with some dark, fine-grained minerals (hornblende?), and soft to slightly firm, white calcite. Contains medium-brown aphanitic volcanics (ash?) as in 350-362' interval. 390-394.3' (CORE): <u>Andesite Agglomerate</u> . Medium gray to gray-green to green, hard, dense, but can be scratched with knife. Core shows no fractures other than coring mechanical fractures but some slickens apparent. Groundmass: Medium gray-green, fine-grained. Clasts: Light gray to medium gray-green, fine-grained, angular to subrounded, size fine to up to 3". Common calcite veins and vug fillings; common pyrite. 394.3-415': <u>Andesite Agglomerate</u> . Similar to 390-394.3' interval. 415-460': <u>Andesite Agglomerate</u> . Similar to 390-394.3' interval with variable amounts of light gray, soft clay, probably ash. Minor to common white calcite veinlets. 460-475': <u>Andesite Agglomerate</u> . Similar to 415-460' interval with increased white to clear calcite veins and remineralization (?). Minor fine-grained mafic minerals. 475-500': <u>Volcanics</u> . Light to medium gray, moderately soft and hydrated to firm and brittle, aphanitic, with common light gray calcareous inclusions (remineralization?) and clear to white calcite veinlets. Occasional white, moderately soft aphanitic tuff. Occasional very fine to fine, some medium, multicolored, subrounded lithic fragment inclusions. 500-500.5': <u>Volcanics</u> . Mud turned light gray but no change in lithic samples--probably completely hydrated ash. 500.5-507': <u>Volcanics</u> . As in 475-500' interval. 507-511.5' (CORE): <u>Andesite Agglomerate</u> . Light to medium gray to gray-green, dense to fractured, fractures mostly healed with white calcite; some slickens apparent. Groundmass: Light gray to gray-green, very soft and flaky to moderately firm; can be scratched in places with fingernail others only with knife. Fine to medium-grained, common hornblende and recrystallized calcite. Clasts: Light to medium gray, usually hard and aphanitic; angular to subrounded, up to 3" in size. Large voids filled with white calcite. Common pyrite. 511.5-595': <u>Andesite Agglomerate</u> . Similar to 507-511.5' interval with variable amounts of white and clear calcite veinlets. 595-630': <u>Volcanics</u> . Medium gray, aphanitic, moderately soft to firm, brittle, calcareous in part (remineralization?) with variable but minor amounts of light to medium green minerals (saussurite?). Occasional subrounded, fine to medium, red-brown lithic
Caving Conditions 0-10.5': Caving cobbles 73-75': Caving gravel	
Casing Record: 0-31': 12" blank steel casing 0-78': 8" blank steel casing.	
Geophysical logging: The following geophysical logs were run by the USBR, Denver Office on August 21, 1979, and October, 1979. Logs were run in open hole on August 21, 1979 and in 2" steel pipe, October, 1979.	
(1) Resistivity (2) Gamma-Gamma (3) Caliber (4) Temperature (5) Natural Gamma (6) Neutron	Ran in open hole to 687'. Ran in 2" water-filled steel pipe to 818' total depth.
Hole Completion: Ran 819' of 2" steel pipe to 818' with ±1" stickup. Bottom of pipe sealed and pipe filled with clear water. Only upper 5' of pipe cemented in because the City of Susanville may desire to use well for testing at a future date. Pipe protected with steel triangle guard.	
NOTE: 2 rockbit cones at bottom of hole--818'.	

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET

FEATURE: Susanville Anomaly-- Lassen County PROJECT: Susanville Geothermal Investigations
 HOLE NO. SUZY-9A SHEET: 4 OF 4

FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Continued)

- 595-630' (Continued): fragment inclusions and occasional common, fine-grained mafic minerals. Common clear to white calcite veinlets.
- 630-682.5': Volcanics. As in 595-630' interval with increasing amounts of light to medium green minerals (saussurite?). Less clear to white calcite; trace of white quartz. Minor dark gray, moderately firm aphanitic volcanics.
- 682.5-687' (CORE): Volcanic Agglomerate. Light to dark gray to black, hard, but can be scratched locally with a knife. Dense but locally fractured. Fractures and voids healed or partially filled from two events of secondary mineralization: White calcite first and white to clear, crystalline quartz secondly. Matrix aphanitic, dark gray to black with vug fillings of feldspar and calcite. Clasts light to dark gray, hard, angular to subrounded, fine to up to 1".
- 687-⁺702': Volcanic Agglomerate. Similar to 682.5-687' interval.
- ⁺702-719': Volcanics. Light to medium gray to black, aphanitic, predominantly moderately firm, brittle with some light to medium green minerals (saussurite?) and minor red, subrounded, fine grain lithic fragment inclusions. Minor medium brown aphanitic ash with subrounded quartz inclusions. Common clear to white calcite veinlets.
- 719-762': Volcanics. Similar to ⁺702-719' interval with increasingly common, white aphanitic tuff. Trace of pyrite, epidote, biotite.
- 762-⁺790': Volcanics. Light gray to white, some dark gray, moderately soft to firm, brittle, aphanitic, with very common white, moderately soft aphanitic tuff with very fine to medium grained, mafic inclusions. Trace of pyrite, locally common epidote.
- ⁺790-818': Volcanics. As in 762-790' interval with increasing dark gray to black, moderately firm aphanitic volcanics (basalt?).

SUSANVILLE GEOTHERMAL		STATE OF CALIFORNIA	
FEATURE		PROJECT	STATE
Lassen County		Investigations	California
HOLE NO.	LOCATION	GROUND ELEVATION	ANGLE FROM
SUZY-10	See Notes	4237'	VERTICAL
COORDINATES		TOTAL DEPTH	VERTICAL
N. 400, 625; E. 2, 372, 595		647.5'	Vertical
BEGUN		FINISHED	
4-16-79		5-11-79	
DEPTH TO WATER		HOLE LOGGED BY	
Not Determined		Robert L. Turner	
DRILLER		N. Tuggle; D. Warren	
NOTES	Type and Size of Hole	RECOVERY	DEPTH
On water table levels, water return, character of drilling			
Purpose of Hole:			
(1) Temperature gradient; (2) Geologic physical properties; (3) geologic evaluation.			
Landowner: City of Susanville			
Location: SE 1/4 Section 30, T. 30 N., R. 12 E., MDB&M.; at intersection of N. Roop and Cherry Terrace roads, Susanville, CA.			
Drill Rig: Failing 1500			
Drilling Methods:			
Drilled with bentonite mud and additives as required. Used two mudpits.			
0-72': 6-3/4" rockbit.			
0-25': 9-7/8" rockbit for 8" casing.			
72-132': 6-3/4" rockbit--8" casing failed.			
0-52': Reamed for reinstallation of 8" casing.			
132-643': 6-3/4" rockbit.			
643-647.5': 4x 5/4" diamond bit with split-tube inner barrel.			
Drilling Conditions:			
0-12': Medium, smooth to rough.			
12-85': Slow, rough to very rough.			
85-115': Medium, smooth to rough.			
115-132': Slow, rough.			
132-153': Slow, rough to medium smooth.			
153-393': Mostly medium fast to			
DAILY SUMMARY OF DRILLING OPERATIONS:		FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION	
4-16-79: Failing 1500 moved to site and rigged up.		0-13': FILL & RECENT SOIL	
4-17-79: Rigged up.		Medium-brown, silty with fine to coarse, angular to rounded, black to brown, volcanic sand. Common white quartz. Occasional sub-rounded brown gravel and cobbles.	
4-18-79: Drilled to 18', much caving.		13-647.5': PLEISTOCENE VOLCANICS AND LAHONTAN (near shore) LAKE DEPOSITS.	
4-19-79: Drilled to 32'.		13-17': Basalt. Black, hard, angular cuttings, possibly boulders.	
4-20-79: Drilled to 54'.		17-18': Clay. Gray-brown, silty, soft.	
4-23-79: Drilled to 73'; stuck in hole at 43'.		18-65': Basalt. Black to medium gray, locally common red-brown weathered basalt, angular fine to coarse cuttings. Occasionally medium tan, soft clay in very thin (less than 4") beds, possibly tuff.	
4-24-79: Stuck in hole, pulled free. Reamed to 17' to open hole for casing.		65-66': Clay. Medium tan, soft, silty, probably weathered and hydrated tuff or basalt.	
4-25-79: Reamed to 24'. Ran 8" casing to 24'. Drilled to 74'.		66-85': Basalt (Flow or boulders?). Medium gray to black, angular, fine to coarse cuttings. Occasional minor milky quartz veinlets on vug fillings.	
4-26-79: Drilled to 132'. Stuck in hole when pulling bit.		85-105': Sand/Gravel. Fine to very coarse, predominantly angular but some subrounded, mostly black basalt with minor light to medium brown, soft to slightly firm clay.	
4-27-79: Stuck in hole. Pulled free. 8" casing failing.		105-115': Sand/Gravel. Fine to very coarse, angular to subrounded, dark volcanics with some medium brown, weathered volcanics. Minor medium brown, soft clay, occasional hard black basalt cobbles.	
4-30-79: Repair rotary transmission.		115-139': Basalt (Flow or boulders?). Medium gray to black, fine to very coarse, angular cuttings. Locally common milky quartz.	
5- 1-79: Completed repairs. Reamed hole to 40' for reinstallation of 8" casing.		139-157': Sand. Fine to coarse, angular to subrounded, predominantly dark volcanics, with light tan to medium-brown, soft silty clay. Minor brown, weathered volcanics, occasional thin, dark volcanic gravel beds.	
5- 2-79: Reamed to 51'. Stuck pipe.		157-159': Cobbles. Black basalt, hard.	
5- 3-79: Stuck in hole. Repaired clutch and pulled free. Ran 8" casing to 50'. Drilled to 52'.			
5- 4-79: Drilled to 273'; cemented in 8" casing to 50'.			
5- 7-79: Drilled to 473'. Stuck pipe when pulling bit.			

EXPLANATION

Sheet 1 of 3

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly--		Susanville Geothermal	
FEATURE	Lassen County	PROJECT	Investigations
HOLE NO. SUZY-10	LOCATION See Notes	GROUND ELEVATION 4237'	STATE California
BEGUN 4-16-79	COORDINATES N. 400,625; E. 2,372,595	TOTAL DEPTH 647.5'	ANGLE FROM VERTICAL Vertical
FINISHED 5-11-79		DRILLER N. Tuggle; D. Warren	
DEPTH TO WATER Not Determined		HOLE LOGGED BY Robert L. Turner	

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Core Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
Drilling Condi- tions (Cont.) 153-393': (Cont.) fast, smooth to occasionally rough. 393-473': Medium, smooth. 473-593': Medium, smooth to occa- sionally rough. 593-615': Slow, smooth. 615-647.5': Slow, smooth to medium rough.				
Estimated Drill- ing Fluid Return: 0-647.5': 95-100% NOTE: Hole mak- ing some water, 564-570'.				
Representative Drilling Fluid Temperature (°F): 59° at 14' 66° at 72' 72° at 128' 69° at 150' 72° at 240' 73° at 270' 66° at 273' after 165 hours down- time--cold weather. 67° at 350' 68° at 450' 70° at 520' 73° at 615' 73° at 643'				
Caving Conditions: 12-32': Caving. 68-72': Caving. 115-132': Caving.				
Casing Record: Installed 8" black steel cas- ing to 52'.				
Geophysical Log- ging: The following geophysical logs were run by the USBR, Denver Of- fice, on 6-29-79.				
Daily Summary of Drilling Operations (Cont.): 5-10-79: Drilled to 643'. Cored from 643 to 647.5' total depth. 5-11-79: Ran 2" water-filled pipe to bottom. Tear out and move to SUZY-11.				
				159-162': Sand. Fine to medium, angular to subrounded, predominant- ly dark volcanics with medium brown, moderately soft, reworked, fine-grained tuff. Occasional thin, coarse-grained volcanic sand beds.
				162-180': Sand. Fine to medium, an- gular to subrounded, medium brown to medium gray, predominantly weathered and unweathered volcan- ics. Locally common white to med- ium brown, partially welded tuff. Trace of milky quartz, angular to subrounded.
				180-200': Sand as in 162-180' in- terval with increased amounts of light to medium brown, partially welded tuff.
				200-238': Sand as in 180-200' inter- val with less tuff. Common fine to coarse, angular to subrounded, black volcanic sands.
				238-240': Sand. Fine to medium, some coarse, angular to subrounded, predominantly dark volcanics with some medium brown, fine to medium- grained tuff. Minor soft brown clay.
				240-255': Sand as in 238-240' in- terval with increased amounts of soft medium-brown clay.
				255-260': Sand. Fine to medium, some coarse, angular to subrounded, predominantly dark volcanics, with red-brown to brown, weathered vol- canics. Common milky quartz, var- iable amounts but minor brown soft clay.
				260-275': Clayey Sand. Fine to med- ium, minor coarse, angular to sub- rounded, multicolored but predomi- nantly dark volcanics. Common med- ium brown clay, trace of milky quartz and white angular tuff.
				275-306': Sandy Clay. Medium gray- brown, soft, with multicolored sand as in 260-275' interval. Common light to medium gray, slightly firm, fine grained tuff. Trace of quartz.
				306-335': Sandy Clay. Medium brown to red-brown, some medium gray, soft, with minor angular to sub- rounded, fine to medium, multicol- ored sand. Minor light gray, fine- grain tuff.

EXPLANATION

Sheet 2 of 3

Hole No. SUZY-10

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET	
FEATURE <u>Susanville Anomaly--</u> PROJECT <u>Susanville Geothermal Investigations--</u> <u>Lassen County</u> <u>California</u> HOLE NO <u>SUZY-10</u> SHEET... <u>3</u> OF... <u>3</u>	
NOTES (Continued)	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (Cont.)
<p><u>Geophysical Logging (Cont.):</u> Logs were run in 2" steep pipe--no open hole logs were run:</p> <p>(1) Natural Gamma (2) Neutron (3) Temperature</p> <p><u>Hole Completion:</u> Ran 647.5' of 2" steel pipe to 647.5' and cut off ±1' below ground surface. Bottom of pipe sealed and pipe filled with clear water. Pipe protected in water meter box cemented into street at ground level. Upper 20' of pipe cemented in.</p>	<p>335-342': <u>Sandy Clay</u>. Similar to 306-335' interval with predominantly dark volcanic, fine to medium, angular to subrounded sands. Minor multicolored sand.</p> <p>342-420': <u>Clay</u>. Medium-gray brown, soft with minor, predominantly dark, fine to medium, angular to subrounded volcanic sand.</p> <p>420-475': <u>Clay</u>. Medium gray-brown, soft, with predominantly fine-grain, angular to subrounded, dark volcanic sand.</p> <p>475-492': <u>Sandy Clay</u>. Medium gray-brown, occasionally light gray, soft clay with fine to medium, some coarse, angular to subrounded, multicolored but predominantly dark and red volcanic sands. (NOTE: Medium to coarse sand may be sloughing from casing grout.)</p> <p>492-498': <u>Sand</u>. Fine to coarse, angular to rounded, multicolored with minor soft, medium gray-brown clay. Some gravel, possibly slough from casing grout.</p> <p>498-535': <u>Sand</u>. Similar to 492-498' interval with light gray to pink, slightly firm claystone. Minor medium brown, fine-grain tuff.</p> <p>535-564': <u>Clayey Sand</u>. Fine to coarse (minor gravel), angular to subrounded, multicolored with common brown, weathered volcanics. Common light gray, soft to moderately firm clay or very fine-grain tuff. Minor medium brown soft clay.</p> <p>564-570': <u>Sand/Gravel</u>. Fine to very coarse, angular to rounded, multicolored but predominantly black and red volcanics. COMMON MILKY QUARTZ, WHITE CALCITE, VERY MINOR CLAY (NOTE: May be volcanic flow and rounded cuttings sloughing or recirculation in mud.)</p> <p>570-593': <u>Sand (Possible Volcanic Flow)</u>. Fine to medium, angular to subrounded (possible slough), multicolored but predominantly black volcanics; common red volcanics and light gray, fine-grain volcanics. Some white calcite.</p> <p>593-643': <u>Volcanics</u>. Light gray to black, angular, hard black basalt with light gray, soft to slightly firm, fine-grain volcanics, possibly ash. Very common multicolored sands, most likely slough and recycled mud. Some white calcite</p> <p>643-647.5' (CORE): <u>Andesite Breccia</u>. Medium to dark gray with local green cast. Hard but can be locally scratched with knife, mostly dense but locally fractured (no particular direction), and most fractures and voids healed with white quartz, calcite and minor clay, some microfractures healed with iron oxide (?). Matrix and clasts fine grain with some calcite remineralization and green mineralization (saussurite?). Clasts fine to up to 2" in size, angular to subrounded, predominantly black to red volcanics.</p>

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly-- Susanville Geothermal
 FEATURE Lassen County PROJECT Investigations STATE California
 HOLE NO. SUZY-11 LOCATION See Notes GROUND ELEVATION 4284' ANGLE FROM
 COORDINATES N. 397.306; E. 2.371.270 TOTAL DEPTH 798.0' VERTICAL Vertical
 BEGUN 5-14-79 FINISHED 7-17-79 N. Tuggle; D. Warren;
 DEPTH TO WATER 52.0' HOLE LOGGED BY Robert L. Turner DRILLER W. Skaggs; R. Swank

NOTES On water table levels, water re- turn, character of drilling	Type and Size of Hole	Core Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION NOTE: Log prepared from rockbit cuttings.
Purpose of Hole: (1) Temperature gradient; (2) geo- physical proper- ties; (3) geologic evaluation.	9 3/8" RB	0	Daily Summary of Drilling Operations: 5-14/15-79: Moved to site and rigged up.	0-798': <u>PLEISTOCENE VOLCANICS</u>
Landowner: Jim Pearson; Susan- ville, California	50'		5-16-79: Continued rigging up and drilled to 23'.	0-6': <u>Soil and Fill</u> . White to med- ium brown, silty, clayey, with glass chards and very fine to coarse, angular to well rounded, light to medium brown, weathered volcanic sand. Common clear quartz. Occasional subrounded, fine to coarse, black to red-brown volcanic gravels and cobbles.
Location: NE 1/4 SE 1/4 Section 31, T. 30 N., R. 12 E.; south of Miller Road.	6 3/4" RB		5-17-79: Drilled to 30'; ran 8" casing to 28.5'	6-28': <u>Volcanics</u> (ash or decomposed flow). Red-brown, firm to medium soft, very fine-grained with common very fine to fine, black basalt cuttings, predominantly angular. Occasional fine to coarse gravel and cobbles as in 0-6' interval.
Drill Rig: Falling 1500	105'	0	5-18-79: Cemented in surface casing 5-21-79: Added cement to casing an- nulus, mixed mud.	28-35': <u>Volcanic Basalt</u> . Hard, black, fine-grained, angular cut- tings with thin (less than 2") in- terbeds of red-brown clay; soft to slightly firm.
Drilling Methods: Drilled with bentonite mud and additives as re- quired. Used one long mudpit due to space limita- tions.	200'		5-22-79: Drilled to 104'	35-37': <u>Clay</u> . Gray-brown to pink, soft, hydrated with red-brown de- composed volcanics and black ba- salt. Minor milky quartz.
0-30': 9-7/8" rockbit for 8" surface casing.	250'		5-23-79: Drilled to 213'.	37-54': <u>Clay</u> . Pink, soft, with very minor basalt, probably slough.
30-533': 6-3/4" rockbit.	4 1/2" x 9"		5-24-79: Drilled to 273'; cored from 273-275'.	54-70': <u>Sand/Clay</u> . Light brown to pink, soft clay with fine to medium, some coarse, angular to subrounded, multicolored sands. Occasional coarse gravel or cobble, predom. black volcanics. Locally common quartz sand.
533-797.5': 6 1/2" rockbit.	300'		5-25-79: Drilled to 333'.	70-118': <u>Tuff</u> . Light to medium gray-brown, very fine-grained; soft and hydrated to moderately firm. Continued sand as in 54-70' interval, possibly slough. Occa- sional flood of tan soft clay.
273-275' } 4x5 1/2" diamond	350'		5-28-79: Holiday.	118-121': <u>Tuff</u> . Light gray to light red, predominantly soft, hydrated clay, minor multicolored sands as in 54-70' interval, possibly slough.
388-390.5' } bit	6 3/4" RB	0	5-29-79: Drilled to 388'.	NOTE: ABUNDANT RECYCLING OF CUTTINGS
533-537.8' } with			5-30-79: Cored from 388-390.5'; drilled to 400' and twist- ed off. Retrieved fish.	121-128': <u>Tuff</u> . Light gray-brown, fine-grained, soft and hydrated to moderately firm. Minor white vein quartz, minor fine to medium, mul- ticolored sand.
643-647' } split-tube inner barrel			5-31-79: Drilled to 401' and twist- ed off. Retrieved fish and drilled to 438' after rig engine repairs.	
Drilling Condi- tions: 0-28.0': Moderate- ly fast, erratic.	400'		6-1-79: Drilled to 447' when kelly swivel washed out.	
28-30': Slow, rough.	450'		6-4-79: Replaced swivel and over- hauled mud pump. Drilled to 454', when rig radiator leaked through large hole.	
30-35': Slow, rough.			6-5-79: Repaired radiator; drilled to 480'.	
35-56': Medium, smooth.	500'		6-6-79: Drilled to 510' and twisted	
56-104': Slow, moderately rough.				
104-133': Medium, moderately rough.				
133-138': Fast, smooth.				
138-213': Medium, moderately rough.				

EXPLANATION

Sheet 1 of 4

Hole No. SUZY-11

GEOLOGIC LOG OF DRILL HOLE

Susanville Anomaly--		Susanville Geothermal		STATE California			
FEATURE Lassen County		PROJECT Investigations		ANGLE FROM			
HOLE NO. SUZY-11		LOCATION See Notes		GROUND ELEVATION 4284'			
COORDINATES N.397,306; E.2,371,270		TOTAL DEPTH 798.0'		VERTICAL Vertical			
BEGUN 5-14-79		FINISHED 7-17-79		N.Tuggle;D.Warren;			
DEPTH TO WATER 52.0'		HOLE LOGGED BY Robert L. Turner		DRILLER W.Skaggs;R.Swank			
NOTES On water table levels, water return, character of drilling	Type and Size of Hole	Core Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION			
Drilling Conditions: (Cont.) 213-273': Medium, smooth. 273-333': Slow, smooth. 333-438': Slow, moderately rough. 438-480': Very slow, moderately rough. 480-510': Slow to medium fast, smooth to rough. 510-512': Slow, rough. 512-520': Very slow, rough. 520-533': Slow, rough. 533-538': Slow, smooth. 538-550': Slow, erratic; moderately smooth to rough. 550-603': Slow, moderately smooth. 603-692': Slow to medium, smooth to rough. 692-715': Slow, smooth to slightly rough. 715-797.5': Slow, rough (erratic).			6 1/2" RB 550 600 650 700 750 800 850 900 950	Daily Summary of Drilling Operations 6- 6-79: (Cont.) off. Retrieved fish and drilled to 520'. 6- 7-79: Drilled to 533' and twisted off. Retrieved fish and cored to 537.8'. 6- 8-79: Drilled to 573'. 6-11-79: Drilled to 603'. 6-12-79: Replaced all drilling rods. Drilled to 643'. 6-13-79: Cored from 643-647'. Drilled to 692'. 6-14-79: Mud pump chain drive bearings worn. Unable to drill. 6-15-79: Tore down rig and moved rig to Folsom. 6-18/22-79: Another Failing 1500 rig being outfitted in Folsom. 6-25/26-79: Moved rig to Susanville; pulled 2" pipe out of SUZY-9, rig up on SUZY-11. 6-27-79: Completed rigging up, cleaned out hole for open hole geophysical logging. 6-28-79: Repaired rig carburetor, drilled to 695'. 6-29-79: Rebuilt rig carburetor, pulled out of hole for temperature logging. 7- 2-79: Rig down for repairs. 7-3- 79: Replaced carburetor, drilled to 705'. 7-4/6-79: Shut down. 7- 9-79: Repaired wiring on rig engine; drilled to 715'. 7-10-79: Drilled to 743'. 7-11-79: Drilled to 772'. 7-12-79: Drilled to 797.5' total depth. Lay down rods. 7-13-79: Ran 2" water-filled steel pipe to bottom. Started tearing out. 7-16/17-79: Completed tearing out and moving to SUZY-9A.		128-133': Tuff. Light to medium gray-brown, predominantly moderately firm, some soft and hydrated. Increase in predominantly angular, multicolored lithic fragments in tuff. 133-138': Clay. Medium gray-brown, soft, with minor angular to subrounded, fine to medium, predominantly dark volcanic sands. 138-162': Clayey Sand or Tuff (?) (Samples very contaminated). Clay: Soft, medium gray-brown. Sand: Fine to medium, angular to subrounded, some rounded, multicolored but predominantly dark volcanics. Tuff: as in 128-133' interval. Drilling moderately rough, moderately slow. 162-183': Clay. Medium gray, soft with medium brown, fine-grained tuff (moderately firm) and angular to subrounded, fine to medium, multicolored sand. 183-225': Volcanic (andesite ?). Medium gray, very fine-grained, soft to moderately firm cuttings with medium-brown tuff as above. 225-240': Volcanics. Dark gray to black, soft and hydrated to moderately firm, brittle. Minor brown tuff, probably recycled. 240-248': Volcanics. As in 225-240' interval with some tan to brown, soft clay. 248-273': Volcanics. Medium brown to tan, soft to slightly firm with volcanics as in 225-240' interval. Occasional milky, angular quartz and some subrounded, fine to medium sand, possibly slough or recycled 273-275' (CORE): Volcanics. Dark red gray to red with local green cast, dense, brittle and flakes when dry; easily scratched with knife, aphanitic, fractured (no particular orientation); fractures healed with white quartz and calcite; red iron oxide (?) and soft brown clay. Extensively remineralized. 275-300': Volcanics. as in cored interval (273-275'). Samples contaminated with recycled cuttings. 300-330': Volcanics. Medium	
Estimated Drilling Fluid Return: 0-797.5': 90-100% Representative Drilling Fluid Temperatures (°F): 66° at 23' 70° at 60' 72° at 100' 77° at 175' 82° at 210' 84° at 275' after about 18 hours downtime. 77° at 310' 86° at 333' after about 80 hours downtime. 84° at 370' 86° at 410' 93° at 430' 95° at 447' after about 77 hours downtime.							
EXPLANATION							

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET

FEATURE Susanville Anomaly-- PROJECT Susanville Geothermal Investigations--
 HOLE NO. SUZY-11 Lassen County California SHEET 3 OF 4

NOTES (Continued)	FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Cont.)									
<p><u>Representative Drilling Fluid Temperatures (°F) (Cont.)</u></p> <p>88° at 493' 92° at 535' 93° at 565' 97° at 573' after about 72 hours downtime. 95° at 600' 108° at 603' after about 10 hours downtime. 103° at 640' 101° at 643' after about 10 hours downtime. 104° at 680' 100° at 705' 102° at 705' after about 130 hours downtime. 105° at 743' 108° at 770' 110° at 797'</p> <p><u>Caving Conditions:</u> 0-30': Caving.</p> <p><u>Casing Record:</u> 0-28.5': 8" black steel casing.</p> <p><u>Geophysical Logging:</u> The following geophysical logs were run by the USBR, Denver Office, on June 27, 1979 and August 20, 1979. Logs were run in open hole on June 27, 1979 and in 2" steel pipe on August 20, 1979; additional natural gamma and neutron logs were run on</p> <table border="0"> <tr> <td>(1) resistivity</td><td rowspan="3">} Ran in open hole to 692'</td></tr> <tr> <td>(2) Gamma-Gamma</td></tr> <tr> <td>(3) Sonic</td></tr> <tr> <td>(4) Caliber</td><td rowspan="4">} Ran in 2" water filled steel pipe to 797.5' total depth.</td></tr> <tr> <td>(5) Temperature</td></tr> <tr> <td>(6) Natural gamma</td></tr> <tr> <td>(7) Neutron</td></tr> </table> <p><u>Hole Completion:</u> Ran 801.5' of 2" steel pipe to 797.5' with #4' stickup. Bottom of pipe sealed and pipe filled with clear water. Pipe not cemented in because landowner may desire to use well at a future date.</p>	(1) resistivity	} Ran in open hole to 692'	(2) Gamma-Gamma	(3) Sonic	(4) Caliber	} Ran in 2" water filled steel pipe to 797.5' total depth.	(5) Temperature	(6) Natural gamma	(7) Neutron	<p>†300-330': (Continued) gray to gray-green, fine-grained, moderately firm, brittle.</p> <p>330-388': <u>Volcanics</u>. Medium gray to gray-green to occasionally dark red, fine-grained, moderately firm; brittle with occasional minor medium gray, soft clay. Trace of milky, angular quartz.</p> <p>388-390.5' (CORE): <u>Volcanics (basalt ?)</u> Dark gray to green-gray, hard, dense, vesicular with vugs filled mostly with white calcite, fractured (mostly microfractures with no particular orientation); fractures healed with calcite, iron oxide (?) and soft brown clay. Extensively remineralized. Minor volcanic clast inclusions up to 2".</p> <p>390.5-399': <u>Volcanics (basalt ?)</u> as in cored interval, 388-390.5'.</p> <p>399-403': <u>Sandy Clay</u>. Medium gray, soft clay with angular occasionally subrounded (recycled ?) fine to medium, dark gray to gray-green, fine-grained sand. Possibly a brecciated interflow or weathered flow.</p> <p>403-449': <u>Volcanics</u>. Medium to dark gray, some gray-green and medium red, fine-grained, angular cuttings. Moderately firm, brittle, with variable but minor amounts of medium gray to red, soft clay. Very minor, subrounded, fine to medium-size, medium gray sands, probably slough or recycled</p> <p>449-488': <u>Volcanics</u> as in 403-449' interval with minor light brown, soft to moderately firm clay.</p> <p>488-495': <u>Volcanics</u>. Medium gray to gray-green, moderately firm, brittle, fine-grained with common medium red, soft to slightly firm clay. Locally common white calcite and quartz.</p> <p>495-502': <u>Volcanics</u>. Light to medium gray, gray-green and black, moderately firm, brittle, fine-grained with minor white calcite and quartz and light brown, soft clay.</p> <p>502-533': <u>Volcanics</u>. Light gray-green, firm to slightly soft, fine-grained with some medium gray and black volcanics as in 495-502' interval. Variable but minor amounts of soft, medium-brown clay.</p> <p>533-537.8' (CORE): <u>Volcanic Agglomerate</u>. Groundmass Gray-brown, aphanitic, easily scratched with knife, brittle, dense. Clasts angular to subrounded, multicolored, fine to up to 3", easily scratched with knife, some with altered surfaces. Extensive remineralization in clasts. Locally fractured (no particular orientation) with some fractures healed with white calcite and/or brown clay. Some slickensides along some fractures with serpentine and talc.</p> <p>537.8-†573': <u>Volcanic Agglomerate</u>. As in 533-537.8' interval.</p> <p>†573-579': <u>Clay</u>. Medium-gray, very soft and hydrated with minor medium-gray to gray-green, angular volcanic fragments as in cored interval (533-537.8').</p> <p>579-585': <u>Volcanics</u>. Medium-gray to gray-green, moderately firm, brittle, fine-grained with minor clay as in 573-579' interval.</p> <p>585-595': <u>Volcanics</u> as in 579-585' interval with some dark gray, moderately firm, brittle, fine-grained volcanics.</p> <p>595-615': <u>Volcanics</u>. Predominantly light to medium gray, soft clay with gray-green to medium gray to black, moderately firm, fine-grained volcanics. Occasional minor medium brown and red, moderately firm, fine-grained volcanics.</p> <p>615-630': <u>Volcanics</u>. Medium gray to gray-green, moderately firm, brittle, fine-grained with minor soft, medium gray clay. Trace of white calcite and quartz.</p> <p>630-643': <u>Volcanics</u>. Gray-green, soft, fine-grained with</p>
(1) resistivity	} Ran in open hole to 692'									
(2) Gamma-Gamma										
(3) Sonic										
(4) Caliber	} Ran in 2" water filled steel pipe to 797.5' total depth.									
(5) Temperature										
(6) Natural gamma										
(7) Neutron										

GEOLOGIC LOG OF DRILL HOLE-CONTINUATION SHEET

FEATURE Susanville Anomaly--..... PROJECT Susanville Geothermal.....
 HOLE NO. SUZY-11 Lassen County Investigations

SHEET 4 OF 4

FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Cont.)

630-643' (Cont.): minor firm, dark gray to black, fine-grained volcanics. Continued medium-gray soft clay.

643-647' (CORE): Volcanic Agglomerate. Gray-green, locally dense, hard. Groundmass: Fine to medium grained, common medium-grained feldspar and calcite; hard with extensive calcite mineralization. Clasts: Angular to subrounded, predominantly fine-grained, locally intensely remimeralized. Core is locally extensively fractured and sheared (no particular direction), some fractures healed with clear quartz and white calcite.

647-680': Volcanic Agglomerate as in 643-647' interval with firm, black basalt, probably recycled cuttings. Variable but minor amounts of medium gray, soft clay.

680-698': Volcanic Agglomerate as in 643-647' interval with increased amounts of black, firm, fine-grained volcanics. Less medium gray, soft clay as in 647-680' interval.

698-708': Volcanics. Mostly medium gray, soft clay with gray-green and black, firm, fine-grained volcanics.

708-755': Volcanics. Black to gray-green; firm, fine-grain, with minor medium gray, soft clay. Gradual lithology change.

755-798' (TOTAL DEPTH): Volcanics. Green to gray-green, soft to moderately firm, fine-grained. Minor dark gray to black, firm, fine-grained volcanics.

APPENDIX C

GEOPHYSICAL WELL LOGS

NEUTRON

GAMMA-GAMMA RAY

TEMPERATURE

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY1 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY1 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY2 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY2 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY3 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY3 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY4 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZYS -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY5 -- GEOPHYSICAL WELL LOGS

NATURAL GAMMA RAY

NEUTRON

GAMMA-GAMMA RAY

TEMPERATURE

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY6 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY7 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY8 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY9 -- GEOPHYSICAL WELL LOGS

SUSANVILLE GEOTHERMAL INVESTIGATION
NAEF WELL -- GEOPHYSICAL WELL LOGS