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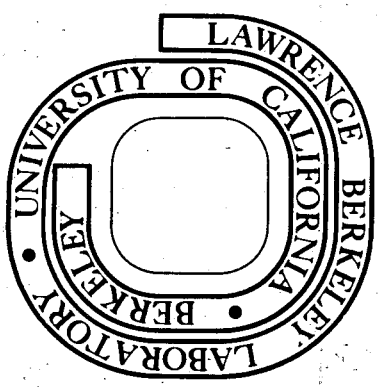

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June 1980

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.

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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 aglomerate-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 furthur 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 identified[1] 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.

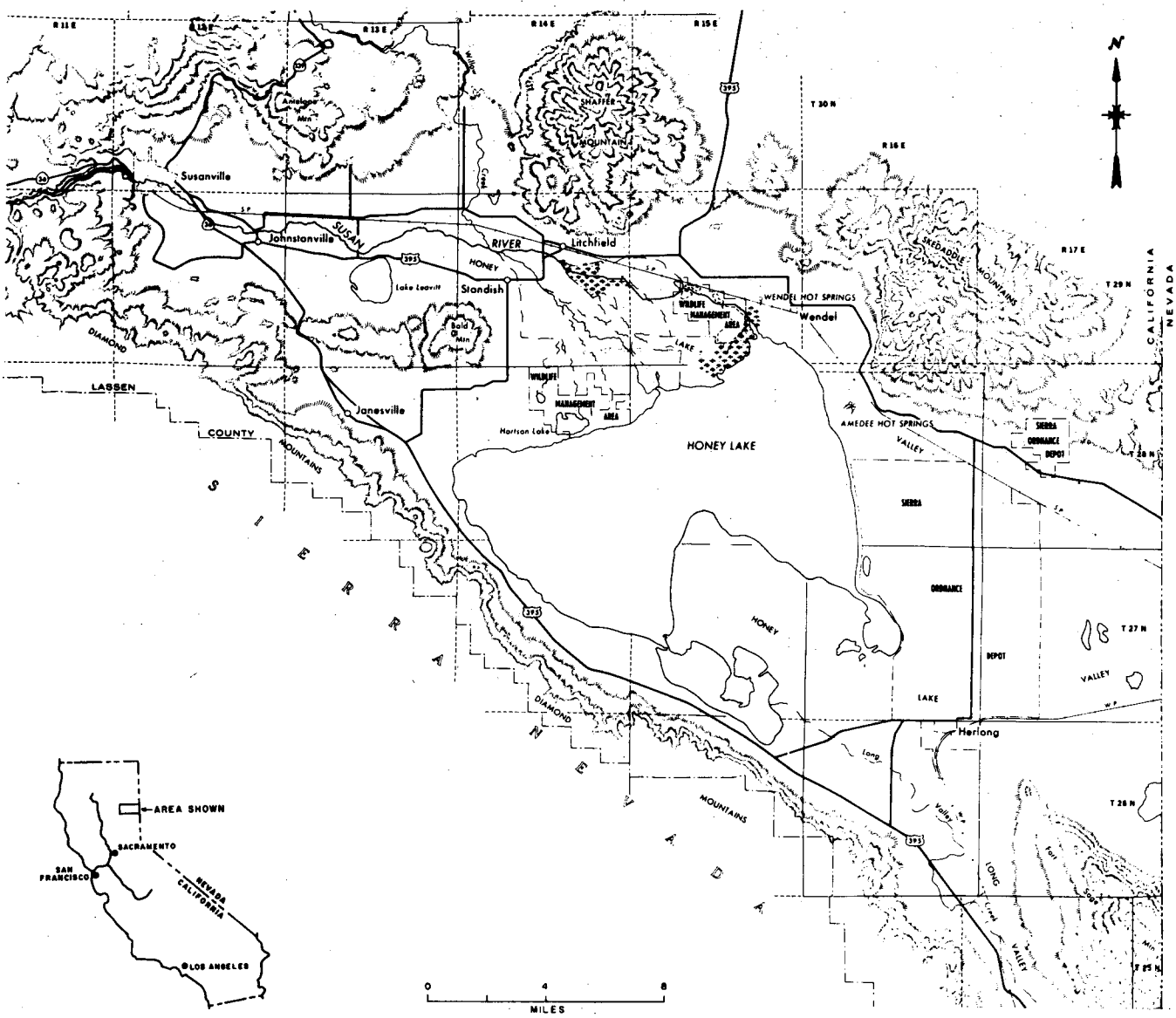


Fig. 1. Location map of Susanville Geothermal anomaly.

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.

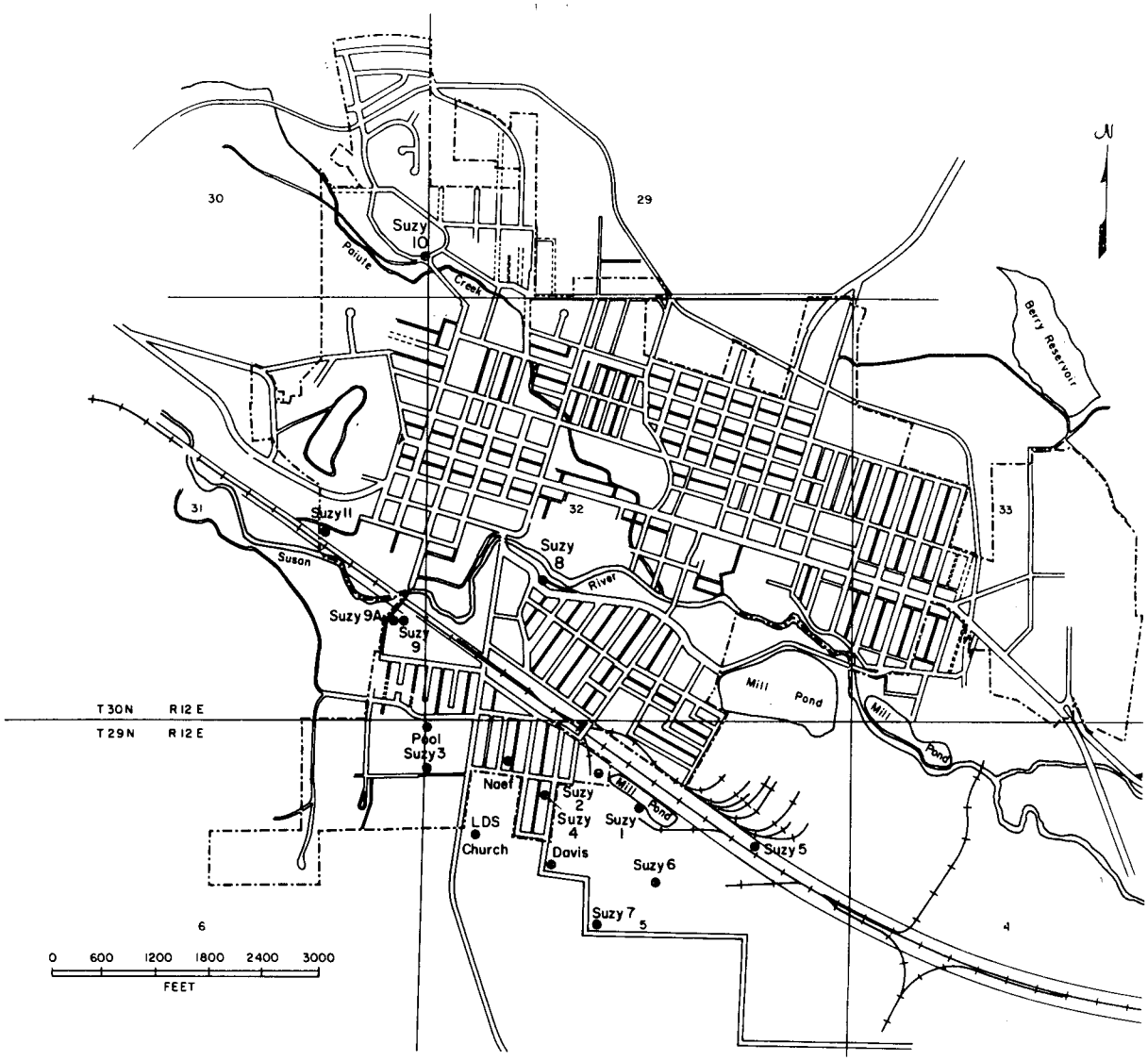


Fig. 2. Location map of wells drilled to date in Susanville. (XBL 801-6767)

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°C/m to 0.21°C/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°C/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

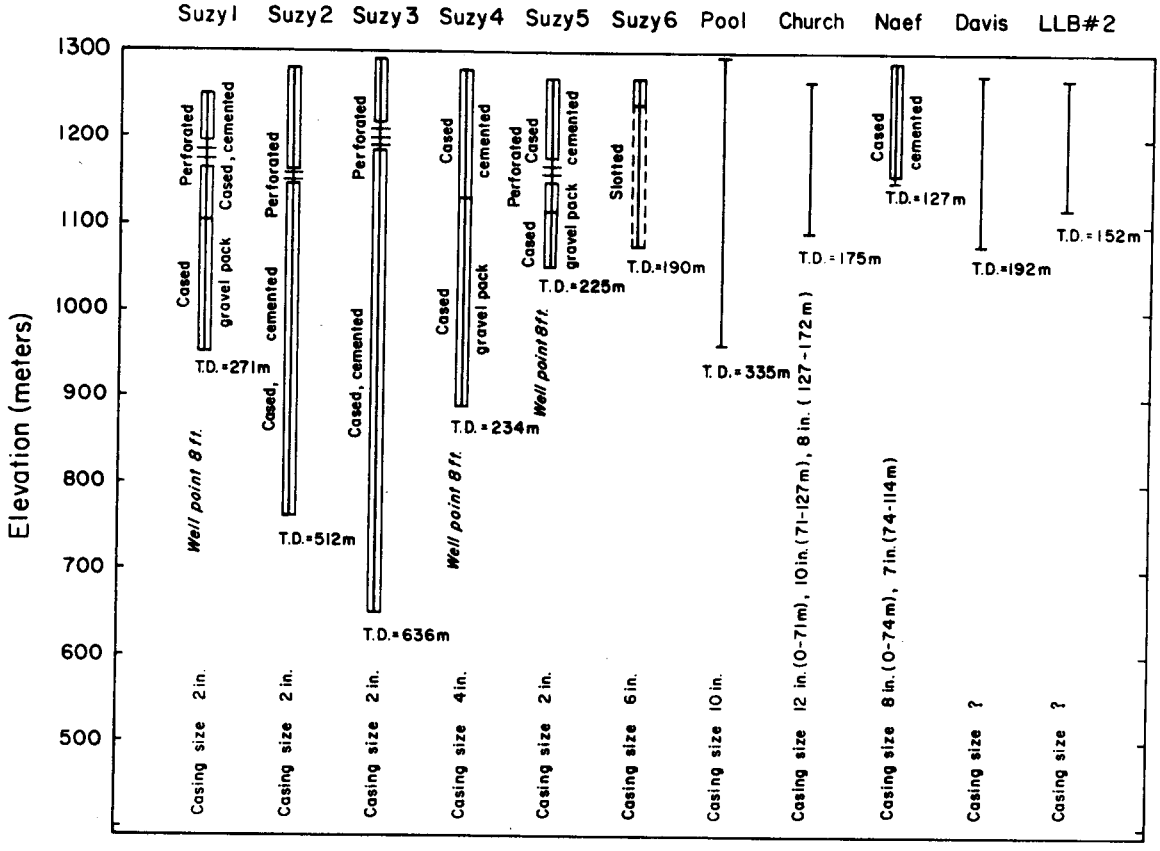


Fig. 3. Well completion data: Suzy 1-6, Pool, Church, Naef, Davis, LLB #2. (XBL 795-7442)

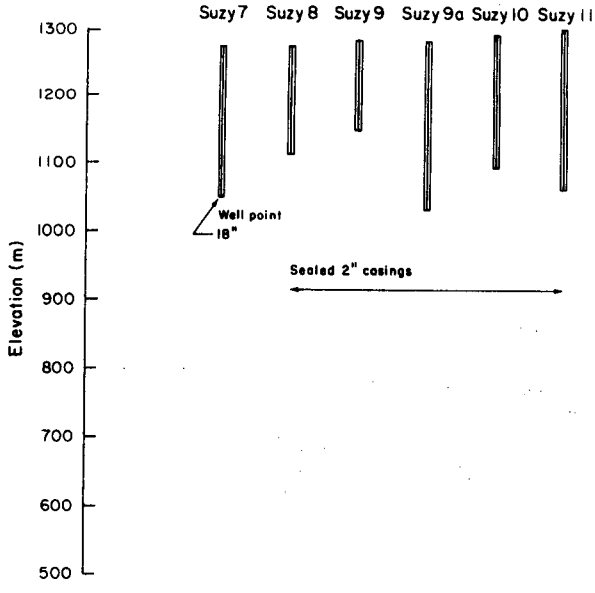


Fig. 4. Well completion data: Suzy 7-11. (XBL 7912-1348A)

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

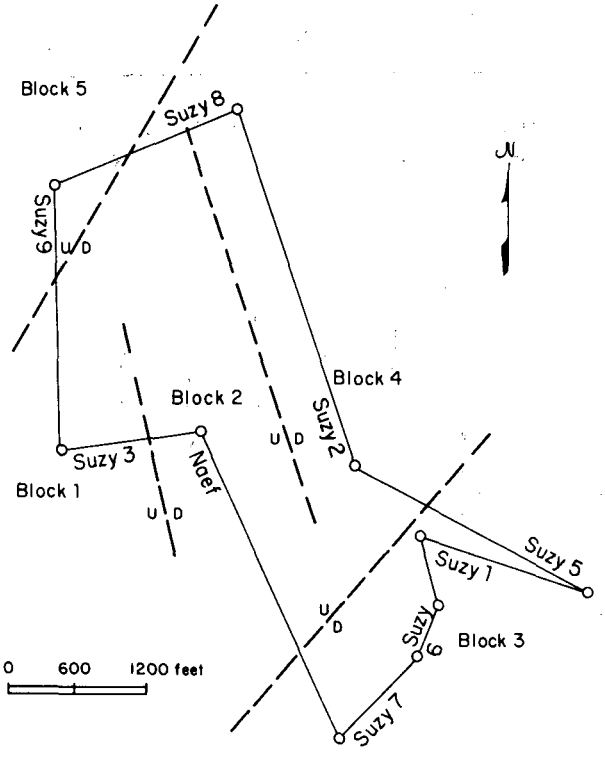


Fig. 5. Division of the Susanville geothermal prospect into five structural units. (XBL 806-7210)

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

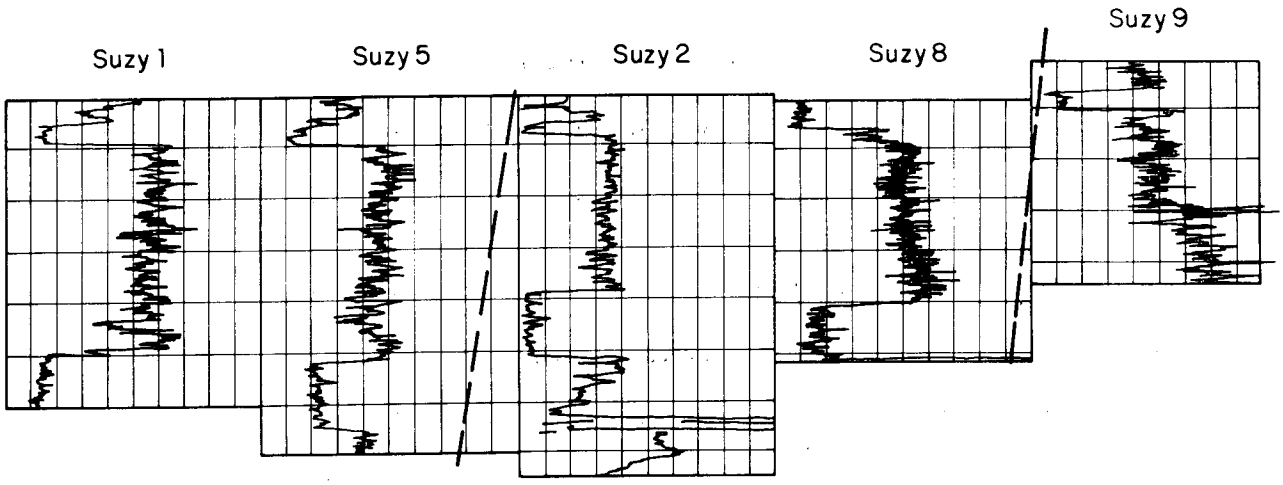


Fig. 6. Cross sections showing relationships between various structural units (as indicated by the natural gamma logs). Each vertical division equals 100 ft. (XBL 806-72111)

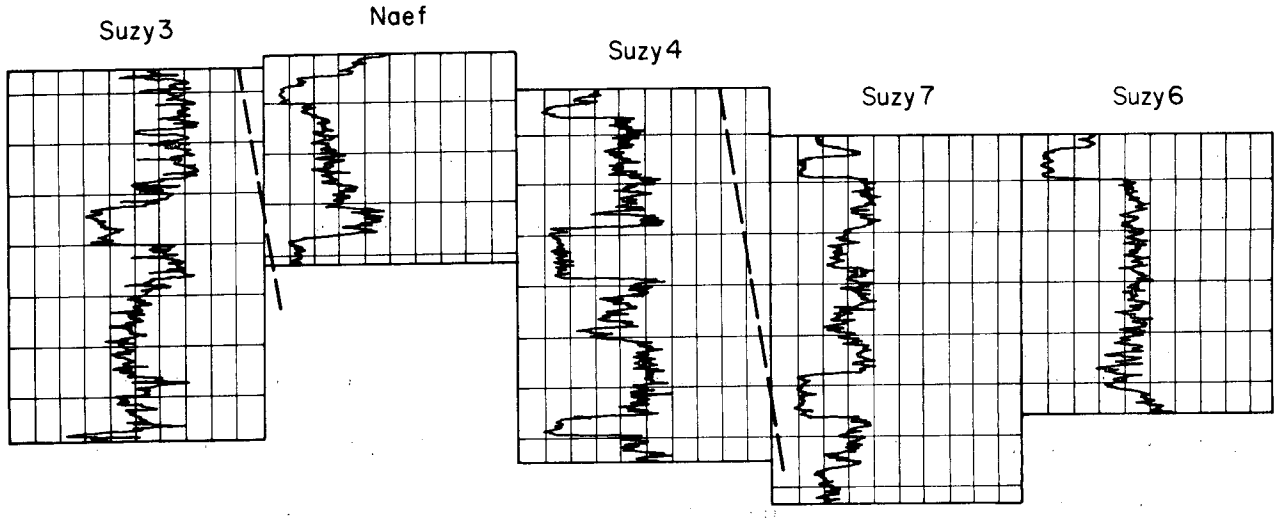


Fig. 7. Cross sections showing relationships between various structural units (as indicated by the natural gamma logs). Each vertical division equals 100 ft. (XBL 806-7209)

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 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.

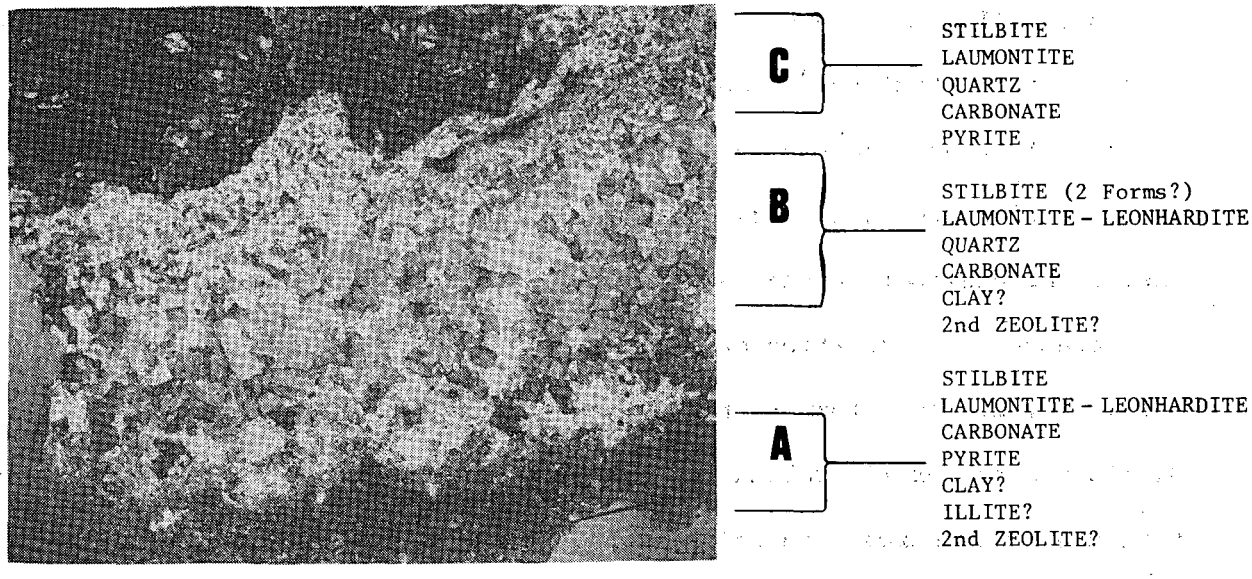
Drs. H. Williams and A. Pabst (University of California, Berkeley) examined the core and concluded that it was andesitic. Thin section studies identified highly altered pyroxenes and some similarly altered olivines and feldspars. Some feldspars were relatively unaltered.

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 nichols.

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 Tomasson[3] 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

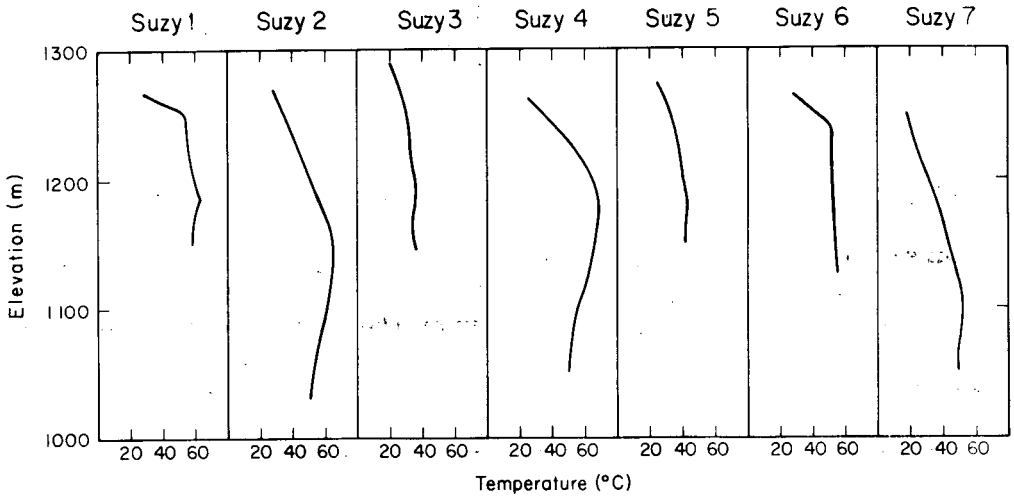
layer B 70° - 110°C

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.



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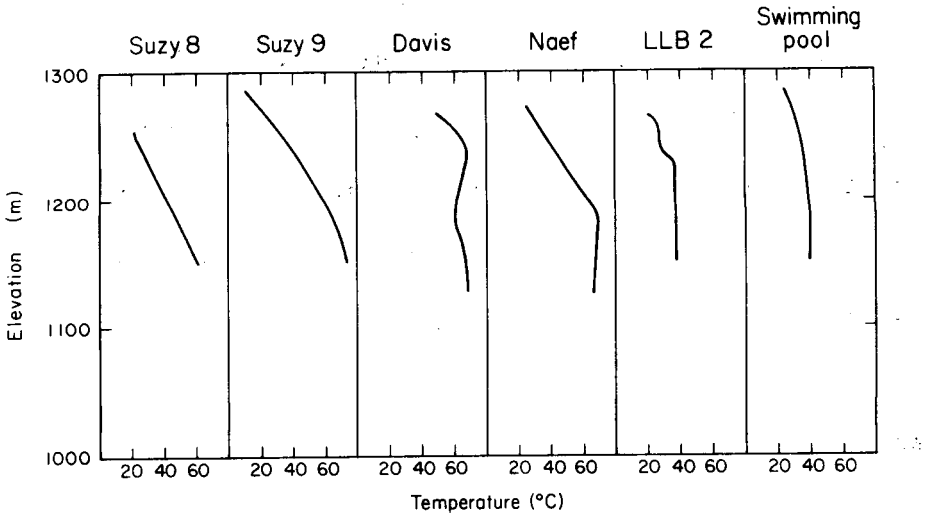

C.

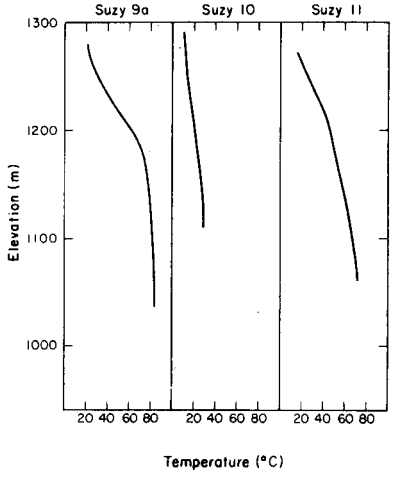

Fig. 9. Temperature profiles from wells (A) Suzy 1 through 7; (B) Suzy 8 and 9, the Davis, Naef, LLB #2, and Swimming Pool wells; and (C) Suzy 9A, 10, and 11 (XBL 8011-6422)

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).

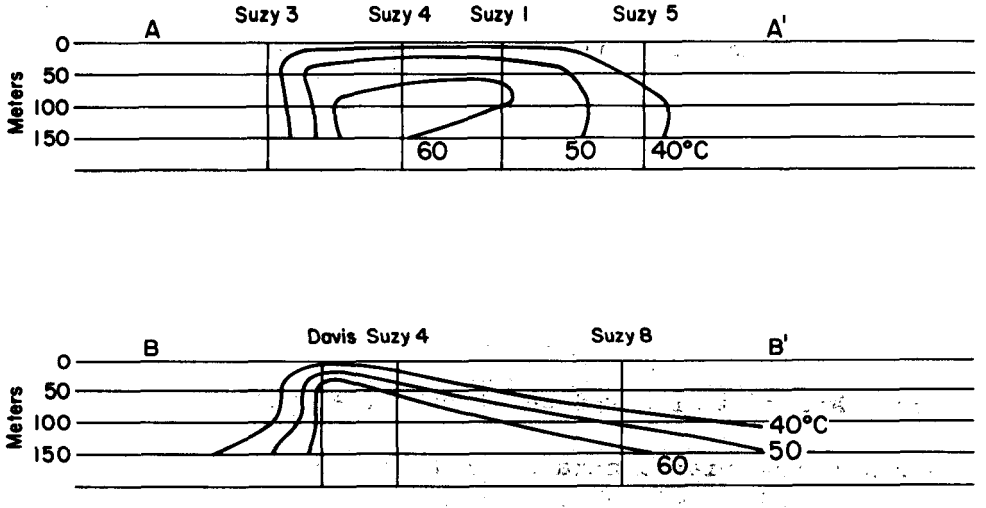

Fig. 10. Cross sections of the thermal anomaly. See Fig. 15 for lines A-A' and B-B'. (XBL 796-7511)

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.

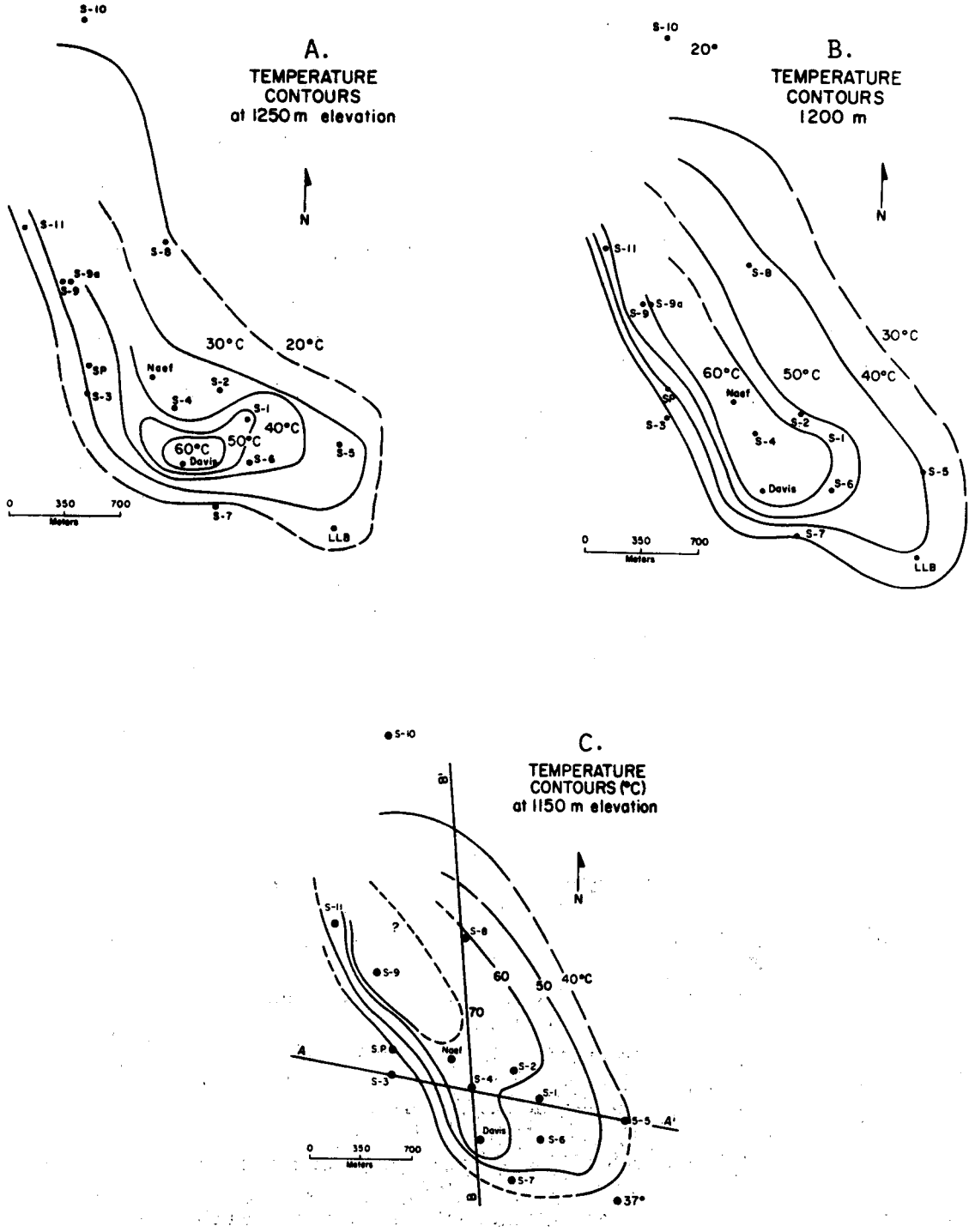

Fig. 11. Subsurface temperature contours: (A) at 1250 m elevation; (B) at 1200 m elevation; and (C) at 1150 m elevation. (XBL 8011-6423)

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 $\pm$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 ($\pm$0.5 psi) by atmospheric temperature and pressure changes. Table 2 summarizes the instrumentation used for the well testing.

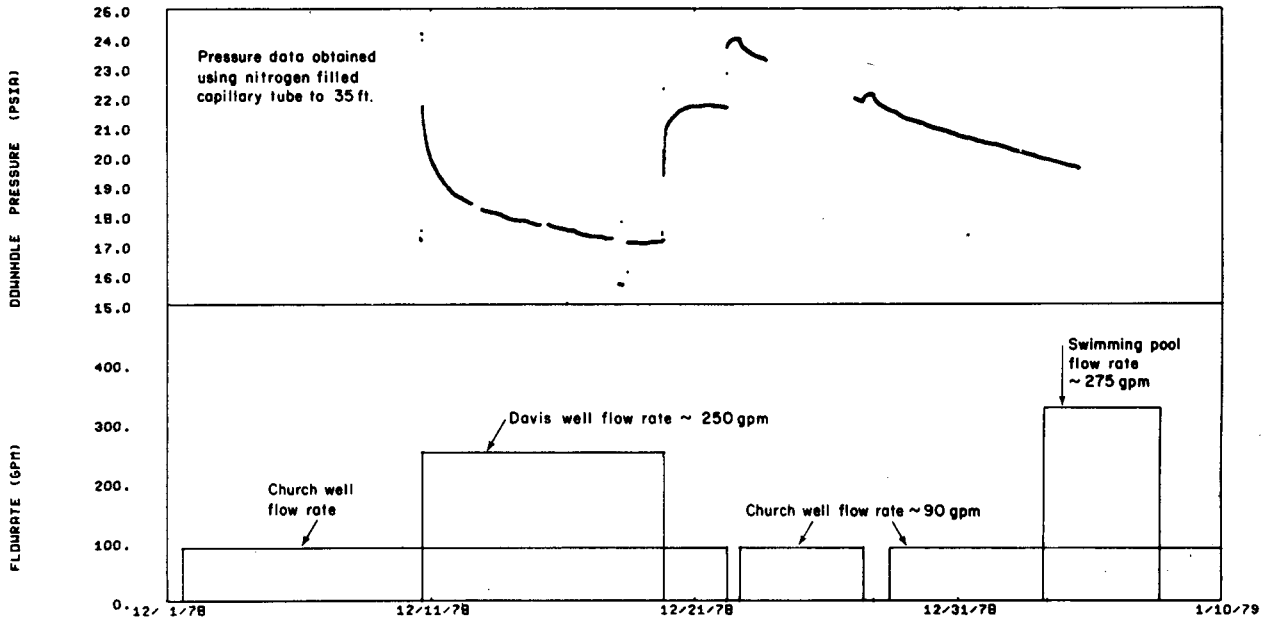

Fig. 12. Davis well pressure and flow rate data. (XBL 795-7439)

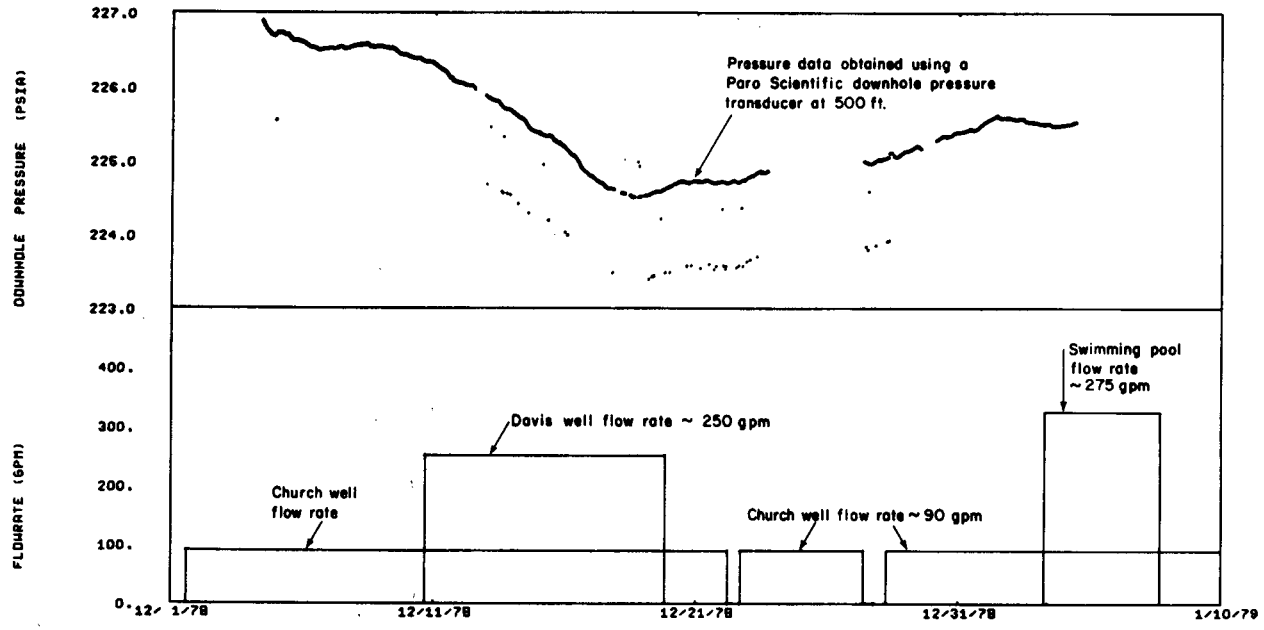

Fig. 13. Suzy 4 interference test data. (XBL 795-7436)

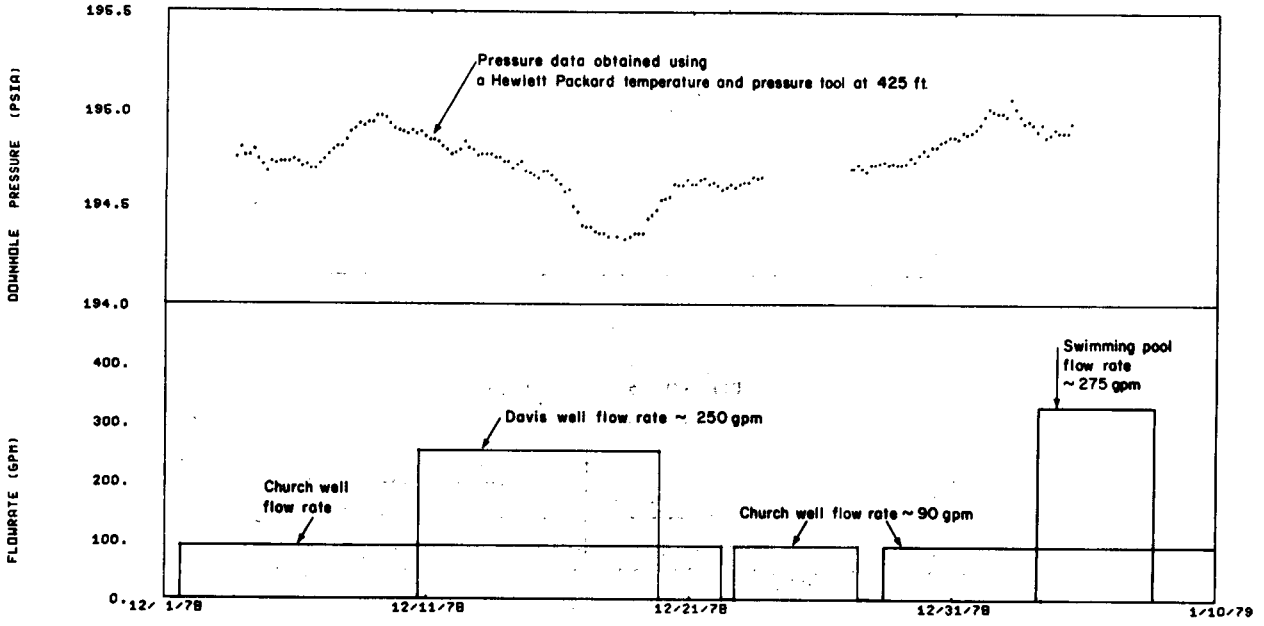

Fig. 14. Lassen Lumber and Box #2 interference test data. (XBL 795-7438)

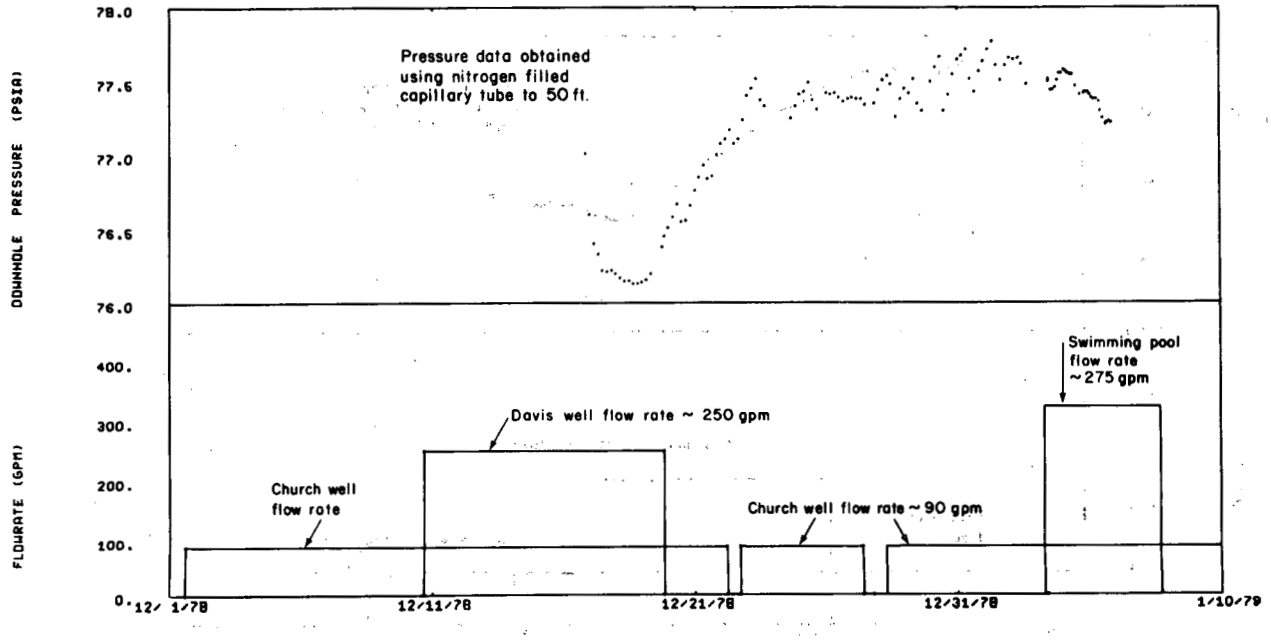

Fig. 15. Suzy 3 interference test data. (XBL 795-7438)

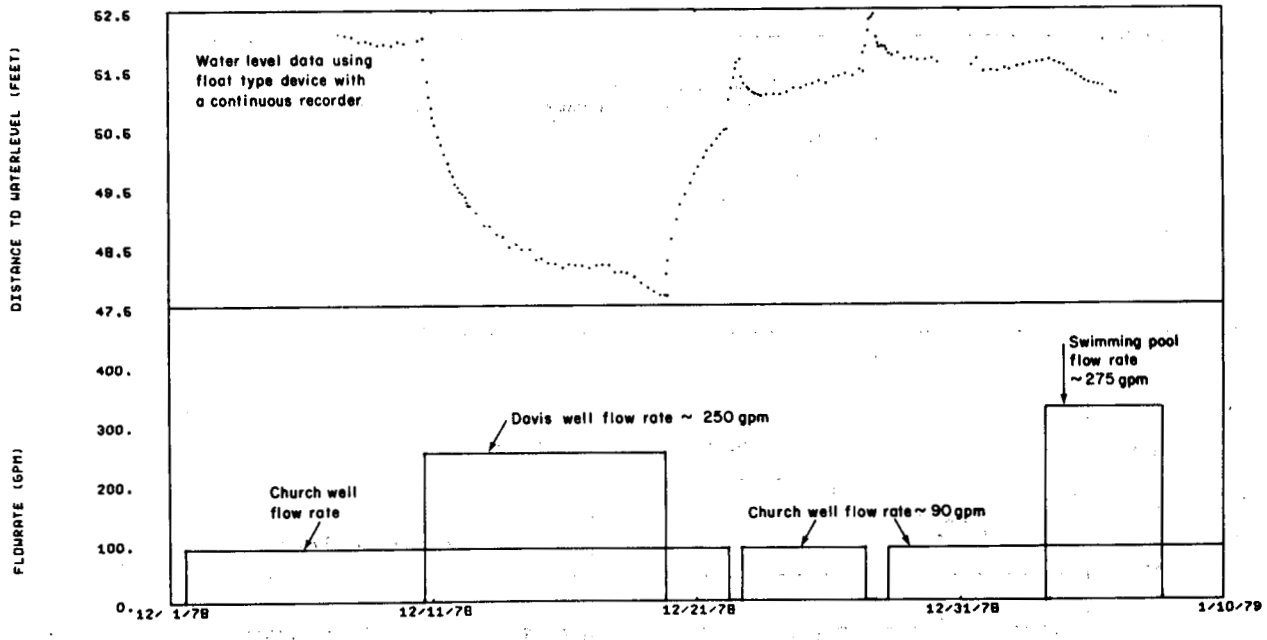

Fig. 16. Naef well interference test data (XBL 795-7441)

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
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.				
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%
Comments: After 12/19/79 probable nitrogen leak in tubing which caused subsequent pressure change. Clear evidence of communication with the Church well.				
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 0.1°F set at 425 ft	
Suzy 1	observation	pressure	50 ft tubing connected to Paroscientific pressure transducer	0.01 psi
Comments: The perforation job was not successful. No pressure change due to flowing wells was recorded.				
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
Comments: Did not respond to the reservoir pressure due to unsuccessful perforation job.				
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 decease 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 $\pm$ 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

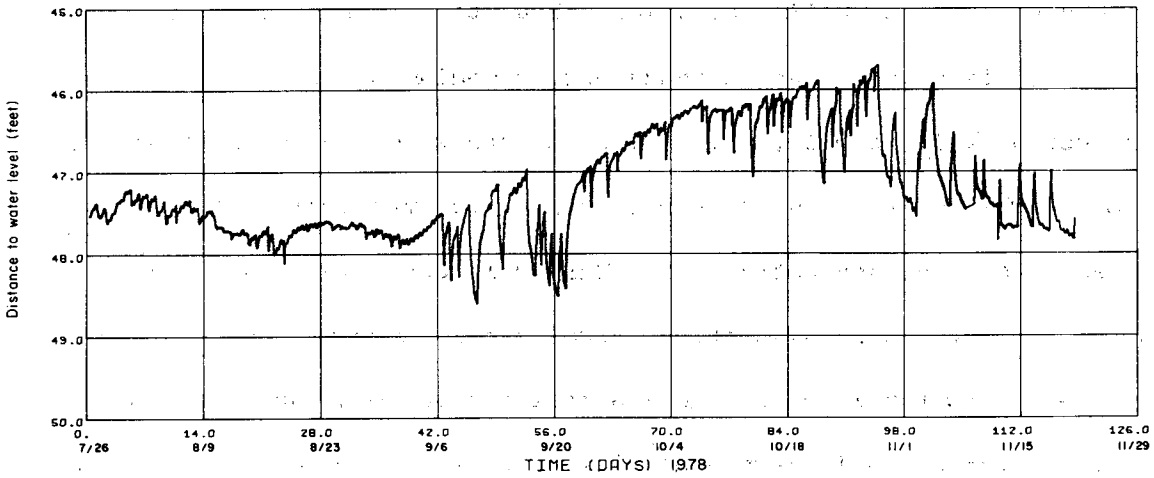

Fig. 17. Naef well pre-test data. (XBL 795-7441)

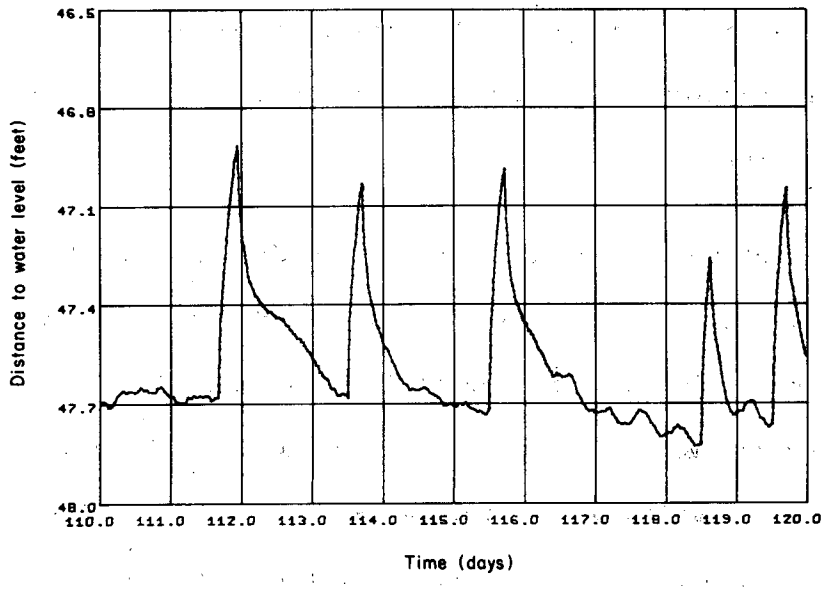

Fig. 18. Naef well pre-test data. (XBL 795-7492)

for several hours and then pumped again. Analysis of this data returned a transmissivity value of 3.6 x 10^6 md-ft/cp (2.8 x 10^4 gal/day/foot) and a storativity value of 2.3 x 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.

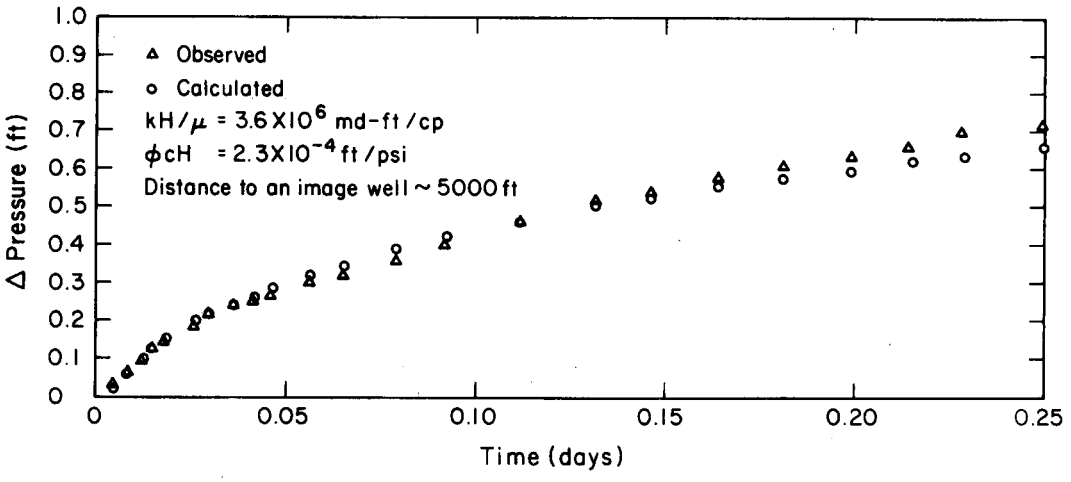

Fig. 19. Match of calculated and observed values for pre-test drawdown at Naef due to production of the Church well. (XBL 796-7508)

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 x 10^5 md-ft/cp (3.4 x 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]

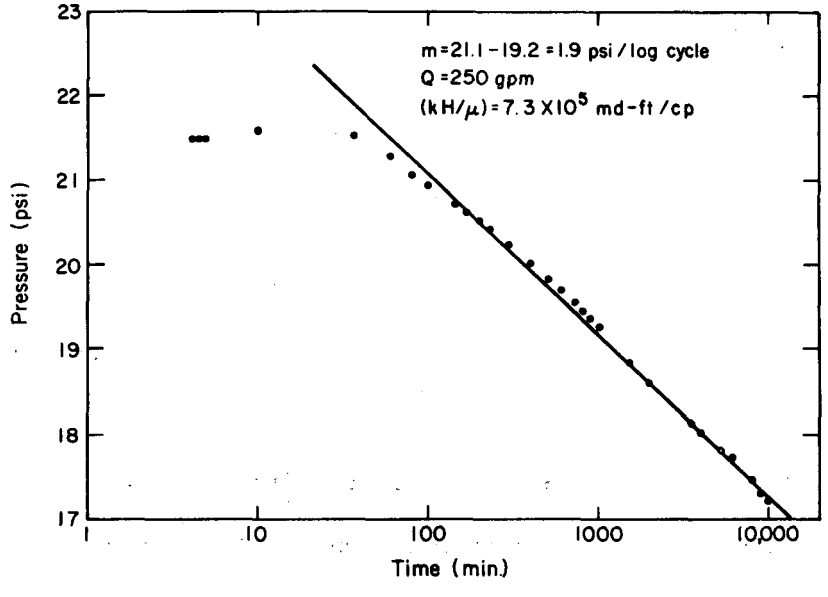

Fig. 20. Semilog plot of Davis well drawdown versus time. (XBL 796-7507)

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

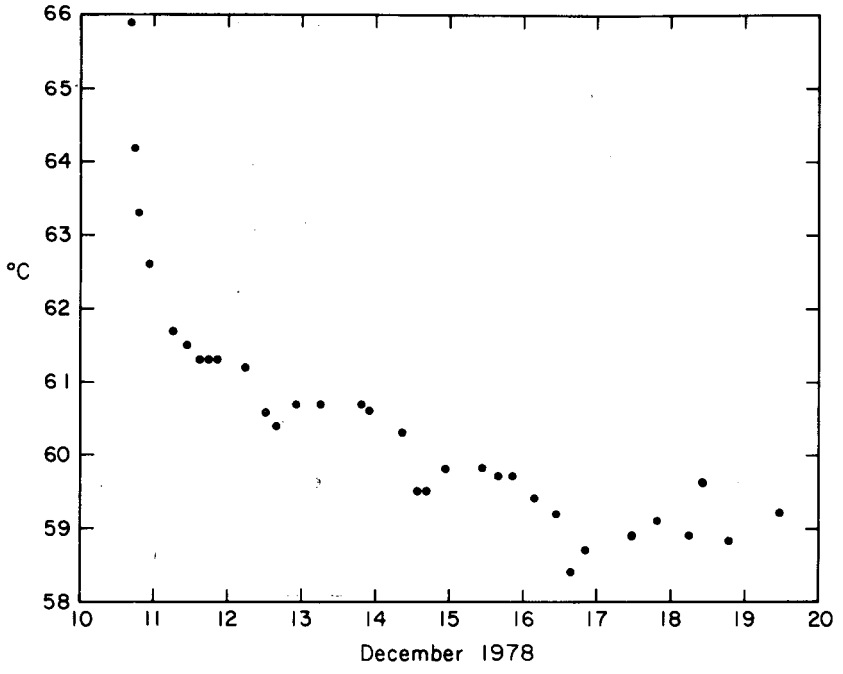

Fig. 21. Davis wellhead temperature. (XBL 795-7494)

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 φch 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.

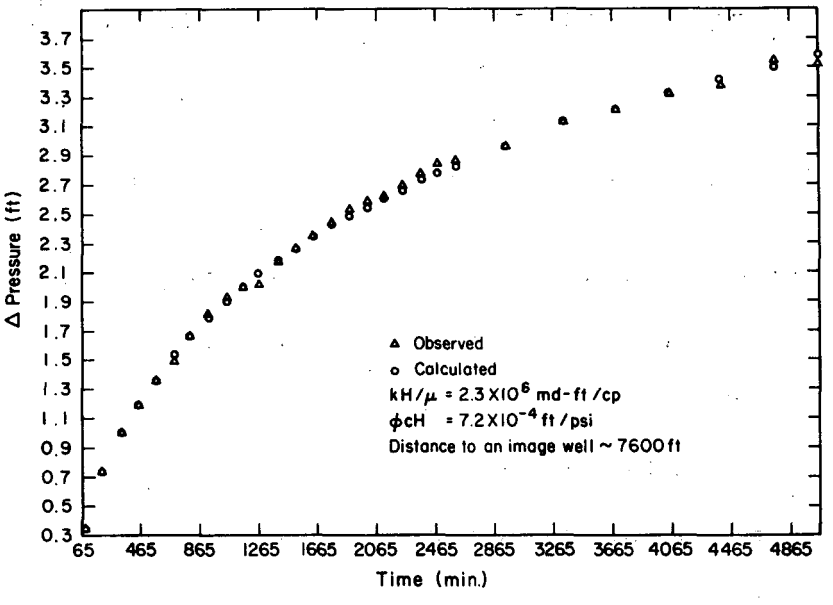

Fig. 22. Match of calculated and observed values for the drawdown of the Naef well due to production of the Davis well. (XBL 796-7507)

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.

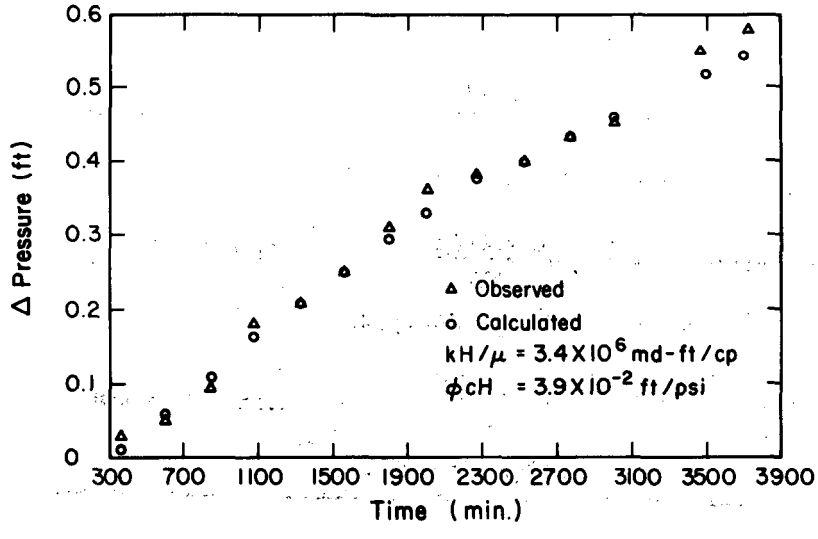

Fig. 23. Match of calculated and observed values for the drawdown at the Naef well while pumping the Swimming Pool well.
(XBL 796-7506)

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 sensitity 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	$3.6 \times 10^6 \frac{md\text{-}ft}{cp}$ (2.8×10^4 gal/day/ft)	2.3×10^{-4} ft/psi	Barrier Boundary
Naef	Davis	$2.3 \times 10^6 \frac{md\text{-}ft}{cp}$ (1.8×10^4 gal/day/ft)	7.2×10^{-4} ft/psi	Barrier Boundary
Naef	Swimming Pool	$3.4 \times 10^6 \frac{md\text{-}ft}{cp}$ (2.7×10^4 gal/day/ft)	3.9×10^{-2} ft/psi	None
Davis	Davis	$7.3 \times 10^5 \frac{md\text{-}ft}{cp}$ (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 betwen 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.

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APPENDIX A

TABLE OF SYMBOLS AND UNITS

Symbol	Definition
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

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

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

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

APPENDIX B

LITHOLOGIC WELL LOGS

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County **PROJECT** Susanville Geothermal 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 return, character of drilling

Purpose of Hole:
(1) Temperature gradient; (2)geophysical properties; (3) geologic evaluation.

Landowner:
D. G. Wood Products; Susanville, CA.

Location:
NE¼ NW¼ Sec. 5, T. 29 N., R.12 E.

Drill Rig:
Failing 1500

Drilling Methods:
Rockbit drilled using bentonite mud and additives as required. Two mud pits used.
0-60': 13-3/4" rockbit for permanent installation of 10" surface casing.
60-890': 6½" rockbit.
At 333': 4"x5' haystellite core run; recovered 3'.
At 432': 4"x5' diamond core run. Core lost from barrel on up-hole trip.
At 462': 4"x5' haystellite core run; recovered 3'.

Drilling Conditions:
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.

Type and Size of Hole	% Recovery
13¾" RB	0
6½" RB	
4"H	60
6½" RB	0
4"D	0
6¼" RB	0
4"H	60
6½" RB	0

DAILY SUMMARY OF DRILLING OPERATIONS

7-18-78: Move Failing 1500 to site and rig up. One shift/day.
7-19-78: Complete rigging up. Drill to 13' with 6½" rockbit and small portable mud pit.
7-20-78: Drill to 23'. Down 1½ hours to mix new mud twice.
7-21-78: Drill to 46'. Secure for weekend. Gravel caving problems.
7-24-78: Drill to 56'. Down 1½ hours for mud pump repair and mixing mud. Serious gravel caving problems.
7-25-78: Drill to 73'. Down 1½ hours for mud conditioning.
7-26-78: Drill to 80'. Down 1 hour due to water pump failure on drawworks engine. Caving problems.
7-27-78: Drill to 83'. Down 6 hours to replace water pump and clean mud pump.
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.
7-31-78: Ream hole to 24' with 13-3/4" rockbit.
8- 1-78: Ream hole to 35' using two shifts per day. Down 4½ hrs to repair kelly swivel and break-out table.
8- 2-78: Ream hole to 60'. Caving problems. Installed 60' of 10" steel casing with 1½' stickup. Cemented in with 25 sacks.
8- 3-78: Drilled to 140' with 6½" rockbit. Down 3½ hours to build decking and mix mud.
8- 4-78: No drilling. Condition hole and mud for weekend.
8- 7-78: Drilled to 143'. Down 12½ 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 2½ hrs to repair carburetor and replace cable.
8-10-78: Drilled to 333'. Down 9½ hrs for mud pump repair.
8-11-78: Drilled to 336'. Down 9½ hrs to repair mud pump and clean pits. Made core run at 333'.

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

NOTE: Log based on rockbit cuttings and limited core.

0-4.0':
MODERN FILL.
Fine to coarse, predominantly angular sand with clay, silt and charcoal. On edge of old lumber mill pond.

4.0-8.0':
RECENT ALLUVIAL DEPOSITS.
Sandy Silt and Clay. Brown, fine-grained.

8.0-500'(?)*
PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS

8-33': Basalt. Broken flow and/or cobbles and boulders, gray to black, hard, occasional thin smooth drilling zones less than 6" thick.
33-35': Sandy Clay. Reddish brown, fine-grained.
35-40': Sandy Clay with Gravel. Volcanic fragments probably from gravel; smooth layers less than 4" thick.
40-46': Gravel and Sandy Clay. Gravel is fine to coarse, mostly subrounded, dark, volcanic; minor light colors; caves; contains warm water.
46-56': Sandy Clay. Reddish brown, mostly fine with medium grains, occasional gravel.
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.
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. Occasional gravel-free bed ±6" thick. Gravel highly weathered below 68'.
70-75': Sand. Fine to medium, highly 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.
75-86': Basalt. Generally massive, black, angular fragments; very minor blue clay.

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

GEOLOGIC LOG OF DRILL HOLE

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

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	% Recovery	DAILY SUMMARY OF DRILLING OPERATIONS	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
Drilling Conditions (Cont.): 86-104': Fast and smooth. 104-140': Medium smooth. 140-176': Slow, smooth to rough. 176-203': Fast and smooth. 203-252': Intermittent, slow and smooth to slow and rough. 252-262': Smooth and fast. 262-322': Intermittent, slow and smooth to slow and rough. 322-336': Hard and slow. 336-352': Medium speed, medium rough. 352-357': Fast and smooth. 357-432': Medium speed, smooth. 432-462': Fast and smooth. 462-465': Hard, slow and smooth. 465-500': Slow, medium speed and medium rough. 500-512': Very slow and fairly smooth. 512-550': Slow, smooth to very rough. 550-599': Hard, slow, rough; occasional very soft zone. 599-615': Very hard and very slow, rough. 615-620': Very slow and hard. 620-660': Medium smooth. 660-726': Fast and smooth. 726-760': Hard, slow, rough to smooth. 760-840': Soft, smooth to medium rough, fast.	550 / 6¼" RB / 600 / 650 / 700 / 750 / 6¼" RB / 800 / 850 / 900 / 950	0	8-11-78: (Cont) Secure for weekend. 8-14-78: Drilled to 432', Down 5 hrs to repair break-out table, chuck and swivel. 8-15-78: Drilled to 462', Down 9 hrs due to mud pump failure. Made core run at 432' but lost core. 8-16-78: Drill to 515', Made 5' core run at 462'. 8-17-78: Drilled to 600'; down 1 hr due to pulley and radiator damage. 8-18-78: Hole logged by USGS. Down 7½ hrs for repairs. Secure for weekend. 8-21-78: Drill to 615', Down 7½ hrs for mud pump repair. 8-22-78: Drill to 720'; down ½ hr to repair sand line. 8-23-78: Drill to total depth of 890'; extent of drill rods. 8-24-78: Install and gravel pack 2" pipe with well point. Repair mud circulation line. 8-25-78: Finish cementing in pipe. Test hole completed. 10-7-78: BOTTOM PORTION OF HOLE GEOPHYSICAL LOGGED WITH "THROUGH CASING" METHODS BY USGS.	550 / 600 / 650 / 700 / 750 / 800 / 850 / 900 / 950	86-96': Sandy Clay. Blue-gray, soft. 96-104': Sand. Fine to coarse, predominantly medium, subrounded. 104-140': Basalt with Sand and Clay. Weathered volcanic gravel and cobbles with sand and clay in alternating layers; clay soft and squeezing. 140-157': Sand. Predominantly coarse, subangular, dark, volcanic and fine gravel; minor light-colored grains. Gradational contact from 104-140' zone. 157-165': Sandy Clay. Blue-gray; brown below 163'. Predominantly medium 165-176': Sand and Gravel. Fine to coarse, subangular to subrounded sand and fine gravel. Multicolored, mostly dark weathered volcanic. Minor light colors. Common quartz in thin intervals with occasional decomposed granite; minor gray brown clay. 176-500': Pebble Conglomerate. Multicolored, fine to coarse gravel from many sources, predominantly volcanic, minor granitic, occasional 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. *Cuttings recovered mostly as* sandy clay and volcanic fragments. Drill action indicates weak bedding. Minor fluctuations in color and clay content throughout total interval. Clay content highest in 285-290', 305-322' and 352-357' zones. 500(?)-890': PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS. 500-525': Basalt. Angular black fragments; very little clay. 525-553': Basalt with Alternating Sand and Clay Layers. Clay soft, brown; sand is fine to coarse, subangular to subrounded, multicolored; often highly weathered; variable amounts of light gray to white grains. 551-553': Very soft clay or cavity. 553-560': Basalt. Hard, black fragments.

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE—CONTINUATION SHEET

FEATURE Susanville Anomaly-- PROJECT Susanville Geothermal Investigations
HOLE NO. SUZY-1 Lassen County SHEET 3 OF 3

NOTES (Continued)

Drilling Conditions (Continued):

840-860': Fast and smooth.
860-890': Medium smooth.

Estimated Drilling Fluid Return:
0-890': 95% to 100%

Representative Drilling Fluid Temperature (°F):

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.

Caving Conditions:
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

Casing Record: 10" steel surface casing installed to 58.5'. Casing permanently cemented into hole.

Geophysical Logging: 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

Hole Completion: 2" steel pipe with 8' of 60 mesh well screen installed in hole. Screen about 10' off bottom. Bottom ± 390' of hole gravel-packed, top portion cemented in. Site protected with steel guard rail.

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (Cont.)

560-570': Clay. Grades from soft, red brown to hard, bluish clay with weathered volcanic sand.

570-600': Sandy Clay and Basalt Gravel and Cobbles. Clay is hard, compact, gray. Sand mostly fine, basaltic fragments, medium to coarse, angular, black.
585-590': Especially hard.
590-600': Increase in sand.

600-616': Basalt Cobbles (?). Black to brown and gray-brown, hard.

616-619': Basalt and Clay. Basalt similar to 600-616' interval; clay gray and soft.

619-675': Sandy Clay. Medium gray, soft with fine to coarse, multicolored lithic fragments. Subangular, mostly volcanic, weathered.

675-726': Sandy Clay. Medium brown, soft clay as in 619-675' interval.

726-733': Basalt. Cobbles (?) black, hard; minor brown clay.

733-760': Clay and Sand. Medium brown soft clay with multicolored fine to coarse, predominantly volcanic sand.

760-815': Sandy Clay. Medium brown to gray. Soft with fine to medium sand as in 733-760' interval.

815-860': Sandy Clay. Similar to 760-815' interval with common light pink and red clay.

860-890': Claycy Sand (?). Fine to very coarse, subangular to subrounded, multicolored sand with minor brown to gray clay.

GEOLOGIC LOG OF DRILL HOLE

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

NOTES
On water table levels, water return, character of drilling

Purpose of Hole:
(1) Temperature gradient.
(2) Geophysical properties.
(3) Geologic evaluation.

Land Owner:
Lassen Molding Co.; 755 Alexander St.; Susanville, CA.

Location:
~~NW¼~~ NW¼ Section 5, T. 29 N., R. 12 E.

Drill Rig:
Failing 1500

Drilling Methods:
Rockbit drilled using bentonite mud and barite weight material. Three mud pits and shaker used.
0-44.0': 12¼" rockbit for installation of 8" surface casing.
44.0-1680.0': 6½" rockbit.
140': Attempted coring, hole caved; could not complete.
875.0-879.8': 3-7/8" Haystellite bit. Recovered 2.4' (50%)

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.

Type and Size of Hole	% Recovery
12¼" RB	0
6½" RB	
6½" RB	0

DAILY SUMMARY OF DRILLING OPERATIONS

8-24-77: Rig up Failing 1500, unload trucks, dig 3 mud pits, mud up, crews on day and swing shifts.

8-25-77: Drill 44' of 12¼" hole. Install 38.9' of 8" steel casing, cement into hole using 24 sacks.

8-26-77: Install blow-out equipment (8" gate valve and two 2" bleed lines). Build decking and prepare rig for drilling. Spudded swing shift. Drill 6½" hole to 91.4 feet, replace bit. Operations ceased for weekend.

8-29-77: Drilled to 270'; changed swivel. Repair swivel and chuck; new bits at 140' & 170'. Drilling 24 hours/day.

8-30-77: Drilled to 640'. Set up shaker; repaired chuck; pulled to change bit stuck at 440'; new bits at 399', 459', and 499'.

DEPTH

CLASSIFICATION AND PHYSICAL CONDITION

Log based on rockbit cuttings.

0-9.8':
RECENT ALLUVIAL DEPOSITS
Fine to medium sand and clay. Increase in sand past 5 feet.

9.8-372'(?):*
PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS.

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.
44-65': Clay. Brown with fine sand. Fine gravel at 45'.
65-96': Basalt. Fine to coarse, hard, black fragments with sand.
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.
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':
PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS

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
HOLE NO. SUZY-2 **LOCATION** See Note, Sheet 1 **GROUND ELEVATION** 4185 **ANGLE FROM**
COORDINATES N.394,305; E.2,374,717 **TOTAL DEPTH** 1680.0' **VERTICAL** Vertical
BEGUN 8-25-77 **FINISHED** 9-15-77
DEPTH TO WATER Not Determined **HOLE LOGGED BY** Gary A. Hollinger & Robert L. Turner **DRILLER** Taylor; Hutchins; & Tuggle

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	% Recovery	DAILY SUMMARY OF DRILLING OPERATIONS (Cont):	DEPTH	CLASSIFICATION AND PHYSICAL CONDITION
Drilling Conditions (Continued): 860.0-870.0': Fast. 870.0-879.8': Slow and rough. 879.8-950.0': Slow and smooth. 950.0-960.0': Medium speed and medium rough. 960.0-980.0': Slow and rough. 980.0-1000.0': Slow and fairly smooth. 1000.0-1020.0': Slow to fast. 1020.0-1200.0': Medium to fast and smooth, occasional rough spots. 1200.0-1270.0': Slow and smooth. 1270.0-1330.0': Fast and fairly smooth. 1330.0-1350.0': Slow and smooth. 1350.0-1540.0': Fast to slow. 1540.0-1640.0': Medium and smooth. 1640.0-1680.0': Slow and smooth.	550 600 6½" RB 650 700 750 6½" RB 800 850 3⅞" 40 900 6½" RB 950 1000	0 0	8-31-77: Drilled to 880'. Repaired mud pump and chuck; replace sand line. New bit at 875'; core run at 875'. 9- 1-77: Drilled to 1200'. Service engines. New bit at 1040'.	550 600 650 700 750 800 850 900 950 1000	420-460': Sand. Fine to medium, brown and black. Slight increase in coarseness below 450'. 460-510': Sand. Fine to medium, predominantly black with minor light-colored grains; minor clay. Slight increase in dark grains below 480' and slight increase in clay below 490'. 510-620': Sand. Medium to fine, predominantly black, subangular to subrounded grains. Minor quartz and feldspars, grain size predominantly fine below 530'. Slight increase in grain size and granitic material from 540-560'; increase in light gray to pink clay from 570-600'; increase in light-colored granitic material below 610'. 620-630': Volcanic fragments. About 2/3 of material are dark-colored grains; and 1/3 are light-colored granitic minerals and light tan clay. 630-660': Sand and Volcanic Fragments. Fine to medium, black and light-colored. Minor light tan, soft clay. 660-700': Sand. Fine to medium with minor fine, rounded gravel and light brown clay. Grains mostly dark. Slight increase in grain size below 680'. 700-720': Sand and clay. Mostly fine to medium, dark sand with minor light-colored grains; minor light pinkish gray. 720-730': Clay, & sand. Similar to above with clay predominant. 730-760': Clay. Gray with minor sand and black and brown volcanic fragments. Minor white ash at about 740'. 760-785': Sand & Clay. About 50% fine to medium, multicolored sand, and 50% light pinkish clay. Grain size increases to fine gravel at 780'. Clay mostly brown at 780'. 785-800': Sand, with minor gravel, mostly fine to medium dark sand. 800-810': Sand, Predominantly fine to coarse, dark grains with minor multicolored grains. 810-870': Sand. Mostly fine with minor medium grains, predominantly dark with minor light-colored grains, minor clay. 870-905': Basalt with thin clay and gravel filled layers. Light gray, vesicular; vugs and fractures filled with hydrothermally (?) altered light-colored material and quartz crystals. 905-940': Volcanic fragments and volcanic gravel. Fine to coarse, mostly dark colored with minor multicolored grains; minor sand. 940-960': Sand and Gravel fragments. Fine to coarse, mostly dark with chert and
Estimated Drilling Fluid Return: 0-93.9': 100% 93.9-99.0': 95% 99.0-270.0': 100% 270.0-398.8': 90% 398.8-640.0': 100% 640.0-785.0': 90% 785.0-880.0': 100% 880.0-950.0': 90% 950.0-1200.0': 100% 1200.0-1270.0': 90% 1270.0-1540.0': 100% 1540.0-1640.0': 90% 1640.0-1680.0': 100%					
Representative Drilling Fluid Return Temperatures (°F): 64° - Initial 69° at 23' 70° at 61' 78° at 130' 82° at 140' 87° at 162' after trip 84° at 200' 88° at 230'					

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal

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

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	% Recovery	DAILY SUMMARY OF DRILLING OPERATIONS (Cont):	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'	1050 1100 6½" RB 1150 1200 1250 1300 6½" RB 1350 1400 1450 1500	0	9- 2-77: Drilled to 1330'. Repaired breakout 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.	1050 1100 1150 1200 1250 1300 1350 1400 1450 1500	940-960' (Continued): multicolored grains, minor clay. 960-1010': Sand with clay. Fine to medium gray to brown grains, minor black; increase in dark grains and gray clay below 990'. 1010-1030': Clay with Sand. Clay is light brown with mostly fine to medium, dark-colored sand; minor light colors. 1030-1040': Clay. Blue-gray. 1040-1060': Clay with Sand. Clay is brown with fine black and dark brown sand. 1060-1150': Sand and Clay. 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': Sand. Fine to medium, dark grains, minor multicolored lithic fragments. Minor light tan to pink clay. Slight increase in fines and clay below 1170'. 1260-1270': Sand & Gravel. Fine sand to fine gravel. Material mostly dark colored with minor light colors. 1270-1290': Sand and Clay. Predominantly fine, dark-colored sand with minor light colors; clay light brown to pinkish brown. Increase in brown sand below 1280. 1290-1350': Sand. 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': Sand and Clay. 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': Sand and Clay. 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': Sand and Granitic (?) Material. Fine-grained, highly weathered. 1450-1490': Sand. 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

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal

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
On water table levels, water return, character of drilling

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.
As 870.0': Rods stuck.
1250-1280': Caving.

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.

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

Hole Completion:
2" sealed, water-filled steel pipe installed and cemented into hole to 1659' for temperature gradients. Site protected with a steel guard rail.

Type and Size of Hole: 6½" RB

% Recovery: 0

DAILY SUMMARY OF DRILLING OPERATIONS (Cont):

9- 7-77: Drilled to 1680'. Total depth of rods available, condition hole for Schlumberger.

9- 8-77: Pulled rods from hole. Schumberger geophysical logging started swing shift.

9- 9-77: Schlumberger logging tool stuck in hole at 650'. Circulating mud to clear hole. Fishing 2 shifts per day.

9-10-77: Fishing for tool with oil field rods supplied by Midway Fishing Tool Co. of Woodland.

9-11-77: Continued fishing.

9-12-77: Continued fishing. Work over fish but could not latch on.

9-13-77: Continued fishing with Failing rods.

9-14-77: Latched fish at bottom of hole and recovered tool. Completed geophysical logging. Condition hole and mud for completion.

9-15-77: Set 1659' of 2" steel pipe, rig for cementing, pump in 10 cubic yards neet cement and chase cement with latch down plug and clear water.

9-16-77: Move rig from site.

DEPTH: 1550, 1600, 1650, 1700, 1750, 1800, 1850, 1900, 1950

CLASSIFICATION AND PHYSICAL CONDITION

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.

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'.

1630-1680': Sand. Fine to medium, dark gray with minor multicolored grains. Minor clay. Increase in light gray clay below 1660'.

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

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

NOTES
On water table levels, water return, character of drilling

Purpose of Hole:
(1) Temperature gradient.
(2) Geophysical properties.
(3) Geologic evaluation.

Land Owner:
Lassen County.

Location: NW¼ NW¼ 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.

Drill Rig:
Failing 1500

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': 6½" rockbit.
80-84': 3-7/8" Hay-stellite cor run; recovered 2.5' or 63%.
100': Attempted 3-7/8" Haystellite core run; destroyed bit; no recovery.
100-102': 2½" diamond core run; recovered 2.0' or 100%.
2088': Attempted 3-7/8" diamond core run; blocked with clay, no recovery.

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.

Type and Size of Hole	% Recovery
12¾" RB	0
6½" RB	0
3⅞" 6½" RB	63 0
2¾" D	
6½" RB	0
6½" RB	
6½" RB	

DAILY SUMMARY OF DRILLING OPERATIONS:

9-19-77: Rig up Failing 1500. Mix mud. 3 mud pits and 1 waste sump used. Drill 20' of 12-3/4" hole and cement in 8" steel surface casing. Install flow line.

9-20-77: Drilled to 220' with 6½" rockbit. Replace Kelly hose feed line. Core runs 80-84' and 100-102'. Replace bit at 100'. Drilling 24 hours per day.

9-21-77: Drilled to 590'. Replace bit at 320'.

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION LOG BASED ON ROCKBIT CUTTINGS

0-2,088':
PLEISTOCENE LAHONTAN LAKE (near shore) DEPOSITS WITH INTERBEDDED BASALTS AND PLIOCENE LAKE DEPOSITS WITH INTERBEDDED BASALTS (?).*

0-20.0': Silt and Sand. Predominantly fine-grained, brown.

20.0-40.0': Silty Clay. Minor sand, light brown to medium gray.

40.0-50.0': Sand. Medium to coarse, volcanic, dark gray with coarse quartz fragments.

50.0-68.0': Sand and Clay. Fine to medium volcanic sand, dark gray, common coarse quartz with dark gray clay. Increase in fine gravel from 60-68'.

68.0-73': Gravel and Clay with Sand. Fine to coarse, subrounded gravel, and gray clay. Sand is fine to coarse.

73.0-78.0': Basalt. Hard, dark colored, volcanic fragments.

78.0-94.0': Sandy Clay with Gravel. 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).

94-110': Basalt and/or Cobbles and Gravel. 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.

110-130': Clay and Sand. 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'.

130-140': Sandy Clay. Sand fine with minor medium grains, light yellow brown.

140-230': Basalt with Interbedded Clay. Basalt black to dark gray with red and tan common. Clay, brown, content increasing below 200', minor quartz and chalcedony.

230-260': Sand and Clay. Fine to coarse volcanic sand, light brown clay.

260-280': Sand. Fine to coarse, dark colored sand, minor light and brown colors.

EXPLANATION

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

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

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal

FEATURE Susanville Anomaly--Lassen County PROJECT Investigations 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

DEPTH TO WATER Not Determined HOLE LOGGED BY G. A. Hollinger and R. L. Turner DRILLER Taylor, Tuggle & Hutchins

NOTES
On water table levels, water return, character of drilling

Drilling Conditions (Continued):
260-280': Slow and rough.
280-320': Very slow and rough.
320-440': Smooth with occasional rough zones.
440-590': Medium and smooth.
590-680': Fast and smooth.
680-740': Medium and smooth.
740-830': Fast and smooth.
830-880': Hard and smooth.
880-1175': Medium and smooth, occasional rough zone.
1175-1300': Slow and smooth.
1300-1360': Medium and smooth.
1360-1500': Medium to slow and smooth.
1500-1600': Medium and smooth, occasional rough zone.
1600-1690': Medium and smooth.
1690-1840': Fast and smooth, occasional rough zone.
1840-1885': Medium and smooth.
1885-1960': Slow and smooth.
1960-2088': Medium and smooth.

Estimated Drilling Fluid Return:
0-140': 100%
140-220': 90%
220-440': 100%
440-590': 90%
590-620': 95%
620-640': 80%
640-660': 40%
At 660': Complete loss
660-680': Loss at intervals.
680-740': Complete loss to 70% return.
740-830': 100%
At 830': Complete loss.

Type and Size of Hole

550 — 6½" RB — 600 — 650 — 700 — 750 — 6½" RB — 800 — 850 — 900 — 950 — 1000

% Recovery

0

DAILY SUMMARY OF DRILLING OPERATIONS:

9-22-77: Drilled to 740'. Mud loss problems at intervals. Replaced bit at 660'.

9-23-77: Drilled to 940'. Mud loss problems. Replace bit at 880' and 940'. Repair mud pump and truck engine. Operations ceased for weekend.

9-26-77: Drilled to 1075'. Repair hydraulic pump drive chain and mud pump. Mud loss problems.

DEPTH

550 — 600 — 650 — 700 — 750 — 800 — 850 — 900 — 950 — 1000

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

260-280 (Cont.): Minor volcanic fragments, increasing below 270'; minor green clay.

280-300': Sand and Basalt. Fine to coarse volcanic sand and volcanic fragments. Minor green clay.

300-310': Clay and Sand. Brown to pinkish brown clay. Fine to medium, dark sand.

310-320': Basalt and Clay. Black volcanic fragments and light gray clay.

320-340': Sand. Fine to medium, dark sand, minor coarse; minor light brown clay.

340-430': Clay and Sand. Brown clay, sand fine to medium, mostly black and brown, minor quartz and light colors, few volcanic fragments and coarse zones, trace of white ash (?) at about 390'. Slight decrease in clay content below 410'.

430-450': Clay and Sand. Gray clay; fine to medium, dark sand, scattered coarse.

450-490': Sand and Clay. Fine to medium, dark sand, minor coarse grains and light-colored material; clay is brown and gray.

490-530': Sand and Clay. Fine to medium, subangular, mostly black to dark brown sand with common quartz, occasional thin coarse zones; clay is red to brown. Decrease in clay below 520'.

530-590': Sand with Clay. Fine to medium, some coarse, gray brown, subangular volcanic sand, common quartz, common brown to pink clay. Many thin, coarse intervals.

590-670': Sand with Clay. Fine to medium, some coarse, reddish brown, weathered volcanics, minor quartz, decrease in clay from above, decrease in grain size below 600' to predominantly fine below 660'.

670-690': Sand and Clay. Fine to medium, dark sand; gray clay.

690-770': Sand with Clay. Fine to medium, some coarse, black, volcanic sand, common quartz, minor red volcanics. Brown to red clay. Increase in red volcanics, 710-730'; absent below 740'.

770-890': Sand. Fine with minor medium, dark volcanic sand, scattered red grains. Increase in medium size, 790-830'. Minor brown clay, content increasing 870-890'.

890-950': Sand. Fine to medium, dark gray to black subangular volcanic sand with common quartz, some feldspars, variable amounts of pink to gray clay, some decomposed red volcanics. Decrease in medium

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal

FEATURE Susanville Anomaly--Lassen County PROJECT Investigations STATE California

HOLE NO. SUZY-3 LOCATION See Note, Sheet 1 GROUND ELEVATION 4,230 ANGLE FROM VERTICAL Vertical

BEGUN 9-19-77 FINISHED 10-13-77 TOTAL DEPTH 2,088.0' G. A. Holinger and R. L. Turner DRILLER Taylor, Tuggle & Hutchins

DEPTH TO WATER Not Determined HOLE LOGGED BY

NOTES
On water table levels, water return, character of drilling

Type and Size of Hole

% Recovery

DAILY SUMMARY OF DRILLING OPERATIONS:

DEPTH

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

Estimated Drilling Fluid Return (Continued):

830-880': Loss at intervals.
880-940': 80%
940-1000': Partial loss (?).
1000-1040': 70%
1040-1075': 90%
At 1075': Complete loss.
1075-1090': Slow loss
At 1090': Complete loss.
1090-1120': Slow loss
At 1120': Complete loss.
1120-1140': Slow loss
1140-1175': 50%
At 1175': Complete loss
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 encountered. Minor caving from 240-660' after trip.

Type and Size of Hole: 6½" RB; 6¼" RB

% Recovery: 0

9-27-77: Drilled to 1175'. Mud loss problems. Deck engine flywheel failed. Pull rods.

9-28-77: No drilling. Repairing deck engine. Replace all cables and service equipment.

9-29-77: Drilled to 1200'. Completed repairs on deck engine. Replaced bit at 1175'.

9-30-77: Drilled to 1360'. Mud loss problems continue. Additives being used to regain circulation. Pulled rods and replaced bit at 1360'. Secured for weekend.

10- 3-77: Drilled to 1500'. Mud loss problems continue. Additives being used. Replaced bit at 1480'. Repaired mud line guide cable.

890-950' (Continued): sand below 930'.

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 predominantly fine below 1010'. Occasional rough zones below 1060'.

1080-1120': Sand. Fine to coarse, minor gravel, subangular to subrounded black volcanic sand, common quartz and red to tan volcanics, some feldspars. Slight decrease in coarse grains at approximately 1090'. Increase in pink clay below 1100'.

1120-1130': Sand with Clay. Fine dark volcanic sand and pink clay.

1130-1140': Sand. Fine to coarse, subangular to subrounded, dark gray to black, volcanic, minor tan to red volcanics and quartz, minor tan to pink clay.

1140-1200': Sand. Fine to medium, mostly dark gray to black volcanics with tan and red volcanics, minor clay.

1200-1230': Sand. Predominantly fine with medium, dark gray and tan, angular to subangular, minor clay. Increase in medium size grains and quartz below 1220'.

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'.)

1330-1380': Sand. Fine, dark gray to pink and tan, minor clay. Increase in grain size to fine to medium at approximately 1360-1370'.

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 below 1570'.

EXPLANATION

Hole No. SUZY-3

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal

FEATURE Susanville Anomaly--Lassen County PROJECT Investigations 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

DEPTH TO WATER Not Determined HOLE LOGGED BY G. A. Hollinger and R. L. Turner DRILLER Taylor, Tuggle, & Hutchins

NOTES
On water table levels, water return, character of drilling

Casing Record:
Cemented 8" steel surface casing to 20.9'.

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.

Hole Completion: 2058' of two-inch sealed, water-filled steel pipe installed and cemented in hole for temperature gradients. Site protected with a steel guard rail.

Type and Size of Hole: 6¼" RB; 6½" RB

% Recovery: 0

DAILY SUMMARY OF DRILLING OPERATIONS:

10- 4-77: Drilled to 1775'. Repaired mud line guide cable.

10- 5-77: Drilled to 1920'. New bit at 1900'.

10- 6-77: Drilled to 2070'.

DEPTH: 1550, 1600, 1650, 1700, 1750, 1800, 1850, 1900, 1950, 2000

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

1640-1760': Clay and Sand. Gray clay, fine to medium, dark volcanic sand, minor light colors and quartz. Sand grades to predominantly fine below 1740'.

1760-1810': Sand. Fine, gray with minor light-colored grains, minor clay.

1810-1830': Sand with Gravel. Predominantly fine-grained, dark volcanic sand with coarse rock fragments; red, white, green and brown (drillers report boulders).

1830-1990': Clay and Sand. Gray clay, mostly fine, dark-colored sand, very minor medium, very minor light colors. About 30% multicolored lithic fragments at approximately 1900'.

1990-2088': Sandy Clay. Fine to medium, gray sand, common multicolored lithic

EXPLANATION

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

Susanville Geothermal

FEATURE Susanville Anomaly--Lassen County PROJECT Investigations STATE California

HOLE NO. SUZY-3 LOCATION See Note, Sheet 1 GROUND ELEVATION 4,230 ANGLE FROM VERTICAL Vertical

COORDINATES N.394,298; E.2,372,571 TOTAL DEPTH 2,088.0'

BEGUN 9-19-77 FINISHED 10-13-77 G. A. Hollinger and R. L. Turner DRILLER Taylor, Tuggle, & Hutchins

DEPTH TO WATER Not Determined HOLE LOGGED BY

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	% Recovery		DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	6¼" RB	0	DAILY SUMMARY OF DRILLING OPERATIONS: 10- 7-77: Drilled to 2088' T.D. Schlumberger geophysical logged hole. Secured for 3-day holiday weekend. 10-11-77: Assemble core barrel and service equipment. Two crews per day. 10-12-77: Attempted core run at 2088'. No recovery. Start running 2" steel pipe. 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. 10-14-77: Move rig from site.	2050 2100 2150 2200 2250 2300 2350 2400 2450	1990-2088' (Continued): fragments; clay light gray with minor gray-green. Increase in gray-green clay below 2030'. 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. 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.

EXPLANATION

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**

COORDINATES N.393,965; E.2,373,944 **TOTAL DEPTH** 769' **VERTICAL** VERTICAL

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

PURPOSE OF HOLE:
(1) TEMPERATURE GRADIENT.
(2) GEOPHYSICAL PROPERTIES.
(3) GEOLOGIC EVALUATION.
(4) PIEZOMETRIC OBSERVATION.

LANDOWNER: CITY OF SUSANVILLE, CA

LOCATION: NE¼ NW¼ 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

Type and Size of Hole	Recovery	DAILY SUMMARY OF DRILLING OPERATIONS
9⅝" RB	0	10-13-78: RIG MOVED TO SITE FROM SUZY-5. RIGGING UP. TWO SHIFTS PER DAY. SECURE FOR WEEKEND.
		10-16-78: CONTINUED RIGGING UP AND MIXING MUD.
		10-17-78: DRILLED 9-5/8 INCH ROCKBIT HOLE TO 27'. DOWN 6 HOURS TO REPLACE SWIVEL AND REPAIR MUD PUMP
		10-18-78: DRILLED TO 52'. DOWN 1 HOUR TO REPAIR MUD PUMP.
		10-19-78: DRILLED TO 63' AND CEMENTED IN 8" SURFACE CASING. MODIFIED AND REPAIRED RIG AFTER RUNNING CASING.
		10-20-78: DRILLED TO 167' WITH 6-1/2" ROCKBIT. SECURE FOR WEEKEND.
		10-23-78: DRILLED TO 255'. LOST CIRCULATION.
		10-24-78: ATTEMPTED TO REGAIN CIRCULATION.
		10-25-78: ATTEMPTED TO REGAIN CIRCULATION.
		10-26-78: DRILLED TO 287' WITH MAJOR MUD LOSS.
6½" RB		10-27-78: CONDITION MUD AND HOLE. CLEAN UP SITE. SECURE FOR WEEKEND.
		10-30-78: DRILLED TO 367'.
		10-31-78: DRILLED TO 547'.
		11- 1-78: DRILLED TO 693'.
		11- 2-78: DRILLED TO 769' TOTAL DEPTH. CONDITION HOLE FOR LOGGING.
		11- 3-78: HOLE LOGGED BY USGS. SECURE FOR WEEKEND.
	0	11- 6-78: REAMED HOLE TO 7-7/8" SIZE TO 278'.
		11- 7-78: REAMED HOLE TO 680'.
		11- 8-78: REAMED HOLE TO 768'. PREPARED TO RUN 4" CASING.
		11- 9-78: RAN 4" CASING. ONE SHIFT.
		11-10-78: NO CREWS ON SITE.
		11-13-78: PLACING GRAVEL PACK. TWO SHIFTS.
		11-14-78: FINISHED PLACING GRAVEL PACK.
		11-15-78: PLACED CEMENT SEAL. MOVED RIG OFF HOLE.

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

NOTE: LOG BASED ON ROCKBIT CUTTINGS.

0-25.0':
RECENT SOIL AND ALLUVIAL DEPOSITS.

0-14': SILTY CLAY. SOIL, RED BROWN. SLIGHTLY SANDY.

14-23': SAND. FINE TO COARSE, PREDOMINANTLY FINE TO MEDIUM; MULTICOLORED, WEATHERED VOLCANICS, GRANITE, QUARTZ, AND FELDSPARS. SUBROUNDED TO SUBANGULAR; INCREASE IN DARK BROWN FAT CLAY BELOW 20'.

23-25': SAND AND GRAVEL. FINE SAND TO FINE GRAVEL, MULTICOLORED, ANGULAR TO SUBROUNDED VOLCANIC AND GRANITIC SAND. GRAVEL WEATHERED VOLCANIC. CONSIDERABLE MEDIUM TO DARK BROWN CLAY.

25.0-282'(?):*
PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS.

25-32': BASALT. BLACK, HARD, ANGULAR FRAGMENTS, POSSIBLY COBBLES TO 29', AND FLOW BELOW 29'.

32-38': SANDY CLAY. MEDIUM RED-BROWN, SOFT, WITH MINOR PREDOMINANTLY FINE WITH MEDIUM VOLCANIC SAND.

38-41': GRAVEL AND CLAY. FINE TO COARSE, BLACK, VOLCANIC GRAVEL IN A MEDIUM RED-BROWN, SOFT CLAY MATRIX.

41-50': SANDY CLAY. MEDIUM RED BROWN, SOFT WITH FINE TO MEDIUM, OCCASIONAL COARSE VOLCANIC SAND. INCREASE IN COARSE SAND BELOW 47'.

50-62': CLAYEY GRAVEL. FINE SAND TO COARSE GRAVEL, PREDOMINANTLY VOLCANIC, ANGULAR TO SUBROUNDED, WITH MEDIUM GRAY AND RED-BROWN SOFT CLAY. INCREASE IN LITHIC FRAGMENTS AND GRAY CLAY BELOW 58'.

62-66': GRAVEL AND SAND. DARK GRAY TO BLACK, ANGULAR TO SUBROUNDED, FINE TO COARSE; PREDOMINANTLY VOLCANIC SAND AND GRAVEL WITH MINOR LIGHT GRAY, FIRM TO SOFT CLAY. COMMON QUARTZ.

66-73': CLAY. RED ORANGE, VERY SOFT, MINOR SAND.

73-80': CLAYEY SAND. MULTICOLORED, WEATHERED, FINE TO COARSE, VOLCANIC WITH QUARTZ, ANGULAR TO SUBROUNDED. MINOR RED-BROWN CLAY.

80-87': SANDY CLAY. RED-BROWN, SOFT, MINOR SAND SIMILAR TO 73-80' INTERVAL.

87-130': GRAVEL AND SAND. MULTICOLORED TO PREDOMINANTLY DARK GRAY, FINE TO VERY COARSE, ANGULAR TO SUBROUNDED SAND AND FINE GRAVEL. MINOR MEDIUM GRAY, SOFT CLAY. INCREASE IN CLAY BELOW 97'.

EXPLANATION

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

Hole No. SUZY-4

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, SHEET 1 **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** SKAGGS; FERRELL; TUGGLE

NOTES
On water table levels, water return, character of drilling

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.

ESTIMATED DRILLING FLUID RETURN:
0-255': 95-100%
255': TOTAL CIRCULATION LOSS, REQUIRED 4 SHIFTS TO REGAIN.
255-292': 10-60%
292-769': 90-95%

REPRESENTATIVE DRILLING FLUID TEMPERATURE (° 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' reported 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 INTO HOLE to 62'.

GEOPHYSICAL LOGGING:
THE FOLLOWING GEOPHYSICAL LOGS WERE RUN BY THE USGS DENVER OFFICE:
(1) ELECTRIC
(2) NATURAL GAMMA
(3) GAMMA GAMMA
(4) NEUTRON
(5) TEMPERATURE
(6) CALIPER

Type and Size of Hole

6½" RB

% Recovery

0

DEPTH

550 600 650 700 750 800 850 900 950 1000

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

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 COMPOSITION 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 FRAGMENTS. MINOR CLAY. TOTAL LOSS IN CIRCULATION AT 255'.

255-282': SAND AND GRAVEL. PREDOMINANTLY COARSE, BLACK VOLCANIC SAND AND FINE GRAVEL. MINOR FINE TO MEDIUM SAND AND BLUE-GRAY CLAY. CUTTINGS HIGHLY CONTAMINATED BY EFFORTS TO REGAIN CIRCULATION.

282(?)* -769':
PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS

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 SUBANGULAR VOLCANIC WITH MINOR QUARTZ.

360': SAND. MULTICOLORED, PREDOMINANTLY DARK, FINE TO COARSE, SUBANGULAR TO SUBROUNDED, PREDOMINANTLY VOLCANIC WITH MINOR QUARTZ, MINOR PINK SOFT CLAY.

480-487': SANDY CLAY. PINK, SOFT WITH SUBROUNDED, FINE TO MEDIUM MULTICOLORED SAND.

487-575': CLAY. PINK, SOFT, WITH MINOR FINE TO MEDIUM, PREDOMINANTLY SUBANGULAR MULTICOLORED, 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 BELOW 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 SUBROUNDED SAND WITH LIGHT PINK, SOFT TO MODERATELY 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'.

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE—CONTINUATION SHEET

FEATURE SUSANVILLE ANOMALY—LASSEN COUNTY **PROJECT** SUSANVILLE GEOTHERMAL INVESTIGATIONS—CALIFORNIA

HOLE NO. SUZY-4 **SHEET** 3 **OF** 3

NOTES (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.

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)

675-687': GRAVEL, SAND AND BASALT. FINE TO PREDOMINANTLY COARSE, BLACK VOLCANIC SAND AND GRAVEL FRAGMENTS. SAND ROUNDED TO PREDOMINANTLY SUBANGULAR, 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 SUBROUNDED, PREDOMINANTLY DARK VOLCANIC SAND AND GRAVEL WITH VARYING AMOUNTS OF PINKISH GRAY SOFT CLAY.

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 Notes | GROUND ELEVATION: 4171' | ANGLE FROM VERTICAL: Vertical

BEGUN: 9-12-78 | FINISHED: 10-12-78 | TOTAL DEPTH: 706.0'

DEPTH TO WATER: 4.0' (9-12-78) | HOLE LOGGED BY: G. Hollinger; R.Turner; J. Darling | DRILLER: N.Tuggle; R. Swank

NOTES On water table levels, water return, character of drilling

Purpose of Hole: (1) temperature gradient; (2) geophysical properties; (3) geologic evaluation; (4) piezometric observation.

Landowner: Sierra Pacific Industries; Eagle Lake Division; Susanville, CA

Location: SE¼ NE¼ Section 5, T. 29 N., R. 12 E., on lumber mill property.

Drill Rig: Failing 1500

Drilling Methods: Rockbit drilled using bentonite mud and additives, as required. Three mud pits used. 0-80': 9-5/8" rockbit for installation of 8" surface casing. 60-706': 6½" rockbit.

Drilling Conditions:
0-15': Very fast and smooth.
15-45': Fast and smooth, squeezing at 45'.
23-30': Slow and rough.
45-91': Slow and rough to very rough.
91-120': Intermittently slow to fast and smooth to rough.
120-160': Slow to medium speed, smooth to rough. Squeezing from 131-141'.
160-220': Hard, slow rough.
220-271': Intermittently smooth and fast to slow and rough.
271-316': Medium

Type and Size of Hole

9⅝" RB (0-80')

6½" RB (80-706')

Recovery

0 (0-80')

0 (80-706')

DAILY SUMMARY OF DRILLING OPERATIONS

9-12-78: Moved rig from SUZY-1 and rig up. One shift per day.
9-13-78: Completed rigging up. Drilled to 15' with 9-5/8" rockbit. Down 1 hour to repair mud pump.
9-14-78: Drilled to 45'. Down 4 hours to repair and replace swivel.
9-15-78: Drilled to 55'. Down 3 hours to locate mud pump knock. Secured for weekend.
9-18-78: Drilled to 72'.
9-19-78: Drilled to 80' and installed 77' of 8" surface casing. Two shifts per day. Down 6 hours for deck engine repair. Drilled to 91' with 6½" rockbit.
9-20-78: Drilled to 160'. Down 7 hours to repair breakout table.
9-21-78: Drilled to 271'. Hole could not be advanced; rods stuck at 191'. Down 1 hour to retrieve casing.
9-22-78: Attempted to pull rods. Secure site for weekend.
9-25-78: Twisted off rods. Fishing. One shift.
9-26-78: Fishing. Equipment maintenance. Two shifts.
9-27-78: Fishing.
9-28-78: Fishing. Recovered fish.
9-29-78: Prepared site to continue drilling. Down 7½ hours to repair rig. Secured for weekend.
10- 2-78: Drilled to 377'. Down 1 hour to repair truck and drill.
10- 3-78: Drilled to 512'. Down 3 hours to replace kelly cable.

DEPTH

50, 100, 150, 200, 250, 300, 350, 400, 450, 500

FIELD CLASSIFICATION AND PHYSICAL CONDITION

NOTE: Log based on rockbit cuttings.

0-23.0':
RECENT ALLUVIAL DEPOSITS

0-10': Sandy Silt with Clay. Fine-grained, brown, abundant mica and weathered granitic material.
10-20': Sand. 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.
20-23': Clay and Sand. Pinkish brown, soft, predominantly coarse with similar composition to weathered granitic material as above.

23.0-512'(?)*:
PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS.

23-29': Basalt. Black fragments from a flow or cobbles.
29-35': Sandy Clay. Dark brown, soft, fine-grained.
35-40': Clay. Light gray grading to brown near 40'; soft.
40-48': Sandy Clay. Dark brown, hard, fine-grained; minor sand.
48-58': Basalt. Black fragments, minor dark gray and brown clay.
58-60': Clay. Light brown, fat.
60-62': Basalt. Hard, with minor soft medium-brown clay.
62-77': Sand and Conglomerate. Black and gray, firm with moderately firm to soft clay. Occasional secondary white to yellow calcite (?) and quartz (?).
77-80': Clay. Red-brown, soft, with decomposed basalt (?)
80-95': Basalt and Clay. Black volcanic fragments, minor red-brown clay beds less than 6 inches thick, minor quartz.
95-104': Clayey Sand. Dark gray to black, subangular to angular, fine to coarse volcanic sand with light gray, soft clay.
104-155': Sand and Conglomerate. 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.

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;

DEPTH TO WATER 4.0' (9-12-78) **HOLE LOGGED BY** R. Turner; J. Darling **DRILLER** N. Tuggle; R. Swank

NOTES On water table levels, water return, character of drilling

Drilling Conditions (Cont.)
271-316' (Cont.): speed and smooth.
316-327': Slow and rough.
327-340': Slow to medium and smooth to slightly rough.
340-350': Squeezing, slow and smooth.
350-442': Medium fast to fast and smooth.
442-482': Intermittently smooth to rough.
482-512': Medium rough to rough, slow with some caving.
512-542': Slow and smooth to rough.
542-609': Hard, slow and rough.
609-612': Rough.
612-621': Smooth and fast.
621-646': Slow, hard and rough.
646-677': Medium speed to fast and smooth to slightly rough.
677-700': Rough and slow.
700-706': Fast and smooth.

Estimated Drilling Fluid Return:
0-55': 95-100%
55-639': 100%
639-706': 90-100%

Representative Drilling Fluid Temperatures (°F)
64° at 12'
68° at 55' after 60 hours downtime
64° at 64'
67° at 91' after 8 hours downtime.
60° at 100'
64° at 141' after 1 hour downtime
70° at 170'
75° at 215'
80° at 270'

Type and Size of Hole: 6½" RB

Recovery: 0

DAILY SUMMARY OF DRILLING OPERATIONS (Cont):

10- 4-78: Drilled to 562'. Down ½ hour because of fuel pump problem.
10- 5-78: Drilled to 576'. Hole geophysical logged by USGS.
10- 6-78: Drilled to 612'. Secured for 3-day holiday weekend.
10-10-78: Drilled to 646'. Down 6½ hours fishing for twisted off rods and mud pump problems.
10-11-78: Completed drilling to 706'. Down 2½ hours to repair tower cable roller and kelly.
10-12-78: Installed 2-inch pipe and completed hole.
10-13-78: Moved rig from hole to SUZY-4.
11-5-78: BOTTOM PORTION OF HOLE GEOPHYSICAL LOGGED WITH " THROUGH CASING" METHODS BY USGS.

DEPTH

CLASSIFICATION AND PHYSICAL CONDITION

104-155' (Continued): alternating between rough and smooth every few inches below 141'.
155-160': Sandy Clay with Volcanic Fragments. Brown to red brown, fine-grained, soft with increasing black volcanic fragments toward 160'.
160-179': Conglomerate and Clayey Sand. Rough and smooth alternating 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'.
179-182': Sandy Clay. Light medium brown, soft.
182-199': Pebble Conglomerate and Clayey Sand. Similar to 160-179' interval with common brown clay.
199-203': Sandy Clay. Fine to medium volcanic sand in medium brown soft clay.
203-220': Pebble Conglomerate and Clayey Sand. Angular to subrounded, fine to coarse, predominantly black basaltic with minor multicolored fragments in medium gray to brown clay. Gradual change from conglomerate to sand toward 220'.
220-230': Clayey Sand. Fine to coarse, angular to subrounded, predominantly dark volcanic sand with medium gray soft clay, minor gravel.
230-261': Sand. Fine to coarse, angular to subrounded, predominantly dark volcanic, minor clay.
261-265': Sandy Clay. Fine to coarse volcanic sand with medium brown, soft clay.
265-271': Sand. Fine to coarse, angular to subrounded, predominantly dark volcanic, minor clay.
271-295': Clayey Sand. Multicolored, fine to coarse, angular to subangular, predominantly volcanic in medium gray-brown to pink soft clay. Minor gravel.
295-347': Gravel and Clay. Multicolored, unconsolidated, fine sand to fine gravel; angular to subrounded. Clay is gray-green to light gray. Increase in gray-brown clay from 335-347'.
347-357': Clayey Sand. Multicolored

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE—CONTINUATION SHEET

FEATURE. SUSANVILLE ANOMALY-- PROJECT. Susanville Geothermal Investigations..
HOLE NO. SUZY-5 LASSEN COUNTY SHEET. 3 OF.....

NOTES (Continued)

Representative Drilling Fluid Temperatures (° F) (Continued)
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'

Casing Record:
77' of 8" surface steel casing permanently installed in hole from 3-80'; 10" casing, surface to 5', cemented in around 8" casing.

Geophysical Logging:
The following geophysical logs were run by the USGS, Denver Office:
(1) Electric
(2) Natural Gamma
(3) Gamma Gamma
(4) Neutron
(5) Temperature
(6) Caliper

Hole Completion: 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.

FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Cont.)

347-357' (Continued): but predominantly dark volcanic, fine to coarse, angular to subrounded, clay. Medium gray-brown.

357-481': Sandy Clay. 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'.

481-512': Gravel. Predominantly basaltic, subrounded to angular fragments, minor light colors decreasing toward 512'. Minor clay.

512(?)* -706.0':
PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS.

512-521': Clayey Sand. Angular to subrounded, predominantly dark volcanic sand with blue-gray clay increasing below 516'.

521-609': Basalt. Black angular, hard fragments, minor sand and clay. Occasional thin light gray clay seams. Very minor light-colored fragments.

609-642': Clayey Sand. 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.

642-646': Sandstone (?). Subangular to subrounded, light gray, fine to medium, silicic-cemented with common basaltic fragments, minor brown clay.

646-675': Sandy Clay. Medium gray to chocolate brown, soft, minor multicolored, fine to medium, predominantly subangular sand.

675-706': Clayey Sand. 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'.

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

DEPTH TO WATER Not determined **HOLE LOGGED BY** G. Hollinger; R.Turner; L.Phillips **DRILLER** Tuggle, Parrell, VanEtten, Skaggs, Warren

NOTES
On water table levels, water return, character of drilling

Purpose of Hole:
(1) Temperature gradient; (2) geophysical properties; (3) geologic evaluation; (4) piezometric observation.

Landowner: Dr. Beams and Dr. Sturges; City of Susanville lease.

Location: SW¼ NE¼ Sec. 5, T.29 N., R. 12 E.

Drill Rig:
Failing 1500

Drilling Methods:
Rockbit drilled using bentonite mud and additives as required. Three mud pits used.
0-58': 12½" rockbit for permanent installation of 10" surface casing.
58-624': 8½" rockbit.

Drilling Conditions:
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'.
108-169': Slow to very slow, hard to very hard, rough.
169-193': Medium speed and roughness.
193-244': Slow, rough and hard.
244-295': Medium slow and rough.

Type and Size of Hole | % Recovery

12½" RB | 0

8½" RB | 0

DAILY SUMMARY OF DRILLING OPERATIONS

11-16-78: Moving and set up, one shift per day.
11-17-78: Complete rigging up, secured for weekend.
11-20-78: Drilled 12½" rockbit hole to 22', two shifts per day, down 1 hour to repair light plant.
11-21-78: Drilled to 24', down 4½ hours fishing for twisted off rods and to repair chuck.
11-22/27-78: Rig down for repair.
11-28-78: Drilled to 32'; down 1½ hrs to repair chuck.
11-29-78: Drilled to 42'; down 5 hrs fishing and repairing rig.
11-30-78: Drilled to 58'; installed 10-inch surface casing; down 1 hr to repair mud lines.
12- 1-78: Cemented in surface casing. Worked on equipment, secured for weekend.
12- 4-78: No drilling; down 8½ hrs due to drill engine electrical problem.
12- 5-78: Drilled to 80' with 8½" rockbit, surface casing broken and loose.
12- 6-78: Drilled to 93'; worked on surface casing.
12- 7-78: Drilled to 108', rods stuck in hole. Down 1½ hrs to repair truck transmission.
12- 8-78: No drilling; surface casing failed; secured for weekend.
12-12-78: No crews on duty 12-11-78. Casing cemented into hole. Broke loose again on swing. Hole not advanced.
12-13-78: Drilled to 158'; down 4 hrs to repair break-out table and truck water pump.
12-14-78: No drilling. Down 7½ hrs to repair break-out table.
12-15-78: Drilled to 167'; down 3.5 hours due to transmission problem. Secured for weekend.
12-18-78: No drilling. Down 4 hrs due to extreme weather conditions.

DEPTH: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

FIELD CLASSIFICATION AND PHYSICAL CONDITION

NOTE: Log based on rockbit cuttings.

0-49':
RECENT SOIL AND ALLUVIAL DEPOSITS.

0-12': Silty, Sandy Clay. Soil medium brown to yellow with thin sand-pebble beds of predominantly subangular to rounded, fine to very coarse, dark volcanics.

12-15': Clay. Red-brown, fat, with occasional fine to coarse, subrounded, multicolored lithic fragments.

15-21': Sand and Gravel. Predominantly fine to very coarse, subrounded dark volcanics and red-brown, weathered volcanics. Common quartz and multicolored lithic fragments.

21-40': Gravel and Cobbles. Angular to subrounded, fine to very coarse, mostly dark gray to black volcanics. Minor red-brown silty clay, quartz and multicolored, fine to coarse, predominantly subangular sands.

40-49': Sand/Gravel. Fine to very coarse, angular to subrounded, predominantly medium-brown, subrounded, weathered volcanics with dark gray to black volcanics as in 21-40' interval. Common quartz, minor light gray, soft silty clay.

49-589'(?)*:
PLEISTOCENE BASALT AND LAHONTAN (NEAR SHORE) LAKE DEPOSITS.

49-83': Basalt. Black, hard, angular cuttings with light gray to white soft clay, possibly ash interbeds.

83-98': Basalt. Similar to 49-83' interval except with increased light gray clay.

98-120': Sandy Clay. Red-brown to gray-brown, soft, with fine to very coarse, subangular to rounded, multicolored sands, predominantly dark volcanics. Occasional thin, very coarse sands, possibly cobbles.

120-145': Pebble Conglomerate (?) Fine to very coarse, angular to subangular, with some subrounded, multicolored but predominantly

EXPLANATION

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

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal Investigations STATE California

HOLE NO. SUZY-6 LOCATION See Notes GROUND ELEVATION 4176' ANGLE FROM VERTICAL Vertical

BEGUN 11-16-78 FINISHED 1-26-79 COORDINATES N.392,883; E.2,375,452 TOTAL DEPTH 624.0'

DEPTH TO WATER Not determined HOLE LOGGED BY G. Hollinger; R.Turner; L.Phillips DRILLER Tuggle, Farrell, VanEtten, Skaggs, Warren

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	% Recovery	DAILY SUMMARY OF DRILLING OPERATIONS (Continued)	DEPTH	FIELD CLASSIFICATION AND PHYSICAL CONDITION
Drilling Conditions (Cont.): 295-376': Slow, rough and hard. 376-402': Medium slow and rough. 402-426': Medium smooth. 426-464': Fast and smooth. 464-524': Slow, medium smooth to rough. 524-580': Fast and smooth. 580-590': Medium slow to very slow. 590-624': Hard and rough, slow. **Estimated Drilling Fluid Return** 0-26': 90-95% 26-624': 95-100% **Representative Drilling Fluid Temperature (°F):** 52°F at 22' 59°F at 33' 60°F at 49' 59°F at 56' 77°F at 58'; bottoms up after approx. 80 hrs downtime. 71°F at 60'; bottoms up after 10 hrs downtime 58°F at 117' 60°F at 135' 62°F at 150' 79°F at 158'; bottoms up after approx. 24 hrs downtime. 63°F at 165' 59°F at 188' 60°F at 193' 74°F at 193'; bottoms up after approx. 10 hrs downtime. 63°F at 195' 68°F at 240' 73°F at 260' 73°F at 295' 78°F at 320'	550 8½" RB 600 650 700 750 800 850 900 950	0	12-19-78: No drilling. Rig down for major repair. 12-20-78: No drilling. Rig down. 12-21-78: Drilled to 193'. Down 5½ hrs finishing repairs. 12-22-78: No drilling. Twisted off in hole. Secured for 3-day Christmas weekend. 12-26-78: Fishing, 3 shifts. 12-27-78: Recovered fish. 12-28-78: Drilled to 295'. 12-29-78: Drilled to 384'. Secured for 3-day New Year's weekend. 1- 2-79: Thawed out equipment; drilled to 464'. 1- 3-79: Drilled to 564'; deck engine clutch failed. 1- 4-79: Prepared for logging. Down for clutch repair. 1- 5-79: Down due to clutch; hole logged by USGS. Secured for weekend. 1- 8-79: No drilling; rig down. 1- 9-79: No drilling; rig down. 1-10-79: No drilling, rig repairs completed. 1-11-79: Conditioned hole; drilled to 604'. 1-12-79: Drilled to 624', total depth. Down 1½ hrs to re-rig cables, secured for weekend. 1-15-79: Prepared to run casing. 1-16-79: Started running casing, lost casing in hole. 1-17-79: Fishing for casing. 1-18-79: Fishing for casing. 1-19-79: Casing installed, rigged for development; secured for weekend. 1-22-79: Thawed out equipment, conditioned hole. 1-23-79: Washed and air-jetted hole. 1-24-79: Continued to develop hole. 1-25-79: Repaired casing. 1-26-79: Attempted to cement casing. Moved rig to SUZY-7	550 600 650 700 750 800 850 900 950	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': Pebble Conglomerate (?). Similar to 120-145' interval except with increase in medium gray, soft clay. 158-188': Pebble Conglomerate (?). 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': Sandy Claystone (?). Light blue-green, soft to slightly firm claystone with light-colored lithic fragments. 193-240': Pebble Conglomerate (?) Geologist not present at site but drilling characteristics and one sample from 210' depth indicate same lithology as 158-188' interval. 240-284': Pebble Conglomerate (?) 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': Sandy Clay (?) Geologist not at site. 290-402': Pebble Conglomerate (?) Similar to 240-284' interval with occasional light tan, soft clay. 402-420': Pebble Conglomerate (?) similar to 290-402' interval with increase in soft, brown clay. 420-430': Sandy Clay. Medium gray, soft clay with angular to subrounded, fine to coarse, multicolored sand. 430-517': Sandy Clay. Medium brown, soft clay with sands as in 420-430' interval. Occasional very

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE—CONTINUATION SHEET

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal Investigations, California

HOLE NO. SUZY-6 SHEET 3 OF 3

NOTES (Continued)

Representative Drilling Fluid Temperature (°F) (Continued):
82°F at 325'; bottoms up after 2½ hrs downtime.
79°F at 354'
79°F at 370'
100°F at 385'; bottoms up after 50 hrs downtime.
82°F at 400'
87°F at 455'
108°F at 564'; bottoms up after 7½ days downtime.
90°F at 589'
93°F at 604'

Caving Conditions:
32-34': Minor caving.
524-564': Hole squeezing.

Casing Record: 10" steel surface casing installed to 57' and permanently cemented into hole.

Geophysical Logging:
The following geophysical logs were run by the USGS, Denver Office:
(1) Electric
(2) Natural Gamma
(3) Gamma Gamma
(4) Neutron
(5) Temperature
(6) Caliper

Hole Completion: 6" steel casing was installed to the following approximate depths:
0-103': 6" blank steel casing
103-603': 6" factory-perforated steel casing.
603-623': 6" torch-perforated steel casing.
623-624': Solid well point.
Attempt to cement in upper 103' unsuccessful. Site protected with guard rail.

FIELD CLASSIFICATION AND PHYSICAL CONDITION (Continued)

430-517' (Continued): thin, very coarse, angular, multicolored sands or conglomerate.

517-524': Sandy Clay. Medium brown, soft, with fine to coarse, predominantly coarse, multicolored, angular to subrounded sands.

524-530': Clay. Medium brown, soft, with minor multicolored sands similar to 517-524' interval (possibly slough).

530-564': Clayey Sand. Multicolored, fine to medium, subangular to subrounded, predominantly subangular, volcanic sand with medium brown, soft clay.

564-589': Sandy Clay. Medium brown, soft clay with fine to medium, subangular to subrounded, multicolored sands. Minor gray-green claystone.

589-589': Sand. 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.)

589'(?)*-624' T.D.:
PLIOCENE LAKE DEPOSITS AND INTERBEDDED BASALTS

589-602': Basalt. Black, angular, fine to coarse cuttings with sand similar to 530-589' interval (sand possibly slough).

602-624': Basalt. Similar to 589-602' interval but much harder drilling, probably less fractured and/or weathered.

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** VERTICAL

COORDINATES N.392,359; E.2,374,642 **TOTAL DEPTH** 735.0'

BEGUN 1-24-79 **FINISHED** 2-8-79 TUGGLE; WARREN;

DEPTH TO WATER 6.0' **HOLE LOGGED BY** R. TURNER; L. PHILLIPS **DRILLER** SKAGGS; BABBITT

NOTES
On water table levels, water return, character of drilling

PURPOSE OF HOLE:
(1) TEMPERATURE GRADIENT; (2) GEOPHYSICAL PROPERTIES; (3) GEOLOGIC EVALUATION.

LANDOWNER:
DR'S BEAMS AND STURGES

LOCATION: SE¼ of NW¼ SECTION 5, T. 29 N., R. 12 E.; NORTHEAST OF INTERSECTION OF SISKIYOU & EL DORADO STREETS.

DRILL RIGS:
CALWELD BUCKET AUGER AND FAILING 1500 ROTARY.

DRILLING METHODS:
18" BUCKET AUGER TO 50' FOR 12" SURFACE CASING; 6-1/2" ROCKBIT DRILLED USING BENTONITE DRILL MUD AND ADDITIVES AS REQUIRED FROM 50' TO 735' TOTAL DEPTH.

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%

DRILLING CONDITIONS:
BUCKET AUGER:
0-49': MODERATELY FAST AND SMOOTH.
49-50': SLOW AND HARD; RESISTED FURTHER 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, OCCASIONAL SMOOTH ZONE.

Type and Size of Hole	% Recovery
18"	0
6½" RB	0

DAILY SUMMARY OF DRILLING OPERATIONS:

1-24-79: Bucket auger moved to site. 18-inch hole dug to 47'±. One shift.

1-25-79: Bucket auger drilled to 50'±. Ran 12" casing to 30' when welder failed. One shift.

1-26-79: Ran casing to 35'. Hole squeezing, prevented casing to be driven further. Cemented in. Rotary rig moved to site. Secured for weekend.

1-29-79: Rigging up. One shift.

1-30-79: Completed rigging up. Drilled 6½" hole to 55'. Two shifts.

1-31-79: Drilled to 115'. Down 2½ hrs due to mud pump problems. Three shifts.

2- 1-79: Drilled to 170'. Down 6 hrs to repair mud pump, swivel and chuck.

2- 2-79: Drilled to 305'. Secured for weekend.

2- 5-79: Drilled to 405'. Down 2 hrs to start up after weekend. Down 6 hrs for day-shift travel.

2- 6-79: Drilled to 555'. Down 2 hrs to change bit at 515'.

2- 7-79: Drilled to 735'. Ran 733' of 2" pipe with 18" sealed well point to bottom.

2- 8-79: Cleaned up site, set up triangle guard post and moved all equipment to county yard.

DEPTH

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

NOTE: LOG BASED ON BUCKET-AUGER RETURN FROM 0-50' AND ON ROCKBIT CUTTINGS FROM 50-735'.

0-49':
RECENT SOIL AND ALLUVIAL DEPOSITS

0-6': SOIL. GRAY-BROWN, SILTY, CLAYEY, GRADING TO YELLOW-BROWN SILTY FAT CLAY. MOIST AT 3'. SOME FINE TO MEDIUM, SUBANGULAR, PREDOMINANTLY VOLCANIC SAND.

6-7': SAND. MEDIUM GRAY, FINE TO MEDIUM, SUBANGULAR, PREDOMINANTLY DECOMPOSED VOLCANICS. WATER AT 6'.

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.)

39-47': SILTY CLAY. GRAY-GREEN FAT CLAY WITH MINOR VOLCANIC SANDS SIMILAR TO 15-39' INTERVAL.

47-49': SAND/GRAVEL. FINE TO VERY COARSE SUBANGULAR, PREDOMINANTLY GRAY VOLCANIC SANDS WITH GRAY, ROUNDED PEBBLES, OCCASIONALLY COBBLES, PREDOMINANTLY VOLCANICS. 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 ALTERED RED AND GREEN VOLCANIC PEBBLES. FINE TO MEDIUM CHALCEDONY, POSSIBLY VUG FILLINGS.

50-84': BASALT. BLACK, HARD, ANGULAR CUTTINGS 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; FASTER DRILLING.

95-115': PEBBLE CONGLOMERATE (?). FINE TO VERY COARSE, ANGULAR TO SUBROUNDED, MULTICOLORED 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' INTERVAL.

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 DETERMINED FROM CUTTINGS.

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 VERTICAL** VERTICAL

COORDINATES N.392,359; E.2,374,642 **TOTAL DEPTH** 735.0'

BEGUN 1-24-79 **FINISHED** 2-8-79

DEPTH TO WATER 6.0' **HOLE LOGGED BY** R. TURNER; L. PHILLIPS **DRILLER** TUGGLE; WARREN; SKAGGS; BABBITT

NOTES On water table levels, water return, character of drilling	Type and Size of Hole	% Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
DRILLING CONDITIONS (CONT.) 155-185': ALTERNATING HARD AND ROUGH TO SOFT AND SMOOTH. 185-195': HARD AND SLOW. 195-285': FAST AND SMOOTH TO MEDIUM SMOOTH. 285-305': HARD. 305-335': INTERMITTENT SLOW AND HARD TO VERY HARD AND SMOOTH TO ROUGH. 335-397': SLOW AND INTERMITTENTLY SMOOTH TO ROUGH. 397-402': MODERATELY FAST AND SMOOTH. 402-415': SLOW, HARD; INTERMITTENTLY SMOOTH TO ROUGH. 415-475': ERRATIC, SLOW TO MEDIUM FAST, SMOOTH TO ROUGH. 475-480': VERY SLOW, VERY ROUGH. 480-515': SLOW, MODERATE TO VERY ROUGH. 515-555': SLOW TO MODERATELY SLOW; MODERATELY SMOOTH TO ROUGH. 555-562': SLOW AND ROUGH-HARD. 562-575': MEDIUM FAST, SLIGHTLY ROUGH. 575-589': SLOW AND ROUGH. 589-595': MEDIUM FAST, SLIGHTLY ROUGH. 595-650': SLOW TO MEDIUM FAST, SMOOTH TO ROUGH. 650-665': SLOW AND ROUGH. 665-735': MODERATELY FAST, SMOOTH WITH THIN, ROUGH SPOTS. REPRESENTATIVE DRILLING FLUID TEMPERATURES (°F): 46° AT 70' 47° AT 75' 47° AT 100' 48° AT 135'	550 600 6½" RB 650 700 750 800 850 900 950	0	550 600 650 700 750 800 850 900 950	185-188': PEBBLE CONGLOMERATE (?) FINE TO VERY COARSE, PREDOMINANTLY VERY COARSE, MULTICOLORED, SUBROUNDED TO ANGULAR. INCREASE IN SUBROUNDED FRAGMENTS. VERY MINOR, TAN, SOFT CLAY. 188-195': PEBBLE CONGLOMERATE. SIMILAR TO 135-170' INTERVAL EXCEPT WITH MEDIUM GRAY, SOFT CLAY. 195-217': SANDY CLAY. LIGHT TO MEDIUM GRAY BROWN, SOFT CLAY WITH FINE TO MEDIUM SUBANGULAR TO SUBROUNDED, MULTICOLORED SAND. 217-230': SAND/CLAY. LIGHT TO MEDIUM GRAY BROWN, SOFT CLAY WITH OCCASIONAL RED BROWN, SOFT CLAY. SAND IS FINE TO VERY COARSE, ANGULAR TO SUBROUNDED, MULTICOLORED BUT PREDOMINANTLY DARK VOLCANICS. 230-265': SANDY CLAY. MEDIUM GRAY-BROWN, SOFT CLAY WITH FINE TO MEDIUM, OCCASIONAL COARSE, ANGULAR TO SUBROUNDED, MULTICOLORED SAND. 265-280': SANDY CLAY AS IN 230-265' INTERVAL WITH INCREASE IN VERY COARSE, MULTICOLORED BUT PREDOMINANTLY DARK, VOLCANIC LITHIC FRAGMENTS. 280-310': CLAYEY SAND. FINE TO COARSE, ANGULAR TO SUBROUNDED, MULTICOLORED SAND WITH GRAY-BROWN TO RED, SOFT CLAY. (POSSIBLY IN PEBBLE CONGLOMERATE AS ABOVE) 310-335': GEOLOGIST NOT PRESENT AT RIG; NO SAMPLES TAKEN. DRILLING CONDITIONS SIMILAR TO 280-310' INTERVAL. 335-350': CLAYEY SAND. SIMILAR TO 280-310' INTERVAL. 350-397': SANDY CLAY. LIGHT GRAY TO BROWN, SOFT CLAY WITH FINE TO MEDIUM, SUBANGULAR TO SUBROUNDED, MULTICOLORED BUT PREDOMINANTLY DARK VOLCANIC LITHIC FRAGMENTS. 397-402': CLAY. MEDIUM-GRAY BROWN, SOFT WITH MINOR SAND SIMILAR TO 350-397' INTERVAL. 402-415': SANDY CLAY. SIMILAR TO 350-397' INTERVAL. 415-455': SAND. ANGULAR TO SUBROUNDED, FINE TO MEDIUM, MULTICOLORED VOLCANIC FRAGMENTS WITH MINOR SUBANGULAR TO ROUNDED QUARTZ AND FELDSPAR. VERY MINOR LIGHT BROWN SOFT CLAY. 455-475': SAND. SIMILAR TO 415-455' INTERVAL WITH INCREASE IN GRAIN SIZE; COARSE TO VERY COARSE. 475-485': BASALT. BLACK, HARD, ANGULAR CUTTINGS WITH MULTICOLORED SANDS AS ABOVE; PROBABLY SLOUGHING OR RECIRCULATED CUTTINGS. 485- ±562': BASALT. SIMILAR TO 475-485' INTERVAL EXCEPT WITH MINOR THIN INTERBEDS OF LIGHT BROWN TO RED, SOFT CLAY.

EXPLANATION

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)

REPRESENTATIVE DRILLING FLUID TEMPERATURES (° F): (CONTINUED)

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'.

CAVING CONDITIONS:
AT 35': SQUEEZING WHEN RUNNING CASING.
AT 135': CAVING FROM ABOVE.
AT 150': HOLE SQUEEZING.
170-185': CAVING FROM ABOVE.

CASING RECORD:
12" STEEL SURFACE CASING INSTALLED TO 35' (COULD NOT ADVANCE TO 50' BECAUSE OF HOLE SQUEEZING), AND PERMANENTLY CEMENTED INTO HOLE.

GEOPHYSICAL LOGGING
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

HOLE COMPLETION: 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.

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)

±562-575': SAND/GRAVEL. FINE TO MEDIUM, ANGULAR TO SUBROUNDED, PREDOMINANTLY BLACK, ANGULAR VOLCANIC FRAGMENTS WITH INCREASE IN MULTICOLORED LITHIC FRAGMENTS AND RED-BROWN, SOFT CLAY.

575- ±635': SAND/GRAVEL. SIMILAR TO 562-575' INTERVAL EXCEPT WITH SLIGHT INCREASE IN SUBROUNDED, MULTICOLORED LITHIC FRAGMENTS.

±635-665': SAND/CLAY. FINE TO COARSE, ANGULAR TO SUBROUNDED, BLACK TO BROWN VOLCANIC FRAGMENTS WITH MINOR MULTICOLORED LITHIC FRAGMENTS. COMMON GRAY-BROWN SOFT CLAY IN VARYING AMOUNTS.

665-690': SANDY CLAY. 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.

690-735': SANDY CLAY. 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.

NOTE: GEOLOGIST NOT PRESENT AT DRILLING SITE WHILE 555-665' INTERVAL WAS BEING DRILLED.

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly - Lassen County PROJECT Susanville 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 N. Tuggle; D.Warren; R.Babbitt

NOTES
On water table levels, water return, character of drilling

Purpose of Hole: (1) temperature gradient; (2)geophysical properties; (3) geologic evaluation.

Landowner: City of Susanville.

Location: NE¼ SW¼ Section 32, T.29 N., R. 12 E., MDB&M.; on south bank of the Susanville River.

Drill Rig: Failing 1500

Drilling Methods: Drilled with bentonite mud and additives as required. 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 Conditions:
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

Type and Size of Hole	Recovery
6¾"	0
4½" D	
6½" RB	0
4½" D	
6½" RB	0

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 occasional 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 rotary transmission.
3- 1-79: Cored from 90-92'; repaired rotary transmission.
3- 2-79: Rig down for repairs to rotary transmission.
3- 5-79: Drilled to 113'. Hole caving.
3- 6-79: Drilled to 141'. Hole caving 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 circulation 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.

DEPTH: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
NOTE: Log based on rockbit cuttings.

0-27.0':
FILL, RECENT SOIL, AND ALLUVIAL DEPOSITS.

0-4': Compacted Man-Made Fill and Soil. Medium to dark brown clayey sand with fine to coarse, multicolored, subangular to subrounded sands.
4-11': Clayey Sand. Medium brown, fine to medium, predominantly subangular volcanic sands with medium brown soft to slightly firm, silty clay. Occasional coarse to very coarse, subrounded volcanic sands.
11-13': Clayey Sand. Dark chocolate brown; sand as in 4-11' interval with dark chocolate brown decomposed, volcanic sand/clay.
13-16': Sand/Pebbles/Cobbles. Dark gray, fine to very coarse cuttings, angular to subrounded, predominantly dark volcanics. Minor medium gray, soft clay.
16-17': Clayey Sand. Dark chocolate brown as in 11-13' interval.
17-27': Sand/Pebbles/Cobbles. 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, predominantly volcanics and decomposed volcanics. Occasional flood of chocolate brown decomposed volcanic sands/clay.

27-528' (T.D.):
PLEISTOCENE BASALT AND LAHONTAN (near shore) LAKE DEPOSITS

27-31': Basalt. Light gray to black, hard, angular cuttings. Minor light gray clay.
31-33': Fractured & Weathered Basalt (?). Lost circulation but mud turned red just before loss.
33-54': Basalt (?) Samples contaminated by LCM; drilling, and scattered cuttings similar to 27-31' interval.
54-69'(?): Samples very contaminated by LCM and bulk bentonite mud poured down hole.
69-75': Sand. Dark gray, fine to medium, angular to subangular, predominantly dark gray volcanics with minor light gray clay. Samples still contaminated with LCM.
75-90': Pebbles/Cobbles. Fine to

EXPLANATION

FEATURE: Susanville Anomaly--Lassen County PROJECT: Susanville Geothermal Investigations Hole No. SUZY-8

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal Investigations STATE California

HOLE NO. SUZY-8 LOCATION See Notes, Sheet 1 GROUND ELEVATION 4189.89 ANGLE FROM VERTICAL Vertical

COORDINATES N.396,668; E.2,373,994 TOTAL DEPTH 528.0'

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 return, character of drilling	Type and Size of Hole	% Recovery	DEPTH	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
Drilling Conditions (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.	6½" RB	0	550	75-90' (Continued): very coarse cuttings; angular (minor subangular), predominantly dark volcanics. 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 volcanics. 132-144': Cobbles/Pebbles/Sand. Pebbles and sand similar 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, angular to subrounded, multicolored but predominantly dark volcanics. Pebbles subangular to rounded, predominantly 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' interval with locally common light gray to white, soft clay. 215-232': Pebble Conglomerate. Similar to 193-198' interval with minor light brown soft clay. 232-238': Pebbles/Sand (Pebble Conglomerate ?) Fine to very coarse, angular to subrounded, mostly dark volcanic 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': [illegible]; lost circulation
60-527': 85-95%
527-528': 0%; lost circulation.

Representative Drilling Fluid Temperatures
48° at 25'

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE—CONTINUATION SHEET

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal Investigations, California

HOLE NO. SUZY-8 SHEET 3 OF 3

NOTES (Continued)

Representative Drilling Fluid Temperatures (° F): (Cont.)

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.

Caving Conditions:
86-125': Caving sands and gravel.

Casing Record:
No casing used.

Geophysical Logging
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)

Hole Completion: 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.

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (Continued)

238-260' (Continued): fragments with common light gray to white, soft clay. Minor medium brown soft clay.

260-293': Clayey Sand. 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.

293-315': Sand. Fine to coarse, angular to subrounded, dark volcanic fragments with minor multicolored lithic fragments. Minor light gray to white soft clay.

315-355': Clayey Sand. 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.

355-360': Clayey Sand. 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.

360-363': Pebbles/Sand. Fine to very coarse, angular to subrounded, but predominantly angular, dark volcanics with minor light gray soft clay.

363-411': Clayey Sand. 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.

411 - ±415': Pebbles/Sand. Fine to very coarse, angular to subrounded, predominantly dark volcanic fragments with minor multicolored lithic fragments. Minor light gray clay.

±415- ±435': Sandy Clay. Medium red-brown soft clay with multicolored, angular to subrounded, fine to medium sand (not at site at lithologic change).

±435- ±443': Clayey Sand. 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.

±443-450': Basalt (?) (Possibly basaltic sand). Fine to coarse, angular (very minor subrounded) black basalt with very minor flesh-colored claystone as above (gradual lithology change).

450-453': Basalt (?) (Possibly Clayey Sand). Basalt similar to above interval with red, soft clay (possibly weathered volcanics or ash).

453-473': Basalt. Fine to coarse, angular, black with very minor red-brown to medium brown clay. Some multicolored sands, probably slough from above.

473-478' (CORE) Basalt. 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.

478-483': Basalt. Similar to 473-478' interval.

483-500': Basalt. Similar to 473-478' interval but harder; i.e., less fractured and vesicular. No change in samples.

500-528': Basalt. Fine to coarse, angular, hard cuttings with slight increase in red-brown, slightly firm clay (opal ?). Less dense than 483-500' interval.

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County **PROJECT** Susanville Geothermal Investigations **STATE** California

HOLE NO. SUZY-9 **LOCATION** See Notes **GROUND ELEVATION** 4210' **ANGLE FROM VERTICAL** Vertical

COORDINATES N.396,276; E.2,372,187 **TOTAL DEPTH** 445.0'

BEGUN 3-27-79 **FINISHED** 4-12-79

DEPTH TO WATER Not Determined **HOLE LOGGED BY** G.Hollinger; R.Turner **DRILLER** N.Tuggle; D.Warren

NOTES
On water table levels, water return, character of drilling

Purpose of Hole:
(1) Temperature gradient; (2) geophysical properties; (3) geologic evaluation.

Landowner: City of Susanville.

Location: SE¼ SE¼ Section 31, T. 30 N., R. 12 E.; near intersection of S. Lassen Street and S. P. Railroad.

Drill Rig:
Failing 1500

Drilling Methods:
Rockbit drilled using bentonite drilling mud and shaker, 0-443'.
443-445': *4x5½" 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

Type and Size of Hole

50 — 6¾ RB — 100 — 150 — 200 — 6¾ RB — 250 — 300 — 350 — 400 — 7x5½ — 450

% Core Recovery

0 — 100

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.

DEPTH

50 — 100 — 150 — 200 — 250 — 300 — 350 — 400 — 450

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

NOTE: Log based on rockbit cuttings.

0-10.0':
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

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)

Representative Drilling Fluid Temperatures (°F) (Continued)
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

Squeezing Conditions:
0-141': Some squeezing required reaming to keep hole open.

Geophysical Logging:
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

Hole Completion:
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.

FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Cont.)

72.0-82.0': Clayey Sand/Gravel. Fine to coarse, angular to subrounded, red to red-brown decomposed volcanics and black volcanic lithic fragments. Common red-brown soft clay.

82.0-110.0': Sandy Clay. Gray-brown to red-brown soft clay with fine to coarse, angular to subrounded, multicolored sands, locally red-brown decomposed volcanics.

110.0-138.0': Clay. Light to medium gray, occasionally with a brown cast, locally white, soft silty clay with minor very fine to medium, subangular dark sands.

138.0-185'±: Sandy Clay. White to light gray, soft clay; silty with very fine to medium, subangular to subrounded, multicolored sands.

185± -206.0': Sandy Clay. Light to medium gray-green, soft with minor multicolored sands. Gradual change in color.

206.0- ±270.0': Sandy Clay. Light red-brown; soft with minor fine to medium, multicolored sands. Occasional thin, light to medium gray, soft clay.

270± -333': Sandy Clay. Medium gray; soft with slight increase in dark, angular, fine volcanic sands.

333-365': Volcanics (Andesite?) Medium gray-green, soft to slightly firm, fine-grained volcanics with fine to medium, subangular, dark volcanic sands. Minor quartz.

NOTE: Top of volcanics inferred from slightly slower drilling and slight increase in volcanic fragments.

365-380': Volcanics(Andesite ?) 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.

NOTE: Probable much recirculation of cuttings.

380-420': Volcanics(Andesite ?). Medium-gray-green, moderate-soft to firm, with minor multicolored sands as in 365-380' interval. Minor calcite.

420-443': Volcanics(Andesite ?). Similar to 380-420' interval but with increased multicolored, fine to coarse, subangular to subrounded sands.

443-445': (core) Andesite Agglomerate. 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.

FEATURE: Susanville Anomaly--Lassen County PROJECT: Susanville Geothermal Investigations HOLE NO. SUZY-9

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County **PROJECT** Susanville Geothermal Investigations **STATE** California

HOLE NO. SUZY-9A **LOCATION** See Note **GROUND ELEVATION** 4210' **ANGLE FROM VERTICAL** Vertical

COORDINATES N.396,288; E.2,372,122 **TOTAL DEPTH** 818'

BEGUN 7-17-79 **FINISHED** 9-7-79

DEPTH TO WATER ±15' **HOLE LOGGED BY** G. Hollinger; R.Turner **DRILLER** N.Tuggle; R.Swank; A.Velarde

NOTES On water table levels, water return, character of drilling

Purpose of Hole: (1) Temperature gradient; (2) geophysical properties; (3) geologic evaluation.

Landowner: City of Susanville.

Location: SE¼ SE¼ 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.

Drill Rig: Failing 1500

Drilling Methods: Drilled with bentonite mud and additives as required. Used three mudpits.
0-32': 13-7/8" rockbit.
32-78': 10-5/8" rockbit.
78-818': 6½" rockbit.
390-394.3' } 4x5½"
507-511.5' } :diamond
682.5-687' } bit with split tube inner barrel.

Drilling Conditions:
0-6.5': Very slow, very rough.
6.5-22': Medium fast, smooth to slightly rough.
22-32': Slow, smooth to occasionally rough.
32-40': Fast, smooth.
40-55': Slow, rough, erratic.
55-75': Very slow, very rough.
75-78': Slow, smooth.
78-190': Medium to medium fast, smooth to occasionally rough.
190-230': Intermittent

Type and Size of Hole	% Recovery
13⅜" RB	0
10⅝" RB	0
6½" RB	0
6½" RB	0

DAILY SUMMARY OF DRILLING OPERATIONS:

7-17/18-79: Moved to site and rigged up (1 shift)
7-19-79: Complete rigging up and mixing mud. Drilled to 6'.
7-20-79: Repaired rig electrical system. Drilled to 22'.
7-23-79: Drilled to 32'. Attempted to run 12" casing; welder inoperative.
7-24-79: Ran 12" casing to 31' and cemented in.
7-25-79: Drilled to 65'.
7-26-79: Drilled to 78'; made minor rig repairs.
7-27-79: Ran 8" *blank steel casing to 78'. Cemented in 0-26'.*
7-30-79: Repaired rig.
7-31-79: Drilled to 350' (2 shifts).
8- 1-79: Drilled to 390'. Cored from 390-395'. Drilled to 410'.
8- 2-79: Drilled to 454' and lost circulation.
8- 3-79: No drilling due to no bentonite at site.
8- 6-79: Drilled to 460' and twisted off. Recovered fish.
8- 7-79: Drilled to 477'. Rig mud pump unable to start.
8- 8-79: Replaced rig starter motor. Drilled to 507'. Cored to 511.5'. Drilled to 527'.

DEPTH: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

NOTE: Log based on rockbit cuttings. Lithologic descriptions often differ from SUZY-9 due to surface casings preventing contamination and larger tooth bits producing better cuttings on SUZY-9A.

0-60'±:
RECENT SOIL AND STREAM CHANNEL DEPOSITS

0-6': Soil/Sand/Gravel/Cobbles. Medium brown silty, clayey soil with fine to very coarse, angular to rounded, dark volcanics and clear to milky quartz sands and subangular to rounded dark volcanic gravel and cobbles.

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)

34-40': Sand. Fine to coarse, some very coarse, angular to subrounded, multicolored but common dark volcanics, white quartz and red weathered volcanics.

40-55': Sand/Gravel. Fine to coarse, angular to subrounded, multicolored gravels with sand as in 34-40' interval.

55-60': Sand/Gravel. As in 40-55' interval with occasional dark, subrounded cobble and increased fine to coarse gravel.

60± -818':
PLEISTOCENE VOLCANICS

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 cuttings.

74-78': Volcanics (Ash or mudflow). White to light pink, soft, partially hydrated clay to moderately firm and brittle with fine grained, angular to subrounded, multicolored lithic fragments. *Continued* fine to coarse sands and gravels, probably slough.

78-89': Volcanics (Ash or mudflow). Medium brown with pink cast, moderately firm, brittle, predominantly fine grained, angular to

EXPLANATION

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County **PROJECT** Susanville Geothermal Investigations **STATE** California

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

DEPTH TO WATER +-15' **HOLE LOGGED BY** G.Hollinger;R.Turner;N.Tuggle;R.Swank; **DRILLER** A.Velarde

NOTES
On water table levels, water return, character of drilling

190-230' (Cont.): slow to fast, smooth to moderately rough.
230-295': Fast, smooth.
295-395': Slow, smooth.
395-410': Slow, medium 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 occasionally rough.
790-807': Slow, medium rough.
807-818': Slow to medium, medium smooth.

ESTIMATED DRILLING FLUID RETURNS:
0-390': 100%
390-454': 90-95%
@ 454': Lost circulation.
454-467': 95-100%
@ 468': Lost circulation.
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 Drilling Fluid Temperatures (°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'

Type and Size of Hole: 6½" RB; 6½" RB

Recovery: 0; 0

DAILY SUMMARY OF DRILLING OPERATIONS:(CONT)

8- 9-79: Drilled to 584' and twisted off.
8-10-79: Retrieved fish. Mud pump inoperative; need parts from Folsom.
8-13-79: Repaired mud pump (1 shift)
8-14-79: Drilled to 592'
8-15-79: Drilled to 612'
8-16-79: Drilled to 636'
8-17-79: Drilled to 682'
8-20-79: Cored to 687' and conditioned mud for logging.
8-21-79: Ran open-hole geophysical logs, cleaned out *pits*.
8-22-79: Mixed up mud, waiting for additional barite from Folsom.
8-23-79: Mixed up mud; drilled to 694' and twisted off.
8-24-79: Repaired rig; retrieved fish.
8-27-79: Repaired rig; run in hole.
8-28-79: Drilled to 747'.
8-29-79: Drilled to 807'
8-30-79: Drilled to 818' and twisted off. Fishing for drill string.
8-31-79: Fishing for drill string; decided to end hole at 818'.
9- 3-79: HOLIDAY.
9- 4-79: Crew attending meeting in Folsom and traveling to Susanville.
9- 5-79: Recovered fish; two cones missing from bit.
9- 6-79: Installed 2" water-filled pipe to 818' and cemented in guard. Started tearing out.
9- 7-79: Completed tearing out and moving equipment to Folsom.

DEPTH: 550, 600, 650, 700, 750, 800, 850, 900, 950

CLASSIFICATION AND PHYSICAL CONDITION

78-89' (Cont.): subrounded, multicolored lithic fragments.

89-90': Volcanics. Medium-gray, aphanitic, moderately firm, brittle.

90-91': Clayey Sand (?) Fine to very coarse, gray-green, predominantly angular, some subrounded volcanic sand and common pink, soft clay, probably hydrated ash.

91-112': Volcanics (ash or mudflow) Medium-gray brown to pink, slightly soft to moderately firm, brittle, very fine to fine-grained matrix with angular to subrounded, multicolored lithic fragments.

112-125': Volcanics. As in 91-112' interval, predominantly brown-pink.

125-160': Volcanics (ash or mudflow) Light to medium gray, moderately firm, brittle, very fine to fine grain matrix with angular to subrounded, multicolored lithic fragments. Some primary hornblende.

160-175': Volcanics. As in 125-160' interval; predominantly medium gray-green to gray color. Some medium-grained lithic fragments.

175-182': Volcanics (ash or mudflow) Medium pink, soft and hydrated to moderately firm and brittle, very fine-grained matrix with fine to medium-grained, angular to subrounded, multicolored lithic fragments.

182-190': Volcanics as in 175-182' interval with alternating gray-green, medium pink, red, medium brown colors.

190- ±220': Volcanics (ash or mudflow). Medium to dark red, moderately firm, brittle, very fine grained with multicolored lithic fragments as in 175-182' interval.

±220-228': Volcanics (Ash or mudflow), as in 190-220± interval with medium red, very fine grained, slightly soft to moderately firm volcanics with few multicolored lithic fragments.

228- ±240': Volcanics. Medium gray, firm to moderately soft, slightly hydrated, aphanitic, with some dark, fine-grained, predominantly angular lithic fragments.

EXPLANATION

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)

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'

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'.

FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Continued)

228- ±240' (Cont.): Calcareous in part.

±240-252': Clay. Medium gray, soft to slightly firm with minor lithic fragments as in 228-240±' interval. Probably volcanic.

252-295': Volcanics. 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': Volcanics. Medium gray to gray-green, firm, brittle, aphanitic; calcareous in part. Occasional white, soft clay; trace of white calcite.

332-350': Volcanics. As in 295-332' interval with minor red-brown to pink, aphanitic volcanics. Slight increase in white, soft clay.

350-362': Volcanics. As in 332-350' interval with increased red-brown, soft to slightly firm, aphanitic volcanics; probably ash.

362-390': Volcanics. 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): Andesite Agglomerate. 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': Andesite Agglomerate. Similar to 390-394.3' interval.

415-460': Andesite Agglomerate. Similar to 390-394.3' interval with variable amounts of light gray, soft clay, probably ash. Minor to common white calcite veinlets.

460-475': Andesite Agglomerate. Similar to 415-460' interval with increased white to clear calcite veins and remineralization (?). Minor fine-grained mafic minerals.

475-500': Volcanics. 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': Volcanics. Mud turned light gray but no change in lithic samples--probably completely hydrated ash.

500.5-507': Volcanics. As in 475-500' interval.

507-511.5' (CORE): Andesite Agglomerate. 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': Andesite Agglomerate. Similar to 507-511.5' interval with variable amounts of white and clear calcite veinlets.

595-630': Volcanics. 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*

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 ?).

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal Investigations STATE California

HOLE NO. SUZY-10 LOCATION See Notes GROUND ELEVATION 4237' ANGLE FROM VERTICAL Vertical

BEGUN 4-16-79 FINISHED 5-11-79 COORDINATES N.400,625; E.2,372,595 TOTAL DEPTH 647.5'

DEPTH TO WATER Not Determined HOLE LOGGED BY Robert L. Turner DRILLER N.Tuggle;D.Warren

NOTES
On water table levels, water return, character of drilling

Purpose of Hole:
(1) Temperature gradient; (2) Geophysical properties; (3) geologic evaluation.

Landowner: City of Susanville

Location: SE¼ SE¼ 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 5¼" 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

Type and Size of Hole: 9⅞" RB; 6¾" RB; 6¾" RB; 6¾" RB

Recovery: 0; 0

DAILY SUMMARY OF DRILLING OPERATIONS

4-16-79: Failing 1500 moved to site and rigged up.
4-17-79: Rigged up.
4-18-79: Drilled to 18', much caving.
4-19-79: Drilled to 32'.
4-20-79: Drilled to 54'.
4-23-79: Drilled to 73'; stuck in hole at 43'.
4-24-79: Stuck in hole, pulled free. Reamed to 17' to open hole for casing.
4-25-79: Reamed to 24'. Ran 8" casing to 24'. Drilled to 74'.
4-26-79: Drilled to 132'. Stuck in hole when pulling bit.
4-27-79: Stuck in hole. Pulled free; 8" casing failing.
4-30-79: Repair rotory transmission.
5- 1-79: Completed repairs. Reamed hole to 40' for reinstallation of 8" casing.
5- 2-79: Reamed to 51'. Stuck pipe.
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.
5- 8-79: Pulled loose. Reset loosened 8" casing and recemented.
5- 9-79: Drilled to 615'.

DEPTH: 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
NOTE: Log based on rockbit cuttings.

0-13':
FILL & RECENT SOIL
Medium-brown, silty with fine to coarse, angular to rounded, black to brown, volcanic sand. Common white quartz. Occasional subrounded brown gravel and cobbles.

13-647.5':
PLEISTOCENE VOLCANICS AND LAHONTAN (near shore) LAKE DEPOSITS.

13-17': Basalt. Black, hard, angular cuttings, possibly boulders.
17-18': Clay. Gray-brown, silty, soft.
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.
65-66': Clay. Medium tan, soft, silty, probably weathered and hydrated tuff or basalt.
66-85': Basalt (Flow or boulders?). Medium gray to black, angular, fine to coarse cuttings. Occasional minor milky quartz veinlets on vug fillings.
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.
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.
115-139': Basalt (Flow or boulders?) Medium gray to black, fine to very coarse, angular cuttings. Locally common milky quartz.
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.
157-159': Cobbles. Black basalt, hard.

EXPLANATION

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal Investigations STATE California

HOLE NO. SUZY-10 LOCATION See Notes GROUND ELEVATION 4237' ANGLE FROM VERTICAL Vertical

COORDINATES N.400,625; E.2,372,595 TOTAL DEPTH 647.5'

BEGUN 4-16-79 FINISHED 5-11-79

DEPTH TO WATER Not Determined HOLE LOGGED BY Robert L. Turner DRILLER N.Tuggle; D.Warren

NOTES On water table levels, water return, character of drilling

Drilling Conditions (Cont.)
153-393': (Cont.) fast, smooth to occasionally rough.
393-473': Medium, smooth.
473-593': Medium, smooth to occasionally rough.
593-615': Slow, smooth.
615-647.5': Slow, smooth to medium rough.

Estimated Drilling Fluid Return:
0-647.5': 95-100%
NOTE: Hole making 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 ±65 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 casing to 52'.

Geophysical Logging:
The following geophysical logs were run by the USBR, Denver Office, on 6-29-79.

Type and Size of Hole: 6¾" RB

% Core Recovery: 0

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.

DEPTH: 550, 600, 650, 700, 750, 800, 850, 900, 950

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

159-162': Sand. Fine to medium, angular to subrounded, predominantly dark volcanics with medium brown, moderately soft, reworked, fine-grained tuff. Occasional thin, coarse-grained volcanic sand beds.

162-180': Sand. Fine to medium, angular to subrounded, medium brown to medium gray, predominantly weathered and unweathered volcanics. Locally common white to medium brown, partially welded tuff. Trace of milky quartz, angular to subrounded.

180-200': Sand as in 162-180' interval with increased amounts of light to medium brown, partially welded tuff.

200-238': Sand as in 180-200' interval 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' interval 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 volcanics. Common milky quartz, variable amounts but minor brown soft clay.

260-275': Clayey Sand. Fine to medium, minor coarse, angular to subrounded, multicolored but predominantly dark volcanics. Common medium 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 subrounded, fine to medium, multicolored sand. Minor light gray, fine-grain tuff.

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE—CONTINUATION SHEET

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

HOLE NO SUZY-10 SHEET 3 OF 3

NOTES (Continued)	FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION (Cont.)
Geophysical Logging (Cont.): Logs were run in 2" steep pipe--no open hole logs were run: (1) Natural Gamma (2) Neutron (3) Temperature Hole Completion: 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.	335-342': Sandy Clay. Similar to 306-335' interval with predominantly dark volcanic, fine to medium, angular to subrounded sands. Minor multicolored sand. 342-420': Clay. Medium-gray brown, soft with minor, predominantly dark, fine to medium, angular to subrounded volcanic sand. 420- ±475': Clay. Medium gray-brown, soft, with predominantly fine-grain, angular to subrounded, dark volcanic sand. ±475-492': Sandy Clay. 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.) 492-498': Sand. Fine to coarse, angular to rounded, multicolored with minor soft, medium gray-brown clay. Some gravel, possibly slough from casing grout. 498-535': Sand. Similar to 492-498' interval with light gray to pink, slightly firm claystone. Minor medium brown, fine-grain tuff. 535-564': Clayey Sand. 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. 564-570': Sand/Gravel . 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.) 570-593': Sand (Possible Volcanic Flow). 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. 593-643': Volcanics. 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 643-647.5' (CORE): Andesite Breccia. 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.

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Susanville Anomaly--Lassen County | PROJECT: Susanville Geothermal Investigations | STATE: California

HOLE NO. SUZY-11 | LOCATION: See Notes | GROUND ELEVATION: 4284' | ANGLE FROM VERTICAL: Vertical

COORDINATES: N.397,306; E.2,371,270 | TOTAL DEPTH: 798.0'

BEGUN: 5-14-79 | FINISHED: 7-17-79

DEPTH TO WATER: 52.0' | HOLE LOGGED BY: Robert L. Turner | DRILLER: N.Tuggle;D.Warren; W.Skaggs;R.Swank

NOTES
On water table levels, water return, character of drilling

Purpose of Hole: (1) Temperature gradient; (2) geophysical properties; (3) geologic evaluation.

Landowner: Jim Pearson; Susanville, California

Location: NE¼ SE¼ Section 31, T. 30 N., R. 12 E.; south of Miller Road.

Drill Rig: Failing 1500

Drilling Methods:
Drilled with bentonite mud and additives as required. Used one long mudpit due to space limitations.
0-30': 9-7/8" rockbit for 8" surface casing.
30-533': 6-3/4" rockbit.
533-797.5': 6¼" rockbit.
273-275', 388-390.5', 533-537.8', 643-647': 4x5¼" diamond bit with split-tube inner barrel

Drilling Conditions:
0-28.0': Moderately fast, erratic.
28-30': Slow, rough.
30-35': Slow, rough.
35-56': Medium, smooth.
56-104': Slow, moderately rough.
104-133': Medium, moderately rough.
133-138': Fast, smooth.
138-213': Medium, moderately rough.

Type and Size of Hole	% Core Recovery	Daily Summary of Drilling Operations	DEPTH
9⅞" RB	0	5-14/15-79: Moved to site and rigged up.	
		5-16-79: Continued rigging up and drilled to 23'.	
		5-17-79: Drilled to 30'; ran 8" casing to 28.5'	50
		5-18-79: Cemented in surface casing	
		5-21-79: Added cement to casing annulas, mixed mud.	
		5-22-79: Drilled to 104'	
		5-23-79: Drilled to 213'.	100
6¾" RB			
	0		150
		5-24-79: Drilled to 273'; cored from 273-275'.	200
			250
4½"x4½"D		5-25-79: Drilled to 333'.	
		5-28-79: Holiday.	
			300
6¾" RB	0		
		5-29-79: Drilled to 388'.	350
		5-30-79: Cored from 388-390.5'; drilled to 400' and twisted off. Retrieved fish.	
4½"x4½"D			
		5-31-79: Drilled to 401' and twisted off. Retried fish and drilled to 438' after rig engine repairs.	400
6¾" RB	0	6- 1-79: Drilled to 447' when kelly swivel washed out.	
		6- 4-79: Replaced swivel and overhauled mud pump. Drilled to 454', when rig radiator leaked through large hole.	450
		6- 5-79: Repaired radiator; drilled to 480'.	
		6- 6-79: Drilled to 510' and twisted	500

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION
NOTE: Log prepared from rockbit cuttings.

0-798': PLEISTOCENE VOLCANICS

0-6': Soil and Fill. White to medium 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.

6-28': Volcanics (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.

28-35': Volcanic Basalt. Hard, black, fine-grained, angular cuttings with thin (less than 2") interbeds of red-brown clay; soft to slightly firm.

35-37': Clay. Gray-brown to pink, soft, hydrated with red-brown decomposed volcanics and black basalt. Minor milky quartz.

37-54': Clay. Pink, soft, with very minor basalt, probably slough.

54- ±70': Sand/Clay. 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.

±70-118': Tuff. Light to medium gray-brown, very fine-grained; soft and hydrated to moderately firm. Continued sand as in 54-70' interval, possibly slough. Occasional flood of tan soft clay.

118-121': Tuff. Light gray to light red, predominantly soft, hydrated clay, minor multicolored sands as in 54-70' interval, possibly slough.

NOTE: ABUNDANT RECYCLING OF CUTTINGS

121-128': Tuff. Light gray-brown, fine-grained, soft and hydrated to moderately firm. Minor white vein quartz, minor fine to medium, multicolored sand.

EXPLANATION

LS-1264-A (4/75)

GEOLOGIC LOG OF DRILL HOLE

FEATURE Susanville Anomaly--Lassen County | PROJECT Susanville Geothermal Investigations | STATE California

HOLE NO. SUZY-11 | LOCATION COORDINATES See Notes N.397,306; E.2,371,270 | GROUND ELEVATION 4284' | TOTAL DEPTH 798.0' | ANGLE FROM VERTICAL Vertical

BEGUN 5-14-79 | FINISHED 7-17-79

DEPTH TO WATER 52.0' | HOLE LOGGED BY Robert L. Turner | DRILLER N.Tuggle;D.Warren; W.Skaggs;R.Swank

NOTES On water table levels, water return, character of drilling

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).

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.

Type and Size of Hole: 6¾" RB; 6½" RB; 6½" RB

% Core Recovery: 0; 0; 0

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 Failling 1500 rig being outfilled 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.

DEPTH: 550, 600, 650, 700, 750, 800, 850, 900, 950

FIELD VISUAL CLASSIFICATION AND PHYSICAL CONDITION

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 contamined with recycled cuttings.

±300-330': Volcanics. Medium

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)

Representative Drilling Fluid Temperatures (°F) (Cont.)

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'

Caving Conditions:
0-30': Caving.

Casing Record:
0-28.5': 8" black steel casing.

Geophysical Logging:
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

(1) resistivity
(2) Gamma-Gamma
(3) Sonic
(4) Caliber
(5) Temperature
} Ran in open hole to 692'

(6) Natural gamma
(7) Neutron
} Ran in 2" water filled steel pipe to 797.5' total depth.

Hole Completion: 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.

FIELD VISUAL CLASSIFICATION & PHYSICAL CONDITION (Cont.)

±300-330': (Continued) gray to gray-green, fine-grained, moderately firm, brittle.

330-388': Volcanics. 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.

388-390.5' (CORE): Volcanics (basalt ?) 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 cast inclusions up to 2".

390.5-399': Volcanics (basalt ?) as in cored interval, 388-390.5'.

399-403': Sandy Clay. 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.

403-449': Volcanics. 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

449-488': Volcanics as in 403-449' interval with minor light brown, soft to moderately firm clay.

488-495': Volcanics. Medium gray to grey-green, moderately firm, brittle, fine-grained with common medium red, soft to slightly firm clay. Locally common white calcite and quartz.

495-502': Volcanics. Light to medium gray, gray-green and black, moderately firm, brittle, fine-grained with minor white calcite and quartz and light brown, soft clay.

502-533': Volcanics. 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.

533-537.8' (CORE): Volcanic Agglomerate. 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.

537.8-±573': Volcanic Agglomerate. As in 533-537.8' interval.

±573-579': Clay. Medium-gray, very soft and hydrated with minor medium-gray to gray-green, angular volcanic fragments as in cored interval (533-537.8').

579-585': Volcanics. Medium-gray to gray-green, moderately firm, brittle, fine-grained with minor clay as in 573-579' interval.

585-595': Volcanics as in 579-585' interval with some dark gray, moderately firm, brittle, fine-grained volcanics.

595-615': Volcanics. 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.

615-630': Volcanics. Medium gray to gray-green, moderately firm, brittle, fine-grained with minor soft, medium gray clay. Trace of white calcite and quartz.

630-643': Volcanics. Gray-green, soft, fine-grained with

GEOLOGIC LOG OF DRILL HOLE—CONTINUATION SHEET

FEATURE Susanville Anomaly--Lassen County PROJECT Susanville Geothermal Investigations

HOLE NO. SUZY-11 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 remineralized. 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.

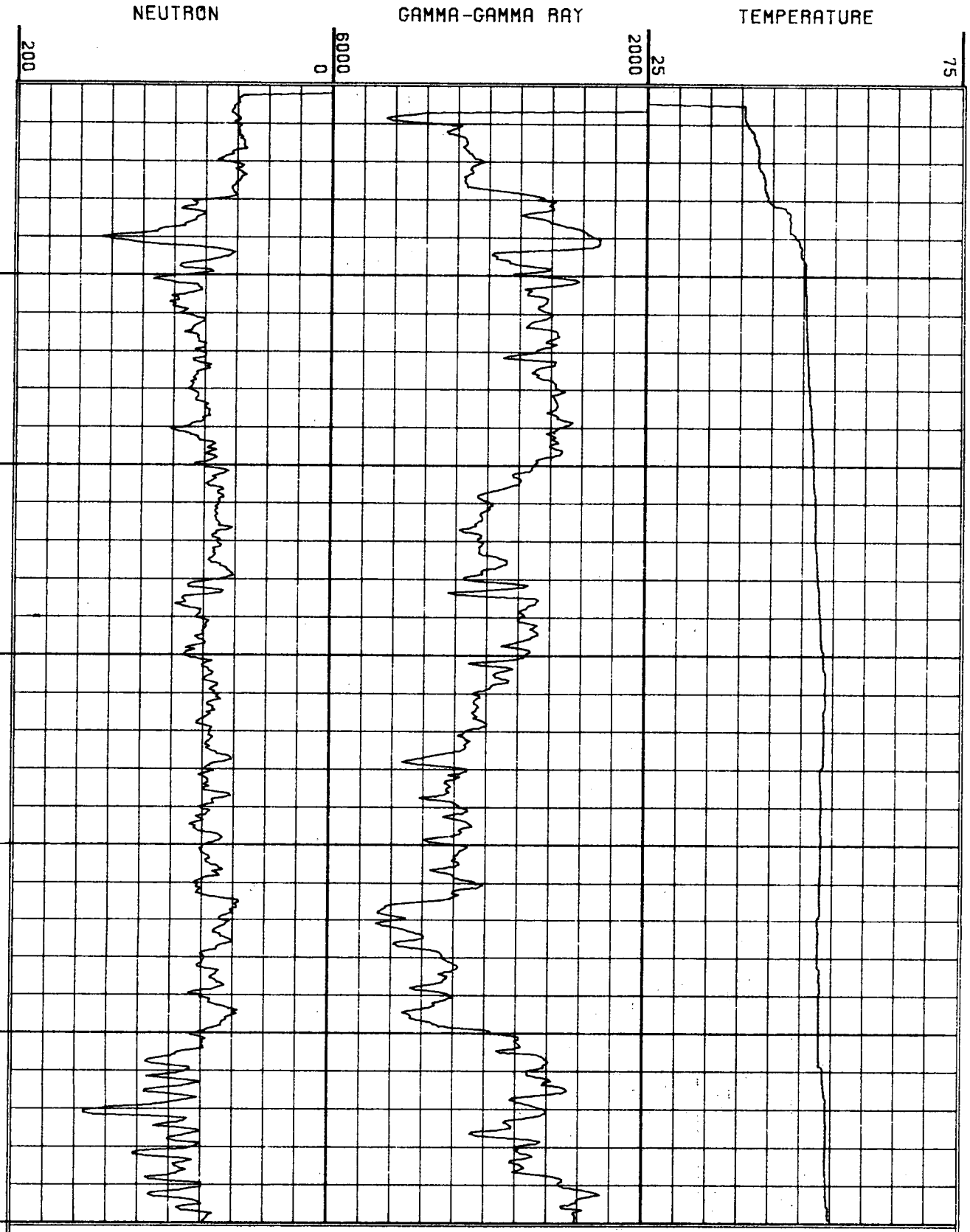
698- ±708': Volcanics. Mostly medium gray, soft clay with gray-green and black, firm, fine-grained volcanics.

±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

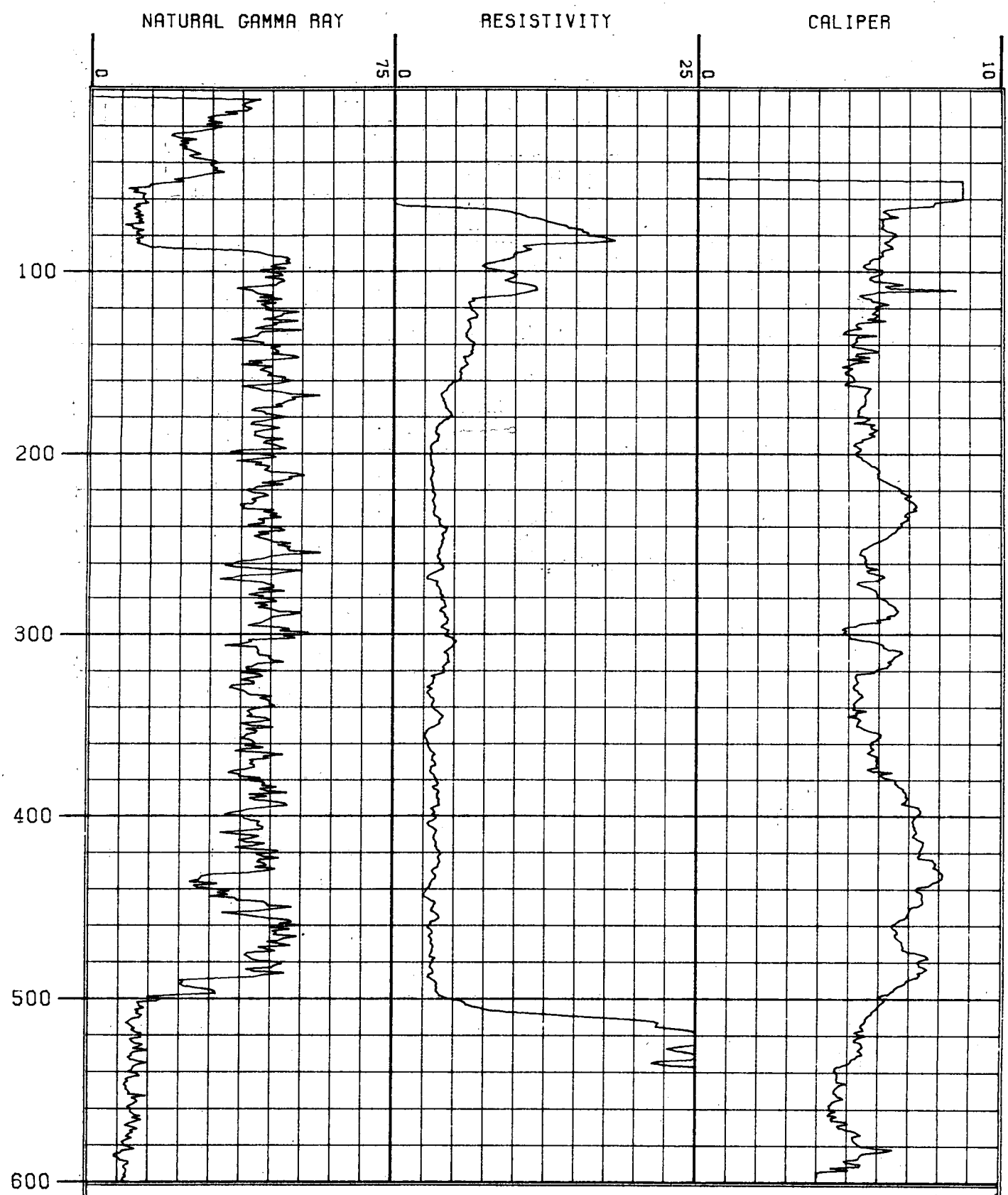
GEOPHYSICAL WELL LOGS



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY1 -- GEOPHYSICAL WELL LOGS

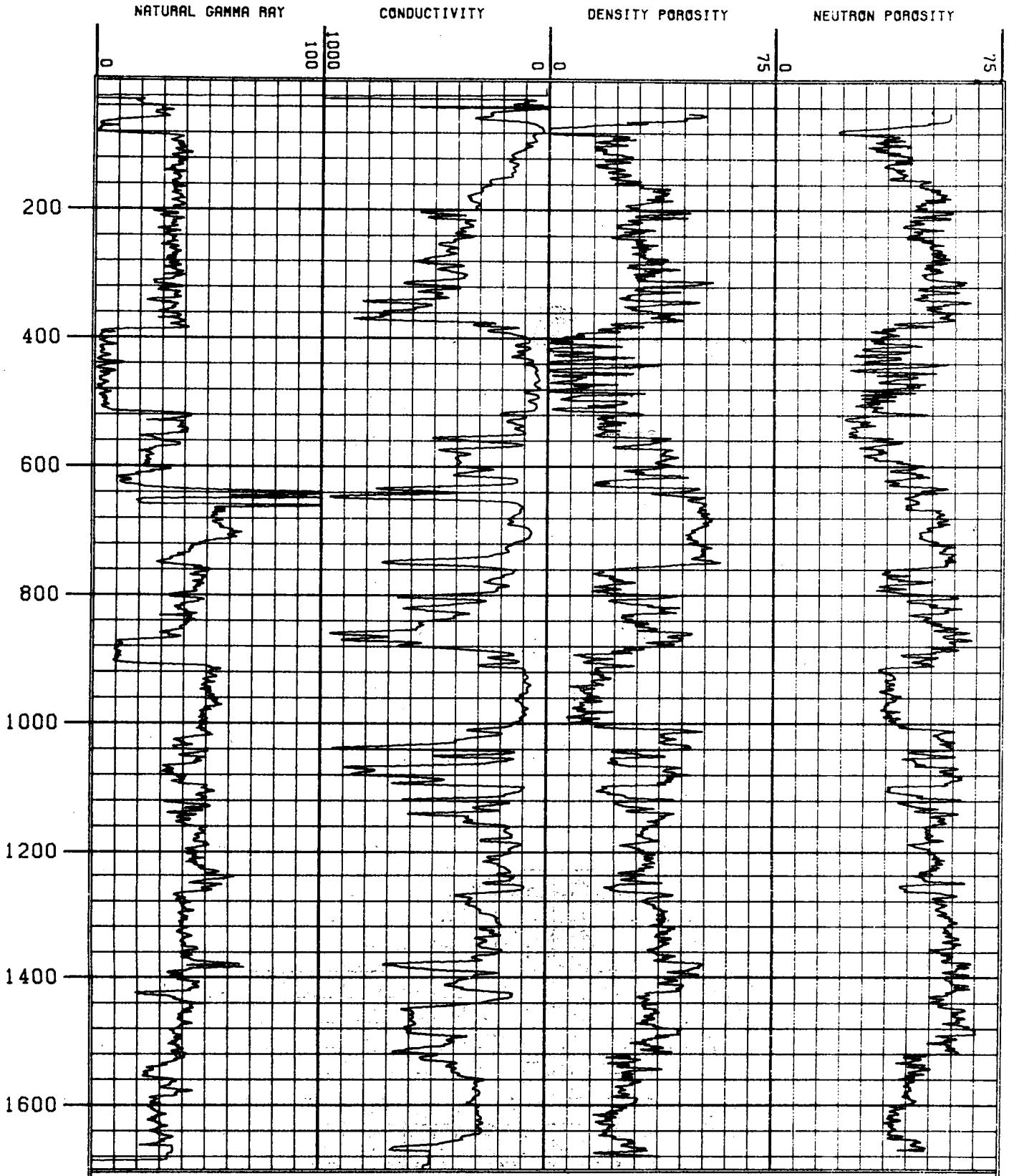
XBL 803-8444



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY1 -- GEOPHYSICAL WELL LOGS

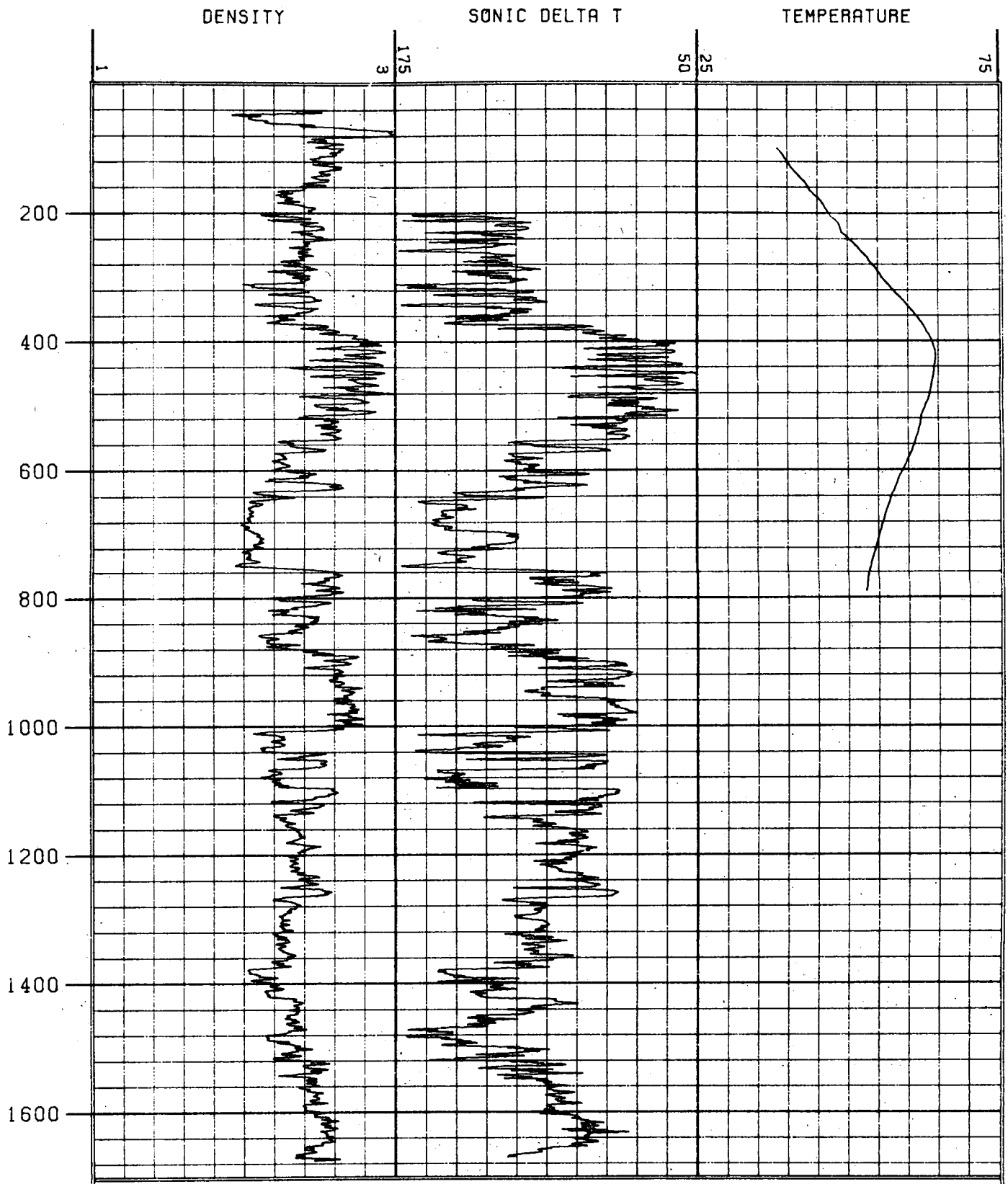
XBL 803-8445



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY2 -- GEOPHYSICAL WELL LOGS

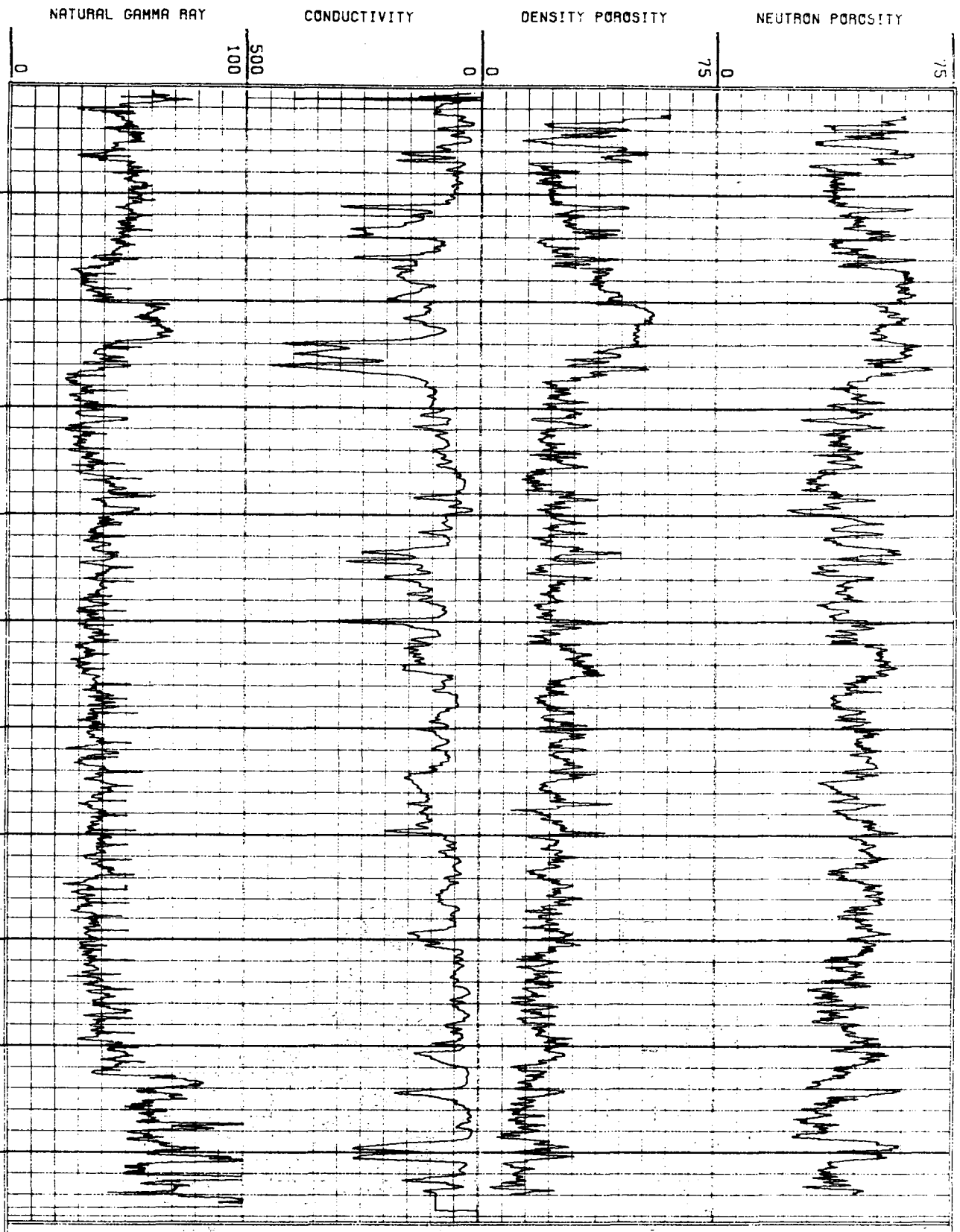
XBL 803-8440



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY2 -- GEOPHYSICAL WELL LOGS

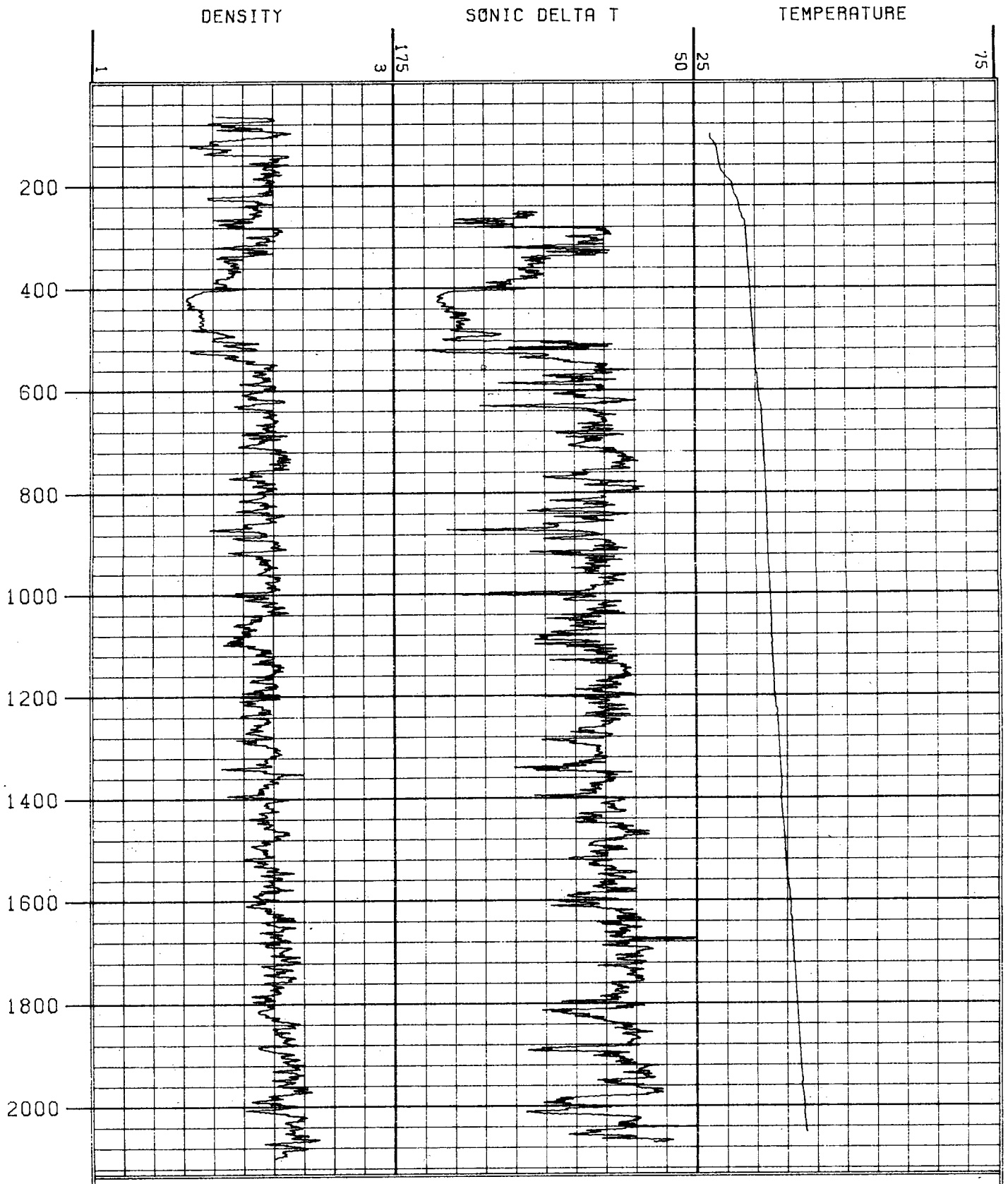
XBL 803-8451



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY3 -- GEOPHYSICAL WELL LOGS

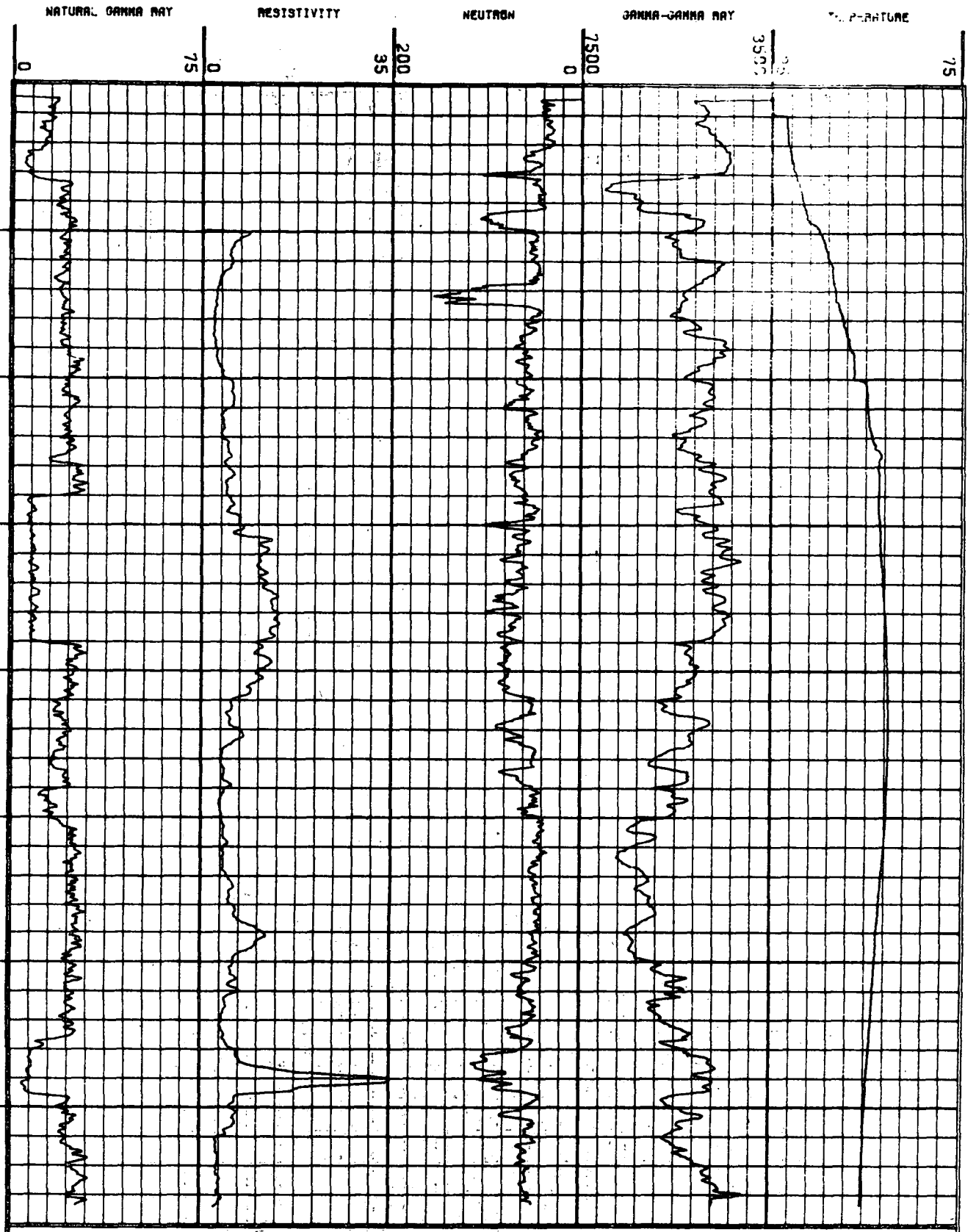
XBL 803-8441



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY3 -- GEOPHYSICAL WELL LOGS

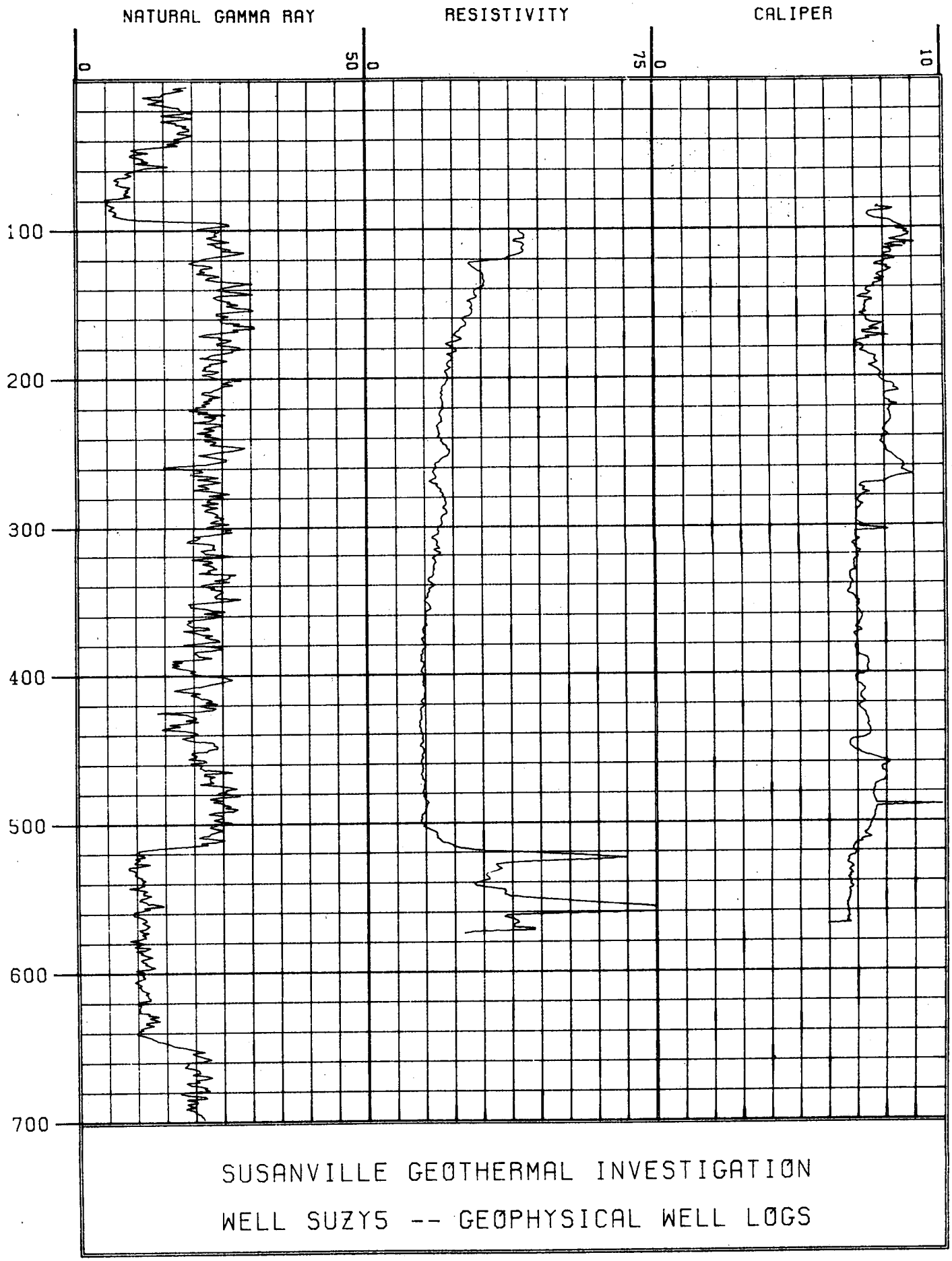
XBL 803-8438



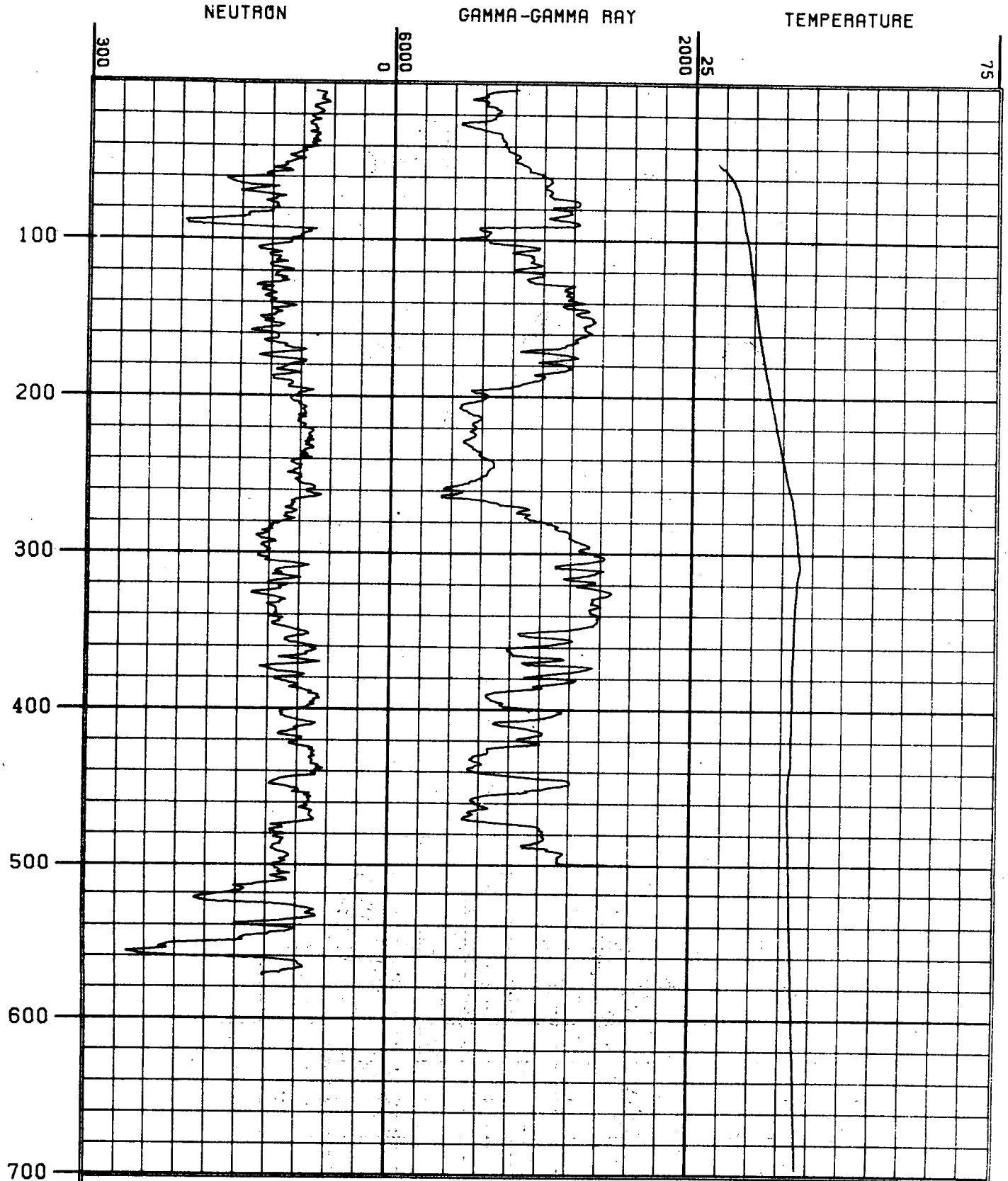
SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY4 -- GEOPHYSICAL WELL LOGS

XBL 803-8443


NATURAL GAMMA RAY
0
50
RESISTIVITY
0
75
CALIPER
0
10
100
200
300
400
500
600
700
SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY5 -- GEOPHYSICAL WELL LOGS

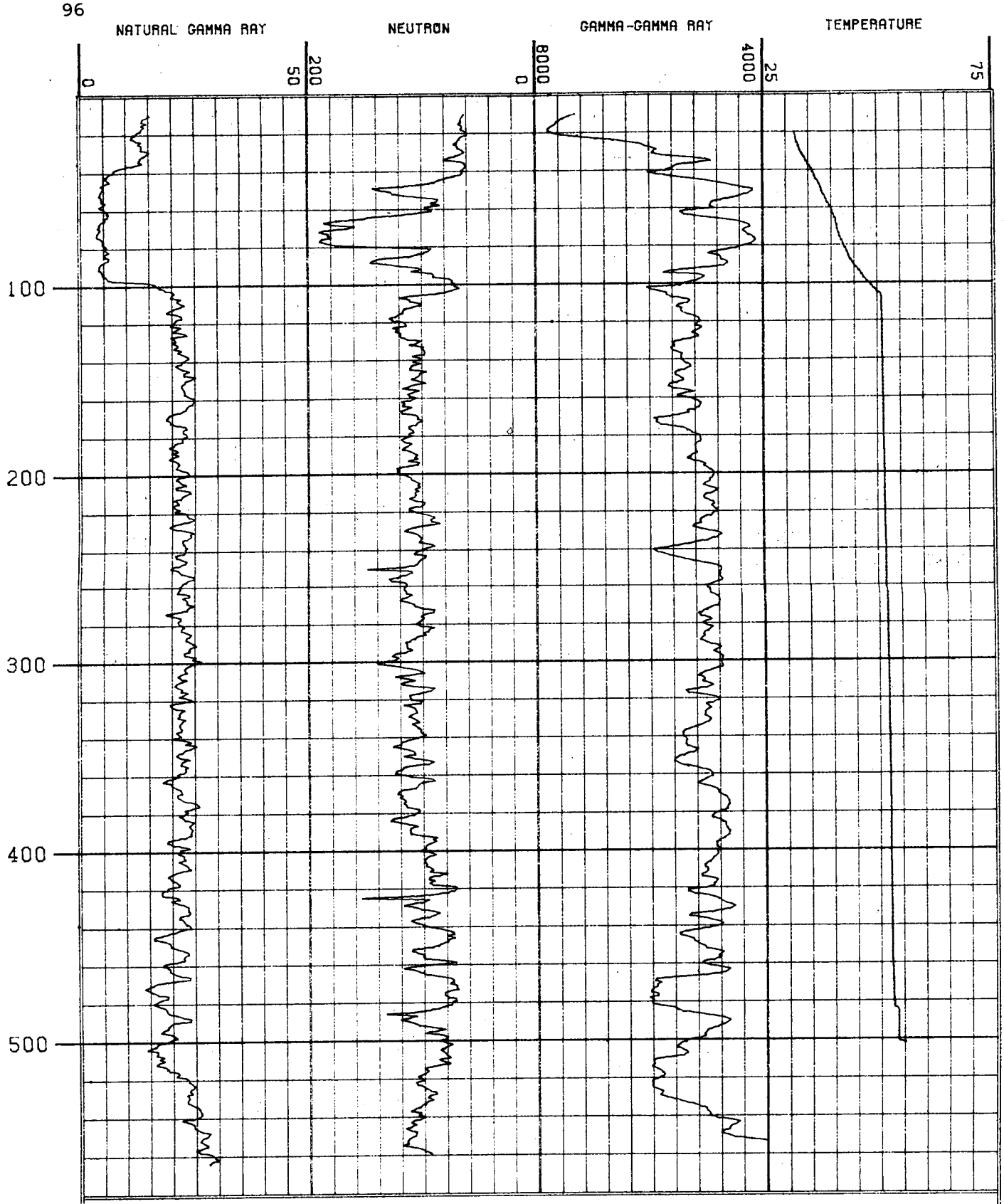
XBL 803-8447



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY5 -- GEOPHYSICAL WELL LOGS

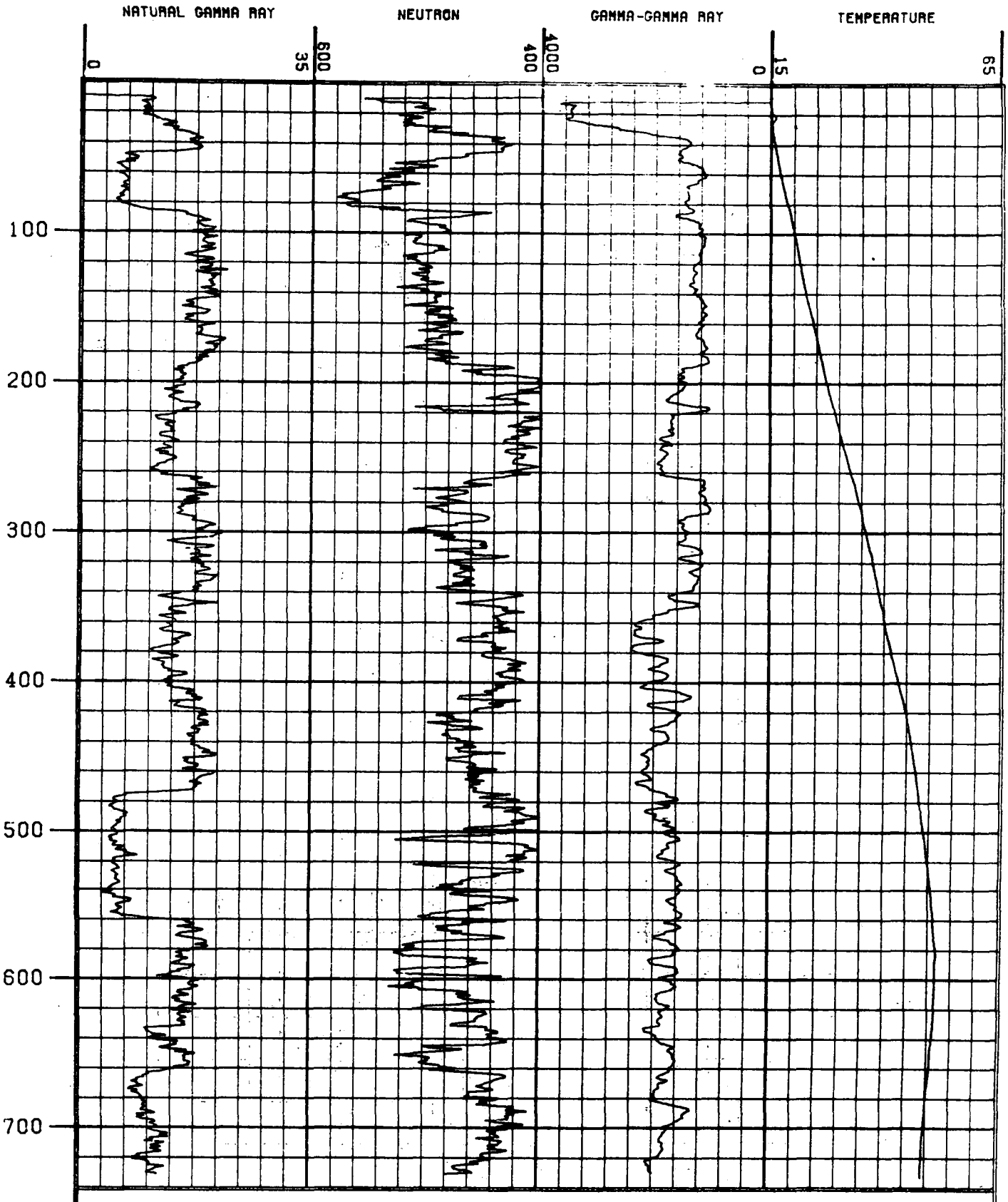
XBL 803-8448



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY6 -- GEOPHYSICAL WELL LOGS

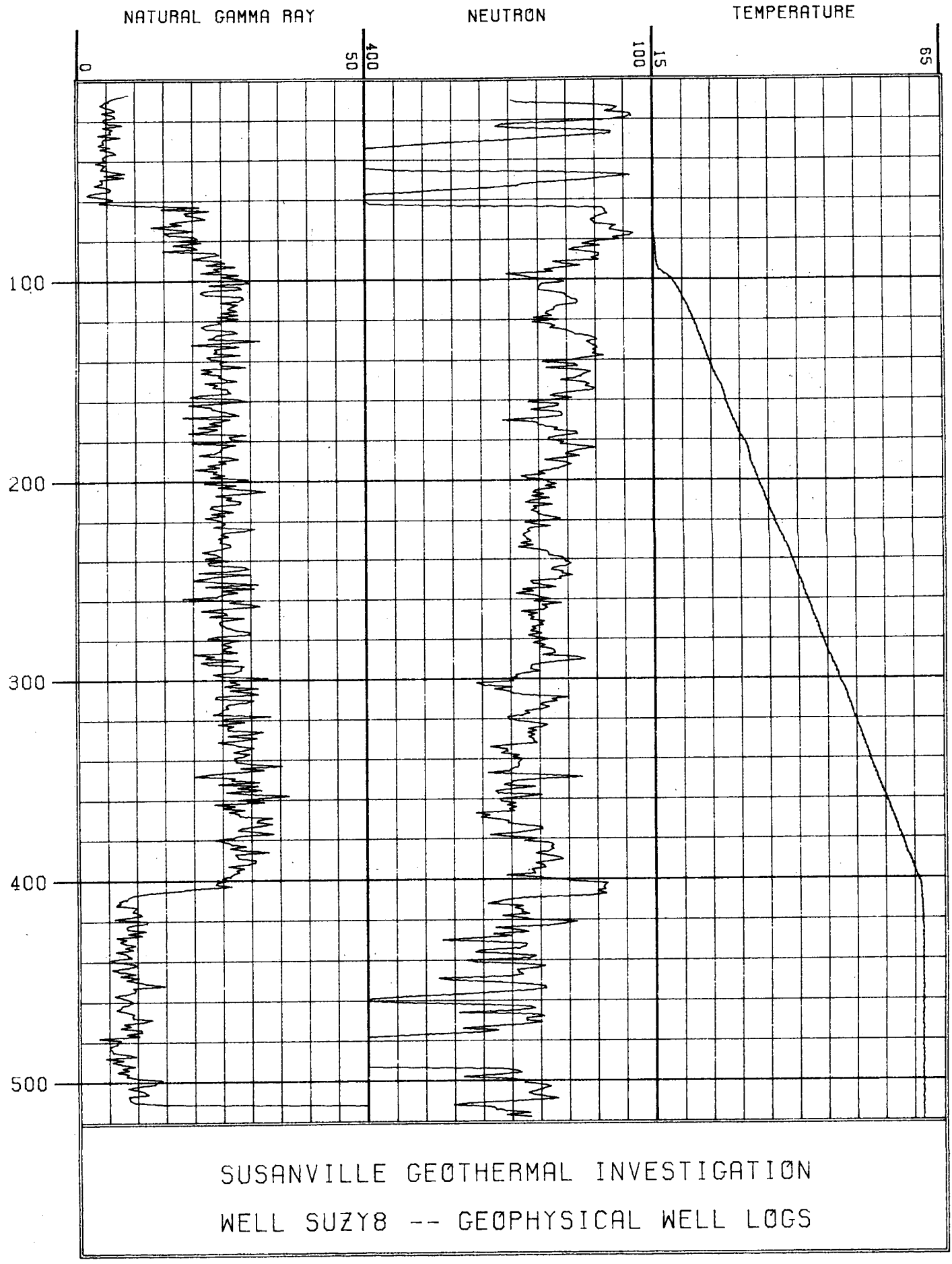
XBL 803-8450



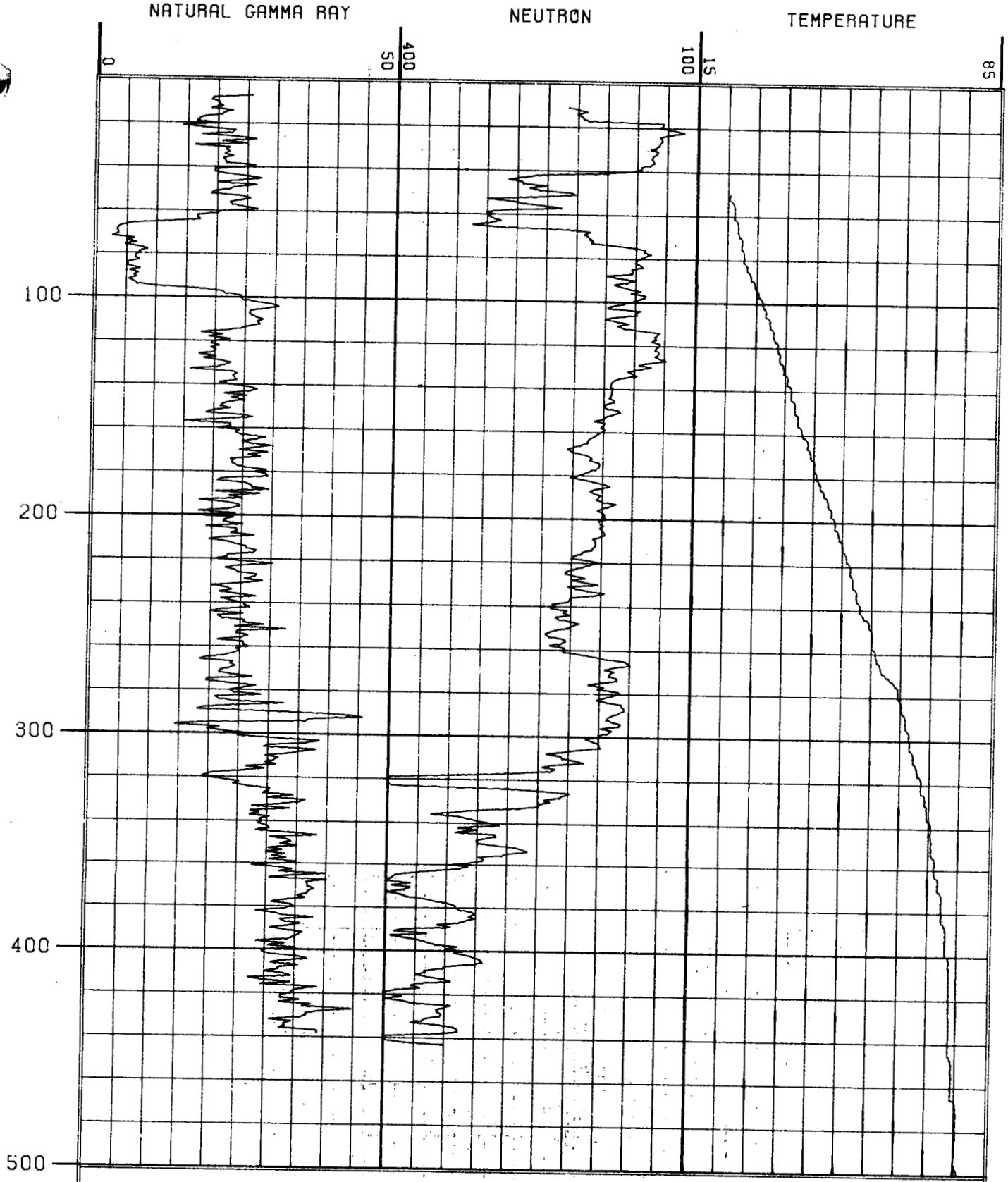
SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY7 -- GEOPHYSICAL WELL LOGS

XBL 803-8442


NATURAL GAMMA RAY
0
50
NEUTRON
400
100
TEMPERATURE
15
65
100
200
300
400
500
SUSANVILLE GEOTHERMAL INVESTIGATION
WELL SUZY8 -- GEOPHYSICAL WELL LOGS

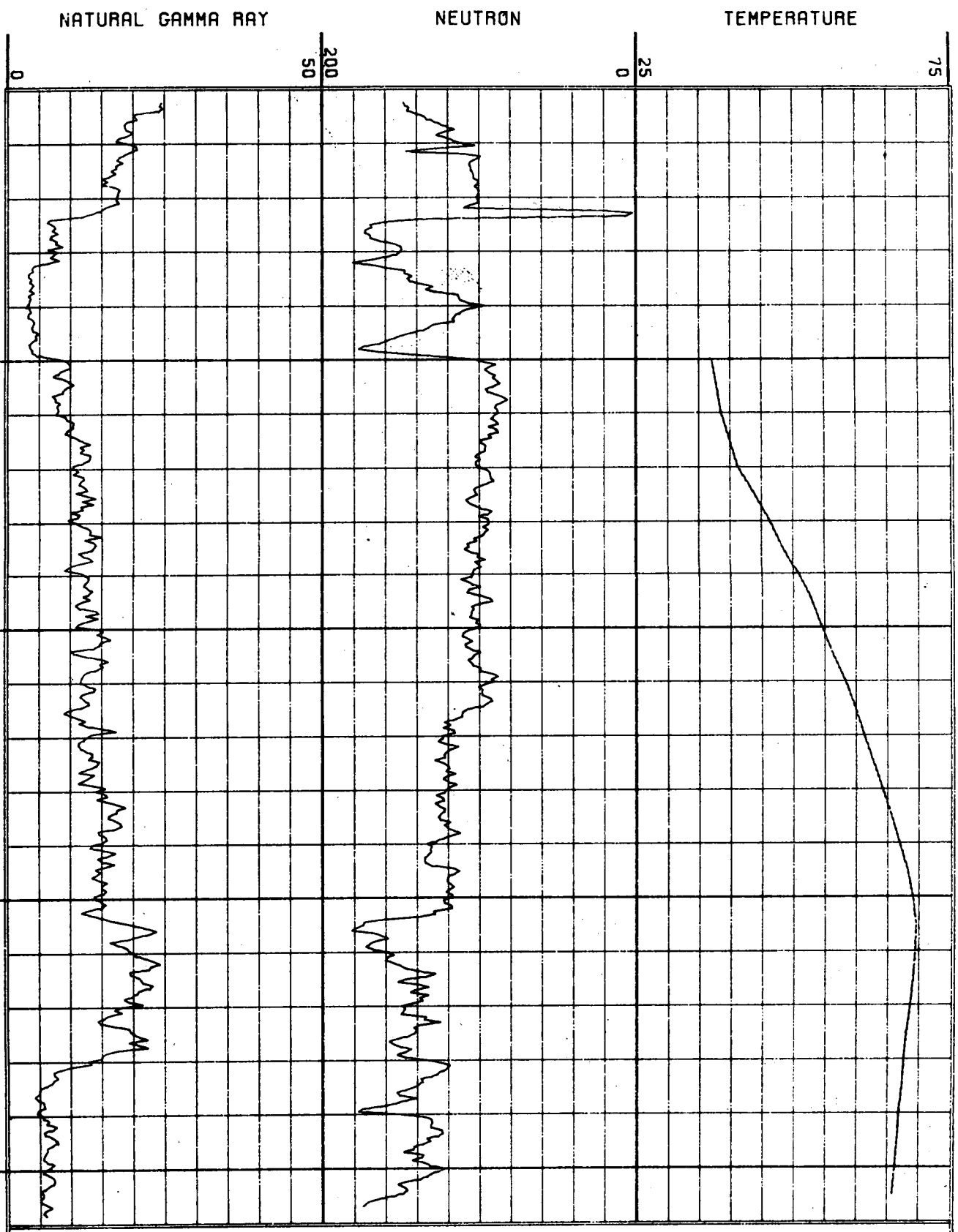
XBL 803-8439



SUSANVILLE GEOTHERMAL INVESTIGATION

WELL SUZY9 -- GEOPHYSICAL WELL LOGS

XBL 803-8449



SUSANVILLE GEOTHERMAL INVESTIGATION

NAEF WELL -- GEOPHYSICAL WELL LOGS

XBL 803-8446