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GEOTHERMAL GRADIENT DRILLING, NORTH-CENTRAL CASCADES OF OREGON, 1979

by
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1980

DISCLAIMER

This report has not been edited for complete conformity with Oregon Department of Geology and Mineral Industries standards.

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INTRODUCTION

In the summer, 1979, a geothermal gradient drilling program was initiated on the western flank of the North-central Cascade Mountains of Oregon, specifically from the vicinity of Santiam Pass on the south, to just south-east of Austin (Carey) Hot Springs on the north (Figure 1), an airline distance of approximately 45 miles. The principal purpose of this drilling program was to gain information on geothermal gradients in selected areas to depths greater than from that obtained in previous drilling.

Except for two wells to approximately 1500 feet in depth, one near Breitenbush Hot Springs, and one near Austin (Carey) Hot Springs, drilled by Sunoco Energy Development Company, the results of which are proprietary, no drilling below the depth of 500 feet had been done in this region. A secondary objective was to gain experience in drilling inter-mediate (2000-foot) wells in these volcanic terrains.

A five to seven well program was proposed, with a budget of $450,000. The range in number of wells to be drilled was established to account for differences in opinions as to what the costs would be of these wells, depending on drilling con-ditions encountered. As these were unknown in advance, the five to seven well program objective was set. Ultimately six wells were drilled; in a sense seven were drilled as two wells were attempted to be drilled at site 3. Projected depth of these wells was to 2000 feet. The deepest well drilled went to 1965 feet (well number 2--Twin Meadows).

<u>Public Information.</u> All information gained from these wells was specified to be public information, with samples to be stored in at least one publicly available site (ultimately two such sites have been established).

<u>Participants/Funding Sources.</u> This project was funded by the U. S. Department of Energy, Region X, Grant No. DE-FG-51-7ET2743 in the amount of $300,000. Southland Royalty Company of Fort Worth, Texas, Sunoco Energy Development Company of Dallas, Texas, and the Eugene Water & Electric Board of Eugene, Oregon each contributed $50,000 to the project. In addition, the Eugene Water & Electric Board made available to the project its facilities at Carmen Dam for supply logistic and storage purposes, and subsequently

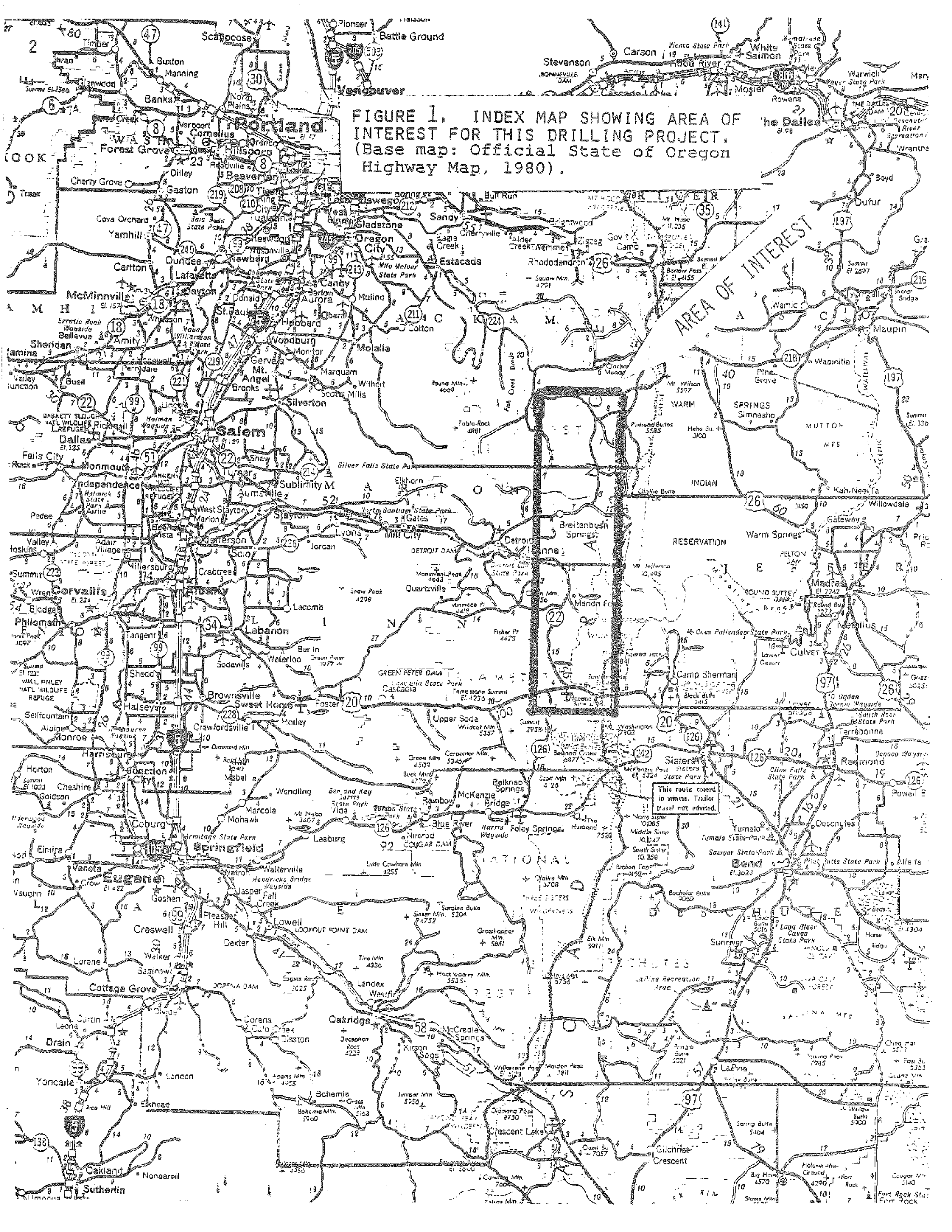


FIGURE 1. INDEX MAP SHOWING AREA OF INTEREST FOR THIS DRILLING PROJECT. (Base map: Official State of Oregon Highway Map, 1980).

also picked up a number of cost over-runs peripheral to the project, including the ultimate abandonment costs of the wells, and the restoration of the drill sites to the satisfaction of the U. S. Forest Service. All drill sites are on Forest Service land. The Eugene Water & Electric Board was the prime contractor for this project.

Drilling Contractor and Technical Manager. The drilling contractor was Southwest Drilling and Exploration Company, Inc. of Central, Utah. Technical Manager was Walter Youngquist, geothermal consultant for the Eugene Water & Electric Board.

Technical Services. Technical services in the form of temperature gradient logging, and gamma ray logging were provided under an actual cost sub-contract agreement between the Eugene Water & Electric Board and the Oregon Department of Geology and Mineral Industries. In turn, the Oregon Department of Geology and Mineral Industries contracted some of the work of gradient analysis and conductivity testing with Dr. David Blackwell, Geothermal Laboratory, Southern Methodist University, Dallas, Texas.

Additional Technical Support. Additional technical support was provided by the Branch of Field Geochemistry and Petrology of the U. S. Geological Survey, Menlo Park, California. A complete suite of well-cuttings was supplied to that organization, and they have subsequently prepared open-file reports of their findings on each of these wells, giving a lithologic log of each well together with detailed observations on such rock alteration as may exist, with interpretations of the significance of such alteration. These open-file reports have been listed at the end of this present report. Their contents, in abstracted form, have been included in this report in the discussions of the individual wells. Terry E. C. Keith, James R. Boden, and Melvin Beeson of the U. S. Geological Survey kindly supplied this information.

Reports of Drilling Operations. During the progress of this project, reports of drilling operations were submitted at two-week intervals to all participants, and were also sent to other concerned organizations including the Oregon Department of Geology and Mineral Industries, and the headquarters personnel of the Willamette and Mount Hood National Forests. Copies of the detailed driller's logs and of all temperature and gamma ray logs were also provided all participants and to the Oregon Department of Geology and Mineral Industries. Upon abandonment of these wells, complete driller's logs were supplied to the Mount Hood National Forest and Willamette National Forest personnel for the wells in their respective areas, and to the District Geothermal Office of the U. S. Geological Survey in Santa Rosa, California.

This present report is the final report on this project, and, as prescribed by contract, is being placed on open-file with the Oregon Department of Geology and Mineral Industries in Portland, Oregon.

Well-cuttings and Their Disposition. Well-cuttings were taken at regular ten-foot intervals for logging purposes. One complete set of cuttings was deposited with the Oregon Department of Geology and Mineral Industries, Portland, Oregon. Sunoco Energy Development Company did not request a separate set of cuttings. Southland Royalty Company specified that their cuttings be placed on file with the University of Utah Research Institute, Salt Lake City, Utah. A smaller set of cuttings from each well was supplied to the U. S. Geological Survey, Branch of Field Geochemistry and Petrology, Menlo Park, California, which samples are the basis for the open-file reports prepared by that organization on each of the wells, and from which information has been drawn for this report. For conductivity information, a set of samples taken at 25-foot intervals were sent to Dr. David Blackwell at the Geothermal Laboratory, Southern Methodist University, Dallas, Texas. Dr. Blackwell subsequently prepared reports on each of these wells with respect to heat flow and apparent thermal gradients. This information has been incorporated into the present study, appearing chiefly in the form of Figures 5, 6, and 7, and Table 1 at the end of this report.

REGIONAL GEOLOGY AND BASES FOR WELL LOCATIONS

Regional Geology. Geologists generally recognize two geological provinces in this portion of the Oregon Cascades--the High (younger) Cascades, and the Western (older) Cascades. The High Cascade crest, in the region where the drilling for this project took place, is marked by a line of young volcanoes which are Mount Jefferson (10,495 feet), Three-Fingered Jack (7,841 feet), and Mount Washington (7,802 feet). Numerous both large and small cinder and spatter cones also exist along and near this general crest line. These include Sisi Butte, Olallie Butte, Big and Little Nash craters, the Sand Mountain lineament with its several craters, the Pinhead buttes, and many others. The time line used to distinguish between High and Western Cascade rocks is commonly taken at the most recent magnetic reversal, or about 670,000 years.

The High Cascade province which exhibits these younger rocks consists of relatively unaltered volcanics ranging in composition from basalt to andesites and dacites, with numerous interculated zones of ash, cinders, and some minor stream and pond deposits; the pond deposits commonly have abundant diatom remains. A typical section of the High Cascades might be an andesitic columnarly jointed lava flow overlying a thin section of pond sediments which in turn overlies a thicker section of laharic breccias. Such a section is well exposed along the North Fork of the McKenzie River, and variations of that sort of rock and sediment assemblage are evident many places, and found also in drilled sections. An appreciable part of the High Cascade section has been reworked through slope wash and landslide movement, and then redeposited and consolidated. This is the origin of the laharic breccias which appear in great abundance both in the High Cascade and Western Cascade rock sequences, in places making up a third to half the rock section.

The Western Cascades are a substantially more weathered series of rocks, much like the High Cascades in composition, but reduced in relief. The physical boundary between these two provinces in the area of this drilling project appears to be a fault or zone of normal faulting trending approximately north-south, with the downthrown side to the east. A rough estimate of the displacement is on the order of 1000 to 2000 feet. A similar fault downthrown to the west is indicated equidistant on the east side of the Cascade crest in this region. Therefore, if these observations are correct, the High Cascades in this area at least would presumably be in a graben. Although this geological interpretation has considerable basis of fact in the region under consideration, it is uncertain as to how far either north or south of this area the concept might apply, and it is not presumed here to so extend it, and there is not entire agreement that the graben concept is valid for this area either.

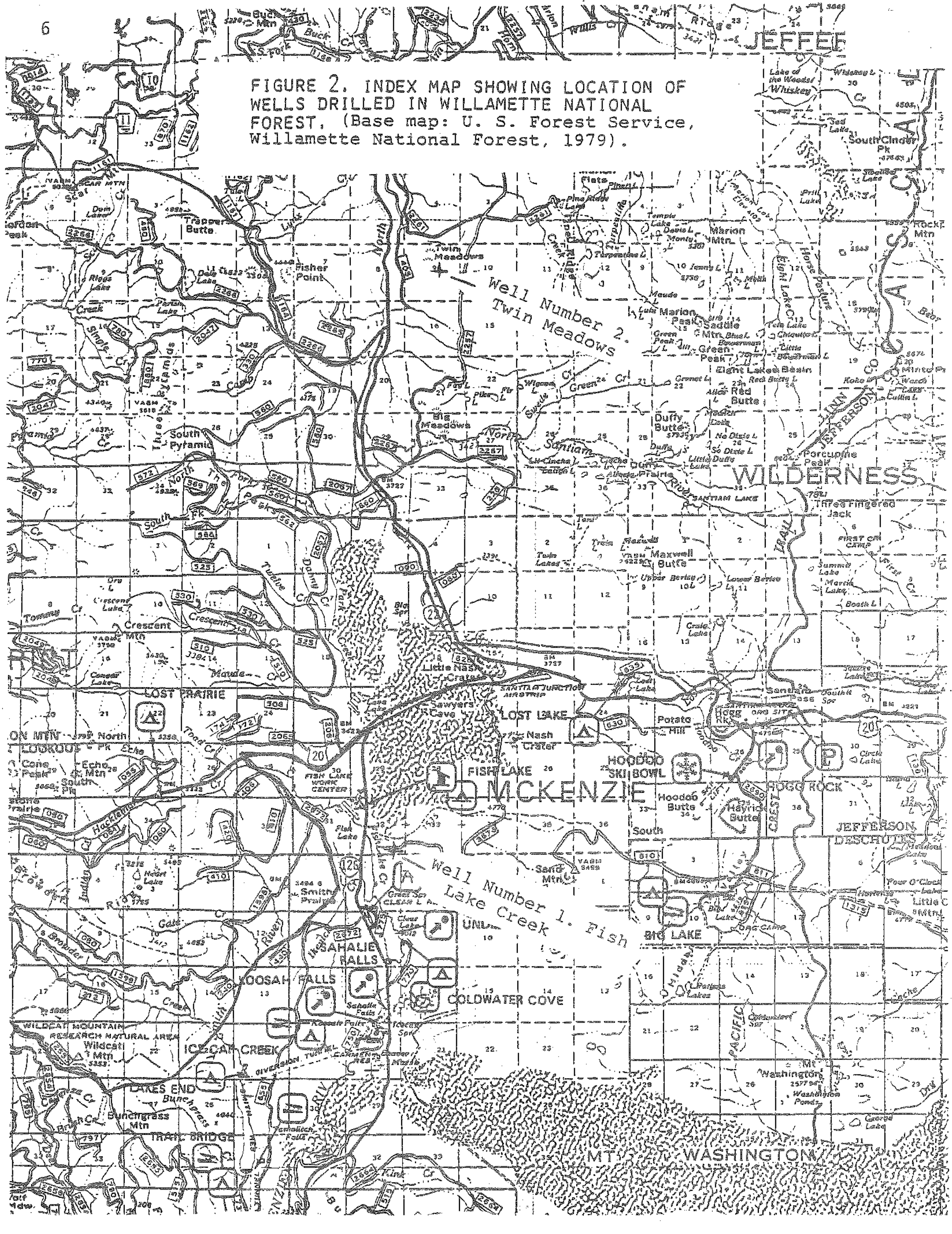
Fracture Trends. The north-south trend of the volcanoes and attendant fractures in this region is striking and dominant, but there also exists a northwest-southeast fracture set, and a northeast-southwest trend. The major volcanoes are aligned along the north-south trend. Lesser volcanic activity is related to the other fracture sets.

Hot Springs. Several hot springs exist in this area, notably Belknap and Bigelow Hot Springs in the McKenzie River Valley , Breitenbush Hot Springs in the Breitenbush Valley, and Austin (also called Carey) Hot Springs in the mid-portion of the Clackamas River Valley. It is noteworthy that these hot springs are in a general north-south alignment, and are situated approximately along what some geologists believe to be the fault boundary (already cited) between the High and Western Cascades.

Bases for Well Locations. The geothermal gradient well locations (shown here on U. S. Forest Service base maps as Figures 2 and 3) were made on the basis of having a geographic spread over the area of interest, and the specific sites were determined by several factors including various geophysical investigations (where available), and regional and local structural patterns. Sites 1, 2, 3, and 4, were all located on the upland bench area which lies between the High Cascade crest and the boundary between the High and Western Cascades, in part marked by the north-south portions of the stream valleys of the McKenzie, North Santiam, and Clackamas Rivers. Site 5 is located on a prominence in a broad bend of the Clackamas River, and site 6 is located at the base of Sisi Butte a short distance up the valley wall of the Clackamas River.

It should be noted that all of these sites except site 1 have been glaciated, and greater or lesser depths of glacial debris were encountered in drilling these wells. Site 1 is located on a lava flow approximately 3,000 years old, and therefore unglaciated.

FIGURE 2. INDEX MAP SHOWING LOCATION OF WELLS DRILLED IN WILLAMETTE NATIONAL FOREST, (Base map: U. S. Forest Service, Willamette National Forest, 1979).



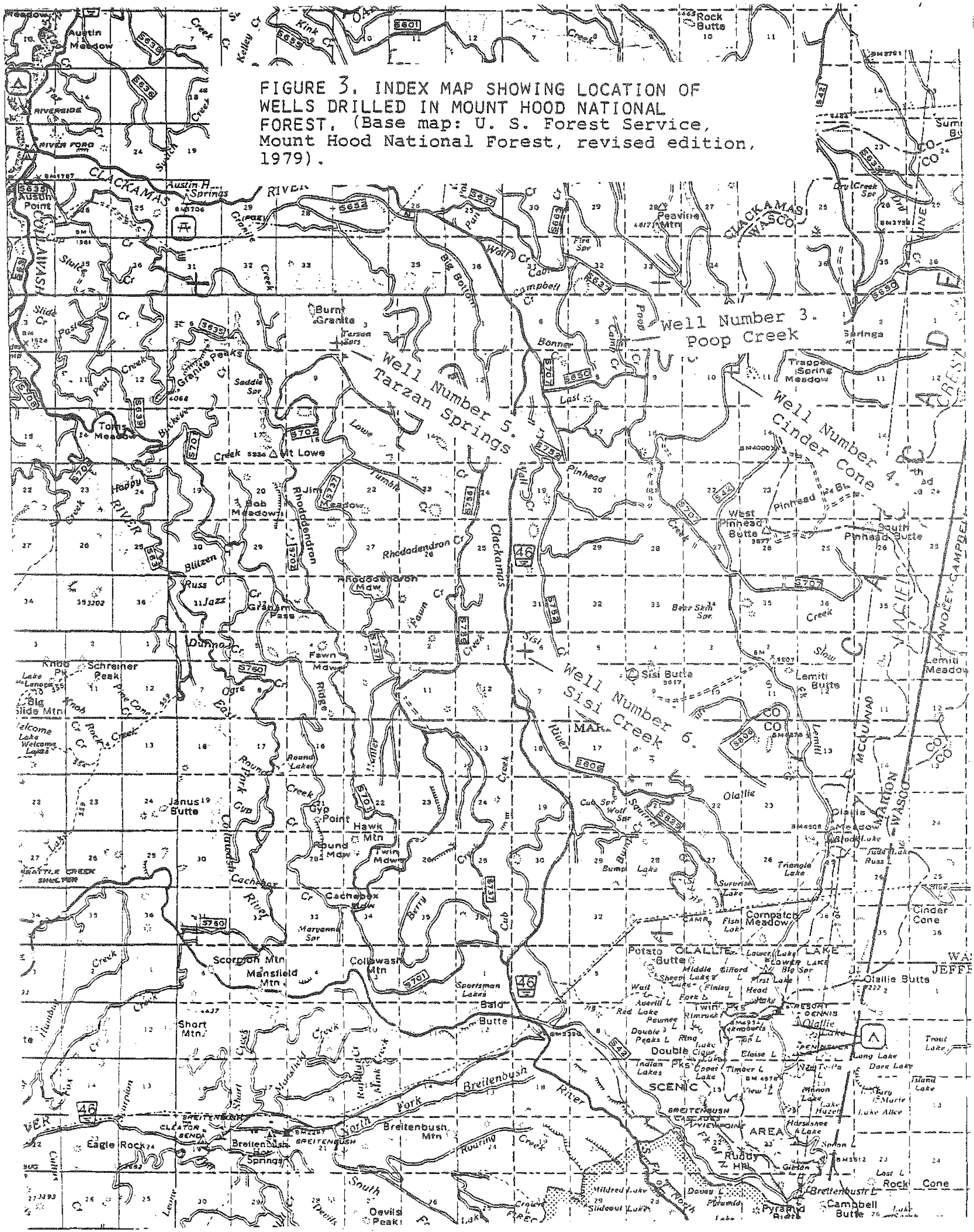


FIGURE 3. INDEX MAP SHOWING LOCATION OF WELLS DRILLED IN MOUNT HOOD NATIONAL FOREST. (Base map: U. S. Forest Service, Mount Hood National Forest, revised edition, 1979).

CASING PROGRAM, DRILLING EQUIPMENT, DRILL BITS, AND DRILLING PROBLEMS

Casing Program. The casing program was to drill 50 feet into the first competent formation and then set 8-inch casing and cement it in. A blowout preventer was then set on the casing, the cement drilled out, and a 6¼-inch bit was used to total depth. No intermediate strings of casing were set. A black iron two or two and one-half inch gradient pipe was set, sealed at the bottom, and filled with water.

Drilling Equipment. Rotary drilling equipment was used entirely. Initially a Chicago Pneumatic 1800 truck-mounted (including all pumps) drill rig with a 3500-foot capacity was brought in on the project. This was subsequently supplemented by a Portadrill (also truck-mounted) with a 2000-foot capacity. Mudpits were lined with plastic to prevent leakage, and fenced to prevent local wildlife from becoming entrapped in the pits during such times as the rig site might be temporarily unmanned.

Drill Bits. Both button-bits and medium-length-tooth rock bits were employed. However, it was found that a 6¼-inch Smith-Gruener medium-hard formation medium-length-tooth bit was the most efficient bit under most drilling conditions encountered in this project. Both basalt and other flows such as dacites and andesites could be drilled with these bits at a rate of 10 feet an hour or better, and the bits functioned well in ash, cinder, and pond and stream sediment sections also.

The sequence of rocks which is drilled at any given location in this portion of the Cascades is relatively unpredictable, as the complexity of the volcanic stratigraphy is great. In any one section laharic breccies usually make up the largest single element, but lava flows of different compositions, ash and cinder beds, and pond and stream sediments are also commonly present. The lava flows are usually less than 100 feet thick, and many are less than 25 feet thick, with the result that the drill encounters markedly different rock types in a relatively short vertical distance. It is, therefore, not possible to drill with the bit most adapted to each rock type, as it is impractical to change bits at relatively short drilling intervals. The optimum bit for drilling andesite is not the bit best designed for drilling pond sediments or weathered volcanic ash. It may be said, given the varied rock section, that regardless of what type of bit you start with, you are actually drilling with the wrong bit for a given rock type almost half the time. Therefore, a compromise has to be made, which, as previously stated, proved to be a medium tooth length rock bit. In the case of laharic breccias, the rock type changes almost foot by foot, as relatively solid boulders are drilled in a matrix of volcanic ash and cinders.

Drilling Problems. Drilling the section in which to set the surface casing proved to be a problem more often than not. This was due chiefly to the presence of a mantle of glacial debris, with boulders up to five feet or more in diameter being encountered. These boulders tended to cause the drill to deviate and the straight hole necessary to land a string of casing was not made. A 11 3/4-inch bit was used on occasion but the results were not appreciably better than those obtained by using a 10¼-inch bit. Also, deviation around the andesite and dacite boulders in the glacial drift tended to put undue strain on the bit and sub connection with the drill string, and on sites 2 (Twin Meadows) and 6 (Sisi Creek), the bit and sub broke off, and could not be fished, and the rig had to be moved in each case and the surface hole re-drilled.

In addition to the various rock types encountered, abundant fractures in the lava flows caused numerous lost circulation problems. Also, in some areas lava tubes are present which may or may not be carrying moving ground water. In lost circulation zones, drilling with air was attempted several times, but in all cases ultimately this procedure had to be abandoned because of the large volumes of water encountered which could not be handled by the pumps.

Lost circulation problems were severe, and as much as 21 tons of cement, and more than 200 sacks of lost circulation materials (cottonseed hulls, cedar fiber) were used in attempts to regain circulation in a given trouble zone. In additon, mud quality was frequently altered substantially by flows of ground water with the result that caving in the holes occurred causing drill strings to be stuck. In some instances, drill strings had to be blasted off. The laharic breccia zones were especially troublesome as large, hard, angular blocks of rock embedded in the soft ash and other sedimentary materials caused the drill string to deviate. Also, as the soft material was occasionally washed out by the action of the drilling mud from around the angular blocks, some of these blocks would move into the hole and stick the drill string so that the drill could neither be pulled nor pushed (hydraulic jack-hammers used in some cases to attempt to free the bit). Larger capacity draw-works would probably alleviate this problem to a considerable extent, but with the relatively light equipment with which we were working, this was a serious problem.

Noting again that the majority of wells were located on the bench area between the Cascade crest and the major valleys adjacent to the west, and that this is a region of high precipitation (80-100 inches annually), it became evident from experience that the bulk of the drilling problems were encountered in the zone of vadose (that is, free-flowing, downward moving) water above the regional water table. The regional water table is for all practical purposes represented by the streams in the major valleys. Once the drill reached the level of this regional water table, the drilling problems became less severe. In the vadose zone, however, through-flowing ground water has cleaned out and enlarged fractures and provides a hydraulic gradient all of which combine to produce an environment where lost circulation is almost a continual problem. In a major deep drilling situation with bigger draw-works to largely eliminate the stuck drill problems from caving, and a heavy mud combined with a casing program to carry a protective string of pipe below the regional water table, these relatively surficial problems would not be nearly so severe as they are when lighter drilling equipment is used, and no casing is carried below the initial few hundred feet.

WELL DATA

This section of the report presents a summary of drilling operations for each well, the generalized geologic section drilled, and petrographic and geochemical information supplied by the U. S. Geological Survey from their examination of the cuttings, together with the temperature gradient information for each hole. Preliminary logs were run on each well shortly after the time of each well completion in 1979. Final logs were run on each well in late spring 1980. Final geothermal gradient logs are plotted together for comparison on Figure 5 (page 27), and individual plots are shown as part of the basic data which makes up Table 1 at the end of this report. Pertinent observations of the technical personnel involved in obtaining the petrographic and geochemical information have also been included with the description of each well.

NAME OF WELL: Eugene Water & Electric Board No. 1. Fish Lake Creek.
LOCATION: Long. 121°59'33" W., Lat. 44°23'20" N. SE¼SE¼ section 32, Township 13 South, Range 7 East, Linn County, Oregon. (Willamette National Forest).
ELEVATION: 3135 feet (955.54 meters).
TOTAL DEPTH: 1837 feet (558.39 meters).
TOPOGRAPHIC/GEOLOGIC LOCATION: On outer apron of large series of basaltic flows from the Sand Mountain lineament; relatively flat-lying basalt with fragments up to two to three feet in diameter but most much smaller. Basalt dated as approximately 3000 years, no glacial debris present. Basalt came from a fissure about 3¼ miles east of the well, which fissure (Sand Mountain lineament) runs in a north-south direction for approximately six miles. Other fractures are also known in the area.
DRILLING DETAILS: Location of well site on a young ä ä lava flow was expected to cause initial drilling and lost circulation problems. Local surface geology indicated this young basalt flow was probably only about 60 to 80 feet thick at this place, overlying andesites (with a normal magnetic direction). This proved to be the case. Using heavy mud, lost circulation was a minor problem, and 150 feet of surface casing was landed into solid andesite with little difficulty. Frequent but minor lost circulation problems were encountered during drilling, but well was bottomed at 1837 feet with no major difficulties. A two-inch black iron gradient pipe was set. A total of four bits were used to drill the well. Estimated cost of drilling, including

proportionate rig-mobilization costs (from Nevada) was approximately $41,400, or $22.54/foot. This attractive figure, however, did not prevail for subsequent wells.

GEOLOGIC SECTION:

Interval (feet)	Lithology and Comments (USGS)
0-80	Basalt flow; black, vesicular basalt with groundmass of plagioclase and clinopyroxene, and phenocrysts of olivine, orthopyroxene, and plagioclase
80-160	Volcanic debris, mostly andesite
160-300	Flow, andesite, scarce hydrothermal minerals
300-330	Tuff, glass, zeolitized
330-340	Andesite flow
340-490	Volcanic debris
490-560	Andesite flow, scarce alteration minerals
560-820	Volcanic debris, mixed andesite and basalt, zeolitized throughout
820-830	Andesite flow
830-1370	Mixed andesite volcanic debris and interlayered thin flows. Zeolites and montmorillonite throughout
1370-1837	Mixed andesitic volcanic debris and interlayered thin flows; less alteration than in debris zone above

GENERAL OBSERVATIONS: (USGS) Hydrothermal alteration has resulted in depositing zeolites (phillipsite, chabazite, paulingite, thompsonite) montmorillonite, chalcedony, chlorite, and biggsite throughtout the older rocks of the Western Cascade Group. There is no evidence of hydrothermal alteration in the overlying flows of the High Cascade Group. Alteration minerals were first identified in this well at depth of 170 feet, and usually occur in vesicles and veinlets in volcanic rock fragments and are clearly of hydrothermal origin. Zeolitization occurs during hydrothermal alteration at temperatures generally between 20°C and 120°C. Hydrothermal alteration of this type has permeated the Western Cascades Group rocks in EWEB 1 drill hole below 170 feet. The date of this alteration is uncertain.

GEOTHERMAL GRADIENT: This is shown on the graph which is Figure 5, and also in the data in Table 1. Dr. Blackwell has commented on this temperature log as follows:

> Hole 13S/7E-32dc has an unusual temperature-depth curve. It is nearly isothermal through young basalts to a depth of 60 m, at which point the gradient is high and constant, with a value of 102°C/km. At a depth of 200 m, the gradient becomes isothermal and finally negative. It gradually increases and becomes positive again toward the bottom of the hole. The cause for this type of curve has been discussed in a previous letter: lateral flow of warm water along an aquifer between 200-220 m, superimposed on a background of relatively low heat flow. If more than one hole were available in this area, it would be possible to estimate the distance to the source and the possible temperature of the water coming up along the fracture zone and feeding this shallow aquifer. Based on a model similar to that discussed by Bodvarsson (1969), we estimate the initiation of the water flow in the age range of 1000 ± 500 years. This curve is typical of what one might expect to find associated with a geothermal system. It has already been recommended that the hole be perforated and samples be obtained from the aquifer at 200 m, in order for a chemical analysis to be performed and geochemical temperatures to be estimated.

Following the recommendation of Dr. Blackwell, an attempt was made, under the direction of James Robison of the U. S. Geological Survey, to sample the water at approximately 200 meters. The gradient pipe was perforated at that depth, and the water in the gradient pipe blown out for a considerable time by compressed air. The water flow obtained from these perforations was substantial. The water was subsequently sampled and analysis of this water was made by the U. S. Geological Survey (Dr. Robert Mariner) at Menlo Park, California. Results are tabulated here, with the note that the sample was not acidized, and was not filtered.

Sample no. GT-34JR80
Figures are in milligrams/liter

Na	32	Cl	4.2
K	2.6	SiO_2	48
Mg	0.1	B	1.0
HCO_3	73.0	Laboratory pH 7.95	
SO_4	1.0		

These data are rather inconclusive. If geothermal waters have been intercepted by perforations in the gradient pipe at approximately 200 meters it appears they may have been substantially diluted by vadose water.

NAME OF WELL: Eugene Water & Electric Board No. 2. Twin Meadows.
LOCATION: Long. 121°58'28" W., Lat. 44°32'20" N. NW¼SE¼ section 9, Township 12 South, Range 7 East, Linn County, Oregon. (Willamette National Forest).
ELEVATION: 3920 feet (1195 meters).
TOTAL DEPTH: 1965 feet (598.9 meters).
TOPOGRAPHIC/GEOLOGIC LOCATION: On upland bench area about 1¼ miles east of the canyon of the North Fork of the Santiam River. Upland has been glaciated and carries overburden of glacial debris with boulders up to five feet in diameter.
DRILLING DETAILS: Glacial boulders caused initial drilling problems. Drilled out of glacial debris about 60 feet, and into basalt. Major circulation loss at 85 feet and bit stuck at 90 feet while drilling blind (without mud). Eventually worked drill string free and pulled up to find bit and sub broken off. Did not attempt to fish. Moved rig 10 feet and drilled new hole. Considerable water flow encountered at 219 feet, eventually plugged off with cement. Drilled ahead with intermittent circulation losses to about 800 feet where drilling problems became less severe. Well drilled to total depth of 1965 feet (598.9 meters) with no additional serious lost circulation problems. Set two-inch black iron gradient pipe.
GEOLOGIC SECTION:

Interval (feet)	Lithology and Comments (USGS)
0-60	Overburden. Glacial debris, large boulders
60-120	Olivine basalt flow
120-410	Andesite flow
410-550	Basalt flow, with three textures: crystalline, vesicular, glassy. Lower 40 feet dominated by glassy layers
550-640	Volcanic debris unit, largely volcaniclastics

Interval (feet)	Lithology and Comments (USGS)
640-770	Volcanic debris unit, mostly olivine andesite
770-830	Volcanic debris unit, largely andesite, some volcaniclastics at base
830-840	Olivine andesite flow. Some hydrothermal alteration
840-890	Olivine andesite flow
890-980	Volcaniclastic unit, fine sand to silt
980-1020	Mixed volcaniclastics
1020-1260	Olivine andesite flow. White pumice ash zone 1180-1220
1260-1520	Volcaniclastic unit, 1260-1360 fine sand to silt; 1360-1430 dominant andesite, possibly a flow. 1430-1460 mixed white pumice. 1460-1520 coarser sand to silt
1520-1580	Mixed volcaniclastics and andesite
1580-1600	Andesite
1600-1670	Mostly andesite
1670-1700	Mostly volcaniclastics
1700-1740	Mostly andesite
1740-1750	Andesitic or basaltic glass flow with olivine phenocrysts
1750-1840	Volcanic debris unit with hydrothermal alteration
1840-1965	Volcaniclastics

GENERAL OBSERVATIONS: (USGS) There are two possible zones of hydrothermal activity evidenced at some time, one at 840 feet and one about 1800 feet. There is no alteration in the upper part of the drill hole.

GEOTHERMAL GRADIENT: The final temperature log was run on May 29, 1980, and the curve thereof and the data on which it is based are shown on Figure 5 and in Table 1. The log is isothermal down to about 787 feet (240 meters) which is approximately the depth of the regional water table, as evidenced by the adjacent valley of the North Santiam River a short distance to the west. Below that depth, the log shows a linear gradient of about 72°C/Km. Gradient data in Table 1, and on plot which is Figure 5.

NAME OF WELL: Eugene Water & Electric Board No. 3. Poop Creek.
LOCATION: Long. 121°50'45" W., 44°59'04" N., SE¼SE¼ section 5, Township 7 South, Range 8 East, Clackamas County, Oregon (Mount Hood National Forest).
ELEVATION: 3200 feet (975.6 meters).
TOTAL DEPTH: 960 feet (292.7 meters).
TOPOGRAPHIC/GEOLOGIC LOCATION: EWEB No. 3 is located on the intermediate bench area on the western slope of the Cascades between the crest of the Cascades and the adjacent valley of the Clackamas River approximately two miles to the west of the drill site.
DRILLING DETAILS: Two wells were drilled at this site. The first (EWEB 3) reached a depth of 960 feet (292.6 meters) with considerable difficulty. Lost circulation problems were encountered almost throughout the hole. Air-drilling was tried but the volumes of water were too great for the pumps to handle and the operation

returned to drilling with mud. AT 960 feet the drill pipe stuck, and could not be freed. The drill string was blown off at 710 feet; a bit, sub, and about 250 feet of drill pipe including two drill collars were left in the hole. The string in the hole was cemented over with a view toward drilling around the fish and continuing the hole. In going back into the hole after the cement had been given time to harden, the drill did not reach the top of the cement, but stuck at 560 feet and could not be pulled. The drill string was reversed in rotation and the drill string separated at about 140 feet. Decision was made to abandon the hole and move the rig 100 feet east, which was done. The second well (EWEB 3A) was begun. Drill reached 640 feet, and was caving badly and it was decided to cement up the hole, and then drill out. This was done but drill got to 560 feet on drilling out and stuck again. Neither jacking up the rig nor using hydraulic jackhammers on the drill string could free the bit. After a day of continued circulation, however, the bit came free and drilling continued to 740 feet where circulation was again lost, and five mud pits of mud and lost circulation materials were lost down the hole. Additional mud and lost circulation materials were put in the hole and circulation eventually was regained and drilling proceeded to 840 feet where circulation was lost again. Two mud men from Nova Mud Corproation were called on the scene but were unable to regain circulation for the operation. Decision was made to switch to air-drilling, but again the pumps could not handle the formation water. Went back to mud drilling and reached depth of 870 feet with great difficulty where severe caving was encountered, and the heaviest mud the pumps could handle was not sufficient to prevent the caving. Drill was stuck several times and the driller could not get past this zone after two days of effort. Decision was made to bottom well at this point, and gradient pipe was set to 870 feet (265.1 meters). (Note: The lithologic section is that taken from the 1st--deeper well. The temperature gradient was run on the second well).

GEOLOGIC SECTION:

Interval (feet)	Lithology and Comments (USGS)
0-40	Overburden, consists of gray, tan, and reddish to orange amphanitic volcanic rock fragments. Darker fragments are andesite, reddish to orange fragments are oxidized basaltic cinders. A few fragments of chalcedony are in the overburden but none found deeper in the drill hole
40-140	Andesite flow, medium-gray, microporphyritic with groundmass of plagioclase
140-160	Porous layer of ash, probably andesitic
160-500	Andesite flow. A more careful study may show this unit actually consists of several flows, but there appears to be little variability and no indication of permeable or altered zones upon which the interval could be subdivided

Interval (feet)	Lithology and Comments (USGS)
500-670	Andesite flow, dark-gray and brown vesicular andesite fragments mixed with microporphyritic andesite. Groundmass consists of plagioclase, clinopyroxene, and cristobalite, and phenocrysts mostly plagioclase and clinopyroxene
670-690	Andesite flow, medium-gray, microporphyritic, fresh-appearing, described as "hard zone" in driller's log
690-820	Andesite flow, with lower part, 740-800 feet, having subordinate amount of gray amorphous obsidian chips mixed with the crystalline andesite chips of the rest of the flow section
820-960	Dacite, vapor-phase crystallization. This interval is significantly different from the overlying units. Vapor-phase tridymite is very abundant and vapor-phase hematite is moderately abundant. Traces of green staining and disseminated blue (azurite?) patches from 950 feet suggest copper mineralization

GENERAL OBSERVATIONS: (USGS) There is little material that can be ascribed to hydrothermal alteration. From 170 to 680 feet the cuttings consist mostly of unaltered gray andesite. Between 700 and 820 feet the proportion of yellowish-altered material to medium-gray unaltered andesite increases with depth. The interval from 830 feet to the bottom of the hole at 960 feet consists of light gray to light pink, and some white fragments of rhyodacite or dacite in contrast to the overlying units. Tridymite first appears in relative abundance at 820 feet. The abundance of tridymite and hematite indicate that the 830-960-foot interval is a zone of high-temperature vapor-phase crystallization. There are no vein of carvity deposits throughout the drill hole. The only possible hydrothermal deposit is very minor sulfides and azurite below 820 feet. The significant secondary crystallization is high temperature vapor-phase from 820-960 feet. Minor alteration activity causing Fe migration, oxidation, and leaching may be due to cooling of the lava flow, ground water circulation, or low temperature hydrothermal alteration.
GEOTHERMAL GRADIENT: The well was isothermal to total depth, temperature at 15 meters 7.44°C; temperature at 187 meters 7.06°C. Graph of gradient shown on Figure 5 and in Table 1.

NAME OF WELL: Eugene Water & Electric Board No. 4. Cinder Cone.
LOCATION: Long. 121°48'18" W., 44°58'34" N. SE¼NE¼ section 10, Township 7 South, Range 8 East, Clackamas County, Oregon. (Mount Hood National Forest).
ELEVATION: 3470 feet (1140 meters).
TOTAL DEPTH: 1160 feet (353.6 meters). Hole ultimately lost for most part and gradient pipe finally set to depth of 447 feet (see DRILLING DETAILS).
TOPOGRAPHIC/GEOLOGIC LOCATION: On south side of recent cinder cone located on the bench area between the Cascade crest and adjacent major valley of Clackamas River to the west. Well about ¼ mile west of pronounced fault scarp (traceable for several miles) with upthrown side apparently to the east.
DRILLING DETAILS: Drilling proceeded with little difficulty to

depth of 1015 feet where a major water zone was encountered. Circulation was lost at this point, and a very loud noise heard down the well (a roar like that of a freight train). Put in 140 sacks of cement and eventually plugged off trouble zone and drilled ahead to 1160 feet where circulation was again lost. Pulled drill back to 1100 feet while changing drilling mud, but in attempting to go back in, drill would not move although circulation was maintained. Used hydraulic jars very hard to try to move bit over period of several hours, but string could not be moved. Made decision to blast off bit at 1100 feet but blasting caps went off but not primer cord. Went in with second charge which stuck about 550 feet, and could not be pulled or pushed (with blasting caps, the amount of pushing is limited). Charge set off at that depth and drill string recovered to depth of 447 feet, and gradient pipe set to that depth. Drill pipe which was recovered had to be separated with aid of blowtorch because of pounding from jars. Drill string joints ruined.

GEOLOGIC SECTION:

<u>Interval</u> (feet)	<u>Lithology and Comments</u> (USGS)
0-110	Overburden, basalt cinders, red, oxidized, porous, unconslidated (south flank of adjacent cinder cone with local relief of about 150 feet)
110-200	Andesite flow, dark-gray, vesicular
200-220	"Soft zone" by driller's log. No recovery
220-290	Andesite flow. Multicolored fragments, gray, tan, red
290-300	Andesite flow
300-420	Andesite flow, massive
420-470	Andesite flow, gray, microporphyritic
470-750	Andesite flow. Massive, gray, occasional pink oxidized andesite
750-810	Andesite(?) flow. Oxidized flow top underlain by slightly coarser grained, massive andesite
810-880	Andesite(?) flow. Oxidized flow top
880-1010	Andesite flow. Dark-gray, massive
1010-1020	Masive, dark-gray andesite
1020-1100	No recovery
1100-1130	Andesite flow, massive, pinkish-gray andesite
1130-1160	No recovery

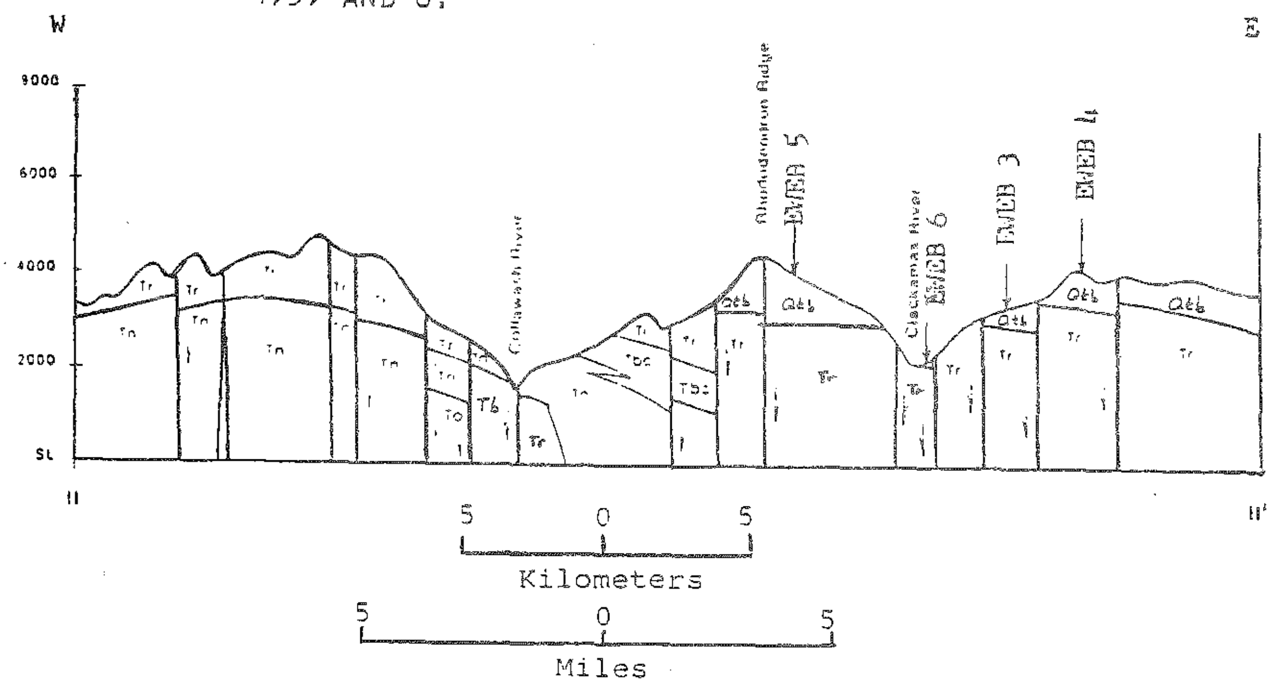
GENERAL OBSERVATIONS: (USGS) This drill hole penetrates twelve andesite flows and flow units. The flows are all similar in appearance and mineralogy. The cuttings show very little material which can be ascribed to hydrothermal alteration. The alteration is mainly Fe oxidation, leaching, and occasional redeposition on fracture surfaces as the mineral hematite. No vein or cavity deposits other than hematite are present in the cuttings.

GEOTHERMAL GRADIENT: The gradient pipe could only be set to 447 feet, and to that depth the well was essentially isothermal, with 10 meter depth temperature of 5.84°C, and bottom temperature of 4.48°C. Graph of gradient is on Figure 5 and in Table 1.

NAME OF WELL: Eugene Water & Electric Board No. 5. Tarzan Springs.
LOCATION: Long. 121°57'03" W., Lat. 44°50'59" N. SE¼SE¼ section 4, Township 7 South, Range 7 East, Clackamas County, Oregon. (Mount Hood National Forest)
ELEVATION 4200 feet (1280.5 meters).
TOTAL DEPTH 730 feet (222.6 meters).
TOPOGRAPHIC/GEOLOGIC LOCATION: On a major ridge on the inside of a bend in the Clackamas River, and about ½ mile southeast of a prominence called "Burnt Granite" which is andesite. This is the highest of the six wells drilled in this project. The adjacent valley to the north and east is about 2000 feet lower than the drill site. A geologic cross-section prepared by the U. S. Geological Survey from work by Dr. Paul Hammond showing the site of this well and the sites of wells 3, 4, and 6 is here reproduced as Figure 4.

Figure 4

CROSS-SECTION SHOWING THE GENERALIZED GEOLOGIC RELATIONSHIPS (AFTER HAMMOND AND OTHERS, 1980) AND RELATIVE LOCATIONS OF EWEB DRILL HOLES 3, 4,5, AND 6.



Qtb - Older High Cascade basalt
Tr - Rhodendron Formation
Tbc - Beds of Bull Creek
Tn - Nohorn Andesite
Tb - Breitenbush Formation

(From: U. S. Geological Survey Open-File Report: Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 5 drill hole, Clackamas County, Oregon).

DRILLING DETAILS: Drilled with mud to about 500 feet but with considerable difficulty. Below 260 feet the section became highly variable with numerous permeable zones carrying water. Set surface casing in firm andesite and began to ream down hole to clear out debris which had fallen in with incoming water, and encountered a severe water flow at 260 feet. A loud roar could be heard down the well and at the same time a strong blast of cold air came out of the well bore. Lost several pits of mud down the hole including 105 sacks of lost circulation materials to no avail. Brought in commercial cement truck and put in 270 sacks of cement but failed to regain circulation. Went in again with lost circulation materials (cottonseed hulls, cedar fiber) and filled well to the top with these. Blizzard conditions forced abandonment of well site for two days. Re-entered well when weather conditions allowed access to site and continued to have drilling problems, drilling ultimately to 710 feet. In process a total of 21.15 tons of cement and 202 sacks of lost circulation material were placed in the hole during this drilling interval. Throughflows of ground water continued to wash out the hole. Abandoned drilling at 710 feet, and tried to set gradient pipe, but could only get it to 660 feet, where a two and one-half inch black iron pipe was set. Well was spudded on October 8 and completed November 7, 1979. It took approximately one month to go 730 feet at this site.

GEOLOGIC SECTION:

Interval (feet)	Lithology and Comments (USGS)
0-21	Overburden (swamp and glacial materials)
21-80	Andesite flow, very fresh, hard, with abundant small plagioclase phenocrysts in fine-grained gray groundmass.
80-120	Volcanic debris, much of it probably mudflow materials
120-130	Andesite flow. Fresh, fine-grained, with phenocrysts of plagioclase, clinopyroxene, and olivine
130-140	Volcanic debris. Dark-gray andesite with abundant white plagioclase phenocrysts is dominant rock type. Vapor-phase cavities are lined with pink oxidized rim, and hematite occurs in groundmass
140-150	Andesite flow. Dark-gray, massive, fine-grained with occasional phenocrysts of oliving, plagioclase, and orthopyroxene. Flow is very different from overlying flows
150-170	Volcanic debris. Mixed lithologies, with medium-gray andesite most abundant
170-300	Andesite flow. Probably more than one flow makes up this interval, but cuttings do not change significantly, except for minor oxidation and vapor-phase cavities increasing with depth

Interval (feet)	Lithology and Comments (USGS)
300-310	Andesite flow, fine-grained, medium-gray with occasional phenocrysts of plagioclase, olivine, and clinopyroxene. Hematite and cristobalite present in groundmass. Distinctive from the overlying flow
310-425	Volcanic debris. Mixture of volcanic fragments in varying proportions, indicating interval may consist of several thin flows between volcanic debris layers, or that several large volcanic boulders were encountered during drilling
425-450	Andesite flow, partly oxidized, with few phenocrysts of plagioclase, olivine, and clinopyroxene. Groundmass contains plagioclase, clinopyroxene, hematite, and cristobalite
450-500	Andesite flow, similar to overlying flow but two are separated by oxidized layer at 450 feet
500-530	Volcanic debris
530-550	Dacite. Fresh, light-gray, medium to fine-grained with scarce phenocrysts of plagioclase and clinopyroxene. Groundmass of plagioclase, cristobalite, clinopyroxene, and hematite
550-580	Volcanic debris
580-600	Andesite flow, medium-gray, to mottle pink porphyritic andesite with sporadic phenocrysts of plagioclase, clinopyroxene, orthopyroxene, and olivine. Vapor-phase hematite and tridymite occur in cavaties
600-660	Volcanic debris
660-720	Andesite flow, thin flow, medium-gray, dense, fine-grained, with few phenocrysts
720-730	Dacite flow, light-gray, fine-grained, equigranular

GENERAL OBSERVATIONS: (USGS) Much of this drill hole is probably in the upper Miocene Rhododendron Formation which is hydrothermally altered nearly everywhere it crops out. Alteration in EWEB 5 drill hole consists of two types:

(1) Fe oxidation which changes color of rock from gray to pink or reddish by staining. This process can occur during cooling of the flows and probably accounts for most of the oxidation described for these rocks.

(2) Alteration of thermal waters due to low-temperature circulation. The brick-red groundmass alteration of the nearby surface outcrops, and the volcanic debris units in the drill hole is probably due to low-temperature hydrothermal alteration.

GEOTHERMAL GRADIENT: The well was essentially isothermal over the entire depth. Temperature at 33 feet (10 meters) was 4.23°C, and at 635 feet (193.5 meters) was 5.31°C. Figures of final logging on May 28, 1980 are in Table 1, with graph of figures, and graph also of well temperature log is on Figure 5.

NAME OF WELL: Eugene Water & Electric Board No. 6. Sisi Creek.
LOCATION: Long. 121°52'52" W., 44°54'19" N., Clackamas County, Oregon. (Mount Hood National Forest).
ELEVATION: 2800 feet. (853.7 meters).
TOTAL DEPTH 1510 feet (460.4 meters).
TOPOGRAPHIC/GEOLOGIC LOCATION: On the west side base of Sisi Butte, on the east edge of the valley of the Clackamas River. Glacial debris mantles the area. Sisi Butte is a conspicuous young volcanic cone with the top about 1.9 miles east of the drill site.
DRILLING DETAILS: Drilling the coarse, boulder (up to 4 feet in diameter) surficial glacial debris was a problem and the drill stuck temporarily several times to base of glacial debris at 69 feet. Drilled into andesite and on to 90 feet where drill stick and twisted off sub and bit. Attempted to fish unsuccessfully. Moved rig 20 feet and began to re-drill. Drilled to 470 feet and then had lost circulation. Gunk plugs and lost circulation materials did not help and cement truck called in. 170 sacks of cement put into hole. Drilled out, and with minor lost circulation problems continued to total depth of 1510 feet. Hung two and one-half inch black iron gradient pipe in hole.
GEOLOGIC SECTION:

<u>Interval</u> (feet)	<u>Lithology and Comments</u> (USGS)
0-69	Glacial debris
70-80	Olivine basalt flow
80-140	Basalt flow, upper 20 feet somewhat vesicular. Small phenocrysts of clear to white plagioclase abundant
140-280	Basalt flow, nearly equigranular fine-grained orthopyroxene, clinopyroxene, plagioclase, and minor olivine
280-320	Flow consisting of interlayered obsidian and andesite
320-460	Volcanic debris; dominant rock types are dense, dark and medium-gray andesites
460-560	Interval of hydrothermal alteration. No recovery was obtained through much of this interval A small amount of material at 500 to 560 feet consists of fine-grained soft, pink to buff hydrothermally altered volcanic rock
560-1300	Dacite, fine-grained, with phenocrysts of plagioclase and partly oxidized reddish black altered hornblende
1300-1350	Volcanic debris, multicolored fragments of volcanic material
1350-1410	Andesite flow, dark-gray, dense, fine-grained
1410-1440	Andesite flow, dark-gray, with scattered clear plagioclase phenocrysts
1410-1510	Andesite flow, mostly pink oxidized, some dark-gray andesite

GENERAL OBSERVATIONS (USGS) Hydrothermal alteration in EWEB 6 is significant in two intervals:

(1) 470-560 feet where recovery consists of a few pieces of light pink altered dacite which has been extensively altered to montmorillonite. A possibility is that the 470-560 foot interval is a fault zone that formerly served as a channel for low-temperature hydrothermal fluid. Temperature data from the drill log give no indication of present hydrothermal fluids.

(2) 760-800 feet where there are red to orange iron-stained fracture surfaces. The driller's log at 800 feet mentions red clay, but nothing other than iron hydroxide appears in the cuttings.

GEOTHERMAL GRADIENT: Temperature data for this well in final log on April 29, 1980 are shown on Table 1, and plot of the geothermal gradient data is shown on Figure 5 and in a plot also in Table 1. The gradient for the first approximately 82 feet (25 meters) is essentially isothermal. This represents the vadose water zone. From 82 feet (25 meters) to total depth of 1510 feet (460 meters) the gradient is essentially linear at about 51.9°C/Km which is about average for this portion of the Cascades.

SUMMARY AND CONCLUSIONS

Six wells were drilled during this program, although in effect seven were drilled as two wells were drilled at site 3, the second well, however, actually going to a lesser depth than the first. Three of the wells (3, 4, and 5) were drilled in areas which topographically are subject to strong through-flows of ground water. None of these wells reached the regional ater table, and all showed essentially isothermal geothermal gradients. The single well which was started essentially at the water table (well 6) shows a linear temperature rise with depth essentially from the top of the well bore. Well number 2 (Twin Meadows) shows an isothermal gradient down to the level of the regional water table (the main stream valley adjacent to the well site on the west) and then shows a linear gradient of about 70°C/Km from the regional water table to total depth.

Well number 1 (Fish Lake Creek), which was drilled on a broad interstream divide between the headwaters of the North Fork of the McKenzie River, and the North Santiam River and is not immediately adjacent to any deep valleys, shows essentially an isothermal gradient in much of the lower part of the well, reflecting cold water saturation of this portion of the drilled section, but the upper part of the wells shows a high gradient (102°C/Km) which may be due to the presence at about 655 feet (200 meters) of a fracture which is carrying warm water from a geothermal system in the region. The most probable location of such a system is to the east and northeast, which is topographically up-slope and is a fracture line marked by several young (3000 years) volcanic cones (the Sand Mountain, and Nash Crater-Little Nash Crater lineaments). This area should be investigated further.

Little alteration was found in cuttings from any of the wells which could be ascribed to active geothermal systems. However, only two of the wells got below 1160 feet, so the sampling is from rather surficial rocks. It is likely that the continual flow of cold vadose waters through the surficial rocks of the Cascades (from the 80 to 100 or more inches of annual precipitation) does now and did also in the past preclude the the ability of thermal waters to reach these surficial rocks, and therefore evidence of geothermal systems is not likely to be found at shallow depths in the upland areas of these terrains.

Drilling with light equipment to depths of 2000 feet or less appears to be feasible and rewarding only where the well site can be located so that the regional water table can be found at shallow depth. Wells located where there is a thick interval of vadose waters to be penetrated are likely to have severe drilling problems, and unless the vadose zone is completely penetrated and the drill goes a reasonable distance below the regional water table, the wells will simply shown an isothermal gradient. This area where shallow wells are generally of little use is the broad upland bench-like area which lies west of the Cascade crest and east of the first major system of stream valleys.

DR. BLACKWELL'S OBSERVATIONS ON THESE GRADIENTS

Dr. David Blackwell of the Geothermal Laboratory at Southern Methodist University made conductivity tests on a complete suite of cuttings from all the wells and provided the data and graphs which are on Figure 5 and in Table 1. He also has provided a written summary of his observations on these data and his statement is here reproduced on the following three pages in its entirety.

HEAT FLOW AND GEOTHERMAL IMPLICATIONS OF THE EWEB CASCADE DRILL HOLES

David D. Blackwell

A series of holes drilled under the direction of Walter Youngquist, Ph.D., with the sponsorship of the Eugene Water and Electric Board and supported by DOE, represent the first intermediate-depth drilling information in the public domain in the central Oregon High Cascade Range. Temperature measurements have been made in these holes by personnel from the Oregon Department of Geology and Mineral Industries and from Southern Methodist University. In addition, gamma logs were obtained on the accessible holes. Thermal conductivity measurements were made in the SMU Geothermal Laboratory, and terrain corrections and heat flow calculations have also been made by this laboratory. A set of equilibrium temperature logs measured in the late spring of 1980 are shown in Figure 5 and a summary of location and thermal data are included in Table 1.

The holes fall into two different groups of "type" temperature-depth curves, with five of the holes associated with one type and one hole associated with the second type. The characteristic feature of temperature-depth curves drilled in the Western Cascade volcanic rocks in earlier years by DOGAMI has been linear temperature-versus-depth curves. It has become clear that the altered volcanic rocks of the Western Cascade province in general are relatively impermeable. It was also clear in the shallower drilling that, as sites were moved into the High Cascade rocks, the shallow temperatures would be swamped by copious water circulation in the porous young volcanic rocks at the surface, and that deeper holes would be necessary in order to investigate conditions below the young volcanic rocks. The EWEB series of holes illustrates the truth of these conclusions. Five of the drill holes indicate very low gradients to depths in excess of 100 m, and in four cases, to depths in excess of 150 m. The observed gradients approach the "regional" gradient (60-70°C/km) at a depth of approximately 150 m in 8S/8E-6dd, and rather abruptly at a depth of 220 m in hole 12S/7E-9da. The average temperature gradient below 150 m in hole 8S/8E-6dd is 63°C/km, corrected for topographic effects, while the average temperature gradient below 250 m in hole 12S/7E-9da is 69°C/km, corrected for topographic effects. Both of these mean gradients are typical background gradients similar to those observed in the Western Cascade Range east of the heat flow transition, which appears to mark the western thermal boundary of the High Cascade Range thermal anomaly (see Blackwell _et al._, 1978, 1979).

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The very high gradients between 290 and 310 m in hole 8S/8E-6dd are either due to lithology or due to a slight fluid upflow in the borehole from near the bottom. Thermal conductivity measurements indicate a rock-type change in this depth range; however, the gamma log does not indicate a major change in the nature of K, U or Th content, although near the bottom of the hole, the gamma log does show more character, typical of interbedded basic volcanic rocks and tuffs or volcanoclastic rocks.

Even though the shallow gradients have been "swamped" to depths of 150-220 m in these holes, this effect might not be present everywhere. If active hydrothermal systems are present in High Cascade rocks, the rocks might be highly altered to a relatively impermeable state. In this case shallow holes might give conductive gradients.

The best heat flow values determined for holes 8S/8E-6dd and 12S/7E-9da are the same, 94 mW/m^2. Holes 7S/7E-4dd, 7S/8E-5dd and 7S/8E-10ad were drilled at the highest elevations, and failed to penetrate through the carapace of young, porous volcanic rocks. Consequently, the temperature-depth curves are essentially isothermal in these holes, and we are able to obtain no information about possible temperature gradients at depth.

Hole 13S/7E-32dc has an unusual temperature-depth curve. It is nearly isothermal through young basalts to a depth of 60 m, at which point the gradient is high and constant, with a value of 102°C/km. At a depth of 200 m, the gradient becomes isothermal and finally negative. It gradually increases and becomes positive again toward the bottom of the hole. The cause for this type of curve has been discussed in a previous letter: lateral flow of warm water along an aquifer between 200-220 m, superimposed on a background of relatively low heat flow. If more than one hole were available in this area, it would be possible to estimate the distance to the source and the possible temperature of the water coming up along the fracture zone and feeding this shallow aquifer. Based on a model similar to that discussed by Bodvarsson (1969), we estimate the initiation of the water flow in the age range of 1000 $\pm$ 500 years. This curve is typical of what one might expect to find associated with a geothermal system. It has already been recommended that the hole be perforated and samples be obtained from the aquifer at 200 m, in order for a chemical analysis to be performed and geochemical temperatures to be estimated.

In conclusion, the data have tended to confirm the ideas developed in drilling immediately to the west. The regional background gradient for the High Cascade Range is on the order of 60-70°C/km, with regional heat flow values of 95-110 mW/m^2. The high heat flow and geothermal gradients are maintained by a regional magma chamber at a depth of about 10 km. Superimposed on this background heat flow will be areas of low and high geothermal gradients and heat flow associated with groundwater and geothermal convective systems in the High Cascade Range. Groundwater convective systems obliterate shallow temperature gradients to the depths where groundwater penetration is rapid. Groundwater circulation, if as deep as 5 km, should generate temperatures high enough for commercial exploitation of the fluid in geothermal power production. Local hot spots may be associated with individual volcanoes, but the indications so far are that shallow magma chambers associated with the stratovolcanoes tend to be small. Commercial geothermal systems have not yet been directly identified in the results of the drilling.

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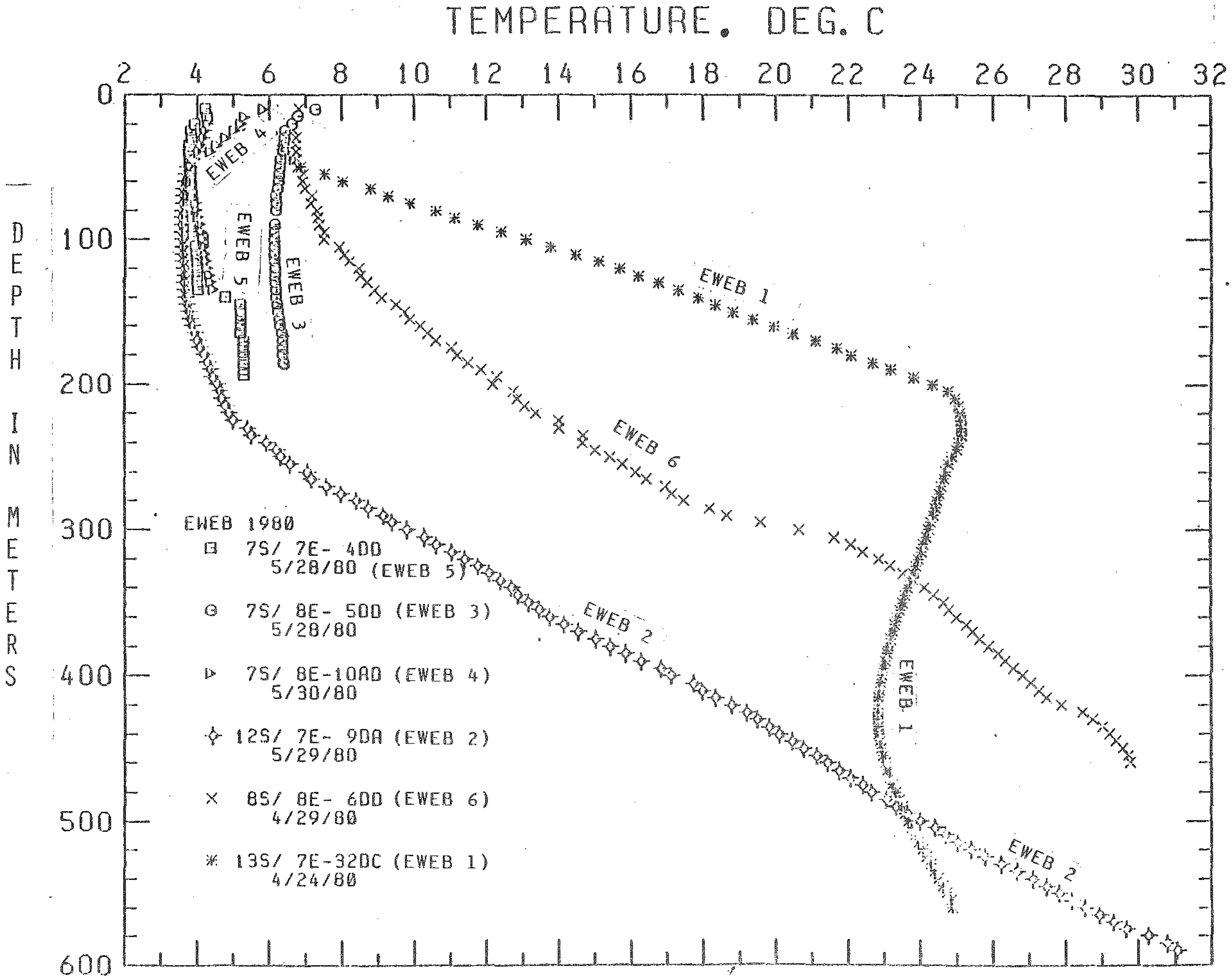
Blackwell, D.D., and J.L. Steele, Heat flow modeling of the Mount Hood volcano, Oregon, pp. 190-264, in Geothermal Resource Assessment of Mount Hood, Final Report, D.O.E. #AC06-77-ET-28369, 1979.

Bodvarsson, G., On the temperature of water flowing through fractures, Journal of Geophysical Research, 74 (8), p. 1987-1992, 1969.

FIGURE 5. Equilibirum temperature-depth plots for all six Eugene Water & Electric Board drill holes. (Supplied by Dr. David Blackwell, Geothermal Laboratory, Southern Methodist University, Dallas, Texas).

FIGURE 5



TEMPERATURE. DEG. C
DEPTH IN METERS
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
0 100 200 300 400 500 600
EWEB 1
EWEB 2
EWEB 3
EWEB 4
EWEB 5
EWEB 6
EWEB 1980
7S/ 7E- 40D 5/28/80 (EWEB 5)
7S/ 8E- 50D (EWEB 3) 5/28/80
7S/ 8E-10AD (EWEB 4) 5/30/80
12S/ 7E- 9DA (EWEB 2) 5/29/80
8S/ 8E- 6DD (EWEB 6) 4/29/80
13S/ 7E-32DC (EWEB 1) 4/24/80

FIGURE 6. Gamma ray log on EWEB no. 5. Tarzan Springs.

GAMMA RAY LOG

HOLE NAME: EWEB-TS EWEB NO. 5 TARZAN SPRINGS

LOCATION: 7S/7E-4DD

BEND AMS, OREGON

DATE: 11/13/79

DEPTH LOGGED: 190 METERS

SPEED LOGGED: 6 METERS/MINUTE

TIME CONSTANT: 3 SECONDS

FULL SCALE: 100 COUNTS/SECOND

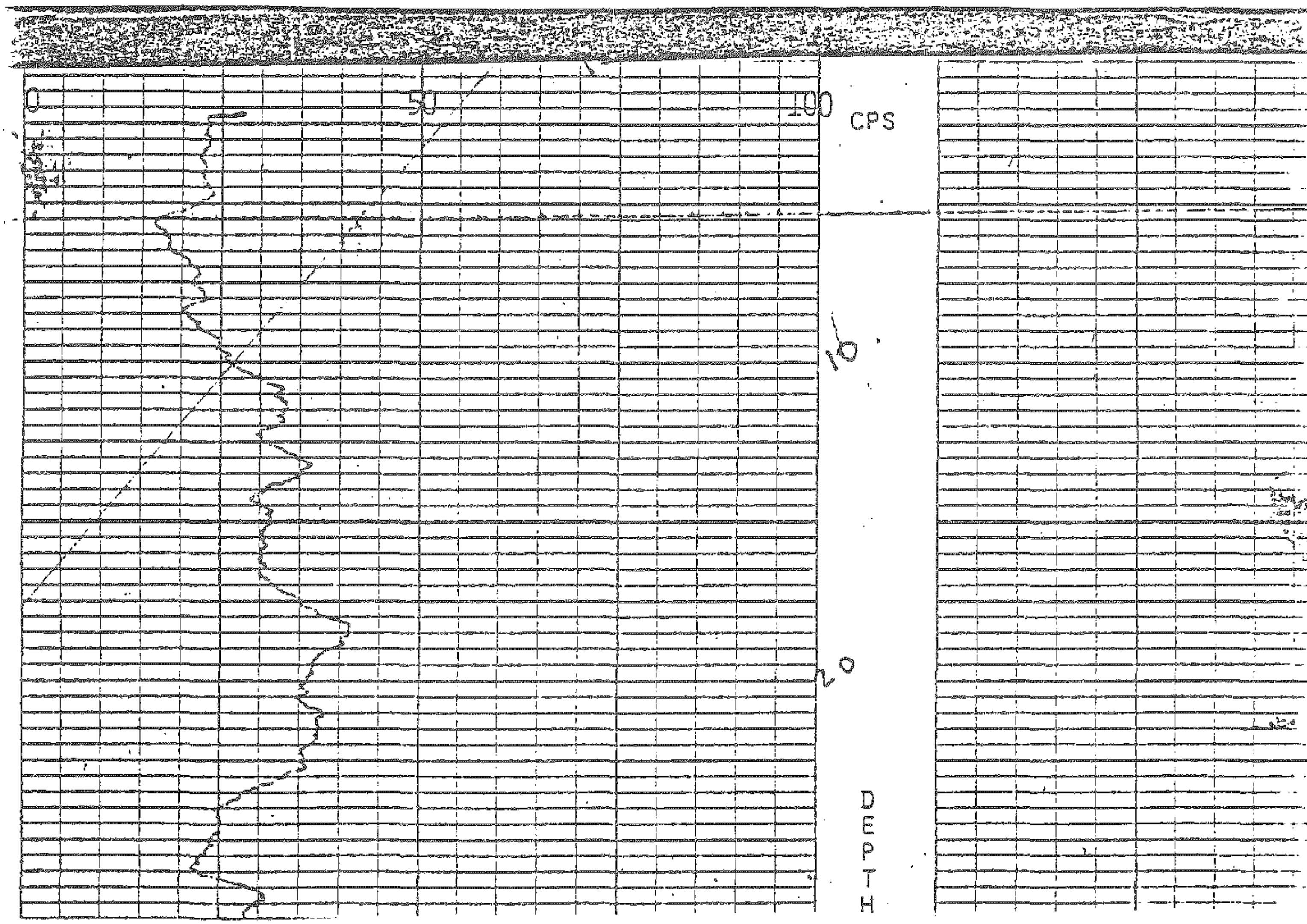


FIGURE 7. Gamma ray log on EWEB no. 6. Sisi Creek.

GAMMA RAY LOG

HOLE NAME: EWEB-SB EWEB NO. 6
SISI CREEK

LOCATION: 8S/8E-6DD

BEND AMS, OREGON

DATE: 11/13/79

DEPTH LOGGED: 457.5 METERS

SPEED LOGGED: 6 METERS/MINUTE

TIME CONSTANT: 3 SECONDS

FULL SCALE: 100 COUNTS/SECOND

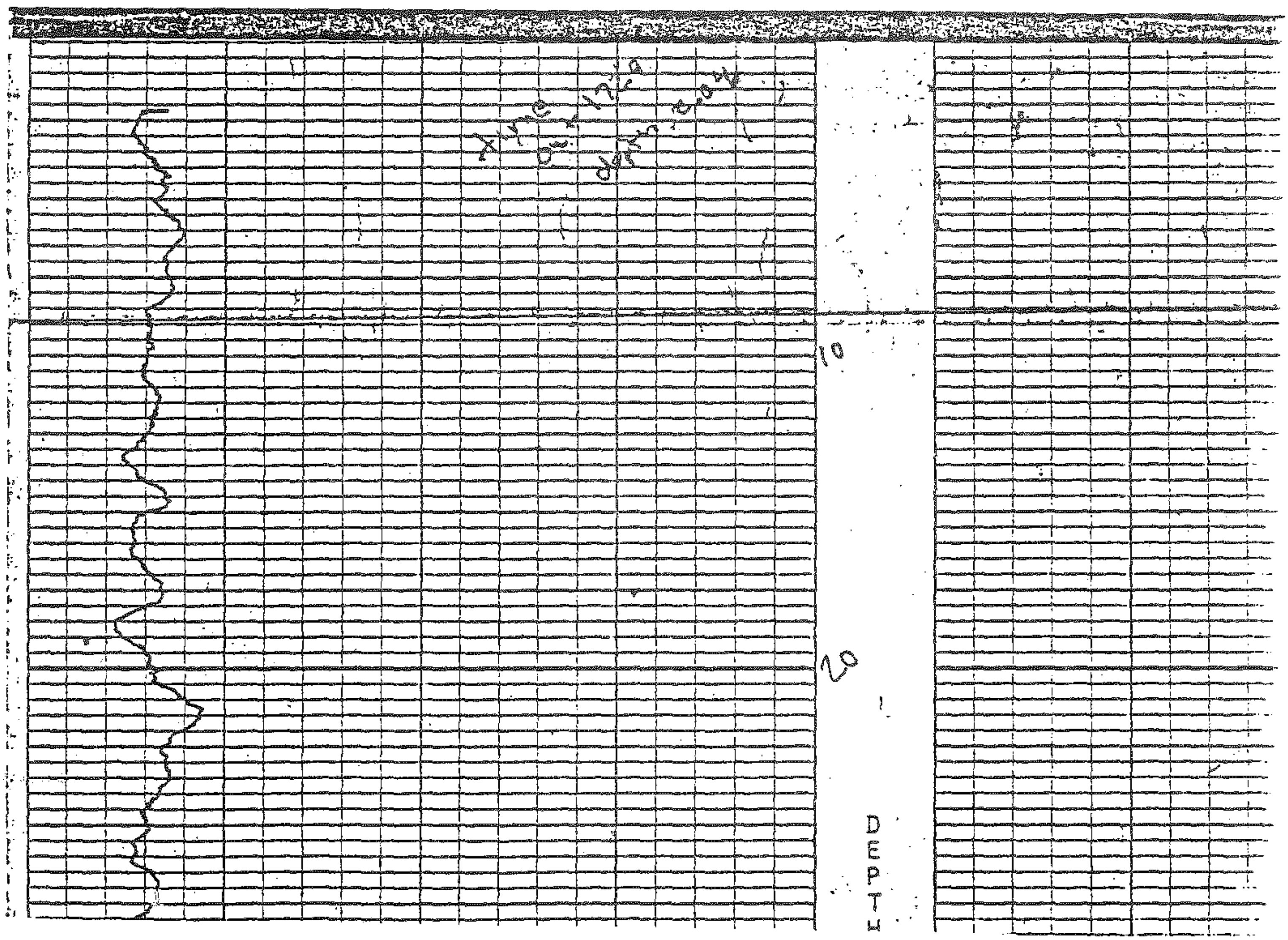


TABLE 1. Equilibrium temperature-depth data for EWEB drill holes, with plots of individual well data. (Supplied by Dr. David Blackwell, Geothermal Laboratory, Southern Methodist University, Dallas, Texas).

TABLE 1. Geothermal data for EWEB holes. (Summary)

Twn/Rng-Section	Prov.	N Lat. Deg.Min.	W Long. Deg.Min.	Hole # Date	Collar Elev. (m)	Depth Interval (m)	Avg. TC $Wm^{-1}K^{-1}$	# TC	Uncorr. Gradient °C/km	Corr. Gradient °C/km	Corr. HF mWm^{-1}	HF Qual.	Lithologic Summary
(EWEB 3) 7S/ 8E- 5DD	HC	44-59.0	121-50.8	EWEB-PC 10/30/79	975	70.0 185.0	1.58 .04	10	4.5 .8			X	BASALT (Q)
(EWEB 5) 7S/ 7E- 4DD	HC	44-59.0	121-57.0	EWEB-TS 11/13/79	1273	165.0 190.0	1.62 .04	10				X	BASALT (Q)
(EWEB 4) 7S/ 8E- 10AD	HC	44-58.5	121-48.4	EWEB-CC 10/18/79	1140	110.0 137.0	1.45 .10	10				X	BASALT (Q)
(EWEB 6) 8S/ 8E- 6DD	HC	44-54.3	121-52.9	EWEB-SB 11/13/79	860	150.0 460.0	1.49 .13	20	71.5 1.1	63.3	94	B	BASALT AND ANDESITE
(EWEB 2) 12S/7E- 9DA	HC	44-32.7	121-57.8	EWEB-TM 10/31/79	1195	300.0 600.0	1.36 .08		71.4 1.3	69.4	94	B	VOLCANICS
(EWEB 1) 13S/7E- 32DC	HC	44-23.3	121-59.7	EWEB-CL 10/30/79	955	50.0 205.0	1.44	10	112.0 2.2	102.8	148	B	ANDESITE & VOLCANICS
						.0 535.0	1.40	19	25.6 11.4	23.9	33	C	

Location System

B	A
C	D

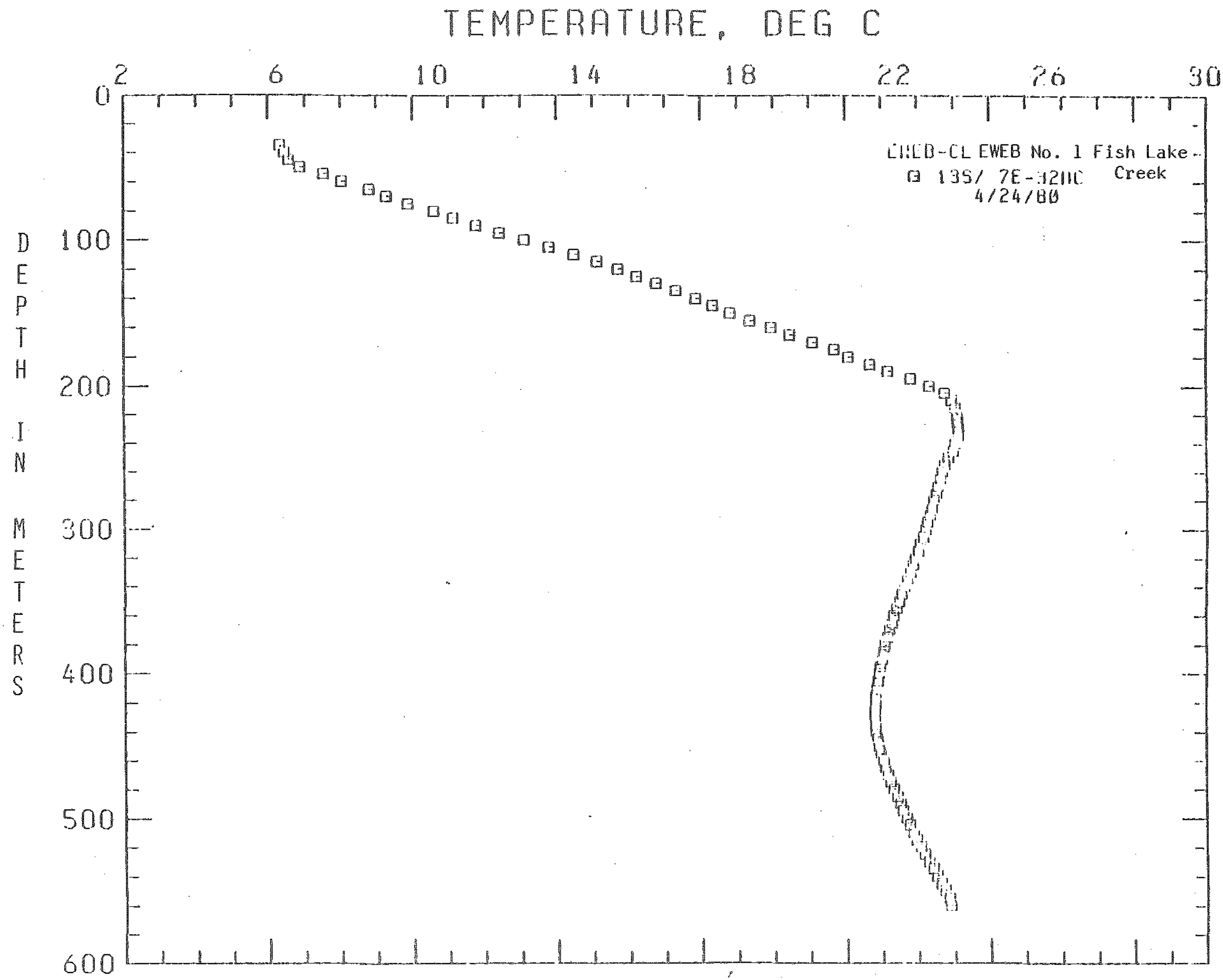
Section

LOCATION: BEND AMS, OREGON
13S/ 7E-32DC
HOLE NAME: EWEB-CL EWEB No. 1 Fish Lake Creek
DATE MEASURED: 4/24/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
35.0	114.8	6.340	43.41	0.0	0.0
40.0	131.2	6.450	43.61	22.0	1.2
45.0	147.6	6.580	43.84	26.0	1.4
50.0	164.0	6.880	44.38	60.0	3.3
55.0	180.4	7.530	45.55	130.0	7.1
60.0	196.8	8.040	46.47	102.0	5.6
65.0	213.2	8.810	47.86	154.0	8.5
70.0	229.6	9.290	48.72	96.0	5.3
75.0	246.0	9.880	49.78	118.0	6.5
80.0	262.4	10.610	51.10	146.0	8.0
85.0	278.8	11.130	52.03	104.0	5.7
90.0	295.2	11.770	53.19	128.0	7.0
95.0	311.6	12.430	54.37	132.0	7.2
100.0	328.0	13.110	55.60	136.0	7.5
105.0	344.4	13.790	56.82	136.0	7.5
110.0	360.8	14.480	58.06	138.0	7.6
115.0	377.2	15.120	59.22	128.0	7.0
120.0	393.6	15.700	60.26	116.0	6.4
125.0	410.0	16.210	61.18	102.0	5.6
130.0	426.4	16.770	62.19	112.0	6.1
135.0	442.8	17.320	63.18	110.0	6.0
140.0	459.2	17.870	64.17	110.0	6.0
145.0	475.6	18.330	64.99	92.0	5.0
150.0	492.0	18.810	65.86	96.0	5.3
155.0	508.4	19.360	66.85	110.0	6.0
160.0	524.8	19.940	67.89	116.0	6.4
165.0	541.2	20.470	68.85	106.0	5.8
170.0	557.6	21.100	69.98	126.0	6.9
175.0	574.0	21.700	71.06	120.0	6.6
180.0	590.4	22.090	71.76	78.0	4.3
185.0	606.8	22.690	72.84	120.0	6.6
190.0	623.2	23.190	73.74	100.0	5.5
195.0	639.6	23.820	74.88	126.0	6.9
200.0	656.0	24.340	75.81	104.0	5.7
205.0	672.4	24.760	76.57	84.0	4.6
210.0	688.8	24.960	76.93	40.0	2.2
215.0	705.2	25.060	77.11	20.0	1.1
220.0	721.6	25.110	77.20	10.0	0.5
225.0	738.0	25.130	77.23	4.0	0.2
230.0	754.4	25.150	77.27	4.0	0.2
235.0	770.8	25.140	77.25	-2.0	-0.1
240.0	787.2	25.050	77.09	-18.0	-1.0
245.0	803.6	25.000	77.00	-10.0	-0.5
250.0	820.0	24.860	76.75	-28.0	-1.5
255.0	836.4	24.760	76.57	-20.0	-1.1
260.0	852.8	24.690	76.44	-14.0	-0.8
265.0	869.2	24.640	76.35	-10.0	-0.5
270.0	885.6	24.580	76.24	-12.0	-0.7
275.0	902.0	24.520	76.14	-12.0	-0.7
280.0	918.4	24.460	76.03	-12.0	-0.7
285.0	934.8	24.410	75.94	-10.0	-0.5
290.0	951.2	24.350	75.83	-12.0	-0.7
295.0	967.6	24.290	75.72	-12.0	-0.7
300.0	984.0	24.230	75.61	-12.0	-0.7
305.0	1000.4	24.160	75.49	-14.0	-0.8
310.0	1016.8	24.080	75.34	-16.0	-0.9
315.0	1033.2	24.020	75.24	-12.0	-0.7
320.0	1049.6	23.940	75.09	-16.0	-0.9
325.0	1066.0	23.870	74.97	-14.0	-0.8
330.0	1082.4	23.800	74.84	-14.0	-0.8
335.0	1098.8	23.720	74.70	-16.0	-0.9
340.0	1115.2	23.640	74.55	-16.0	-0.9
345.0	1131.6	23.570	74.43	-14.0	-0.8
350.0	1148.0	23.490	74.28	-16.0	-0.9
355.0	1164.4	23.420	74.16	-14.0	-0.8
360.0	1180.8	23.350	74.03	-14.0	-0.8
365.0	1197.2	23.290	73.92	-12.0	-0.7
370.0	1213.6	23.220	73.80	-14.0	-0.8
375.0	1230.0	23.170	73.71	-10.0	-0.5
380.0	1246.4	23.110	73.60	-12.0	-0.7
385.0	1262.8	23.060	73.51	-10.0	-0.5
390.0	1279.2	23.010	73.42	-10.0	-0.5
395.0	1295.6	22.970	73.35	-8.0	-0.4
400.0	1312.0	22.930	73.27	-8.0	-0.4
405.0	1328.4	22.900	73.22	-6.0	-0.3
410.0	1344.8	22.860	73.15	-8.0	-0.4
415.0	1361.2	22.830	73.09	-6.0	-0.3
420.0	1377.6	22.820	73.08	-2.0	-0.1
425.0	1394.0	22.810	73.06	-2.0	-0.1
430.0	1410.4	22.810	73.06	0.0	0.0
435.0	1426.8	22.820	73.08	2.0	0.1
440.0	1443.2	22.830	73.09	2.0	0.1

LOCATION: BEND AMS, OREGON
13S/ 7E-32DC
HOLE NAME: EWEB-CL EWEB No. 1 Fish Lake Creek (continued)
DATE MEASURED: 4/24/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
445.0	1459.6	22.880	73.18	10.0	0.5
450.0	1476.0	22.920	73.26	8.0	0.4
455.0	1492.4	22.970	73.35	10.0	0.5
460.0	1508.8	23.030	73.45	12.0	0.7
465.0	1525.2	23.080	73.54	10.0	0.5
470.0	1541.6	23.150	73.67	14.0	0.8
475.0	1558.0	23.230	73.81	16.0	0.9
480.0	1574.4	23.310	73.96	16.0	0.9
485.0	1590.8	23.410	74.14	20.0	1.1
490.0	1607.2	23.490	74.28	16.0	0.9
495.0	1623.6	23.570	74.43	16.0	0.9
500.0	1640.0	23.660	74.59	18.0	1.0
505.0	1656.4	23.750	74.75	18.0	1.0
510.0	1672.8	23.850	74.93	20.0	1.1
515.0	1689.2	23.950	75.11	20.0	1.1
520.0	1705.6	24.060	75.31	22.0	1.2
525.0	1722.0	24.170	75.51	22.0	1.2
530.0	1738.4	24.280	75.70	22.0	1.2
535.0	1754.8	24.400	75.92	24.0	1.3
540.0	1771.2	24.510	76.12	22.0	1.2
545.0	1787.6	24.620	76.32	22.0	1.2
550.0	1804.0	24.730	76.51	22.0	1.2
555.0	1820.4	24.850	76.73	24.0	1.3
560.0	1836.8	24.880	76.78	6.0	0.3

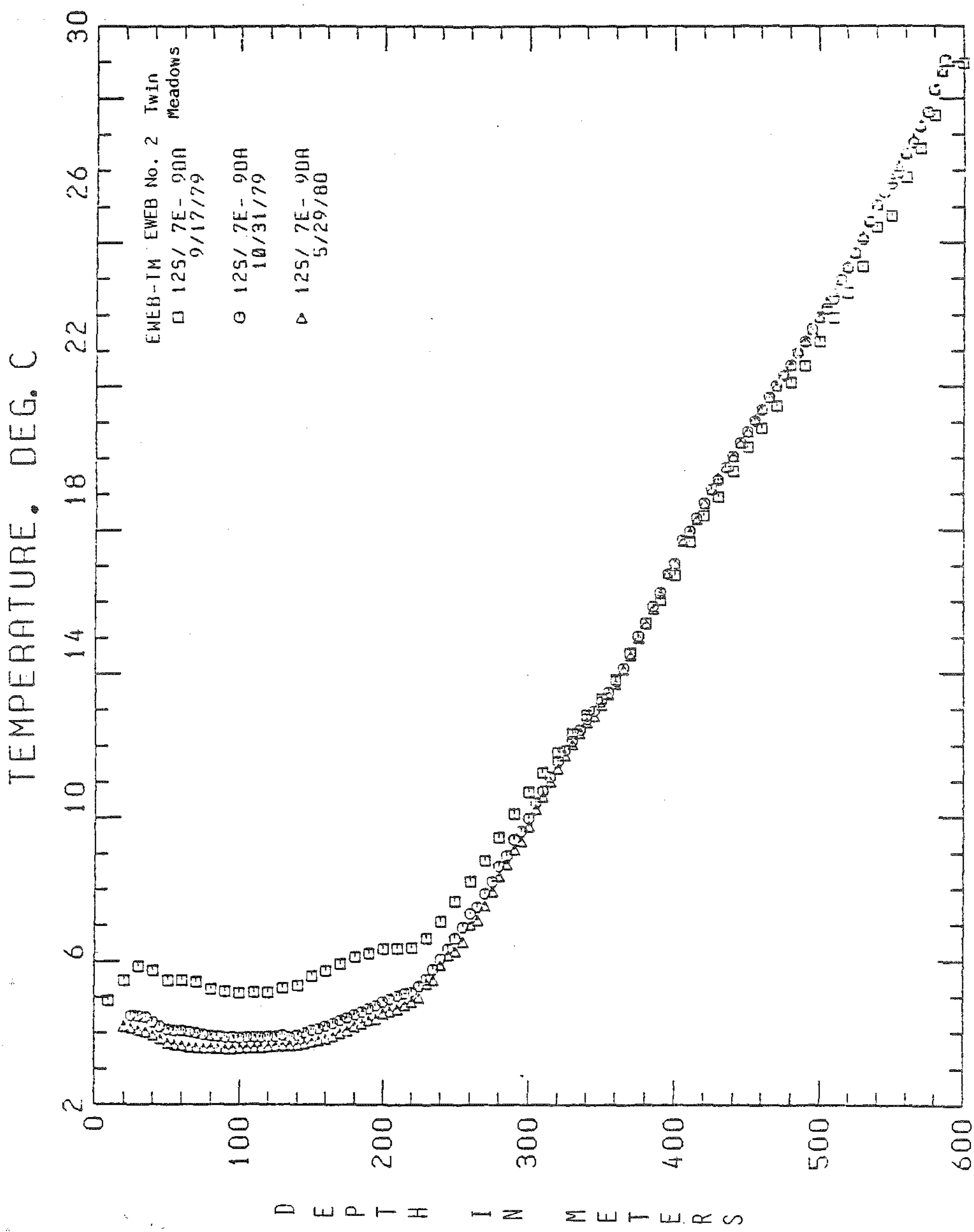

TEMPERATURE, DEG C
2
6
10
14
18
22
26
30
0
100
200
300
400
500
600
DEPTH IN METERS
CHED-CL EWEB No. 1 Fish Lake Creek
13S/ 7E-32DC
4/24/80

LOCATION: BEND AMS, OREGON
12S/ 7E- 9DA
HOLE NAME: EWEB-TM EWEB No. 2 Twin Meadows
DATE MEASURED: 5/29/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
20.0	65.6	4.190	39.54	0.0	0.0
25.0	82.0	4.150	39.47	-8.0	-0.4
30.0	98.4	4.080	39.34	-14.0	-0.8
35.0	114.8	4.030	39.25	-10.0	-0.5
40.0	131.2	3.930	39.07	-20.0	-1.1
45.0	147.6	3.840	38.91	-18.0	-1.0
50.0	164.0	3.710	38.68	-26.0	-1.4
55.0	180.4	3.660	38.59	-10.0	-0.5
60.0	196.8	3.640	38.55	-4.0	-0.2
65.0	213.2	3.600	38.48	-8.0	-0.4
70.0	229.6	3.590	38.46	-2.0	-0.1
75.0	246.0	3.580	38.44	-2.0	-0.1
80.0	262.4	3.570	38.43	-2.0	-0.1
85.0	278.8	3.560	38.41	-2.0	-0.1
90.0	295.2	3.560	38.41	0.0	0.0
95.0	311.6	3.560	38.41	0.0	0.0
100.0	328.0	3.570	38.43	2.0	0.1
105.0	344.4	3.570	38.43	0.0	0.0
110.0	360.8	3.580	38.44	2.0	0.1
115.0	377.2	3.590	38.46	2.0	0.1
120.0	393.6	3.610	38.50	4.0	0.2
125.0	410.0	3.620	38.52	2.0	0.1
130.0	426.4	3.630	38.53	2.0	0.1
135.0	442.8	3.640	38.55	2.0	0.1
140.0	459.2	3.660	38.59	4.0	0.2
145.0	475.6	3.700	38.66	8.0	0.4
150.0	492.0	3.740	38.73	8.0	0.4
155.0	508.4	3.780	38.80	8.0	0.4
160.0	524.8	3.840	38.91	12.0	0.7
165.0	541.2	3.910	39.04	14.0	0.8
170.0	557.6	3.990	39.18	16.0	0.9
175.0	574.0	4.050	39.29	12.0	0.7
180.0	590.4	4.170	39.51	24.0	1.3
185.0	606.8	4.270	39.69	20.0	1.1
190.0	623.2	4.350	39.83	16.0	0.9
195.0	639.6	4.390	39.90	8.0	0.4
200.0	656.0	4.530	40.15	28.0	1.5
205.0	672.4	4.610	40.30	16.0	0.9
210.0	688.8	4.650	40.37	8.0	0.4
215.0	705.2	4.770	40.59	24.0	1.3
220.0	721.6	4.870	40.77	20.0	1.1
225.0	738.0	4.980	40.96	22.0	1.2
230.0	754.4	5.380	41.68	80.0	4.4
235.0	770.8	5.480	41.86	20.0	1.1
240.0	787.2	5.890	42.60	82.0	4.5
245.0	803.6	6.160	43.09	54.0	3.0
250.0	820.0	6.290	43.32	26.0	1.4
255.0	836.4	6.540	43.77	50.0	2.7
260.0	852.8	7.020	44.64	96.0	5.3
265.0	869.2	7.140	44.85	24.0	1.3
270.0	885.6	7.550	45.59	82.0	4.5
275.0	902.0	7.950	46.31	80.0	4.4
280.0	918.4	8.370	47.07	84.0	4.6
285.0	934.8	8.710	47.68	68.0	3.7
290.0	951.2	9.110	48.40	80.0	4.4
295.0	967.6	9.360	48.85	50.0	2.7
300.0	984.0	9.760	49.57	80.0	4.4
305.0	1000.4	10.240	50.43	96.0	5.3
310.0	1016.8	10.580	51.04	68.0	3.7
315.0	1033.2	11.010	51.82	86.0	4.7
320.0	1049.6	11.360	52.48	74.0	4.1
325.0	1066.0	11.730	53.11	70.0	3.8
330.0	1082.4	12.040	53.67	62.0	3.4
335.0	1098.8	12.360	54.25	64.0	3.5
340.0	1115.2	12.670	54.81	62.0	3.4
345.0	1131.6	12.840	55.11	34.0	1.9
350.0	1148.0	13.140	55.65	60.0	3.3
355.0	1164.4	13.430	56.17	58.0	3.2
360.0	1180.8	13.730	56.71	60.0	3.3
365.0	1197.2	14.120	57.42	78.0	4.3
370.0	1213.6	14.510	58.12	78.0	4.3
375.0	1230.0	15.000	59.00	98.0	5.4
380.0	1246.4	15.390	59.70	78.0	4.3
385.0	1262.8	15.820	60.48	86.0	4.7
390.0	1279.2	16.250	61.25	86.0	4.7
395.0	1295.6	16.810	62.26	112.0	6.1
400.0	1312.0	17.080	62.74	54.0	3.0
405.0	1328.4	17.700	63.86	124.0	6.8
410.0	1344.8	17.950	64.31	50.0	2.7
415.0	1361.2	18.310	64.96	72.0	4.0
420.0	1377.6	18.740	65.73	86.0	4.7
425.0	1394.0	19.160	66.49	84.0	4.6

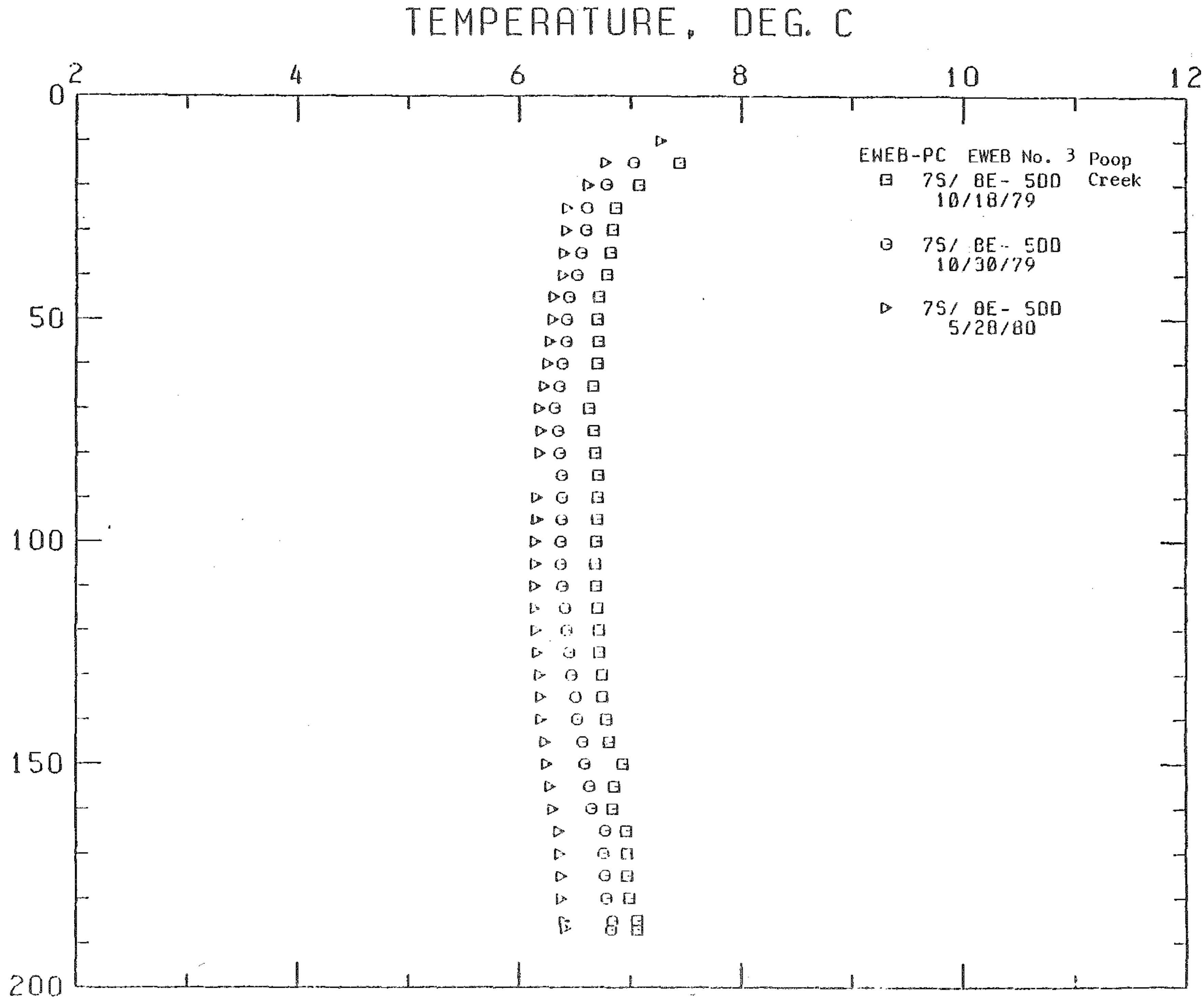
12S/ 7E- 9DA
HOLE NAME: EWEB-TM1 EWEB No. 2 Twin Meadows (continued)
DATE MEASURED: 5/29/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
430.0	1410.4	19.450	67.01	58.0	3.2
435.0	1426.8	19.770	67.59	64.0	3.5
440.0	1443.2	20.050	68.09	56.0	3.1
445.0	1459.6	20.420	68.76	74.0	4.1
450.0	1476.0	20.730	69.31	62.0	3.4
455.0	1492.4	21.090	69.96	72.0	4.0
460.0	1508.8	21.380	70.48	58.0	3.2
465.0	1525.2	21.720	71.10	68.0	3.7
470.0	1541.6	22.020	71.64	60.0	3.3
475.0	1558.0	22.360	72.25	68.0	3.7
480.0	1574.4	22.600	72.68	48.0	2.6
485.0	1590.8	23.020	73.44	84.0	4.6
490.0	1607.2	23.290	73.92	54.0	3.0
495.0	1623.6	23.600	74.48	62.0	3.4
500.0	1640.0	23.960	75.13	72.0	4.0
505.0	1656.4	24.370	75.87	82.0	4.5
510.0	1672.8	24.660	76.39	58.0	3.2
515.0	1689.2	24.990	76.98	66.0	3.6
520.0	1705.6	25.370	77.67	76.0	4.2
525.0	1722.0	25.750	78.35	76.0	4.2
530.0	1738.4	26.180	79.12	86.0	4.7
535.0	1754.8	26.630	79.93	90.0	4.9
540.0	1771.2	27.080	80.74	90.0	4.9
545.0	1787.6	27.450	81.41	74.0	4.1
550.0	1804.0	27.800	82.04	70.0	3.8
555.0	1820.4	28.140	82.65	68.0	3.7
560.0	1836.8	28.510	83.32	74.0	4.1
565.0	1853.2	28.890	84.00	76.0	4.2
570.0	1869.6	29.270	84.69	76.0	4.2
575.0	1886.0	29.640	85.35	74.0	4.1
580.0	1902.4	30.250	86.45	122.0	6.7
585.0	1918.8	30.770	87.39	104.0	5.7
590.0	1935.2	31.040	87.87	54.0	3.0


TEMPERATURE, DEG. C
30
26
22
18
14
10
6
2
0
100
200
300
400
500
600
DEPTH IN METERS
EWEB-TM EWEB No. 2 Twin Meadows
□ 12S/ 7E- 9DA 9/17/79
⊖ 12S/ 7E- 9DA 10/31/79
△ 12S/ 7E- 9DA 5/29/80

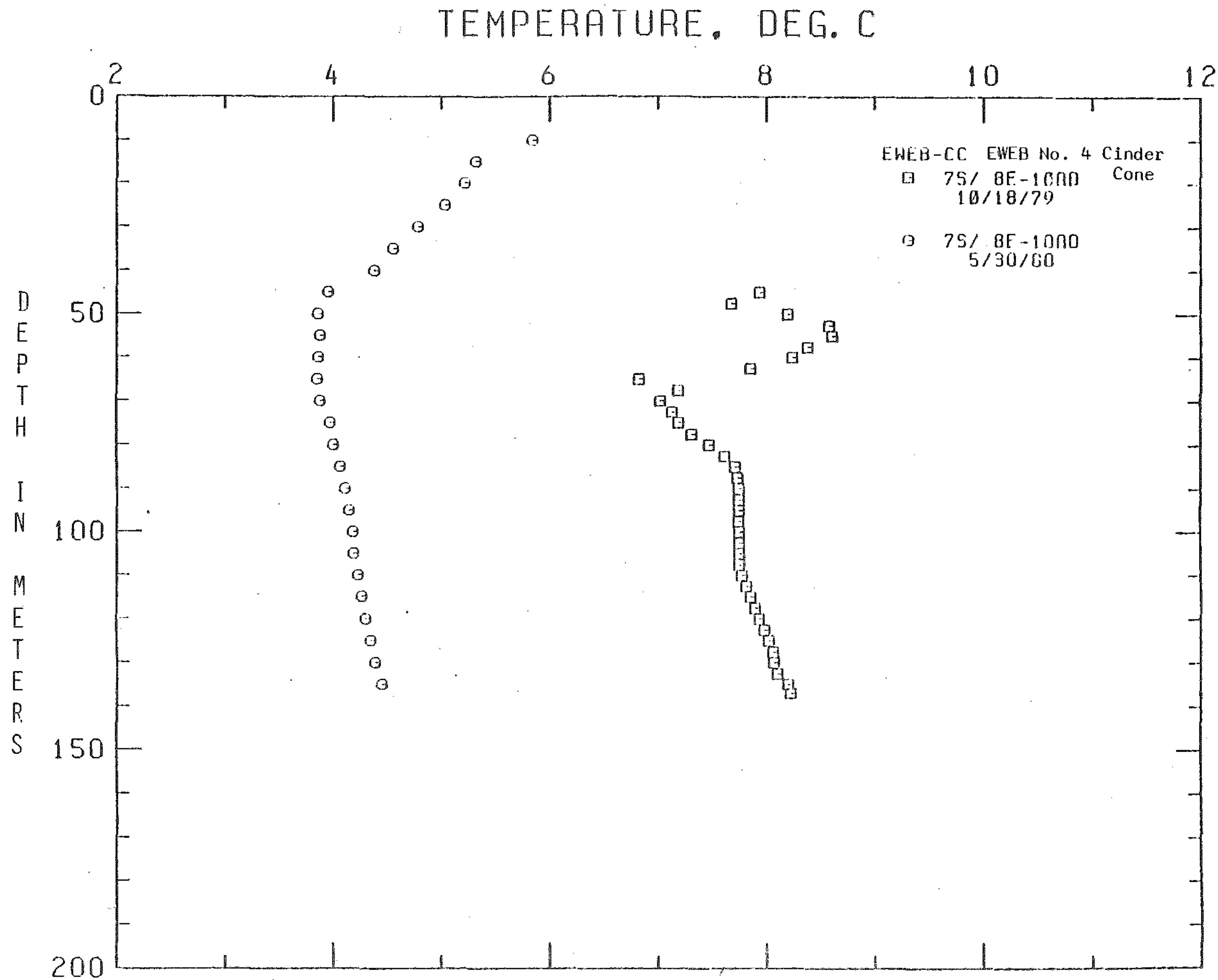
LOCATION: BEND AMS, OREGON
7S/ 8E- 5DD
HOLE NAME: EWEB-PC EWEB No. 3 Poop Creek
DATE MEASURED: 5/28/80

DEPTH	DEPTH	TEMPERATURE		GEOTHERMAL GRADIENT	
METERS	FEET	DEG C	DEG F	DEG C/KM	DEG F/100 FT
10.0	32.8	7.280	45.10	0.0	0.0
15.0	49.2	6.780	44.20	-100.0	-5.5
20.0	65.6	6.630	43.93	-30.0	-1.6
25.0	82.0	6.440	43.59	-38.0	-2.1
30.0	98.4	6.430	43.57	-2.0	-0.1
35.0	114.8	6.410	43.54	-4.0	-0.2
40.0	131.2	6.400	43.52	-2.0	-0.1
45.0	147.6	6.320	43.38	-16.0	-0.9
50.0	164.0	6.310	43.36	-2.0	-0.1
55.0	180.4	6.280	43.30	-6.0	-0.3
60.0	196.8	6.260	43.27	-4.0	-0.2
65.0	213.2	6.230	43.21	-6.0	-0.3
70.0	229.6	6.190	43.14	-8.0	-0.4
75.0	246.0	6.200	43.16	2.0	0.1
80.0	262.4	6.190	43.14	-2.0	-0.1
95.0	311.6	6.170	43.11	-1.3	-0.1
90.0	295.2	6.160	43.09	2.0	0.1
95.0	311.6	6.160	43.09	0.0	0.0
100.0	328.0	6.150	43.07	-2.0	-0.1
105.0	344.4	6.150	43.07	0.0	0.0
110.0	360.8	6.150	43.07	0.0	0.0
115.0	377.2	6.150	43.07	0.0	0.0
120.0	393.6	6.160	43.09	2.0	0.1
125.0	410.0	6.170	43.11	2.0	0.1
130.0	426.4	6.190	43.14	4.0	0.2
135.0	442.8	6.200	43.16	2.0	0.1
140.0	459.2	6.200	43.16	0.0	0.0
145.0	475.6	6.240	43.23	8.0	0.4
150.0	492.0	6.250	43.25	2.0	0.1
155.0	508.4	6.280	43.30	6.0	0.3
160.0	524.8	6.310	43.36	6.0	0.3
165.0	541.2	6.360	43.45	10.0	0.5
170.0	557.6	6.370	43.47	2.0	0.1
175.0	574.0	6.380	43.48	2.0	0.1
180.0	590.4	6.380	43.48	0.0	0.0
185.0	606.8	6.410	43.54	6.0	0.3
186.5	611.7	6.420	43.56	6.7	0.4


TEMPERATURE, DEG. C
2
4
6
8
10
12
0
50
100
150
200
EWEB-PC EWEB No. 3 Poop Creek
7S/ 8E- 500 10/18/79
7S/ 8E- 500 10/30/79
7S/ 8E- 500 5/28/80

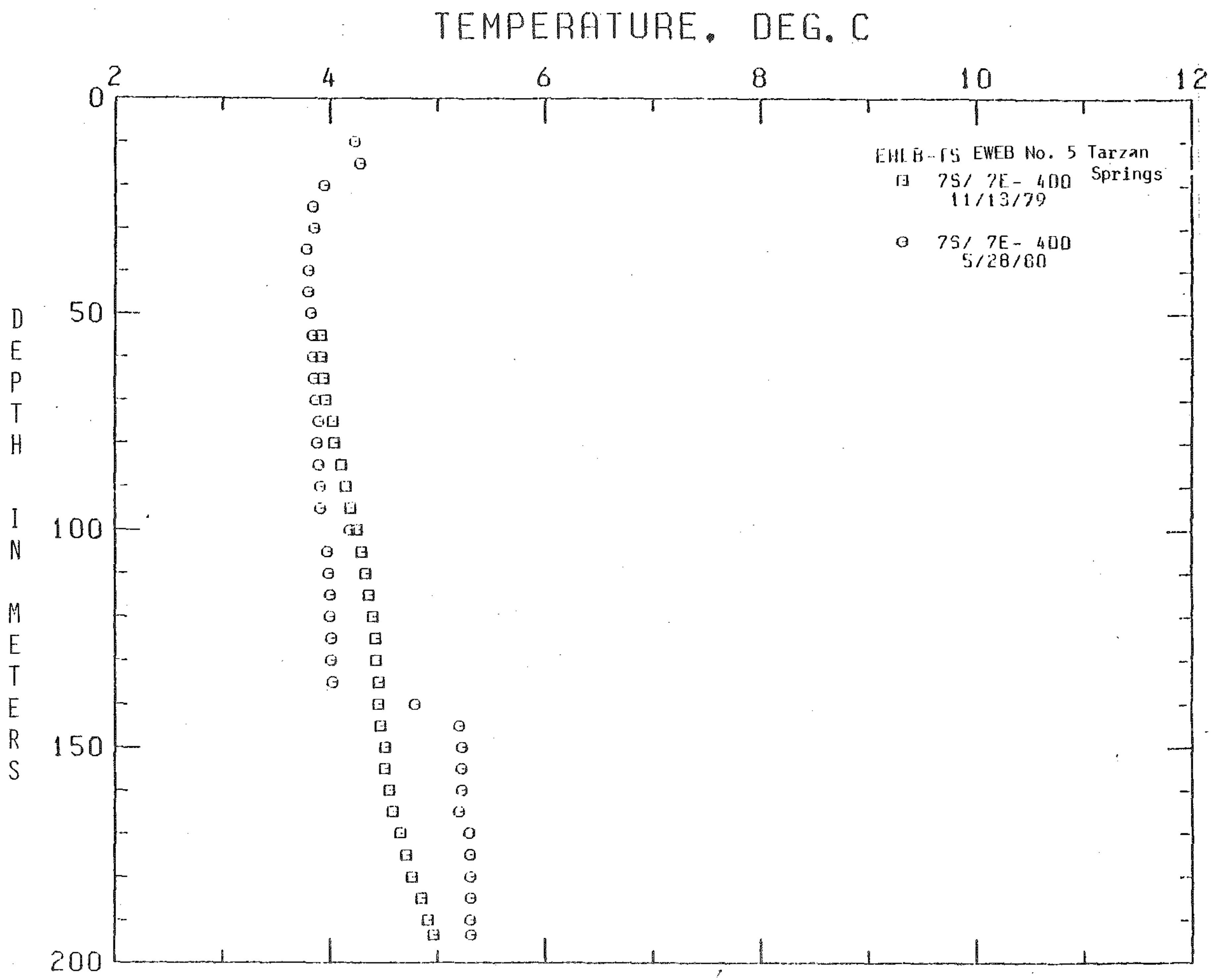
LOCATION: BEND AMS, OREGON
7S/ 8E-10AD
HOLE NAME: EWEB-CC EWEB No. 4 Cinder Cone
DATE MEASURED: 5/30/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
10.0	32.8	5.840	42.51	0.0	0.0
15.0	49.2	5.320	41.58	-104.0	-5.7
20.0	65.6	5.220	41.40	-20.0	-1.1
25.0	82.0	5.040	41.07	-36.0	-2.0
30.0	98.4	4.790	40.62	-50.0	-2.7
35.0	114.8	4.560	40.21	-46.0	-2.5
40.0	131.2	4.380	39.88	-36.0	-2.0
45.0	147.6	3.960	39.13	-84.0	-4.6
50.0	164.0	3.860	38.95	-20.0	-1.1
55.0	180.4	3.880	38.98	4.0	0.2
60.0	196.8	3.860	38.95	-4.0	-0.2
65.0	213.2	3.850	38.93	-2.0	-0.1
70.0	229.6	3.880	38.98	6.0	0.3
75.0	246.0	3.970	39.15	18.0	1.0
80.0	262.4	4.000	39.20	6.0	0.3
85.0	278.8	4.060	39.31	12.0	0.7
90.0	295.2	4.110	39.40	10.0	0.5
95.0	311.6	4.150	39.47	8.0	0.4
100.0	328.0	4.180	39.52	6.0	0.3
105.0	344.4	4.190	39.54	2.0	0.1
110.0	360.8	4.230	39.61	8.0	0.4
115.0	377.2	4.260	39.67	6.0	0.3
120.0	393.6	4.300	39.74	8.0	0.4
125.0	410.0	4.350	39.83	10.0	0.5
130.0	426.4	4.390	39.90	8.0	0.4
135.0	442.8	4.450	40.01	12.0	0.7


TEMPERATURE, DEG. C
2
4
6
8
10
12
0
50
100
150
200
DEPTH IN METERS
EWEB-CC EWEB No. 4 Cinder Cone
7S/ 8E-1000
10/18/79
7S/ 8E-1000
5/30/80

LOCATION: BEND AMS, OREGON
7S/ 7E- 4DD
HOLE NAME: EWEB-TS EWEB No. 5 Tarzan Springs
DATE MEASURED: 5/28/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	DEG F	GEOTHERMAL GRADIENT DEG C/KM	DEG F/100 FT
10.0	32.8	4.230	39.61	0.0	0.0
15.0	49.2	4.280	39.70	10.0	0.5
20.0	65.6	3.940	39.09	-68.0	-3.7
25.0	82.0	3.840	38.91	-20.0	-1.1
30.0	98.4	3.850	38.93	2.0	0.1
35.0	114.8	3.780	38.80	-14.0	-0.8
40.0	131.2	3.800	38.84	4.0	0.2
45.0	147.6	3.800	38.84	0.0	0.0
50.0	164.0	3.820	38.88	4.0	0.2
55.0	180.4	3.840	38.91	4.0	0.2
60.0	196.8	3.840	38.91	0.0	0.0
65.0	213.2	3.850	38.93	2.0	0.1
70.0	229.6	3.860	38.95	2.0	0.1
75.0	246.0	3.890	39.00	6.0	0.3
80.0	262.4	3.880	38.98	-2.0	-0.1
85.0	278.8	3.890	39.00	2.0	0.1
90.0	295.2	3.910	39.04	4.0	0.2
95.0	311.6	3.910	39.04	0.0	0.0
100.0	328.0	4.180	39.52	54.0	3.0
105.0	344.4	3.970	39.15	-42.0	-2.3
110.0	360.8	3.990	39.18	4.0	0.2
115.0	377.2	4.000	39.20	2.0	0.1
120.0	393.6	4.000	39.20	0.0	0.0
125.0	410.0	4.010	39.22	2.0	0.1
130.0	426.4	4.010	39.22	0.0	0.0
135.0	442.8	4.020	39.24	2.0	0.1
140.0	459.2	4.790	40.62	154.0	8.5
145.0	475.6	5.200	41.36	82.0	4.5
150.0	492.0	5.220	41.40	4.0	0.2
155.0	508.4	5.220	41.40	0.0	0.0
160.0	524.8	5.220	41.40	0.0	0.0
165.0	541.2	5.200	41.36	-4.0	-0.2
170.0	557.6	5.290	41.52	18.0	1.0
175.0	574.0	5.300	41.54	2.0	0.1
180.0	590.4	5.300	41.54	0.0	0.0
185.0	606.8	5.310	41.56	2.0	0.1
190.0	623.2	5.300	41.54	-2.0	-0.1
193.5	634.7	5.310	41.56	2.9	0.2

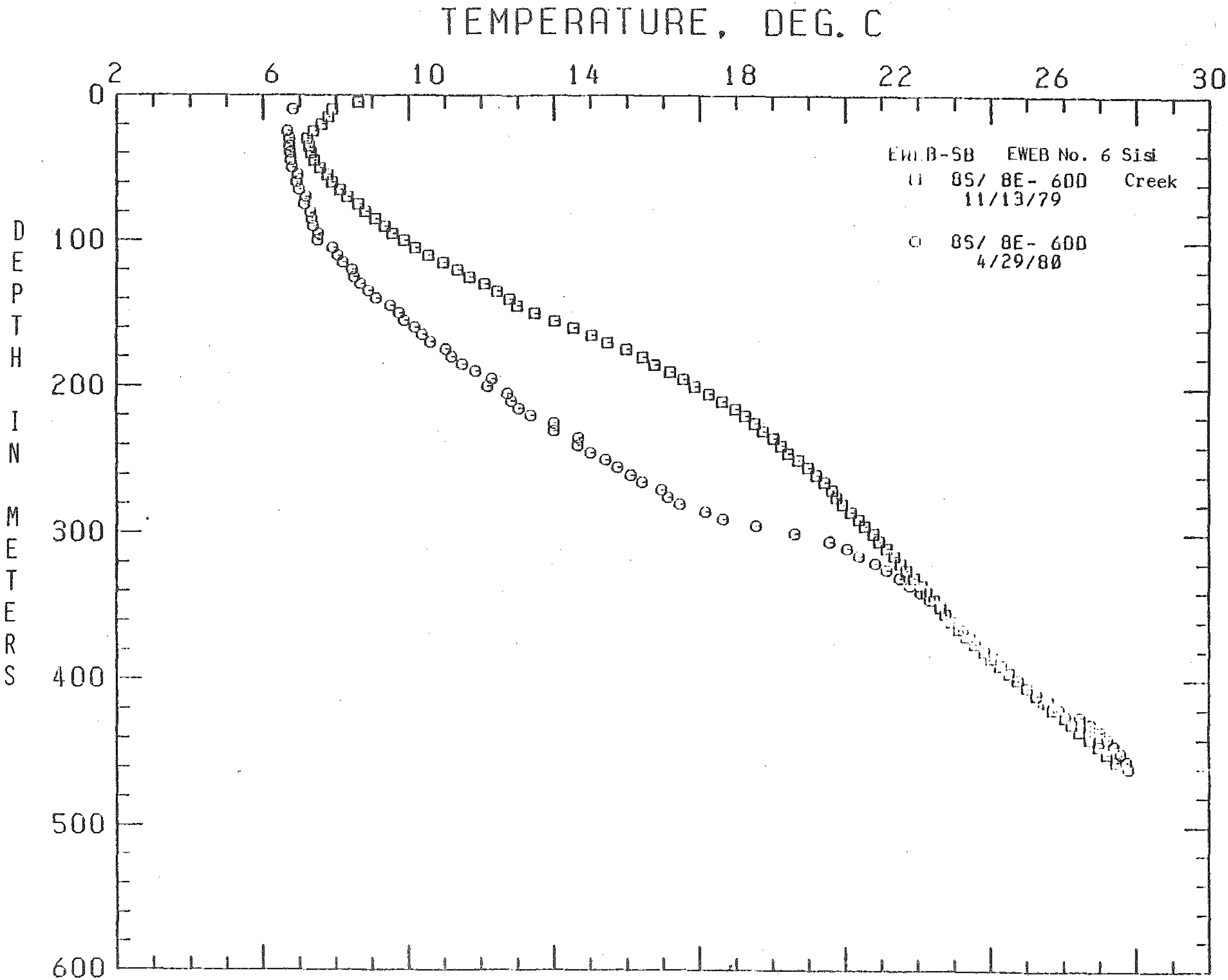

TEMPERATURE, DEG. C
2
4
6
8
10
12
0
50
100
150
200
DEPTH IN METERS
EHLB-FS EWEB No. 5 Tarzan Springs
7S/ 7E- 400 11/13/79
7S/ 7E- 400 5/28/80

LOCATION: BEND AMS, OREGON
8S/ 8E- 6DD
HOLE NAME: EWEB-SB EWEB No. 6 Sisi Creek
DATE MEASURED: 4/29/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
10.0	32.8	6.820	44.28	0.0	0.0
25.0	82.0	6.660	43.99	-10.7	-0.6
30.0	98.4	6.730	44.11	14.0	0.8
35.0	114.8	6.730	44.11	0.0	0.0
40.0	131.2	6.750	44.15	4.0	0.2
45.0	147.6	6.760	44.17	2.0	0.1
50.0	164.0	6.800	44.24	8.0	0.4
55.0	180.4	6.950	44.51	30.0	1.6
60.0	196.8	6.920	44.46	-6.0	-0.3
65.0	213.2	6.980	44.56	12.0	0.7
70.0	229.6	7.170	44.91	38.0	2.1
75.0	246.0	7.140	44.85	-6.0	-0.3
80.0	262.4	7.320	45.18	36.0	2.0
85.0	278.8	7.350	45.23	6.0	0.3
90.0	295.2	7.380	45.28	6.0	0.3
95.0	311.6	7.520	45.54	28.0	1.5
100.0	328.0	7.510	45.52	-2.0	-0.1
105.0	344.4	7.930	46.27	84.0	4.6
110.0	360.8	8.060	46.51	26.0	1.4
115.0	377.2	8.200	46.76	28.0	1.5
120.0	393.6	8.460	47.23	52.0	2.9
125.0	410.0	8.510	47.32	10.0	0.5
130.0	426.4	8.690	47.64	36.0	2.0
135.0	442.8	8.910	48.04	44.0	2.4
140.0	459.2	9.110	48.40	40.0	2.2
145.0	475.6	9.510	49.12	80.0	4.4
150.0	492.0	9.740	49.53	46.0	2.5
155.0	508.4	9.890	49.80	30.0	1.6
160.0	524.8	10.170	50.31	56.0	3.1
165.0	541.2	10.390	50.70	44.0	2.4
170.0	557.6	10.600	51.08	42.0	2.3
175.0	574.0	11.050	51.89	90.0	4.9
180.0	590.4	11.210	52.18	32.0	1.8
185.0	606.8	11.490	52.68	56.0	3.1
190.0	623.2	11.850	53.33	72.0	4.0
195.0	639.6	12.310	54.16	92.0	5.0
200.0	656.0	12.190	53.94	-24.0	-1.3
205.0	672.4	12.740	54.93	110.0	6.0
210.0	688.8	12.850	55.13	22.0	1.2
215.0	705.2	13.050	55.49	40.0	2.2
220.0	721.6	13.390	56.10	68.0	3.7
225.0	738.0	14.020	57.24	126.0	6.9
230.0	754.4	14.020	57.24	0.0	0.0
235.0	770.8	14.680	58.42	132.0	7.2
240.0	787.2	14.660	58.39	-4.0	-0.2
245.0	803.6	15.010	59.02	70.0	3.8
250.0	820.0	15.430	59.77	84.0	4.6
255.0	836.4	15.760	60.37	66.0	3.6
260.0	852.8	16.130	61.03	74.0	4.1
265.0	869.2	16.430	61.57	60.0	3.3
270.0	885.6	16.960	62.53	106.0	5.8
275.0	902.0	17.130	62.83	34.0	1.9
280.0	918.4	17.470	63.45	68.0	3.7
285.0	934.8	18.160	64.69	138.0	7.6
290.0	951.2	18.640	65.55	96.0	5.3
295.0	967.6	19.570	67.23	186.0	10.2
300.0	984.0	20.640	69.15	214.0	11.7
305.0	1000.4	21.590	70.86	190.0	10.4
310.0	1016.8	22.070	71.73	96.0	5.3
315.0	1033.2	22.400	72.32	66.0	3.6
320.0	1049.6	22.850	73.13	90.0	4.9
325.0	1066.0	23.160	73.69	62.0	3.4
330.0	1082.4	23.520	74.34	72.0	4.0
335.0	1098.8	23.800	74.84	56.0	3.1
340.0	1115.2	24.090	75.36	58.0	3.2
345.0	1131.6	24.350	75.83	52.0	2.9
350.0	1148.0	24.630	76.33	56.0	3.1
355.0	1164.4	24.790	76.62	32.0	1.8
360.0	1180.8	24.990	76.98	40.0	2.2
365.0	1197.2	25.260	77.47	54.0	3.0
370.0	1213.6	25.440	77.79	36.0	2.0
375.0	1230.0	25.620	78.12	36.0	2.0
380.0	1246.4	25.860	78.55	48.0	2.6
385.0	1262.8	26.140	79.05	56.0	3.1
390.0	1279.2	26.320	79.38	36.0	2.0
395.0	1295.6	26.550	79.79	46.0	2.5
400.0	1312.0	26.800	80.24	50.0	2.7
405.0	1328.4	27.020	80.64	44.0	2.4
410.0	1344.8	27.260	81.07	48.0	2.6
415.0	1361.2	27.470	81.45	42.0	2.3
420.0	1377.6	27.880	82.18	82.0	4.5
425.0	1394.0	28.460	83.23	116.0	6.4

8S/ 8E- 6DD
HOLE NAME: EWEB-SB EWEB No. 6 Sisi Creek (continued)
DATE MEASURED: 4/29/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	DEG F	GEOTHERMAL GRADIENT DEG C/KM	DEG F/100 FT
430.0	1410.4	28.750	83.75	58.0	3.2
435.0	1426.8	29.020	84.24	54.0	3.0
440.0	1443.2	29.220	84.60	40.0	2.2
445.0	1459.6	29.400	84.92	36.0	2.0
450.0	1476.0	29.590	85.26	38.0	2.1
455.0	1492.4	29.730	85.51	28.0	1.5
460.0	1508.8	29.790	85.62	12.0	0.7


TEMPERATURE, DEG. C
2
6
10
14
18
22
26
30
0
100
200
300
400
500
600
DEPTH IN METERS
EWEB-SB EWEB No. 6 Sisi Creek
8S/ 8E- 600
11/13/79
8S/ 8E- 600
4/29/80

U. S. GEOLOGICAL SURVEY OPEN-FILE REPORTS

U. S. Geological Survey open-file reports prepared on each of the Eugene Water & Electric Board drill holes, based on cuttings and driller's logs supplied to the Branch of Field Geochemistry and Petrology, U. S. Geological Survey, Menlo Park, California. Information in these open-file reports has been extracted and used in this present report.

Keith, Terry E. C., and Boden James R., 1980. Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 1 drill hole, Linn County, Oregon.

----------, 1980. Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 2 drill hole, Linn County, Oregon.

----------, 1980. Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 3 drill hole, Clackamas County, Oregon.

----------, 1980. Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 4 drill hole, Clackasmas County, Oregon.

----------, 1980. Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 5 drill hole, Clackamas County, Oregon.

----------, 1980. Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 6 drill hole, Clackamas County, Oregon.

These are preliminary draft reports which, as of this writing, have not been assigned open-file numbers.

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