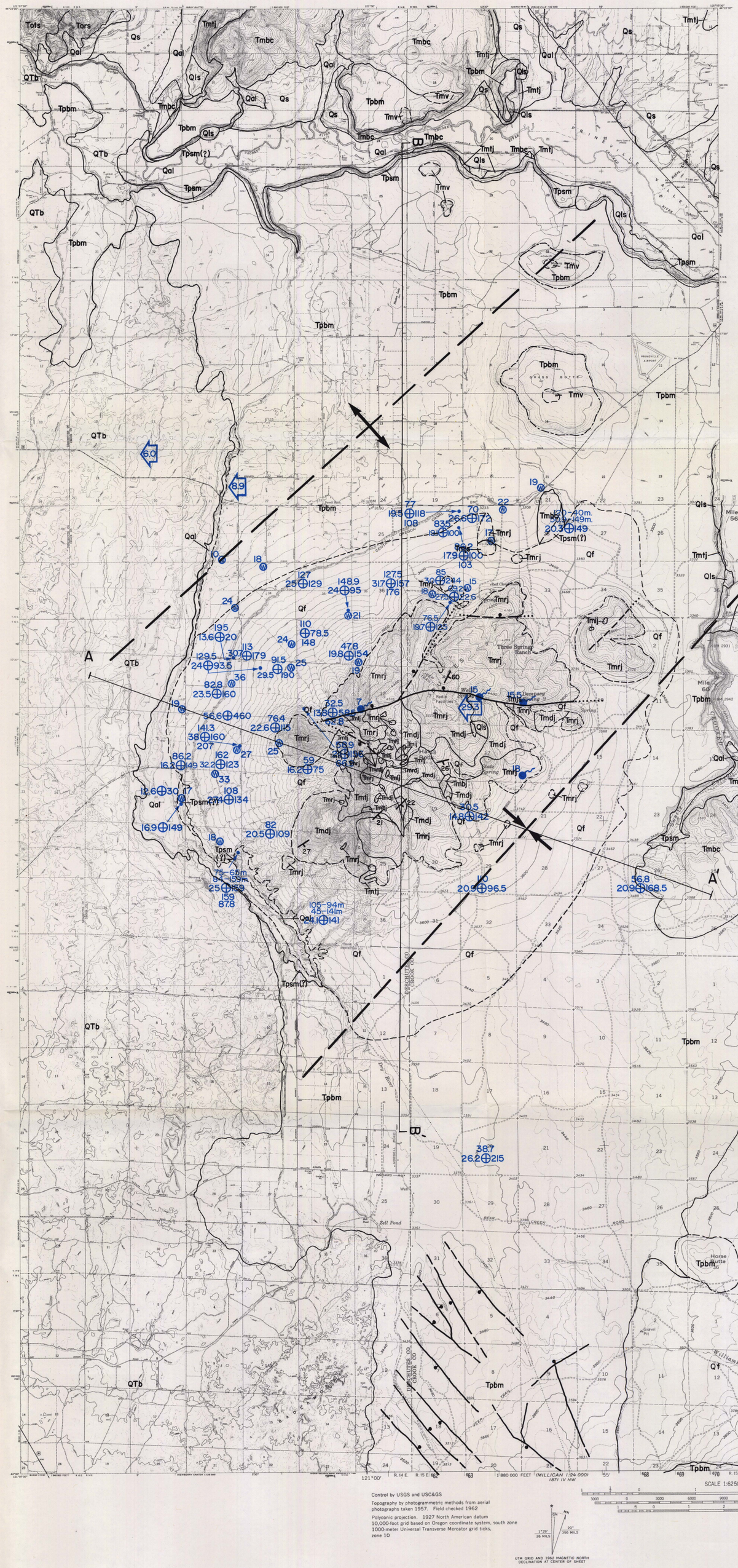
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

OPEN FILE REPORT #0-80-8

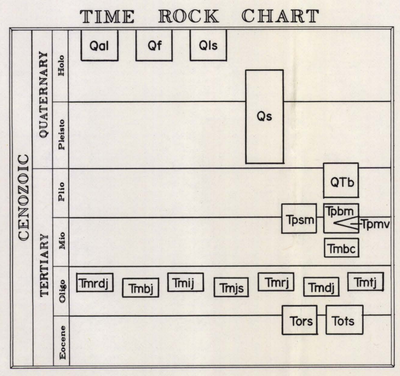
GENERALIZED GEOLOGIC MAP OF THE POWELL BUTTES AREA, OREGON

Geology by David E. Brown and Gary D. McLean after Weidenheim, 1980; Robinson and Stensland, 1979; Swanson, 1969; Walker, Peterson, and Greene, 1967; and Williams, 1957.

PLATE I



TIME ROCK CHART



EXPLANATION

Qal — Alluvium: Unconsolidated lacustrine and fluviatile gravel, sand, and silt in drainages

Qf — Fan deposits: Unconsolidated to cemented foreset-bedded gravel, sand, and silt in alluvial fans

Qls — Landslide deposits

Qs — Fluviatile and lacustrine deposits: Unconsolidated to partially consolidated bedded gravel, sand, and silt found as incised elevated terraces adjacent to major drainages

QTb — Basalt: Dark-gray, diktytaxitic olivine basalt flows overlying Deschutes Formation in southern portion of map area and occurring as intracanyon flows in northern portion. Thought to have erupted from the Newberry volcanic complex to the south

Deschutes Formation

Tpmv — Mafic vent complexes: Pliocene red to gray cinders, scoria, and agglomerate. Forms erosionally modified cinder cones. Possible source for unit *Tpbm*

Tpbm — Basalts: Pliocene dark- to medium-gray diktytaxitic olivine basalts. Found as possible multiple flows overlying unit *Tpsm*

Tpsm — Sediments: Mainly epiclastic silts, sands, and gravels with minor ash flows. Epiclastic rocks are poorly sorted, poorly bedded, loosely to semi-consolidated fluviatile and lacustrine sandstones, siltstones, and conglomerates. Also includes thin olivine basalt flows of limited areal extent

Columbia River Basalt Group

Tmbc — Basalts: Miocene dark-gray aphyric basalt flows. Thought to be part of the Grande Ronde member of the Columbia River Basalt Group

John Day Formation

Tmtj — Undifferentiated tuffs: Tuff, lapilli tuff, and tuffaceous sedimentary rocks overlain by unit *Tmbc*

Tmrj — Rhyolites: Gray to reddish-gray quartz- and sanidine-bearing rhyolite flows and domes. Make up the bulk of Powell Buttes

Tmij — Ignimbrite: Limited outcrops of welded to semiwelded light-brown to light-green sanidine-bearing pumiceous ash-flow tuffs

Tmrdj — Rhyodacites: Limited outcrops of gray to reddish-gray platy rhyodacite

Tmbj — Basalts and andesites: Limited outcrops of highly altered, dark-gray aphyric platy basalts and andesites. Relative age is unclear

Tmjs — Sediments: Limited outcrops of fine-grained tuffaceous sediments and volcanic conglomerate. May be equivalent to unit *Tmtj*

Tmdj — Dacites: Light-gray to reddish-gray, flow-banded, sparsely porphyritic dacites. Together with unit *Tmrj* make up the bulk of Powell Buttes

Pre-John Day units

Tors — Rhyolites of Smith Rocks: Oligocene(?) grayish-red aphanitic rhyolite with well-developed flow banding and lithophysal zones

Tots — Tuffs of Smith Rocks: Oligocene(?) light-brown to yellowish-green poorly bedded tuff and lapilli tuff. Highly indurated but unwelded

GEOLOGIC SYMBOLS

Contacts

Normal faults - Dashed where inferred, dotted where concealed; ball and bar indicate downthrown side

Anticline - Dashed where inferred

Syncline - Dashed where inferred

Approximate limit of shield volcanoes

GRADIENT (°C Km^{-1})
DEPTH PROBED (m)
HOLE LOCATION
HEAT FLOW (mWm^{-2})
BOTTOM HOLE TEMP. (°C)
(e.g. 80 / 22.1 ⊕ 150 / 83)

38 (W) — WATER WELL (NON-FLOWING)
WATER TEMP. (°C)

38 (W) — FLOWING WATER WELL
WATER TEMP. (°C)

38 — SPRING
WATER TEMP. (°C)

7.9 — K/Ar AGE-DATE LOCATION

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1957. Field checked 1962

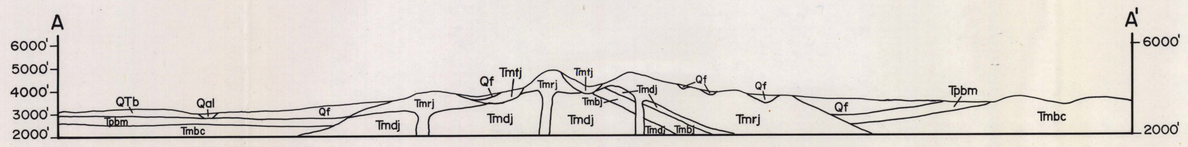
Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 10

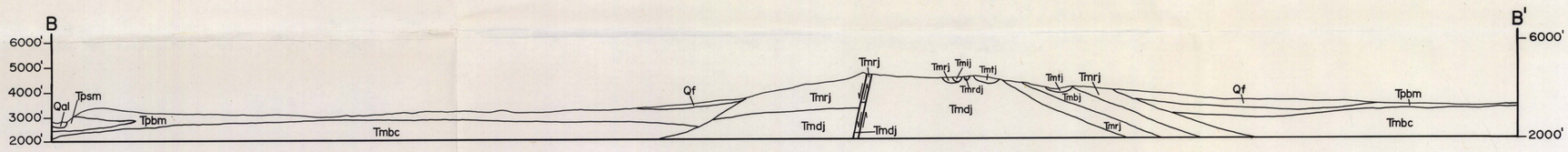
UTM GRID AND 1962 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

OREGON
QUADRANGLE LOCATION

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

Geologic Cross Sections





STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
1005 State Office Building
Portland, Oregon 97201

OPEN-FILE REPORT O-80-8

PRELIMINARY GEOLOGY AND GEOTHERMAL RESOURCE POTENTIAL OF THE POWELL BUTTES AREA, OREGON

by

D. E. Brown,

G. L. Black,

G. D. Mclean,

and J. R. Petros

Under the direction of J. F. Riccio

Study completed under U. S. Department of Energy
Cooperative Agreement No. DE-FC07-79ET27220

1980

DISCLAIMER

This report has not been edited for complete conformity with Oregon Department of Geology and Mineral Industries standards. Data in this document are preliminary and are subject to change upon further verification.

CONTENTS

ILLUSTRATIONS

FIGURES

TABLES

PLATES

INTRODUCTION

Powell Buttes is a major topographic high located on the High Lava Plains of central Oregon (Figure 1). Limits of the study area were arbitrarily set at the boundaries of available U.S. Geological Survey (U.S.G.S.) topographic maps at latitudes $44^{o}15'$ on the north and $44^{o}0'$ on the south, and at $121^{o}7\frac{1}{2}'$ on the west and $120^{o}52\frac{1}{2}'$ on the east. This study, performed under U.S. Department of Energy (USDOE) Contract No. DE FC07-79ET27220, was undertaken to assess the geothermal potential of the area by various methods, including compilation of existing data, reconnaissance geologic mapping, lineament analysis, well and spring geochemistry, collection of geothermal-gradient data, and the drilling of eight 152-m (500 ft.) gradient holes and one 460-m (1512 ft.) gradient hole.

Geographically, the study area is comprised of a hummocky group of closely-knit buttes approximately equidistant from Bend (pop. 17,100), Redmond (pop. 6,450) and Prineville (pop. 6,050). Surrounding the buttes on all sides are the flat, juniper- and sage-covered basalt flows of the northwestern corner of the High Lava Plains geomorphic province. Incising the lava plains in a deep narrow canyon is the Crooked River, which passes to the east and north of the buttes. The west side of Powell Buttes is relatively densely populated with grain and cattle ranches and new housing developments, while the east side is mainly uninhabited, non-irrigated, scrub forest- and sage-covered dry land. Drainage on the buttes is generally downward to the main groundwater bodies, with small amounts of surface water accumulating in ephemeral streams and ponds.

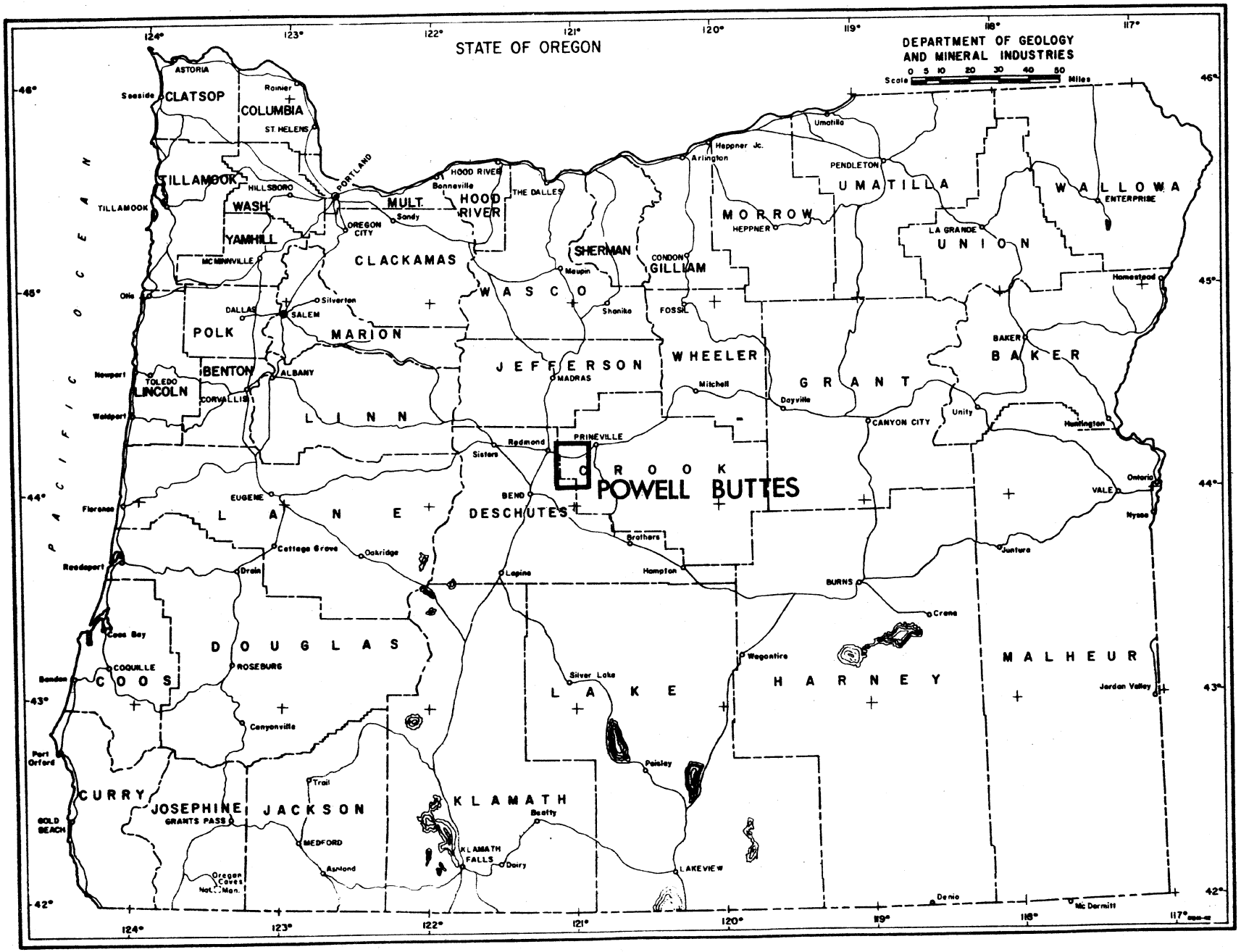


Figure 1: Map showing location of study area.

GEOLOGY

Introduction

The geologic map of the study area (Plate I) is based on a field check by DOGAMI of a recent master's thesis on Powell Buttes by Weidenheim (1980); a map of the Smith Rocks area by Robinson and Stensland (1979); a reconnaissance map of the east half of the Bend AMS sheet by Swanson (1969); and a reconnaissance map of the Bend 30° sheet by Williams (1959). Cross-sections of Powell Buttes are taken, with minor modification, from Weidenheim (1980).

Table 1. Radiometric (K/Ar) ages of selected rocks of the Powell Buttes area, Oregon.

Sample no.	Location	Rock type	Age	Map Unit
Pb-1	T.15S., R.14E., 21 Dcb	Basalt	$^{p}8.9\pm1.4$	Tpbm
*Pb-2	T.15S., R.14E., 20 Bab	Basalt	$^{w}6.0\pm2.1$	QTb
*Pb-3	T.16S., R.15E., 8 Cbb	Rhyolite	$^{s}29.3\pm1.0$	Tmrg

p - plagioclase age; w - whole rock age; s - sanidine age.
Pb - samples taken for this report, unpublished analyses by University of Utah research Institute, Stan Evans, analyst.
*These are very imprecise dates with 91-96% atmospheric Ar.

Volcanic stratigraphy

John Day Formation

The oldest rocks exposed in the study area are the rhyolites, rhyodacites, dacites, and tuffs of the John Day Formation (22-32 m.y.) which makes up the plugs, domes, and flows of the buttes. These units are also exposed in the northern portion of the study area on the southern flanks of Grizzly Mountain and Gray Butte. Weidenheim (1980), based on examination of authigenic zeolites (clinoptilolite) contained within the ash units, concluded that the units exposed

on Powell Buttes are part of the "lower facies" of the John Day Formation. A K/Ar date obtained on a rhyolite flow from the buttes analyzed by the University of Utah Research Institute indicates an age of 29.3±1.0 m.y. (Table 1), which is consistent with Weidenheim's stratigraphy. In general, the rocks are slightly to highly altered and silicified with some areas in the central western area of the buttes completely altered to white to yellow clays, surrounded by areas of intense silicification. These areas show occurrences of both chalcedonic and coarsely crystalline quartz, light-brown to dark-brown hematite, specularite, limonite, hyaline opal, cinnabar, and an unidentified hard, black botryoidal mineral which coated fracture surfaces and showed anomalously high radioactivity. Matthews, 1966; Schafer, 1956; and Peterson, 1958, reported that these areas were extensively prospected for uranium, but no U_3O_8 mineralization was found.

Deschutes Formation

Surrounding Powell Buttes and overlying the John Day Formation in unconformable contact, are the flat-lying flows and interbedded continental sediments of the Deschutes Formation (Weidenheim, 1980), the upper flows of which appear to have issued from low shield volcanoes immediately to the north and south. One Deschutes Formation basalt flow was dated for this study by the University of Utah Research Institute at 8.9±1.4 m.y. (Table 1). These units have been called the Deschutes, Dalles, or Madras Formation by several authors. The term Deschutes Formation has precedence and is adopted herein.

Investigators working in central Oregon describe the Deschutes Formation in the study area as mainly a fine- to medium-grained continental sedimentary unit with minor amounts of basalt and andesite. Drilling for this study indicates that the Deschutes Formation concealed beneath the talus apron surrounding

Powell Buttes is primarily a coarse-grained sedimentary unit grading to medium-grained at depth with thin (10 ft. - 90 ft.) basalt flows grading from olivine-porphyritic at the surface to aphyric at depth (the log of Powell Buttes No. 1 is presented as Figure 2). The coarse nature of the sediments may be due to local variations in the unit, owing to position near the edge of the basin of deposition along possibly active range front faults (Plate I). Alteration of the Deschutes Formation increases with depth. Olivines show more iddingsite; plagioclase is increasingly saussuritized, and the volume of zeolites, calcites, and secondary quartz also increases.

Clarno Formation

Powell Buttes No. 1 drill hole may have encountered the Clarno Formation (approx. 32-42 m.y.) at a depth of 240 m (Figure 2). At this point in drilling, a dark-gray, fine-grained basalt with a saprolite was encountered, which was underlain by altered tuffs, additional fine-grained basalts, and mafic mudflows. This would be atypical of the Deschutes Formation or the John Day Formation, but would be consistent with Clarno Formation stratigraphy described in adjacent areas. A K/Ar sample from a basalt flow at the 310-320 m. depth is currently being analyzed by the University of Utah Research Institute to establish whether it is Clarno in age.

Columbia River Basalt

Also overlying the John Day Formation in unconformable contact is a small amount of the Columbia River Basalt. This unit, seen as a single intracanyon pillowed flow in a quarry at the northeast corner of the buttes, is probably a flow of the Grande Ronde Member of the Columbia River Basalt Group. Other Columbia River Basalt outcrops have been mapped north of the study area and immediately east; however, they were not examined during the field study.

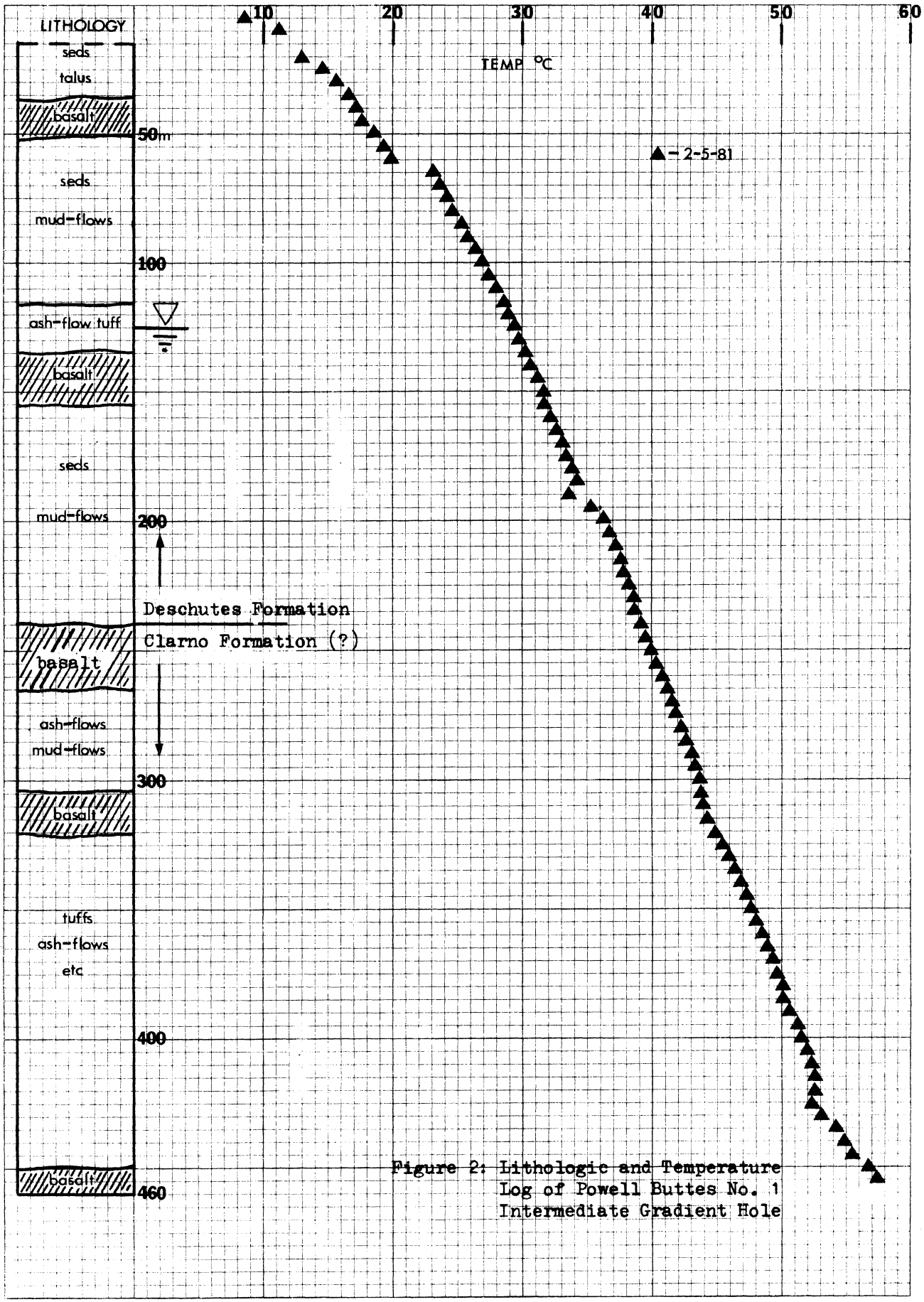


Figure 2: Lithologic and Temperature Log of Powell Buttes No. 1 Intermediate Gradient Hole

Plio-Pleistocene basalts

Overlying the Deschutes Formation is a series of young, thin, diktytaxitic basalt flows showing little or no alteration, which have been dated in a very poor sample (96% atmospheric argon) by the University of Utah Research Institute at 6.0±2.1 m.y. (Table 1). This unit has been assigned a Pliocene or Pleistocene age by earlier investigators (Robinson and Stenslund, 1979; Williams, 1957) and is thought to have issued from the Newberry caldera complex (Williams, 1957).

Surficial deposits

Surrounding the buttes on all sides, and effectively masking contact relationships and structures, is an extensive unit of alluvial fan and colluvial material. This unit has been found in drill holes to be as much as 30 m (100 ft) thick and, in some places, heavily cemented with numerous caliche ($CaCO_3$) layers. This talus is made up entirely of John Day silicic material derived from weathering of the buttes.

Structural geology

A lineament study of the area (Figure 5) taken from U-2 infrared imagery suggests two major structural grains. The first is a series of northeasterly-trending lineations paralleling the Blue Mountain trend, and the second, less conspicuous trend strikes westerly, paralleling a northern splinter of the Brother's Fault Zone. Powell Buttes appears to be situated on the juncture of these two trends.

Faults on Powell Buttes are difficult to discern in the field owing to the talus cover. A number of areas of brecciation were, however, found with fully rotated pieces recemented with quartz, hematite, or both. Lack of outcrop prevented differentiation of fault breccia from flow breccias. Several faults were mappable, however, including an east-west normal fault mapped by Weidenheim

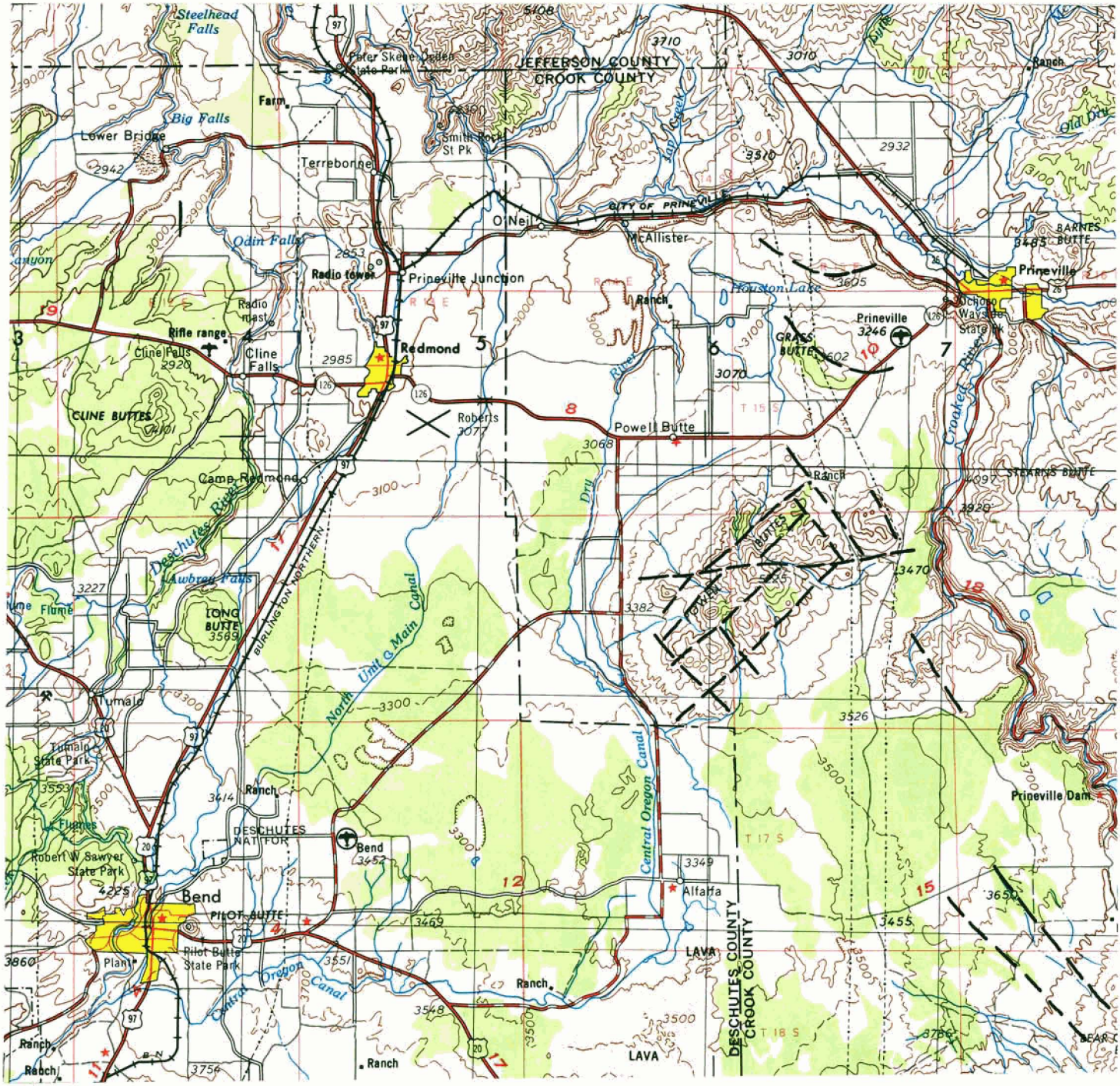
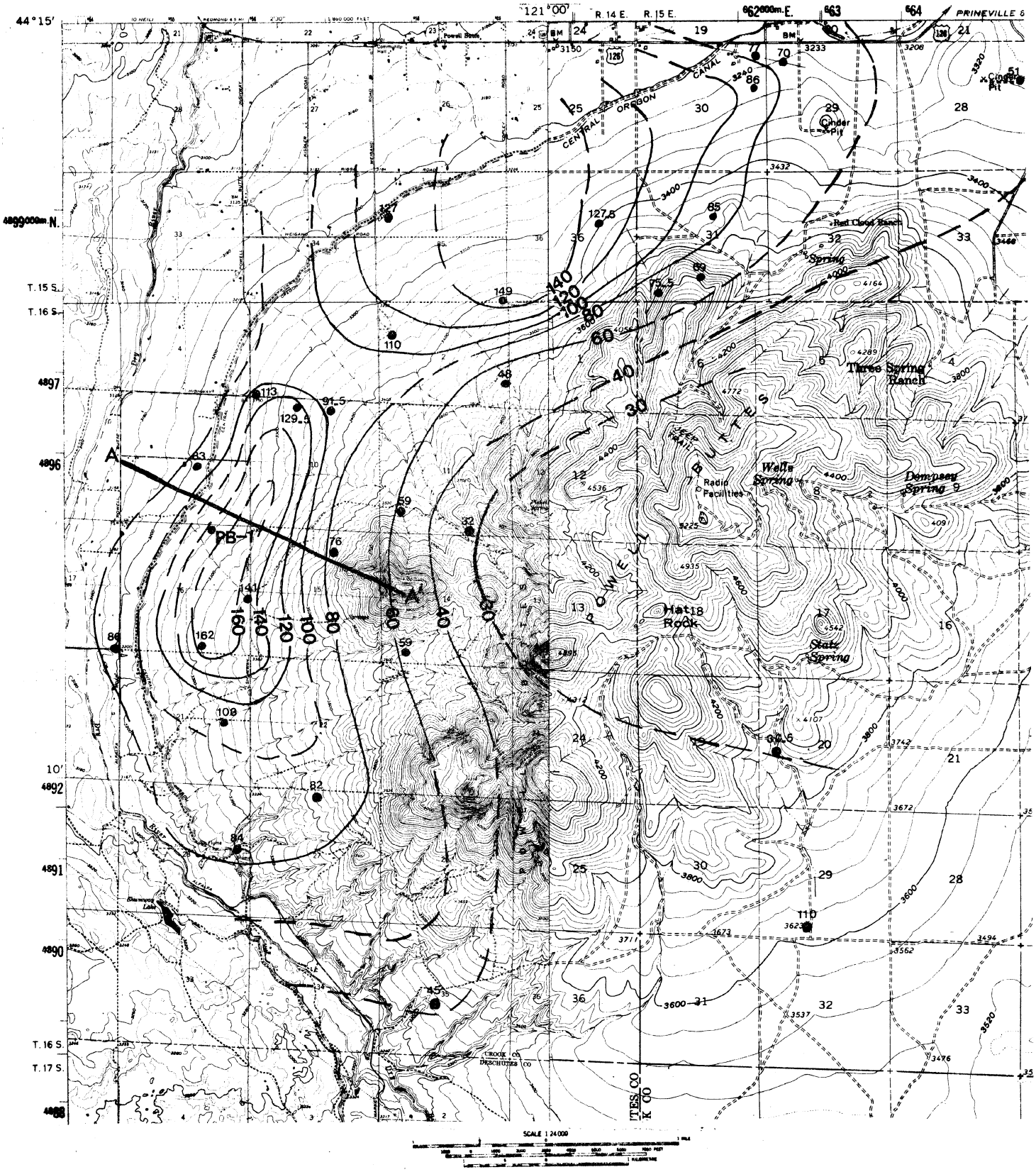


Figure 3 : Photo-lineament map of the Powell Buttes area, Oregon

Taken from U-2 infra-red imagery



•85 Data Point w/gradient (°C/km)

Isogradient line (dashed where inferred) gradients in °C/km

Figure 4: Isogradient map of the Powell Buttes area, Oregon

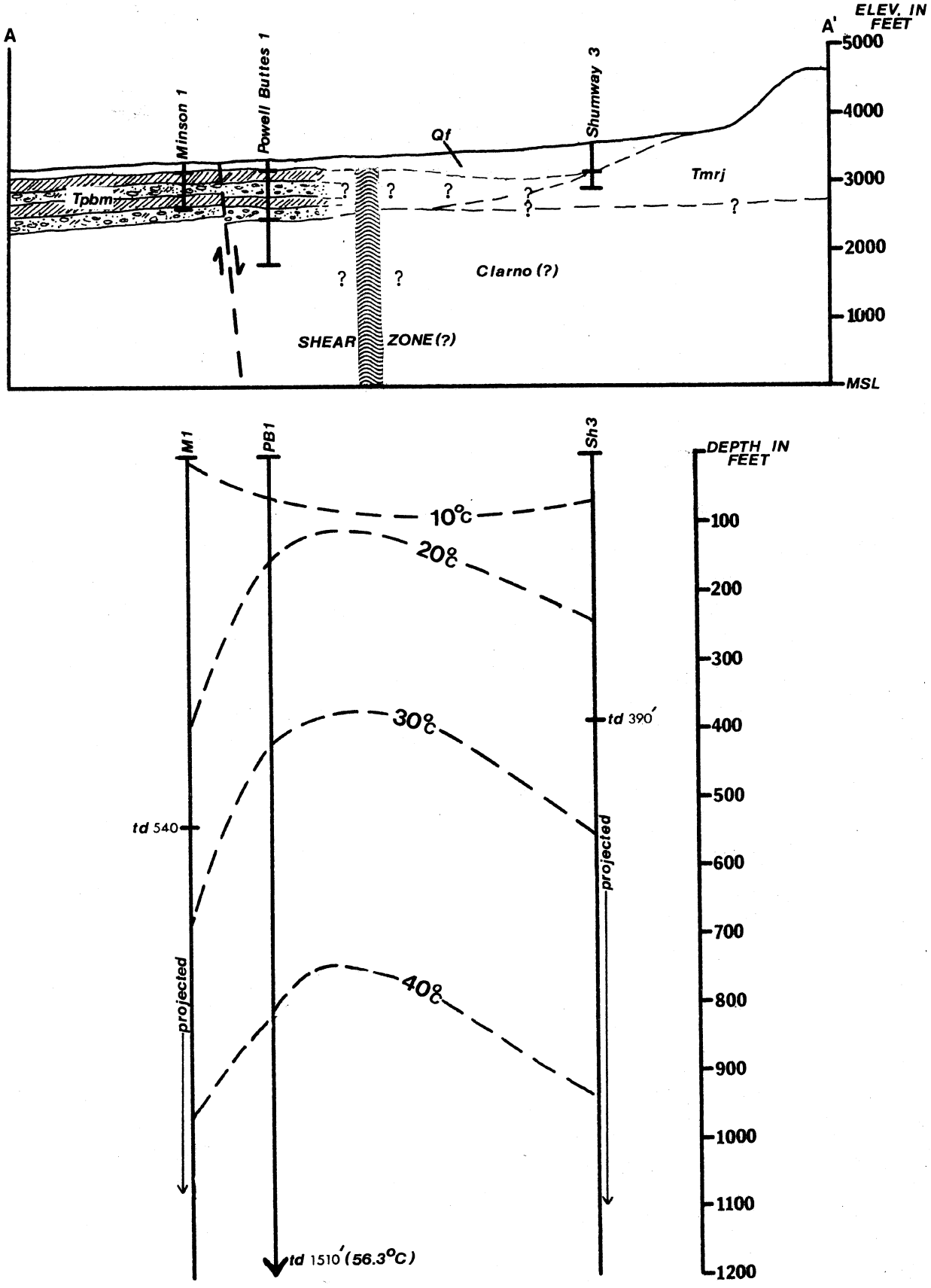


Figure 5: Geologic cross-section and isothermal plot through drill holes

(1980), with north side down. This structure also shows as a topographic and photo-lineament and as an east-west line of year-round springs.

A northwesterly-striking fault zone has been mapped in the southern portion of the area offsetting flows of the Deschutes Formation (Swanson, 1967). This zone, which extends several tens of miles northwest of the study area, may represent the surface trace of a right-lateral fault related to the Brother's Fault Zone, found to the south. It has not, however, been shown to offset the youngest basalt flows found in the area. The thickness of Deschutes Formation penetrated by the Powell Buttes No. 1 hole versus Shumway 3 and the short wavelength temperature gradient anomaly suggest the presence of a fault on the west side of the buttes (Figures 4 and 5). This fault may correspond to the northwesterly striking fault zone in the southern portion of the study area noted above.

The dip of bedded units and flows on the buttes is generally twenty to sixty degrees to the southeast with the steeper dips north of Weidenheim's (1980) east-west fault. These attitudes coincide with Swanson's (1967) structural model of the area, which shows the (pre-Deschutes) Blue Mountain Anticline passing north of the buttes on a northeast-southwest strike. He also shows a contemporaneous syncline paralleling the Blue Mountain trend passing just south of the buttes. Neither of the axes for these structures could be located in the field.

Structural control of the geothermal system

Inasmuch as the Powell Buttes area is a "blind" geothermal anomaly (i.e., no obvious surface manifestations), with a thick colluvial blanket draping the slopes, relating structures to the system is difficult. The pattern of anomalous temperature gradients (Figures 4 and 5) does, however, indicate a probable relationship between a juncture of northeast- and northwest-trending fault zones

and the observed heat. The pattern appears to show rather sharp decreasing gradients moving toward the buttes and gradually decreasing gradients moving down the hydrologic dip, away from the buttes. In other geothermal areas, this particular type of anomaly pattern has been associated with convective upflow of thermal water along fault zones with subsequent horizontal spreading into aquifers.

An alternate hypothesis would be an intrusion implaced in border faults surrounding the buttes or under the buttes themselves. In this case, however, surface thermal manifestations (fumaroles, hot springs, etc.), recent vent complexes, and greater alteration of the buttes and surrounding lava flows would be expected--unless an impermeable caprock, such as the Clarno Formation, were in place to prohibit vertical movement of fluids. This hypothesis is not considered as probable as an explanation involving convective transfer of heat by deeply circulating water.

GEOPHYSICS

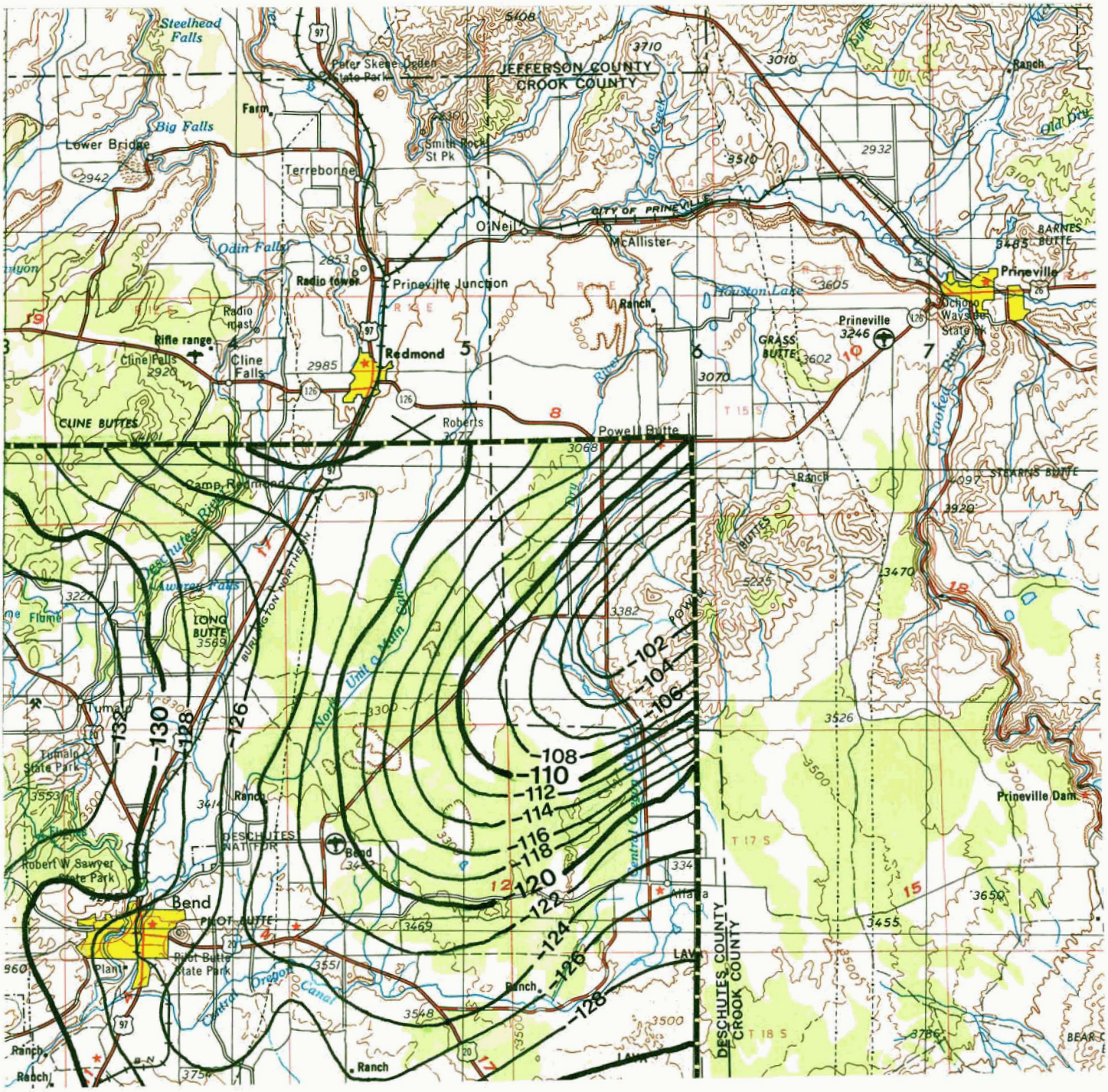
Two geophysical studies are available for analysis and inclusion in this report. The first is a regional gravity study of the central Cascades Mountain Range and adjacent areas (Figures 6 and 7) taken from Pitts (1970) and Pitts and Couch (1978) which covers the western two-thirds of Powell Buttes. The second is a regional aeromagnetic study of the central Cascades Mountain Range (Figure 8) taken from Connard (1980) and Couch and others (1978) which also covers the western two-thirds of the buttes.

The gravity study shows a sharp closed positive anomaly striking toward the northeast on both the complete Bouguer anomaly and residual anomaly maps with highs of -106 and +18 mgals respectively. On the regional residual anomaly map, the buttes appear as a "spike" of high gravity at the northeastern end of a ridge of gravity maxima striking toward the northeast, paralleling the Blue Mountain trend discussed earlier in this report. This ridge of high gravity is not as apparent on the Bouguer anomaly map.

The aeromagnetic map shows no anomalies associated with Powell Buttes. The Oregon State Geophysics Group flew extra flight lines over the buttes when the aforementioned gravity anomaly was observed. These aeromagnetic data were never reduced to graphic form when no anomalous magnetic signature was found.

Several explanations and discussions for the geophysical anomalies are as follows:

1) The gravity high is due to a gabbro-residuum at depth below the buttes (Pitts, 1979). Weidenheim (1980) objects to this hypothesis on the grounds that even drastic differentiation within a magma chamber at depth would not allow for the calk-alkaline silicic suite found on



Scale 1:250,000

5 0 5 10 15 20 Statute Miles

Taken from Pitts and Couch, 1978

Estimated uncertainty 1.0 mgal
Reduction density 2.67 gcm^{-3}
Transverse Mercator Projection
Theoretical gravity: IGF (1930)
Contour interval 2.0 mgal

BEND, OREGON
1955
REVISED 1971

Figure 6: Complete Bouguer gravity anomaly map of the Powell Buttes area, Oregon

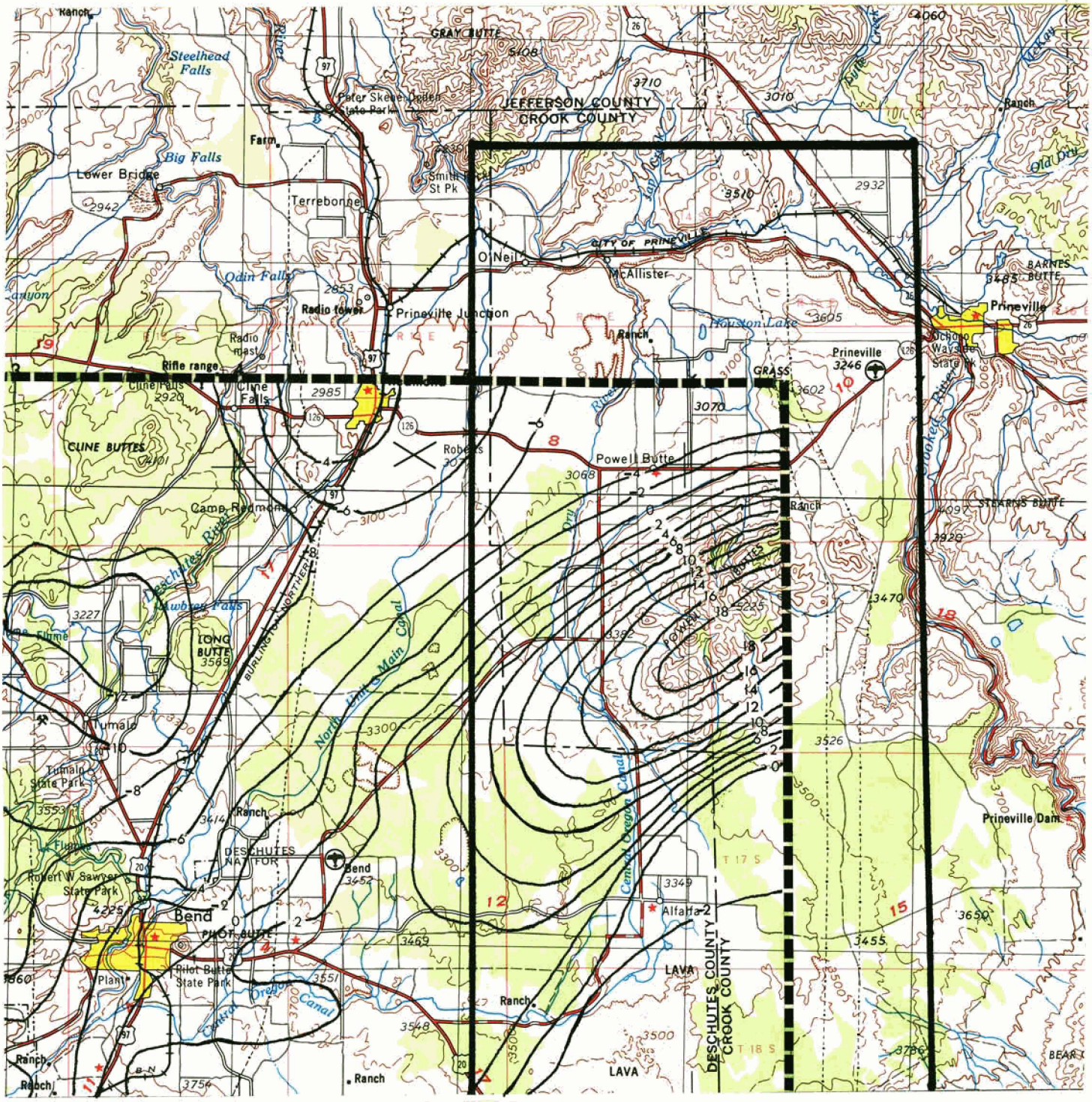


Figure 7 : Residual Gravity Anomaly Map of the Powell Buttes Area, Oregon

From Pitts, 1979

Estimated uncertainty 1.0 mgal
Reduction density 2.43 gcm-3
Regional components greater than 895 km removed
Transverse Mercator Projection
Theoretical gravity IGF (1930)

BEND, OREGON
1955
REVISED 1971

the buttes. If Pitts were correct, however, a magnetic maximum would be expected which is not present on the existing map. This magnetic maximum would not be seen, however, if the intrusion were still above the Curie Point (-600^{o}C), or if the surrounding magnetically susceptible lavas were masking any possible signature. It was found in drilling that the units surrounding the buttes were mainly sediments which would have a lower magnetic susceptibility. It is, thus unlikely that surrounding volcanic rock could mask any magnetic anomaly associated with the other shell of a mafic intrusion.

2) The observed gravity may be due to the presence of a dense silicic intrusion at depth below the buttes. This hypothesis is consistent with the silicic volcanic suite on the buttes and the lack of a magnetic signature. The density contrast between the intrusion and the surrounding lavas and sediments, however, would have to be extremely large to create the intense gravity high seen in both the Bouguer and residual anomaly maps. The present geologic information does not allow for such a contrast.

3) The observed gravity may be due to block-faulting of the buttes. This hypothesis would probably not allow for the intense gravity high over the buttes, unless they were faulted up in an extreme fashion, with possibly an intrusion beneath. A horst also would not fully explain the lack of magnetic signature, unless the degree of up-faulting of a relatively non-susceptible block at the buttes were just enough to overcome relatively highly susceptible lavas and sediments surrounding the buttes. This is highly unlikely.

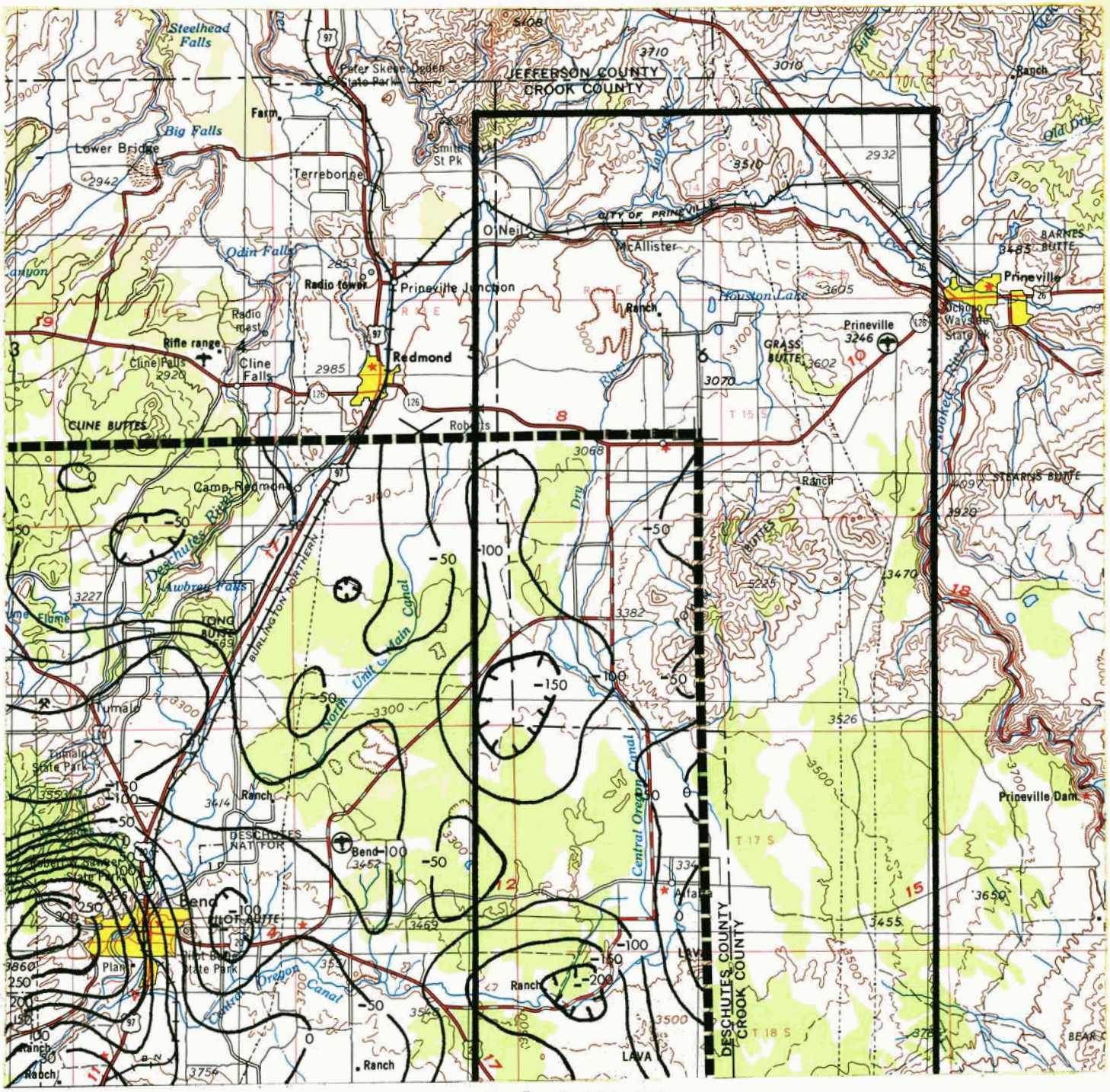


Figure 8: Total field aeromagnetic anomaly map of the Powell Buttes area, Oregon

From Connard, 1980

IGRF 1975
Data reference elevation 9,000 ft.
Cutoff wavelength 15 km
Contour interval 50 gammas
Survey flown 1975

BEND, OREGON
1955
REVISED 1971

The two geophysical studies suggest a number of structural and lithologic problems which cannot be fully explained with readily available data. Additional deep drilling and geophysics will be needed to complete any physical modeling of the geothermal system.

WATER CHEMISTRY

During the course of this study, twenty-five wells and springs, ranging in temperature from 35.5°C down to 6.9°C, were sampled in this heretofore unexplored area. These samples were then analyzed (Table 2) and the analyses were used to calculate estimated minimum reservoir temperatures (Table 3) using standard formulae presented, together with references, in Appendix A. Reservoir temperatures were calculated for the silica constituent only, as the cation thermometers (i.e., Na:K, Na:K:Ca, Na:K:Ca:Mg) were not felt to be representative of true subsurface conditions.

The waters tested appear to be relatively "clean" waters of a mixed-ion type, with the dominant cations being Si, Na, and Ca, and the major anion being SO_4. Though no analysis was made for HCO_3, a charge imbalance in the analysis indicates it probably would be the actual dominant anion. Total dissolved solids is low; hardness is low; and Cl, which is usually in abundance when elevated subsurface temperatures are present, is almost nonexistent.

Another characteristic of this water, which is not seen in the presented analyses, is the presence of a high amount of trace metals such as Cu, Ba, Zn, and Sr. A list of the wells showing anomalous amounts of these elements is as follows:

	Ba mg/l	Zn mg/l	Cu mg/l	Sr mg/l
Berardy Well	1.7	2.6	-	0.12
Jackson Well	-	4.4	1.1	0.12
Foster Well	-	0.4	0.2	0.13
McCaslund Well	6.3	8.1	-	0.11
Meeker Well	0.8	2.2	-	0.12
Richter Spring	-	2.4	-	0.07
Richter Well	6.3	4.9	-	0.24
Sampaulesi Well	-	0.6	-	0.24

These analyses from our reconnaissance study of the area indicate the

Table 2. Spring and well chemistry of the Powell Buttes area. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Berardy Well	Craddock Well	Jackson Well	Foster Well	Johnson Well #1	Johnson* Well #2	Harris Well
Location	16S/14E/ 15Acd	16S/14E/ 3Add	16S/14E/ 16Daa	15S/14E/ 28Dcd	15S/14E/ 35Dad	15S/14E/ Dcd	15S/15E/ 29Cad
Date sampled	12/80	12/80	12/80	12/80	12/80	12/80	12/80
Temp. (^{o} C)	24.5	24.3	27	10	20.5	nt	16.8
pH	7.1	8.05	7.8	7.3	7.65	nt	8.2
Conductance µmhos/cm	260	350	340	325	340	nt	400
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	nt	nt	nt	nt	nt	nt
Hardness as mg/l $CaCO_3$	85.5	51.3	85.5	136.8	102.6	nt	51.3_c
Total dissolved solids	142	140	154	184	176	384	190
SiO_2	32	10	26	26	23	17	13
Na	37	56	31	17	32	28	61
K	<2.5	<2.5	3	3	<2.5	<2.5	<2.5
Ca	23	5	20	21	20	3	7
Mg	5	1	6	12	5	1	2
Cl	9	11	13	2	11	156	22
As	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625
B	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125
Li	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
F	0.4	0.6	2.7	0.3	0.4	0.6	0.6
Fe (total)	0.43	0.25	<0.025	<0.025	0.23	0.06	0.27
Al	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625
HCO_3	nt	nt	nt	nt	nt	nt	nt
PO_4	<1.95	<1.95	<1.95	<1.95	<1.95	<1.95	<1.95
SO_4	31	20	24	7	23	7	19
NO_3	nt	nt	nt	nt	nt	nt	nt
NH_3	nt	nt	tr	nt	tr	nt	nt

*Possible contamination from drilling fluids.

Table 2. Spring and well chemistry of the Powell Buttes area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	McCasland Well	Meeker Well	Lundquist Well	Richter Well	Marshall Well	McDonald Well #1
Location	16S/14E/ 9Adc	16S/14E/ 10Aaa	16S/14E/ 8Ddd	16S/14E/ 1Cbc	16S/14E/ 21Abb	15S/15E/ 32Bcc
Date sampled	12/80	12/80	12/80	12/80	12/80	12/80
Temp. (^{o} C)	35.5	24.9	19	19.2	33.3	14.6
pH	7.4	7.38	7.6	7	7.8	7.5
Conductance µmhos/cm	250	400	300	400	250	250
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	nt	nt	nt	nt	nt
Hardness as mg/l $CaCO_3$	51.3$_c$	85.5$_c$	85.5$_c$	136.8$_c$	17.1	85.5
Total dissolved solids	144	196	142	194	120	136
SiO_2	36	24	29	28	22	32
Na	27	49	19	29	33	15
K	4	<2.5	<2.5	<2.5	<2.5	<2.5
Ca	14	18	13	29	6	15
Mg	2	6	12	13	1	6
Cl	10	9	6	13	13	9
As	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625
B	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125
Li	<0.05	0.06	<0.05	<0.05	<0.05	<0.05
F	0.6	1.7	0.3	1.2	0.4	0.4
Fe (total)	<0.025	0.11	<0.025	0.03	0.03	0.2
Al	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625
HCO_3	nt	nt	nt	nt	nt	nt
PO_4	<1.95	<1.95	<1.95	<1.95	<1.95	<1.95
SO_4	19	30	9	32	18	11
NO_3	nt	nt	nt	nt	nt	nt
NH_3	nt	nt	nt	nt	nt	nt

Table 2. Spring and well chemistry of the Powell Buttes area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	McDonald Well #2	McFarlane Well	Olson Well	Sampaulesi Well	Shumway Well	Silver Dollar Ranch Well
Location	15S/15E/ 32Bcc	15S/14E/ 34Baa	15S/15E/ 31Caa	15S/15E/ 29Aba	16S/14E/ 28Abd	16S/14E/20Add
Date sampled	12/80	12/80	12/80	12/80	12/80	12/80
Temp. (^{o} C)	15	18	18	21.6	18	17
pH	7.5	7.8	7	7.6	8.5	7.72
Conductance µmhos/cm	250	340	320	440	230	250
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	nt	nt	nt	nt	nt
Hardness as mg/l $CaCO_3$	85.5	85.5	68.4	119.7	34.2	85.5
Total dissolved solids	144	170	140	268	128	126
SiO_2	32	29	31	27	24	28
Na	15	21	14	49	32	17
K	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Ca	14	19	12	24	8	12
Mg	6	13	6	6	1	10
Cl	11	7	7	17	5	4
As	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625
B	<0.125	<0.125	<0.125	<0.125	<0.125	<0.125
Li	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
F	0.4	0.4	0.4	1.1	0.6	0.3
Fe (total)	0.2	<0.025	<0.025	<0.025	0.64	0.05
Al	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625
HCO_3	nt	nt	nt	nt	nt	nt
PO_4	<1.95	<1.95	<1.95	<1.95	<1.95	<1.95
SO_4	11	9	7	25	6	5
NO_3	nt	nt	nt	nt	nt	nt
NH_3	nt	tr	nt	nt	tr	nt

Table 2. Spring and well chemistry of the Powell Buttes area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Waibel Well	Weigand Well	Dempsey Spring	Deadman Spring	Tracy Wells Spring	Picket Spring
Location	15S/15E/ 21Cac	15S/14E/ 33Dda	16S/15E/ 9Cb	16S/15E/ 16Cc	16S/15E/ 8Bc	16S/14E/ 1Ccb
Date sampled	12/80	12/80	9/79	9/79	9/79	12/80
Temp. (^{o} C)	19.3	24	15.5	18	15	6.9
pH	7.6	7.75	6.6	6.9	7	7
Conductance µmhos/cm	440	280	145	155	150	200
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	nt	39_c	60_c	68_c	nt
Hardness as mg/l $CaCO_3$	188	85.5	35	51	52	85.5
Total dissolved solids	256	196	102	134	118	94
SiO_2	40	31	34.8	52	43.8	36
Na	20	21	10.5	10.2	9.7	16
K	<2.5	<2.5	2.9	1.3	1.3	<2.5
Ca	27	12	12.1	10.8	11.5	13
Mg	18	9	5.73	5.85	6	8
Cl	16	6	3.2	5.4	4	9
As	<0.625	<0.625	<0.005	<0.005	<0.005	<0.625
B	0.3	0.2	0.13	0.18	0.21	<0.125
Li	<0.05	<0.05	<0.01	<0.01	<0.01	<0.05
F	0.4	0.4	0.2	0.2	0.2	0.3
Fe (total)	<0.025	<0.025	1.9	0.06	<0.05	<0.025
Al	<0.625	<0.625	3	0.13	0.09	<0.625
HCO_3	nt	nt	nt	nt	nt	nt
PO_4	<1.95	<1.95	0.022	0.026	0.039	<1.95
SO_4	25	10	5	3.1	1.8	10
NO_3	nt	nt	0.02	<0.02	<0.02	nt
NH_3	nt	nt	0.58	0.07	0.08	nt

following hypotheses:

1) The water tested may never have been warmer (or at least, not much warmer) than the temperature recorded during sampling.
2) Because of low content of thermal constituents, we can infer the waters have not been deeply circulated; instead, the waters were probably heated conductively by a source at greater depth.
3) The waters sampled are probably meteoric waters which have infiltrated through the buttes, which is the local area of recharge. They have acquired trace metals from locally intense alteration, and have migrated down the hydrologic dip to where they were intercepted by wells.

Table 3. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Powell Buttes area.

	Berardy Well	Craddock Well	Jackson Well	Foster Well	Johnson Well #1	Johnson Well #2	Harris Well
Flow rate liters/min.	45	30	4	<20	<20	nc	56
Measured temperature	24.5	24.3	27	10	20.5	nc	16.8
SiO_2 conductive ^oC	82	39	74	74	69	57	48
SiO_2 adiabatic ^oC	85	47	78	78	74	64	55
SiO_2 chalcedony ^oC	51	6	42	42	37	25	15
SiO_2 opal ^oC	-31	-65	-38	-38	-42	-51	-58

*Methodology for calculations presented in Appendix A. nc = not calculated.

Table 3. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Powell Buttes area--Continued.

	Waibel Well	Weigand Well	Dempsey Spring	Deadman Spring	Tracy Wells Spring	Richter Spring
Flow rate liters/min.	nc	nc	nc	nc	nc	nc
Measured temperature	19.3	24	15.5	18.9	15	6.9
SiO_2 conductive ^oC	92	81	86	104	96	87
SiO_2 adiabatic ^oC	94	84	88	104	97	90
SiO_2 chalcedony ^oC	61	49	55	74	65	56
SiO_2 opal ^oC	-23	-32	-28	-12	-19	-26

*Methodology for calculations presented in Appendix A. nc = not calculated.

Table 3. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Powell Buttes area--Continued.

	McCasland Well	Meeker Well	Lundquist Well	Richter Well	Marshall Well	McDonald Well #1
Flow rate liters/min.	<20	45	nc	<20	nc	<20
Measured temperature	19.1	24.9	19	19.2	33.3	14.6
SiO_2 conductive ^oC	87	70	78	77	67	82
SiO_2 adiabatic ^oC	90	75	82	81	72	85
SiO_2 chalcedony ^oC	56	39	47	45	35	51
SiO_2 opal ^oC	-26	-40	-34	-35	-43	-31

*Methodology for calculations presented in Appendix A. nc = not calculated.

Table 3. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Powell Buttes area--Continued.

	McDonald Well #2	McFarlane Well	Olson Well	Sampaulesi Well	Shumway Well	Silver Dollar Ranch Well
Flow rate liters/min.	<20	20	20	15	34	nc
Measured temperature	15	18	18	21.6	18	17
SiO_2 conductive ^oC	82	78	81	75	70	77
SiO_2 adiabatic ^oC	85	82	84	79	75	81
SiO_2 chalcedony ^oC	51	47	49	43	39	45
SiO_2 opal ^oC	-31	-34	-32	-36	-40	-35

*Methodology for calculations presented in Appendix A. nc = not calculated.

GEOTHERMAL GRADIENT AND HEAT FLOW DATA*

The temperature gradient and heat flow results for the Powell Buttes area are shown in Table 4. Included in the table are township/range-section and latitude and longitude locations of each hole. In addition the hole name, date of logging used, and collar elevation are included. As overlays on Plate I the bottom hole temperature, maximum depth, corrected temperature gradient and (where available) corrected heat flow are shown. These values are also listed in the table as are the depth interval and average thermal conductivity used for the calculation of gradient and heat flow. The values are given in SI units. To transform units 1×10^{-6} cal/cm^{2}sec (HFU) = 41.84 mWm^{-2}, 1×10^{-3} cal/cm sec^{o}C (TCU) = 0.4184 Wm^{-1}. Also 1^{o}C/km - 1 mKm^{-1} = 18.2^{o}F/100 ft. The temperature-depth measurements themselves for each hole have been included in this report as Appendix B. Corrected gradient and corrected heat flow are values for which the topographic effect have been removed. In general, these effects are not significant for most of the sites studied and for holes logged before September, 1980. Only uncorrected gradient values are shown for those holes with no significant topographic effect.

The holes are ranked in terms of quality of the gradient or heat flow information, from high quality (A), to good quality (B), to marginal quality (C), to data with some problems (D), to data for which no useful temperature gradient or heat flow can be estimated (X). All thermal conductivity measurements were made on cutting samples. Most of the heat flow data available were obtained in holes drilled originally as water wells; however, the permeability of most of the rocks in the upper 200 m is very low, and conductive gradients are usually obtained in these holes.

*Written by Dr. David Blackwell, Southern Methodist University, Dallas, Texas.

Studies of gradient and heat flow in existing water wells began in 1978 and resulted in the outlining of a sizable geothermal anomaly on the northwest side of Powell Buttes (Figure 3). There, an area over 10 km long and at least 2 km wide has gradients in excess of 100°C/km. There are no surface manifestations or evidence of this anomaly and, as noted above, the surficial rocks are relatively impermeable. Water bodies are deep, and there is no indication in the water wells of the source of the heat flow anomaly. The maximum depth of the water wells on the average is between 180 and 250 m. In late 1980, several holes were drilled by DOGAMI to investigate the thermal anomaly outlined by the earlier studies. The data from these holes are included in the table (all holes logged after 9/80). However, only uncorrected gradients are shown for these holes as terrain corrections have not yet been calculated and thermal conductivity measurements have not been made so that heat flow values can be calculated. These studies will be carried out in the near future. Following the completion of the shallow drilling program a deeper hole (460 m deep) was drilled in the winter of 1980. The results of that hole have been included in preliminary form as Figure 2.

Table 4. Geothermal gradient data from the Powell Buttes area, Oregon.

Twn/Rng-Section	N Lat. Deg.Min.	W Long Deg.Min.	Hole # Date	Collar Elev.	Bottom Temp. (°C)	Depth Interval (m)	Avg. TC $Wm^{-1}K^{-1}$	# TC	Uncorr. Gradient °C/km	Corr. Gradient °C/km	Corr. HF mWm^{-1}	Q HF
14S/14E-18CC	44-21.15	121- 6.32	SWIFT 4/18/80	874	12.26	25.0 60.1			4.5 1.2			C
15S/14E-15DD	44-15.92	121- 1.68	CRABTREE 4/16/80	930	121.80	.0						D
15S/14E-35BC	44-13.67	121- 1.55	FLOCK 6/18/80	982	25.03	45.0 110.0			127.7 2.3			
						20.0 125.0			111.7 7.3			
15S/14E-36AC	44-13.23	120-59.60	FHRNBKWW 9/22/78	1023	31.67	20.0 155.0	(1.46)		128.4 2.1	120.5	176	C
15S/15E-28AD	44-14.62	120-55.70	KOOPS 8/11/80	998	20.31	15.0 40.0			119.3 18.3			
						40.0 149.0			51.0 1.4			
15S/15E-29BB	44-14.80	120-57.65	POWBUTNE 4/14/80	986	26.57	16.0 35.0			190.0			A
						35.0 172.0			77.1 2.5			A
15S/15E-30AC	44-14.45	120-58.40	CRAWFORD 4/ 5/80	995	19.08	10.0 75.0			81.9 3.7			B
15S/15E-30AD	44-14.44	120-58.01	LOT24WW 9/20/78	1002	17.87	40.0 105.0	(1.46)		70.5 5.7	70.5	103	C
15S/15E-31AC	44-13.68	120-58.52	DEASON 4/ 6/80	1067	29.96	10.0 40.0			266.6 19.8			B
						40.0 244.3			68.7 4.6			B
15S/15E-31DA1	44-13.55	120-58.16	KRANTH 1 7/28/79	1100	27.53	195.0 225.0			69.2 .1			B
						10.0 225.0	1.42	3	73.3 1.6	69.8	99	B

Table 4. Geothermal gradient data from the Powell Buttes area, Oregon--continued.

Twn/Rng-Section	N Lat. Deg.Min.	W Long Deg.Min.	Hole # Date	Collar Elev.	Bottom Temp. (°C)	Depth Interval (m)	Avg. TC $Wm^{-1}K^{-1}$	# TC	Uncorr. Gradient °C/km	Corr. Gradient °C/km	Corr. HF mWm^{-1}	Q HF
15S/15E-31DA2	44-13.55	120-58.16	KRANTH 2 7/28/79	1100	19.73	20.0 120.0			75.5 2.1			A
						90.0 120.0			71.7 .2			A
15S/16E-16DA	44-16.14	120-48.70	PRSTUDCO 7/12/77	936	16.39	7.5 47.5			(68.0)	57.0		C
16S/14E-2BC	44-12.80	121- 1.56	HALLETT 8/12/79	1021	19.09	5.0 78.5	1.35	1	114.1 13.0	110.0	148	C
16S/14E-2DAD	44-12.63	121- .38	RICHTER 9/23/80	1085	19.84	20.0 105.0			57.3 3.4			B
						105.0 154.0			40.4 .5			B
16S/14E-3CC	44-12.53	121- 2.52	P MILLER 4/ 7/80	1003	30.68	10.0 45.0			252.5 13.1			A
						45.0 179.0			113.0 6.0			A
16S/14E-4DD	44-12.62	121- 2.78	SCHOOLHS 8/13/80	991	13.58	10.0 20.0			195.0 12.0			
16S/14E-9DBB	44-12.10	121- 3.33	MINSON 10/ 1/80	975	23.05	10.0 160.0			84.2 6.2			B
16S/14E-10AB	44-12.42	121- 2.13	POWBUTNW 4/ 8/80	1021	29.51	10.0 45.0			198.7 9.6			A
						45.0 170.0			91.5 4.4			A
16S/14E-10BA	44-12.27	121- 2.30	JENSEN 8/ 8/80	1015	24.00	10.0 93.5			129.5 4.9			
16S/14E-11CC	44-11.75	121- 1.50	MATHERS 4/17/80	1086	20.99	20.0 156.0			58.1 1.6			A
16S/14E-11DC	44-11.70	121- .72	POWBUT 4/17/80	1146	13.85	20.0 50.0			33.7 1.5			B

Table 4. Geothermal gradient data from the Powell Buttes area, Oregon--continued.

Twn/Rng-Section	N Lat. Deg.Min.	W Long Deg.Min.	Hole # Date	Collar Elev.	Bottom Temp. (°C)	Depth Interval (m)	Avg. TC $Wm^{-1}K^{-1}$	# TC	Uncorr. Gradient °C/km	Corr. Gradient °C/km	Corr. HF mWm^{-1}	Q HF
16S/14E-14CC	44-10.85	121- 1.35	SANTOS 8/14/80	1103	16.25	5.0 20.0			107.2 5.5			
						20.0 75.2			58.1 1.1			
16S/14E-15ABC	44-12.10	121- 2.00	SHMWAY 3 9/23/80	1067	22.61	10.0 50.0			109.9 4.8			B
						50.0 115.0			68.3 1.0			B
16S/14E-16DAA	44-11.18	121- 2.78	MCDNL-WW 9/21/78	1024	37.36	25.0 160.0	(1.46)		148.4 4.1	141.3	207	B
16S/14E-16DC	44-10.95	121- 3.25	ALF-PBRD 8/14/80	1010	32.25	20.0 123.0			162.2 7.4			
16S/14E-17DDD	44-10.87	121- 4.00	ST HWY 1 11/25/80	975	16.16	.0						C
16S/14E-20AC	44-10.48	121- 4.33	MILLER 8/12/80	963	12.63	10.0 30.0			- 30.4 7.0			
16S/14E-20DA	44-10.37	121- 3.97	SLVDLR R 8/12/80	972	16.91	10.0 149.0			- 12.5 13.7			
16S/14E-21DAB	44-10.47	121- 2.97	SHMWAY 2 10/ 3/80	1013	27.04	10.0 80.0			127.8 4.0			B
						80.0 134.0			96.9 1.0			B
16S/14E-27ABA	44- 9.88	121- 2.02	SHMWAY 1 9/23/80	1062	20.50	10.0 90.0			87.5 4.1			B
						90.0 108.0			43.0 .1			B
16S/14E-28AD	44- 9.58	121- 2.88	SHUMWAY 4/ 7/80	981	24.67	20.0 65.0			82.9 3.8			B
						110.0 158.5			100.7 2.1			B

Table 4. Geothermal gradient data from the Powell Buttes area, Oregon--continued.

Twn/Rng-Section	N Lat. Deg.Min.	W Long Deg.Min.	Hole # Date	Collar Elev.	Bottom Temp. (°C)	Depth Interval (m)	Avg. TC $Wm^{-1}K^{-1}$	# TC	Uncorr. Gradient °C/km	Corr. Gradient °C/km	Corr. HF mWm^{-1}	Q HF
16S/14E-35CAA	44- 8.57	121- 1.08	SBUTTE 2 10/20/80	1035	24.06	10.0 90.0			103.9 1.5			B
						90.0 140.0			47.3 1.0			B
16S-15E-20CBA	44-10.17	120-57.92	SBUTTE 1 10/20/80	1190	14.76	40.0 140.0			29.1 1.0			B
16S/15E-26CC	44- 8.93	120-54.30	H MARTIN 8/19/80	1076	20.90	40.0 165.0			55.9 1.2			
						50.0 140.0			55.6 .7			
16S/15E-29CDD	44-10.17	120-57.90	SHMWAY W 10/20/80	1104	21.31	20.0 95.0			105.6 3.0			B
17S/14E-23AC	44- 5.13	121- .95	LEWIS 8/20/80	1021	18.31	80.0 170.0			74.1 4.8			
						135.0 170.0			68.7 2.0			
17S/15E-20CA	44- 4.67	120-57.60	BOWEN 4/16/80	1036	26.17	10.0 120.0			34.2 2.1			B
17S/16E-32CA	44- 3.12	120-50.40	GLOVER 8/21/80	1163	20.14	20.0 75.0			87.7 4.6			
						75.0 119.0			43.9 3.9			

CONCLUSIONS AND RECOMMENDATIONS

The Powell Buttes area is located within economic piping distance of the industrial districts of three of the major communities in central Oregon; Bend (10 mi), Prineville (5 mi) and Redmond (5 mi). Our preliminary evaluation, based on geology, geophysics, geochemistry, probing of existing water wells, drilling and probing of eight 152-m (500-ft) gradient holes, and the drilling and probing of one 460-m (1510-ft) gradient hole, indicates the potential exists for 100°C (212°F) temperatures at depths of approximately 1000 m (3,300 ft.). The existence of these elevated temperatures and usable fluids has not, however, been proven. To further evaluate this important area in terms of possible development for direct-use, the following types of further study are needed:

1. Development of the existing gravity and aeromagnetic data into highly detailed 1:62,500 scale maps with occupation of additional gravity stations--to define in detail the structure of the buttes.
2. Performance of deep-probing electrical surveys (dipole-dipole, roving dipole, or telluric) on both the east and west sides of the buttes--to determine areas of upwelling of deep thermal waters, if any, to help precise location of deep gradient holes.
3. Drilling of twenty 152-m (500-ft) gradient-stratigraphy holes on both sides of the buttes--to further define the thermal anomaly and assist in siting of deep gradient holes. Geophysical studies listed in 1 and 2 would guide location of these holes.
4. The drilling of several 1000-m gradient holes--to complete development of the Powell Buttes geothermal model and directly test encountered thermal aquifers for future direct-use geothermal production wells.

POWELL BUTTES BIBLIOGRAPHY

Atwater, T., 1970, Implications of plate tectonics for the Cenozoic tectonic evolution of western North America: Geological Society of America Bulletin, v. 81, no. 12, p. 3513-3536.

Baldwin, E.M., 1976, Geology of Oregon (revised ed.): Dubuque, Iowa, Kendall/Hunt, 147 p.

Berg, J.W., and Thiruvathukal, J.V., 1965, Gravity base station network, Oregon: Journal of Geophysical Research, v. 70, no. 14, p. 3325-3330.

Calkins, F.C., 1902, A contribution to the petrography of the John Day Basin: Berkeley, Calif., University of California Publications, Bulletin of the Department of Geology, v. 3, no. 5, p. 109-172.

Chaney, R.W., 1927, Geology and paleontology of the Crooked River Basin, with special reference to the Bridge Creek flora: Washington, D.C., Carnegie Institution of Washington Publication 346, p. 45-138.

Couch, R.W., Gemperle, M., and Connard, G.G., 1978, Total field aeromagnetic anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-9, 2 sheets.

Dalrymple, G.B., Cox, A., Doell, R.R., and Grommé, C.S., 1967, Pliocene geomagnetic polarity epochs: Earth and Planetary Science Letters, v. 2, no. 3, p. 163-173.

Evernden, J.F., and James, G.T., 1964, Potassium-argon dates and the Tertiary floras of North America: American Journal of Science, v. 262, no. 8, p. 945-974.

Evernden, J.F., Savage, D.E., Curtis, G.H., and James, G.H., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: American Journal of Science, v. 262, no. 2, p. 145-198.

Fisher, R.V., 1967, Early Tertiary deformation in north-central Oregon: American Association of Petroleum Geologists Bulletin, v. 51, no. 1, p. 111-123.

Hamilton, W., and Myers, W.B., 1966, Cenozoic tectonics of the western United States: Review of Geophysics, v. 4, no. 4, p. 509-549.

Hodge, E.T., 1932, New evidence of the age of the John Day Formation: Geological Society of America Bulletin, v. 43, no. 3, p. 695-702.

——— 1940, Geology of the Madras quadrangle: Corvallis, Oreg., Oregon State College, Oregon State Monographs, Studies in Geology, no. 1 (geologic map), scale 1:125,000.

——— 1942, Geology of north-central Oregon: Corvallis, Oreg., Oregon State College, Oregon State Monographs, Studies in Geology, no. 3, 76 p.

Laursen, J.M., and Hammond, P.E., 1978, Summary of radiometric ages of Oregon rocks, Supplement 1: July 1972 through December 1976: Isochron/West, no. 23, p. 3-28.

Lipman, P.W., Prostka, H.J., and Christiansen, R.L., 1972, Cenozoic volcanism and plate-tectonic evolution of the western United States; I, Early and middle Cenozoic: Philosophical Transactions of the Royal Society of London, ser. A, v. 271, no. 1213, p. 217-248.

Lowry, W.D., 1940, The geology of the Bear Creek area, Crook and Deschutes Counties, Oregon: Corvallis, Oreg., Oregon State College master's thesis, 29 p.

McLeod, N.S., Walker, G.W., and McKee, E.H., 1975, Geothermal significance of eastward increase in age of upper Cenozoic rhyolitic domes in southeastern Oregon: U.S. Geological Survey Open-File Report 75-348, 22 p.; also 1976, in Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, Calif., 20-29 May, 1975, Proceedings: Lawrence Berkeley Laboratory, University of California (for ERDA, NSF, and USGS), v. 1, p. 465-474.

Marlatte, C.R., 1931, The petrogenesis of the clastic materials of the Madras Formation: Eugene, Oreg., University of Oregon master's thesis, 78 p.

Matthews, T.C., 1955, Oregon radioactive discoveries in 1954 and 1955: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 17, no. 12, p. 87-92.

——— 1956, Radioactive occurrences in Oregon, 1956: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 18, no. 12, p. 105-107.

Peterson, N.V., Groh, E.A., Taylor, E.M., and Stensland, D.E., 1976, Geology and mineral resources of Deschutes County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 89, 66 p.

Peterson, N.V., 1958, Oregon's uranium picture: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 20, no. 12, p. 111-117.

Pitts, G.S., 1979, Interpretation of gravity measurements made in the Cascade Mountains and the adjoining Basin and Range province in central Oregon: Corvallis, Oreg., Oregon State University master's thesis, 186 p.

Pitts, G.S., and Couch, R.W., 1978, Complete Bouguer gravity anomaly map, Cascade Mountain Range, central Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-8, scale 1:125,000.

Riccio, J.F., ed., 1979, Geothermal resource assessment of Mount Hood: Oregon Department of Geology and Mineral Industries Open-File Report O-79-8, 273 p.

——— 1980, Geothermal exploration in Oregon, 1979: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 42, no. 4, p. 59-69.

Robinson, J.W., and Price, D., 1963, Ground water in the Prineville area, Crook County, Oregon: U.S. Geological Survey Water-Supply Paper 1619-P, p. 8-11.

Robinson, P.T., 1969, High-titania alkaki-olivine basalts of north-central Oregon, U.S.A.: Contributions to Mineralogy and Petrology, v. 22, no. 4, p. 349-360.

Robinson, P.T., and Stensland, D.H., 1979, Geologic map of the Smith Rock area, Jefferson, Deschutes, and Crook Counties, Oregon: U.S. Geological Survey Miscellaneous Investigations Series Map I-1142, scale 1:48,000.

Rogers, J.J.W., 1966, Coincidence of structural and topographic highs during post-Clarno time in north-central Oregon: American Association of Petroleum Geologists Bulletin, v. 50, no. 2, p. 390-396.

Rogers, J.J.W., and Novitsky-Evans, J.M., 1977, The Clarno Formation of central Oregon, U.S.A. —volcanism on a thin continental margin: Earth and Planetary Science Letters, v. 34, no. 1, p. 55-66.

Russell, I.C., 1905, Preliminary report on the geology and water resources of central Oregon: U.S. Geological Survey Bulletin 252, 138 p.

Schafer, M., 1956, Uranium prospecting in Oregon, 1956: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 18, no. 12, p. 101-104.

Stearns, H.T., 1931, Geology and water resources of the middle Deschutes River Basin, Oregon, in U.S. Geological Survey, Contributions to the hydrology of the United States: U.S. Geological Survey Water-Supply Paper 637, p. 125-212.

Stroh, H.R., 1980, Geology of the Clarno Formation in the vicinity of Stephenson Mountain, Jefferson, Crook, and Wheeler Counties, Oregon: Corvallis, Oreg., Oregon State University master's thesis, 128 p.

Swanson, D.A., 1969, Reconnaissance geologic map of the east half of the Bend quadrangle, Crook, Wheeler, Jefferson, Wasco, and Deschutes Counties, Oregon: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-568.

Swanson, D.A., and Robinson, P.T., 1968, Base of the John Day Formation in and near the Horse Heaven mining district, north-central Oregon, in U.S. Geological Survey, Geological Survey research 1968: U.S. Geological Survey Professional Paper 600-D, p. D154-D161.

Taylor, E.M., 1980, High Cascade ash-flow tuffs and pumice deposits in the vicinity of Bend, Oregon (abs.): Geological Society of America Abstracts with programs, v. 12, no. 3, p. 155.

Thiruvathukal, J.V., 1968, Regional gravity of Oregon: Corvallis, Oreg., Oregon State University doctoral dissertation, 92 p.

Walker, G.W., 1970, Cenozoic ash-flow tuffs of Oregon: Oregon Department of Geology and Mineral Industries, Ore Bin, v. 32, no. 6, p. 97-115.

——— 1977, Geologic map of Oregon east of the 121st meridian: U.S. Geological Survey Miscellaneous Investigations Series Map I-902, scale 1:500,000.

Walker, G.W., 1979, Revisions to the Cenozoic stratigraphy of Harney Basin, southeastern Oregon: U.S. Geological Survey Bulletin 1475, 35 p.

Walker, G.W., Dalrymple, G.B., and Lanphere, M.A., 1974, Index to potassium-argon ages of Cenozoic volcanic rocks of Oregon: U.S. Geological Survey Miscellaneous Field Studies Map MF-569, scale 1:1,000,000.

Waters, A.C., 1954, John Day Formation west of its type locality (abs.): Geological Society of America Bulletin, v. 65, no. 12, pt. 2, p. 1320.

——— 1968, Reconnaissance geologic map of the Madras quadrangle, Jefferson and Wasco Counties, Oregon: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-555, scale 1:125,000.

Weidenheim, J.P., 1980, The petrography, structure, and stratigraphy of Powell Buttes, Crook County, central Oregon: Corvallis, Oreg., Oregon State University master's thesis, 95 p.

Wells, F.G., and Peck, D.L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-325, scale 1:500,000.

Williams, H., 1957, A geologic map of the Bend quadrangle, Oregon and a reconnaissance geologic map of the central portion of the High Cascade Mountains: Oregon Department of Geology and Mineral Industries in cooperation with the U.S. Geological Survey (text on map), scales 1:125,000 and 1:250,000.

APPENDIX A

Formulas used in calculations

Na:K (revised): $$t\ ^{o}C = \frac{1217}{\log (Na/K) + 1.483} - 273.15$$ (Fournier, 1979)

Na:K:Ca: $$t\ ^{o}C = \frac{1647}{2.24 + F(T)} - 273.15$$ (Fournier and Truesdell, 1973),

where $F(T) = \log (Na/K) + [\ \beta \log (\sqrt{Ca}/Na)\ ]$,

β = 1/3 if t> 100°C, and 4/3 if t <100°C,

$t^{o}C$ = calculated reservoir temperature,

and concentrations are expressed in molality.

Magnesium correction ratio:

$$R = \frac{(\text{milliequivalents Mg})}{(\text{milliequivalents Mg}) + (\text{milliequivalents Ca}) + (\text{milliequivalents K})} \times 100$$

If R <5 or >50, no calculation was made. For R between 5-50,

$$\Delta t_{Mg} = 10.66-(4.7415)(R) + [(325.87)(\log R)^2] - [(1.032 \times 10^5)(\log R)^2/T] - [(1.968 \times 10^7)(\log R)^2/T^2] + [(1.605 \times 10^7)(\log R)^3/T^2],$$

where R = magnesium correction ratio expressed in equivalents,

Δt_{Mg} = the temperature correction that is subtracted from the Na:K:Ca 1/3 β calculated temperature,

T = Na:K:Ca 1/3 β calculated temperature in °K.

Or Δt_{Mg} can be obtained by using the graph compiled by Fournier and Potter (1979).

SiO_2 temperature calculations (Fournier and Rowe, 1966):

SiO_2 (conductive), $$t^{o}C = \frac{1309}{5.19 + \log (SiO_2)} - 273.15$$

SiO_2 (adiabatic), $$t^{o}C = \frac{1522}{5.75 + \log (SiO_2)} - 273.15$$

SiO_2 (chalcedony), $$t^{o}C = \frac{1032}{4.69 + \log (SiO_2)} - 273.15$$

SiO_2 (opal), $$t^{o}C = \frac{731}{4.52 + \log (SiO_2)} - 273.15,$$

where SiO_2 is expressed in mg/l.

References cited:

Fournier, R.O., 1979, A revised equation for the Na/K geothermometer, in Geothermal Resources Council Transactions 3, 1979, p. 221-224.

Fournier, R.O., and Potter, R.W., II, 1979, Magnesium correction to the Na:K:Ca chemical geothermometer: Geochimica et Cosmochimica Acta, v. 43, p. 1543-1550.

Fournier, R.O., and Rowe, J.J., 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet-steam wells: American Journal of Science, v. 264, p. 685-697.

Fournier, R.O., and Truesdell, A.H., 1973, An empirical Na:K:Ca geothermometer for natural waters: Geochimica et Cosmochimica Acta, v. 37, p. 1255-1275.

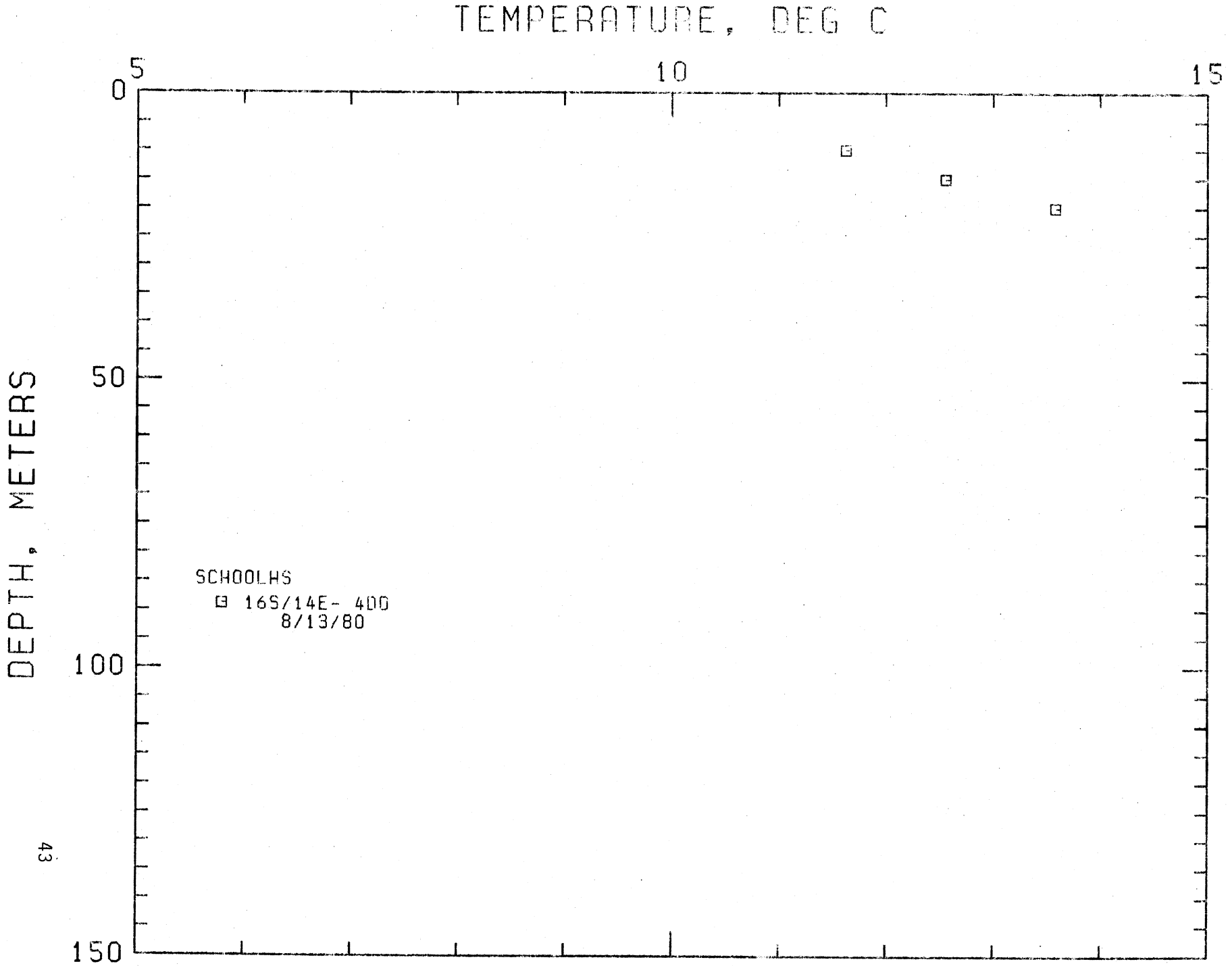
Mariner, R.H., Swanson, J.R., Orris, G.J., Presser, T.S., and Evans, W.C., 1980, Chemical and isotopic data for water from thermal springs and wells of Oregon: U.S. Geological Survey Open-File Report 80-737, 50 p.

APPENDIX B

Geothermal-gradient data

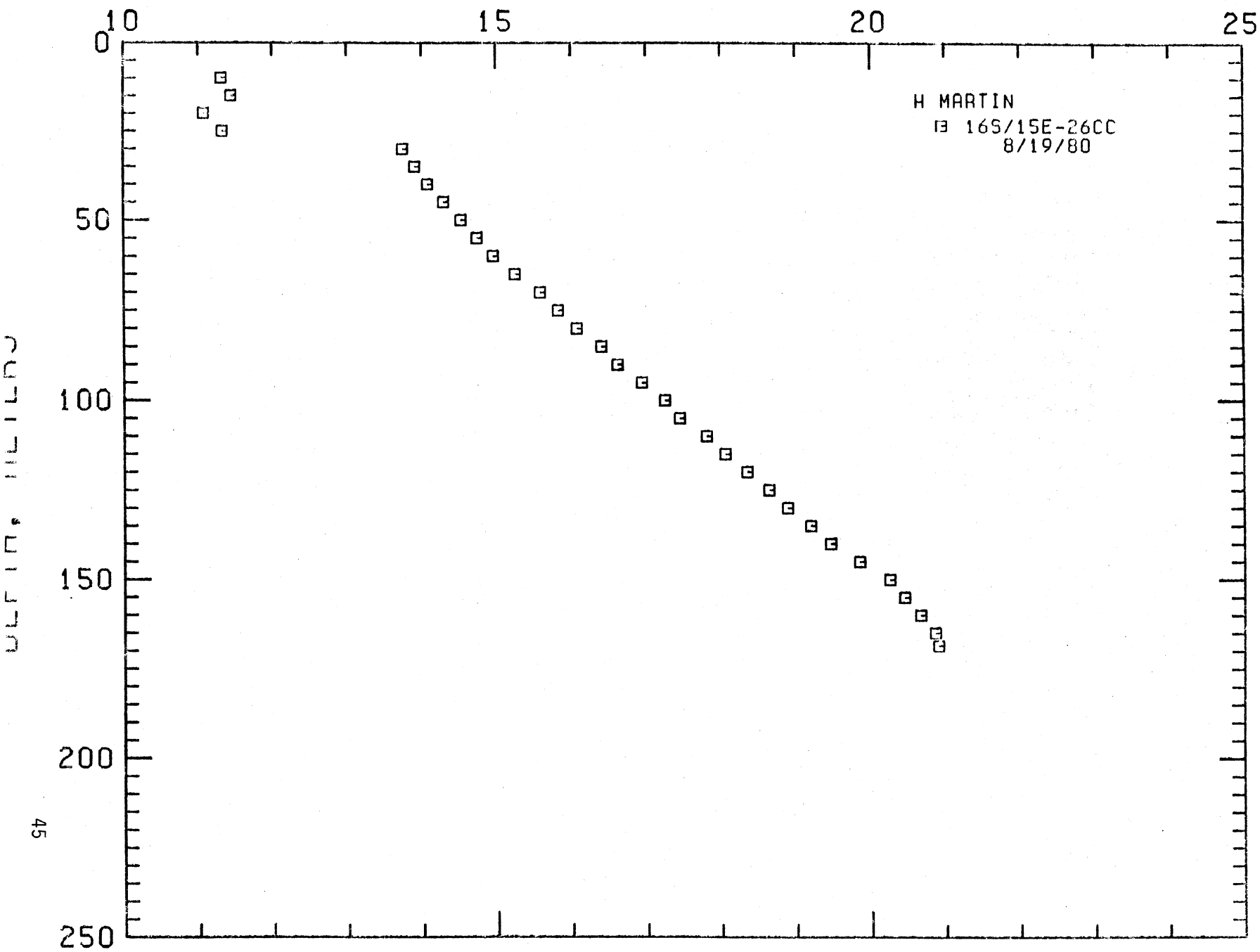
LOCATION: BEND AMS, OREGON
16S/14E- 4DD
HOLE NAME: SCHOOLHS
DATE MEASURED: 8/13/80

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	11.630	52.93	0.0	0.0
15.0	49.2	12.560	54.61	186.0	10.2
20.0	65.6	13.580	56.44	204.0	11.2


TEMPERATURE, DEG C
0
5
10
15
DEPTH, METERS
50
100
150
SCHOOLHS
16S/14E- 4DD
8/13/80

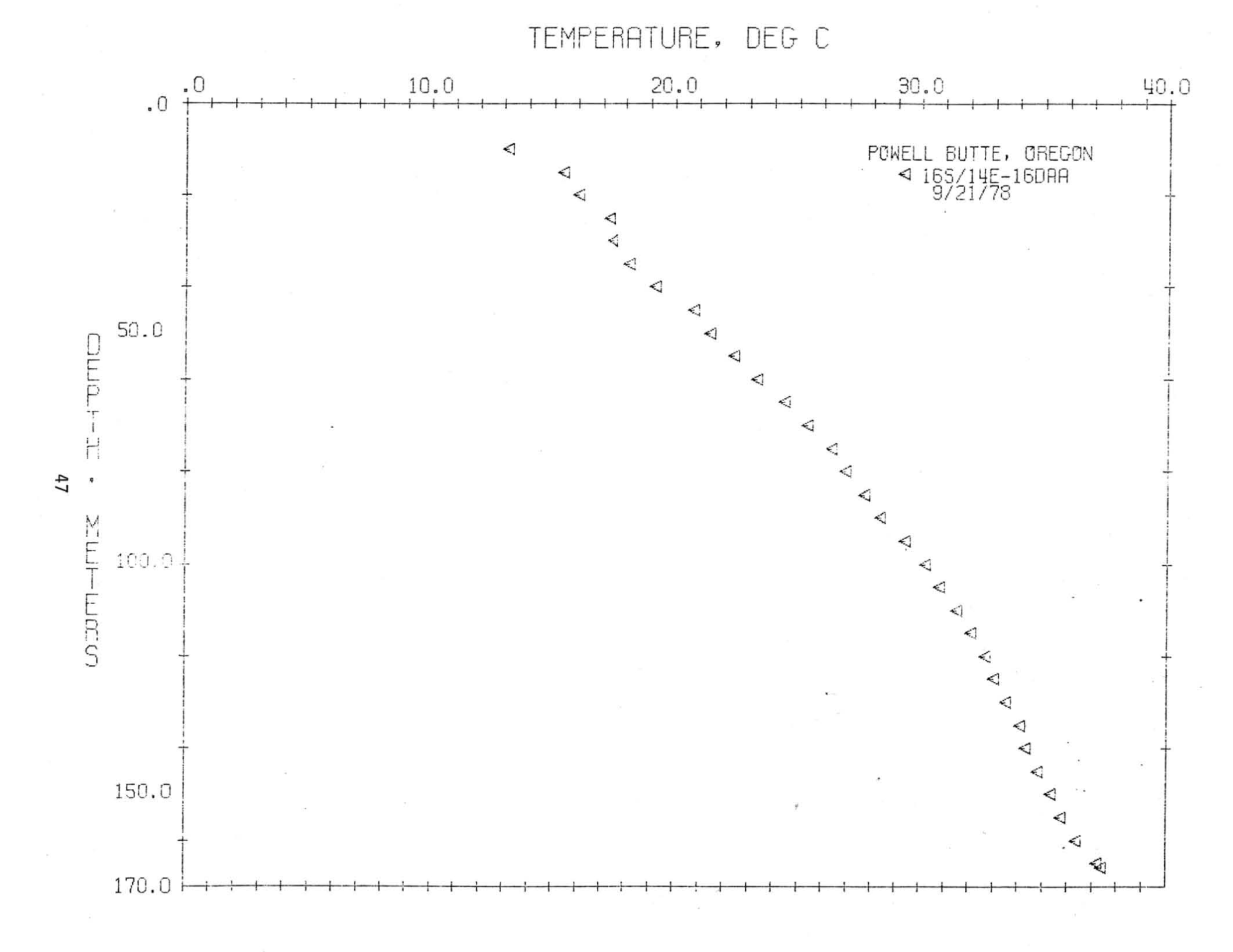
LOCATION: BEND AMS, OREGON
16S/15E-26CC
HOLE NAME: H MARTIN
DATE MEASURED: 8/19/80

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	11.320	52.38	0.0	0.0
15.0	49.2	11.450	52.61	26.0	1.4
20.0	65.6	11.080	51.94	-74.0	-4.1
25.0	82.0	11.330	52.39	50.0	2.7
30.0	98.4	13.750	56.75	484.0	26.6
35.0	114.8	13.920	57.06	34.0	1.9
40.0	131.2	14.090	57.36	34.0	1.9
45.0	147.6	14.300	57.74	42.0	2.3
50.0	164.0	14.530	58.15	46.0	2.5
55.0	180.4	14.750	58.55	44.0	2.4
60.0	196.8	14.960	58.93	42.0	2.3
65.0	213.2	15.250	59.45	58.0	3.2
70.0	229.6	15.590	60.06	68.0	3.7
75.0	246.0	15.830	60.49	48.0	2.6
80.0	262.4	16.080	60.94	50.0	2.7
85.0	278.8	16.400	61.52	64.0	3.5
90.0	295.2	16.620	61.92	44.0	2.4
95.0	311.6	16.940	62.49	64.0	3.5
100.0	328.0	17.250	63.05	62.0	3.4
105.0	344.4	17.450	63.41	40.0	2.2
110.0	360.8	17.810	64.06	72.0	4.0
115.0	377.2	18.060	64.51	50.0	2.7
120.0	393.6	18.350	65.03	58.0	3.2
125.0	410.0	18.640	65.55	58.0	3.2
130.0	426.4	18.890	66.00	50.0	2.7
135.0	442.8	19.200	66.56	62.0	3.4
140.0	459.2	19.460	67.03	52.0	2.9
145.0	475.6	19.850	67.73	78.0	4.3
150.0	492.0	20.250	68.45	80.0	4.4
155.0	508.4	20.450	68.81	40.0	2.2
160.0	524.8	20.660	69.19	42.0	2.3
165.0	541.2	20.860	69.55	40.0	2.2
168.5	552.7	20.900	69.62	11.4	0.6


TEMPERATURE, DEG C
10
15
20
25
0
50
100
150
200
250
H MARTIN
16S/15E-26CC
8/19/80

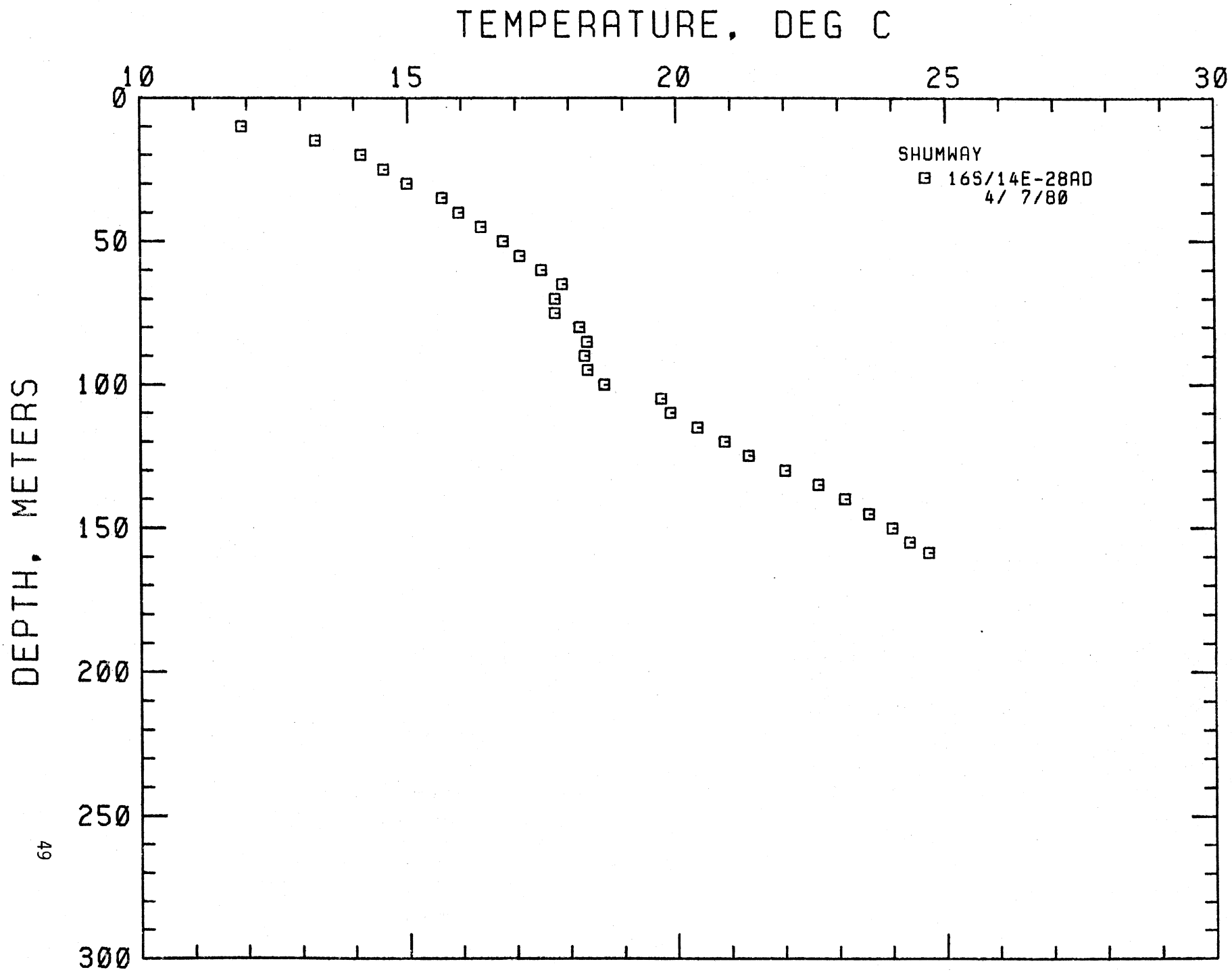
LOCATION: POWELL BUTTE, OREGON
16S 14E-16DAA
HOLE NUMBER: BURNS
DATE MEASURED: 9/21/78

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	13.120	55.62	0.0	0.0
15.0	49.2	15.360	59.65	448.0	24.6
20.0	65.6	16.000	60.80	128.0	7.0
25.0	82.0	17.300	63.14	260.0	14.3
30.0	98.4	17.430	63.37	26.0	1.4
35.0	114.8	18.130	64.63	140.0	7.7
40.0	131.2	19.190	66.54	212.0	11.6
45.0	147.6	20.750	69.35	312.0	17.1
50.0	154.0	21.410	70.54	132.0	7.2
55.0	180.4	22.400	72.32	198.0	10.9
60.0	196.8	23.350	74.03	190.0	10.4
65.0	213.2	24.460	76.03	222.0	12.2
70.0	229.6	25.360	77.65	180.0	9.9
75.0	246.0	26.340	79.41	196.0	10.8
80.0	262.4	26.920	80.46	116.0	6.4
85.0	278.8	27.680	81.82	152.0	8.3
90.0	295.2	28.350	83.03	134.0	7.4
95.0	311.6	29.380	84.88	206.0	11.3
100.0	328.0	30.230	86.41	170.0	9.3
105.0	344.4	30.870	87.48	118.0	6.5
110.0	360.8	31.530	88.75	142.0	7.8
115.0	377.2	32.100	89.78	114.0	6.3
120.0	393.6	32.670	90.81	114.0	6.3
125.0	410.0	33.040	91.47	74.0	4.1
130.0	426.4	33.510	92.32	94.0	5.2
135.0	442.8	34.090	93.36	116.0	6.4
140.0	459.2	34.320	93.78	46.0	2.5
145.0	475.6	34.800	94.64	96.0	5.3
150.0	492.0	35.320	95.58	104.0	5.7
155.0	508.4	35.740	96.33	84.0	4.6
160.0	524.8	36.370	97.47	126.0	6.9
165.0	541.2	37.102	98.92	102.0	6.0
165.0	544.5	37.360	99.25	180.0	9.9


TEMPERATURE, DEG C
.0
10.0
20.0
30.0
40.0
.0
50.0
100.0
150.0
170.0
DEPTH - METERS
POWELL BUTTE, OREGON
16S/14E-16DAA
9/21/78

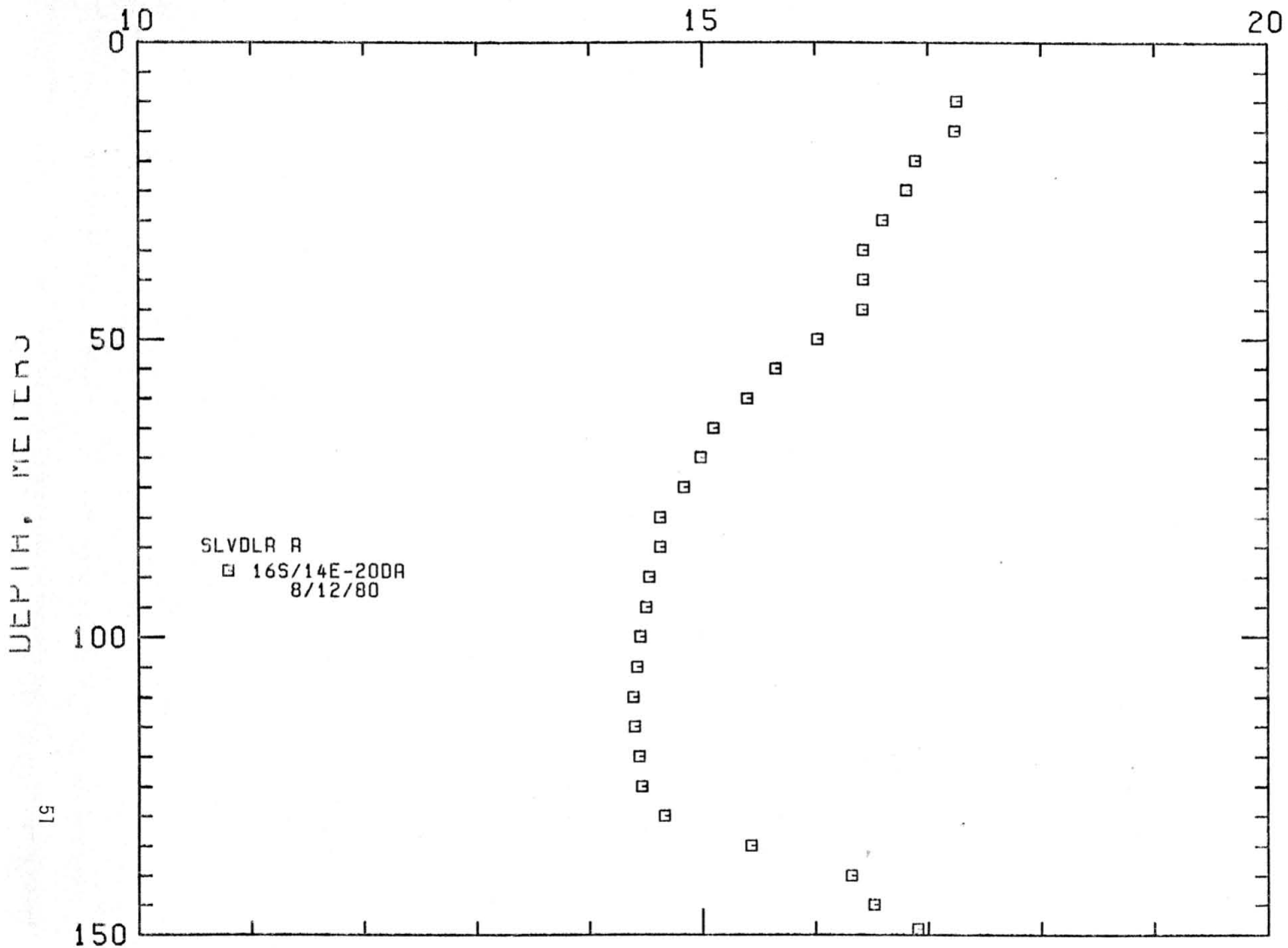
LOCATION: BEND AMS, OREGON
16S/14E-28AD
HOLE NAME: SHUMWAY
DATE MEASURED: 4/ 7/80

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	11.910	53.44	0.0	0.0
15.0	49.2	13.290	55.92	276.0	15.1
20.0	65.6	14.140	57.45	170.0	9.3
25.0	82.0	14.560	58.21	84.0	4.6
30.0	98.4	14.990	58.98	86.0	4.7
35.0	114.8	15.650	60.17	132.0	7.2
40.0	131.2	15.950	60.71	60.0	3.3
45.0	147.6	16.370	61.47	84.0	4.6
50.0	164.0	16.780	62.20	82.0	4.5
55.0	180.4	17.090	62.76	62.0	3.4
60.0	196.8	17.490	63.48	80.0	4.4
65.0	213.2	17.870	64.17	76.0	4.2
70.0	229.6	17.740	63.93	-26.0	-1.4
75.0	246.0	17.740	63.93	0.0	0.0
80.0	262.4	18.190	64.74	90.0	4.9
85.0	278.8	18.330	64.99	28.0	1.5
90.0	295.2	18.280	64.90	-10.0	-0.5
95.0	311.6	18.340	65.01	12.0	0.7
100.0	328.0	18.650	65.57	62.0	3.4
105.0	344.4	19.710	67.48	212.0	11.6
110.0	360.8	19.880	67.78	34.0	1.9
115.0	377.2	20.390	68.70	102.0	5.6
120.0	393.6	20.890	69.60	100.0	5.5
125.0	410.0	21.340	70.41	90.0	4.9
130.0	426.4	22.010	71.62	134.0	7.4
135.0	442.8	22.630	72.73	124.0	6.8
140.0	459.2	23.120	73.62	98.0	5.4
145.0	475.6	23.570	74.43	90.0	4.9
150.0	492.0	24.000	75.20	86.0	4.7
155.0	508.4	24.320	75.78	64.0	3.5
158.5	519.9	24.670	76.41	100.0	5.5


TEMPERATURE, DEG C
10
15
20
25
30
0
50
100
150
200
250
300
DEPTH, METERS
SHUMWAY
16S/14E-28AD
4/ 7/80

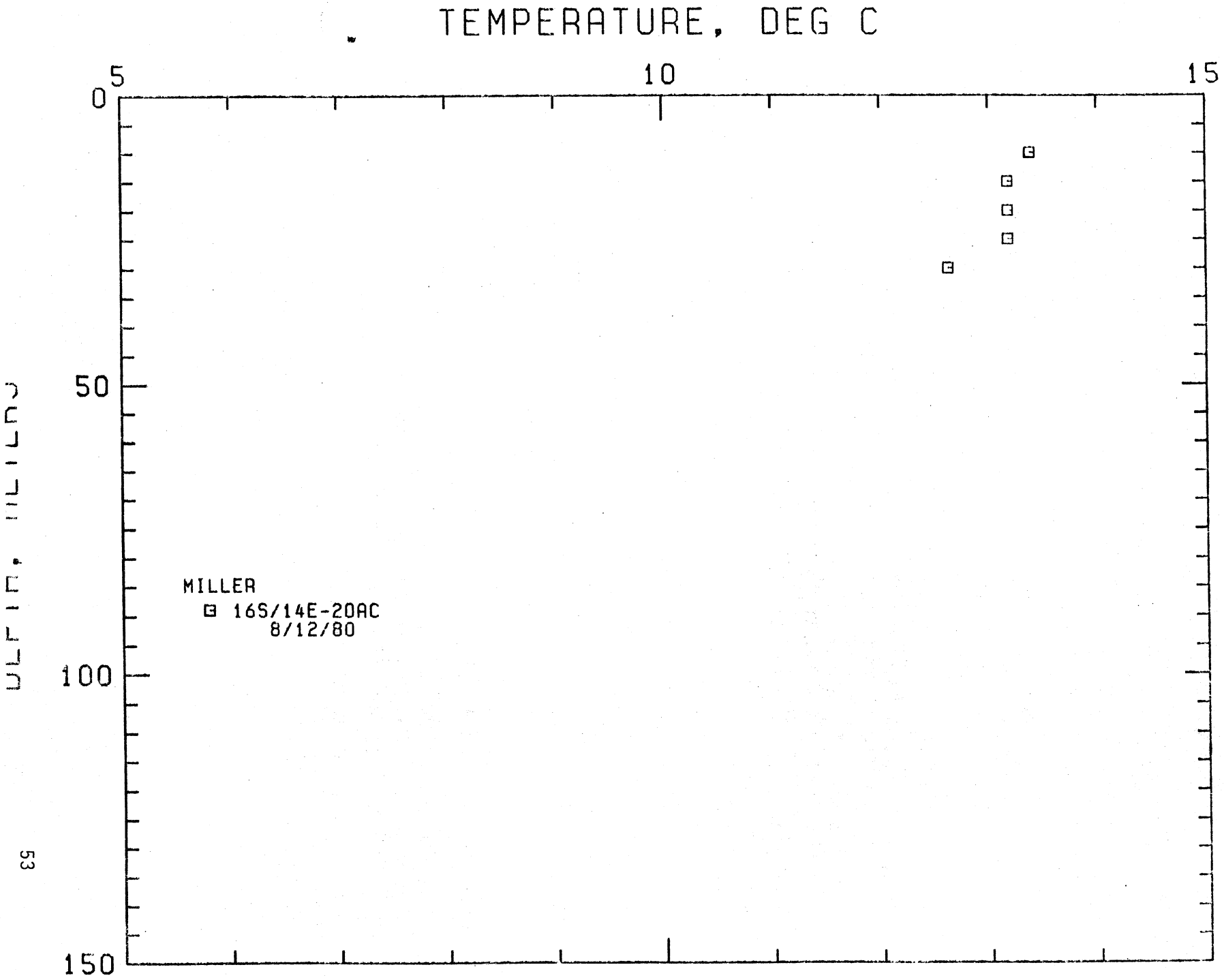
LOCATION: BEND AMS, OREGON
16S/14E-20DA
HOLE NAME: SLUDLR R
DATE MEASURED: 8/12/80

DEPTH METERS	DEPTH FEET	TEMPERATUNE DEG C	TEMPERATUNE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
10.0	32.8	17.260	63.07	0.0	0.0
15.0	49.2	17.240	63.03	-4.0	-0.2
20.0	65.6	16.890	62.40	-70.0	-3.8
25.0	82.0	16.810	62.26	-16.0	-0.9
30.0	98.4	16.600	61.88	-42.0	-2.3
35.0	114.8	16.430	61.57	-34.0	-1.9
40.0	131.2	16.430	61.57	0.0	0.0
45.0	147.6	16.420	61.56	-2.0	-0.1
50.0	164.0	16.020	60.84	-80.0	-4.4
55.0	180.4	15.850	60.17	-74.0	-4.1
60.0	196.8	15.400	59.72	-90.0	-2.7
65.0	213.2	15.100	59.18	-60.0	-3.3
70.0	229.6	14.990	58.98	-22.0	-1.2
75.0	246.0	14.840	58.71	-30.0	-1.6
80.0	262.4	14.630	58.33	-42.0	-2.3
85.0	278.8	14.630	58.33	0.0	0.0
90.0	295.2	14.530	58.15	-20.0	-1.1
95.0	311.6	14.500	58.10	-6.0	-0.3
100.0	328.0	14.450	58.01	-10.0	-0.5
105.0	344.4	14.420	57.96	-6.0	-0.3
110.0	360.8	14.390	57.90	-6.0	-0.3
115.0	377.2	14.400	57.92	2.0	0.1
120.0	393.6	14.440	57.99	8.0	0.4
125.0	410.0	14.460	58.03	4.0	0.2
130.0	426.4	14.660	58.39	40.0	2.2
135.0	442.8	15.430	59.77	154.0	8.5
140.0	459.2	16.320	61.38	178.0	9.8
145.0	475.6	16.520	61.74	40.0	2.2
142.0	466.7	16.910	62.44	97.5	5.4


TEMPERATURE, DEG C
10
15
20
0
50
100
150
DEPTH, METERS
SLVDLR R
16S/14E-20DA
8/12/80

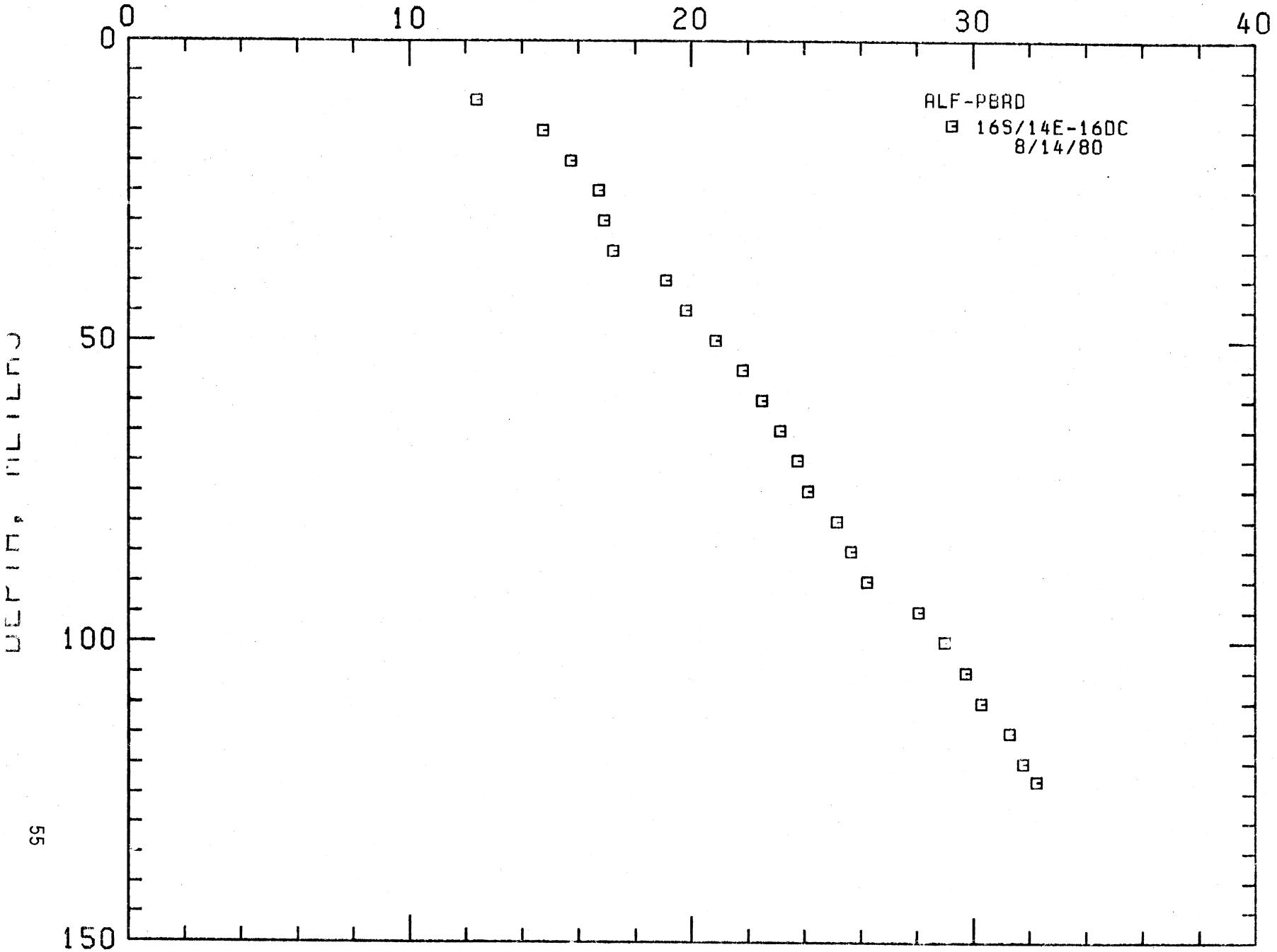
LOCATION: BEND AMS, OREGON
16S/14E-20AC
HOLE NAME: MILLER
DATE MEASURED: 8/12/80

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	13.390	56.10	0.0	0.0
15.0	49.2	13.180	55.72	-42.0	-2.3
20.0	65.6	13.180	55.72	0.0	0.0
25.0	82.0	13.180	55.72	0.0	0.0
30.0	98.4	12.630	54.73	-110.0	-6.0


TEMPERATURE, DEG C
0
5
10
15
50
100
150
DEPTH, FEET
MILLER
16S/14E-20AC
8/12/80

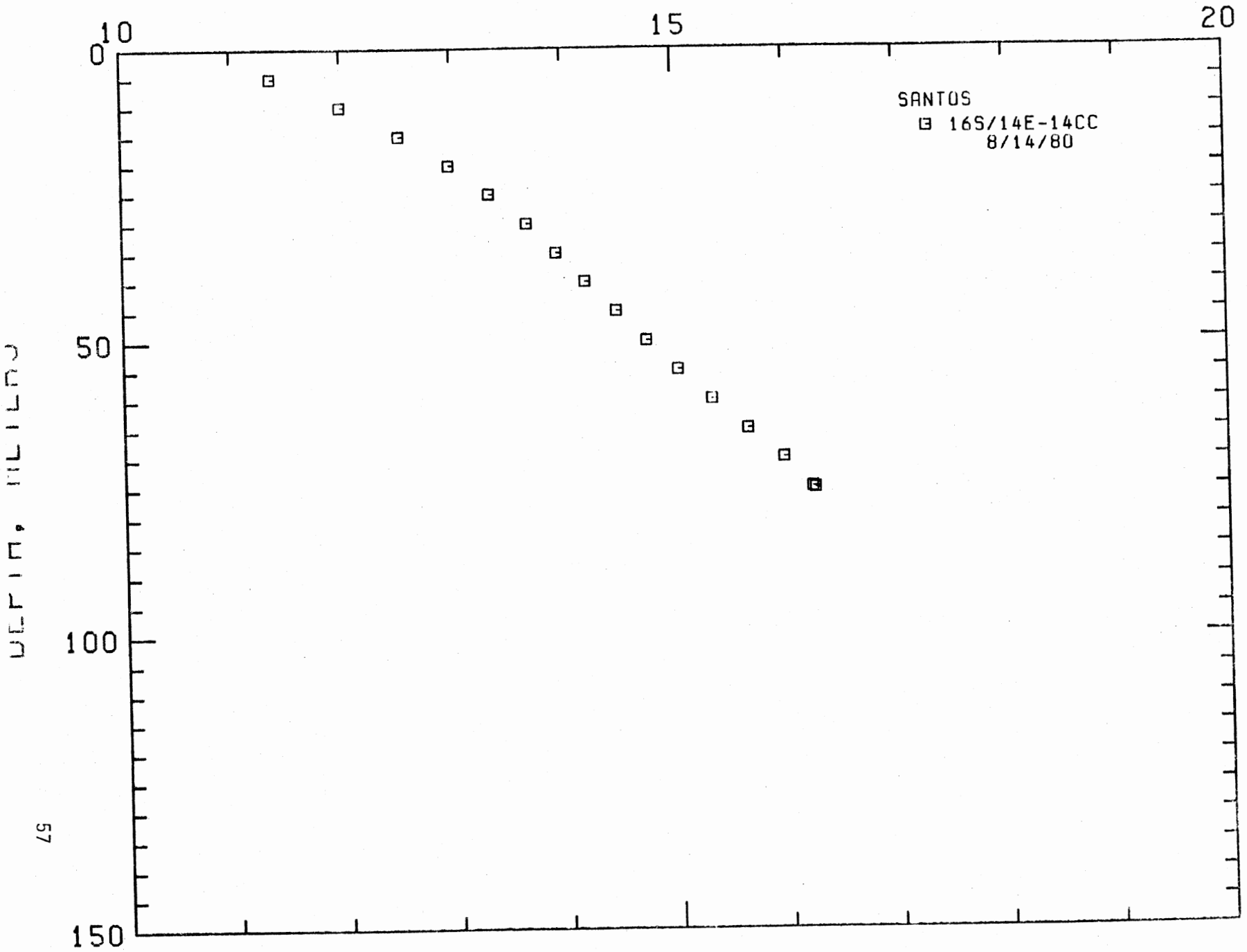
LOCATION: BEND AMS, OREGON
16S/14E-16DC
HOLE NAME: ALF-PBRD
DATE MEASURED: 8/14/80

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	12.400	54.32	0.0	0.0
15.0	49.2	14.770	58.59	474.0	26.0
20.0	65.6	15.750	60.35	196.0	10.8
25.0	82.0	16.720	62.10	194.0	10.6
30.0	98.4	16.920	62.46	40.0	2.2
35.0	114.8	17.230	63.01	62.0	3.4
40.0	131.2	19.100	66.38	374.0	20.5
45.0	147.6	19.820	67.68	144.0	7.9
50.0	164.0	20.870	69.57	210.0	11.5
55.0	180.4	21.830	71.29	192.0	10.5
60.0	196.8	22.510	72.52	136.0	7.5
65.0	213.2	23.150	73.67	128.0	7.0
70.0	229.6	23.760	74.80	122.0	6.9
75.0	246.0	24.140	75.45	72.0	4.0
80.0	262.4	25.170	77.31	206.0	11.3
85.0	278.8	25.660	78.19	98.0	5.4
90.0	295.2	26.240	79.23	116.0	6.4
95.0	311.6	28.060	82.51	364.0	20.0
100.0	328.0	28.990	84.18	186.0	10.2
105.0	344.4	29.740	85.53	150.0	8.2
110.0	360.8	30.290	86.52	110.0	6.0
115.0	377.2	31.300	88.34	202.0	11.1
120.0	393.6	31.770	89.19	94.0	5.2
123.0	403.4	32.250	90.05	160.0	8.8


TEMPERATURE, DEG C
0
10
20
30
40
0
50
100
150
ALF-PBRD
16S/14E-16DC
8/14/80

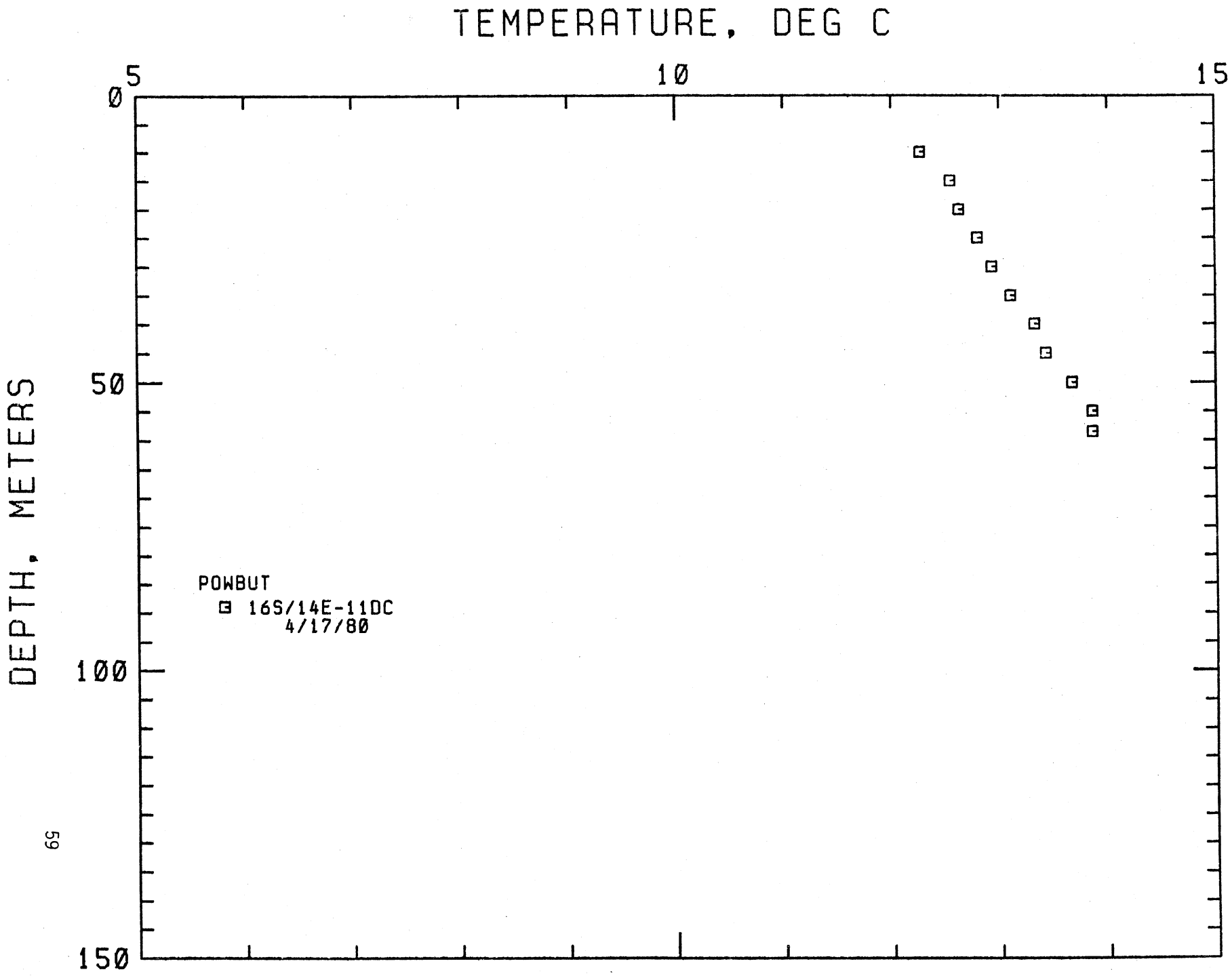
LOCATION: BEND AMS, OREGON
16S/14E-14CC
HOLE NAME: SANTOS
DATE MEASURED: 8/14/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	11.370	52.47	0.0	0.0
10.0	32.8	12.080	53.60	126.0	6.9
15.0	49.2	12.530	54.55	106.0	5.8
20.0	65.6	12.900	55.36	90.0	4.9
25.0	82.0	13.340	56.01	72.0	4.0
30.0	98.4	13.680	56.62	68.0	3.7
35.0	114.8	13.940	57.09	52.0	2.9
40.0	131.2	14.200	57.56	52.0	2.9
45.0	147.6	14.480	58.06	56.0	3.1
50.0	164.0	14.750	58.55	54.0	3.0
55.0	180.4	15.030	59.05	56.0	3.1
60.0	196.8	15.330	59.59	60.0	3.3
65.0	213.2	15.650	60.17	64.0	3.5
70.0	229.6	15.970	60.75	64.0	3.5
75.0	246.0	16.230	61.21	52.0	2.9
75.2	246.7	16.250	61.25	100.0	5.5


TEMPERATURE, DEG C
10
15
20
0
50
100
150
SANTOS
16S/14E-14CC
8/14/80

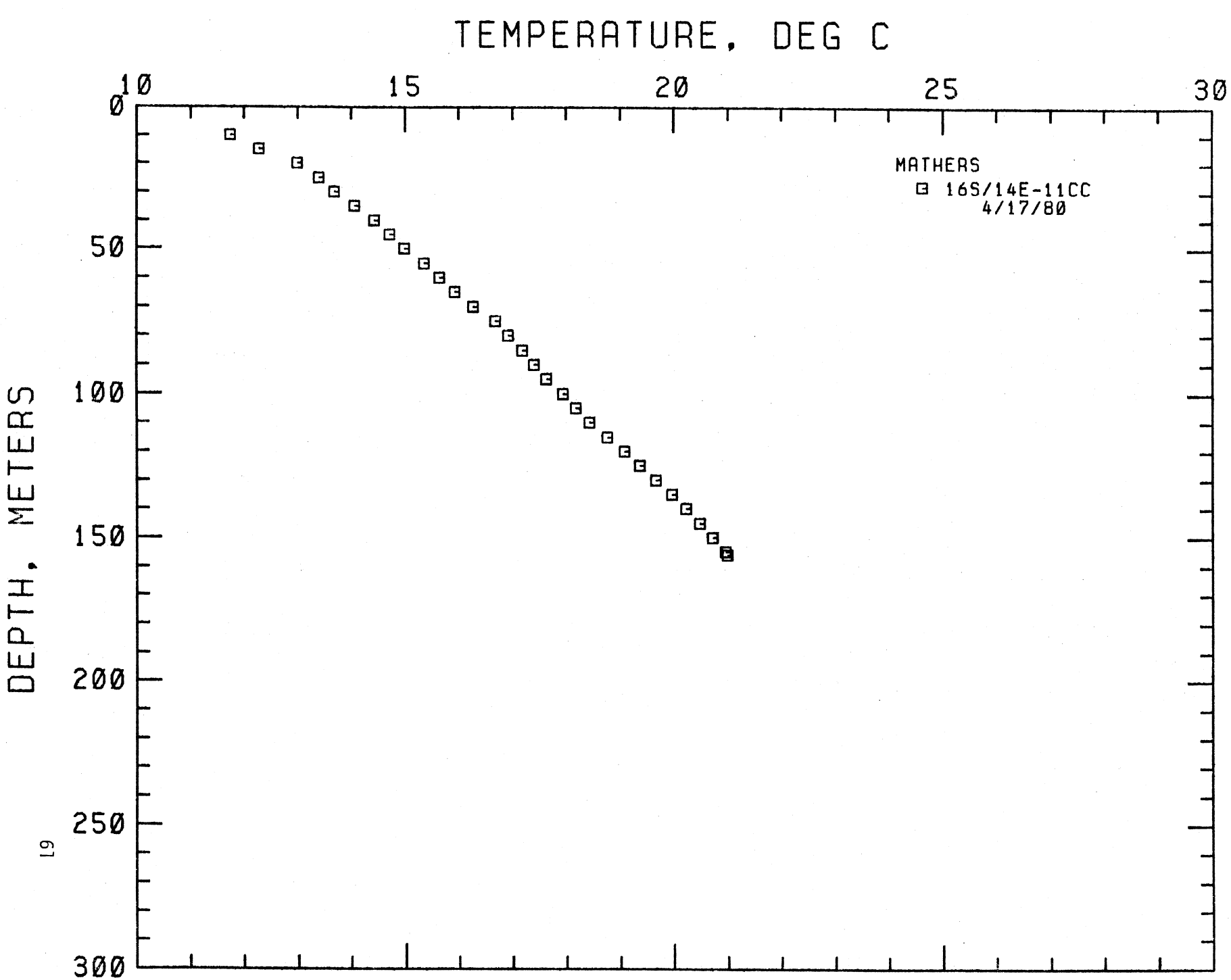
LOCATION: BEND AMS, OREGON
16S/14E-11DC
HOLE NAME: POWBUT
DATE MEASURED: 4/17/80

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	12.270	54.09	0.0	0.0
15.0	49.2	12.550	54.59	56.0	3.1
20.0	65.6	12.630	54.73	16.0	0.9
25.0	82.0	12.800	55.04	34.0	1.9
30.0	98.4	12.930	55.27	26.0	1.4
35.0	114.8	13.100	55.58	34.0	1.9
40.0	131.2	13.320	55.98	44.0	2.4
45.0	147.6	13.420	56.16	20.0	1.1
50.0	164.0	13.660	56.59	48.0	2.6
55.0	180.4	13.850	56.93	38.0	2.1
58.5	191.9	13.850	56.93	0.0	0.0


TEMPERATURE, DEG C
0
5
10
15
DEPTH, METERS
50
100
150
POWBUT
16S/14E-11DC
4/17/80

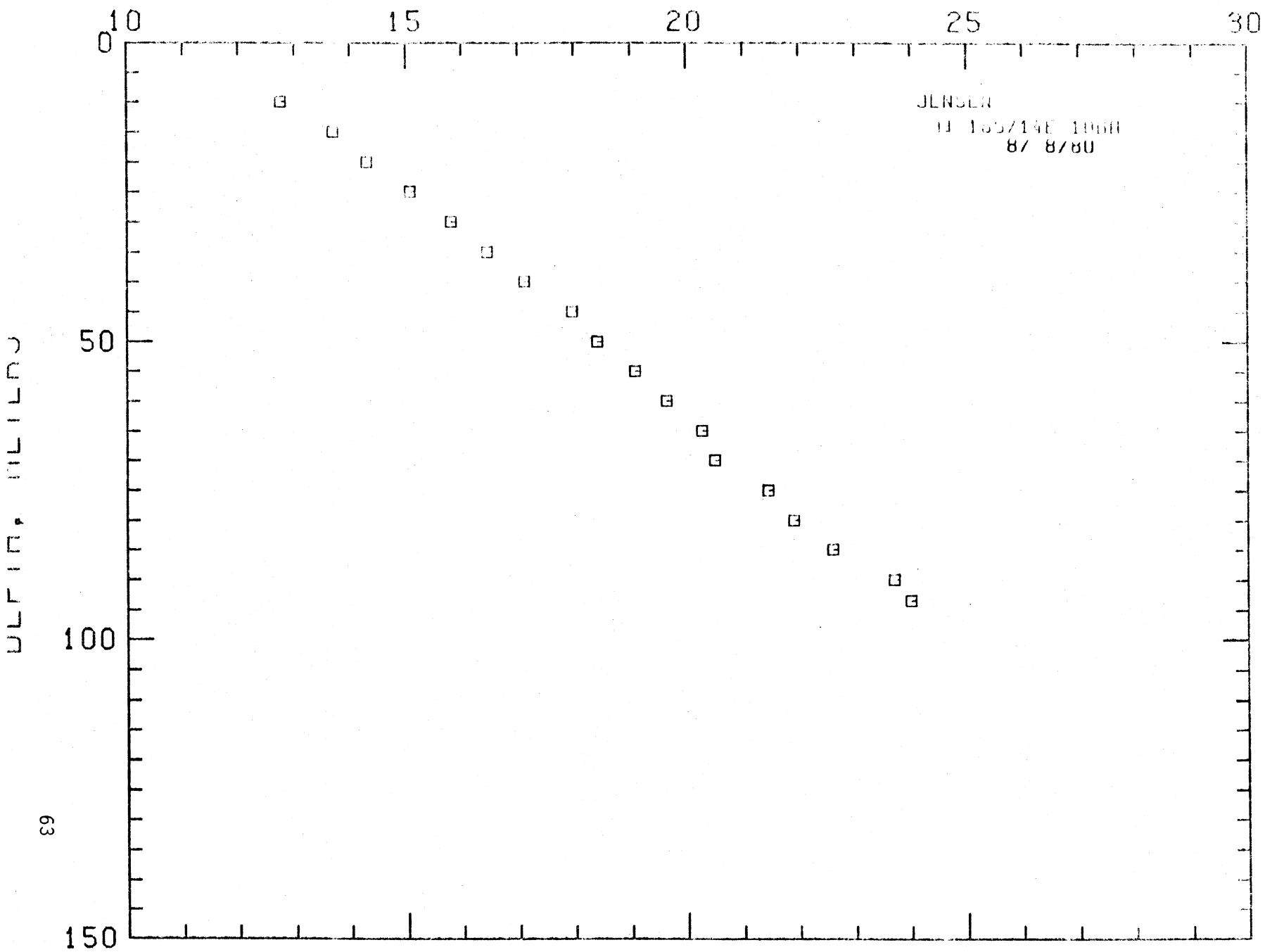
LOCATION: BEND AMS, OREGON
16S/14E-11CC
HOLE NAME: MATHERS
DATE MEASURED: 4/17/80

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	11.750	53.15	0.0	0.0
15.0	49.2	12.290	54.12	108.0	5.9
20.0	65.6	13.000	55.40	142.0	7.8
25.0	82.0	13.410	56.14	82.0	4.5
30.0	98.4	13.690	56.64	56.0	3.1
35.0	114.8	14.070	57.33	76.0	4.2
40.0	131.2	14.430	57.97	72.0	4.0
45.0	147.6	14.720	58.50	58.0	3.2
50.0	164.0	14.990	58.98	54.0	3.0
55.0	180.4	15.360	59.65	74.0	4.1
60.0	196.8	15.650	60.17	58.0	3.2
65.0	213.2	15.930	60.67	56.0	3.1
70.0	229.6	16.270	61.29	68.0	3.7
75.0	246.0	16.690	62.04	84.0	4.6
80.0	262.4	16.920	62.46	46.0	2.5
85.0	278.8	17.190	62.94	54.0	3.0
90.0	295.2	17.410	63.34	44.0	2.4
95.0	311.6	17.630	63.73	44.0	2.4
100.0	328.0	17.940	64.29	62.0	3.4
105.0	344.4	18.180	64.72	48.0	2.6
110.0	360.8	18.430	65.17	50.0	2.7
115.0	377.2	18.770	65.79	68.0	3.7
120.0	393.6	19.090	66.36	64.0	3.5
125.0	410.0	19.370	66.87	56.0	3.1
130.0	426.4	19.670	67.41	60.0	3.3
135.0	442.8	19.970	67.95	60.0	3.3
140.0	459.2	20.230	68.41	52.0	2.9
145.0	475.6	20.480	68.86	50.0	2.7
150.0	492.0	20.720	69.30	48.0	2.6
155.0	508.4	20.960	69.73	48.0	2.6
156.0	511.7	20.990	69.78	30.0	1.6


TEMPERATURE, DEG C
10
15
20
25
30
0
50
100
150
200
250
300
DEPTH, METERS
MATHERS
16S/14E-11CC
4/17/80

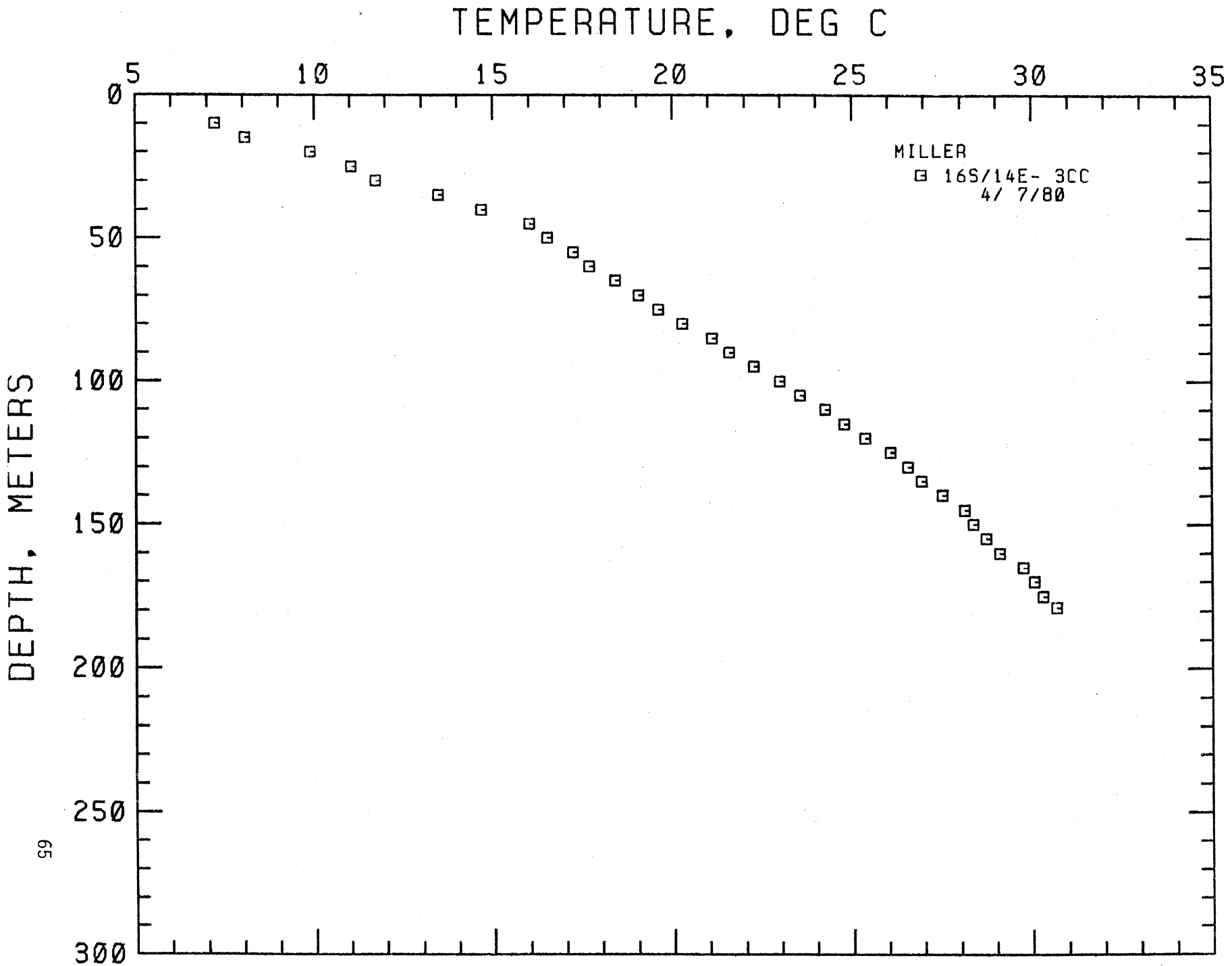
LOCATION: BEND AIS, OREGON
16S/14E-10DA
HOLE NAME: JENSEN
DATE MEASURED: 8/ 8/80

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	12.770	54.99	0.0	0.0
15.0	49.2	13.700	56.66	186.0	10.2
20.0	65.6	14.310	57.76	122.0	6.7
25.0	82.0	15.000	59.16	138.0	7.6
30.0	98.4	15.820	60.48	164.0	9.0
35.0	114.8	16.460	61.62	128.0	7.0
40.0	131.2	17.130	62.82	134.0	7.3
45.0	147.6	17.560	64.38	86.0	4.7
50.0	164.0	18.410	65.14	170.0	9.3
55.0	180.4	19.030	66.34	124.0	6.8
60.0	196.8	19.690	67.37	132.0	7.2
65.0	213.2	20.270	68.49	116.0	6.3
70.0	229.6	20.560	68.90	58.0	3.2
75.0	246.0	21.450	70.61	178.0	10.4
80.0	262.4	21.910	71.44	92.0	5.0
85.0	278.8	22.600	72.68	138.0	7.6
90.0	295.2	23.700	74.66	220.0	12.1
93.5	306.7	24.000	75.20	85.7	4.7


TEMPERATURE, DEG C
10
15
20
25
30
0
50
100
150
JENSEN
87 8/80

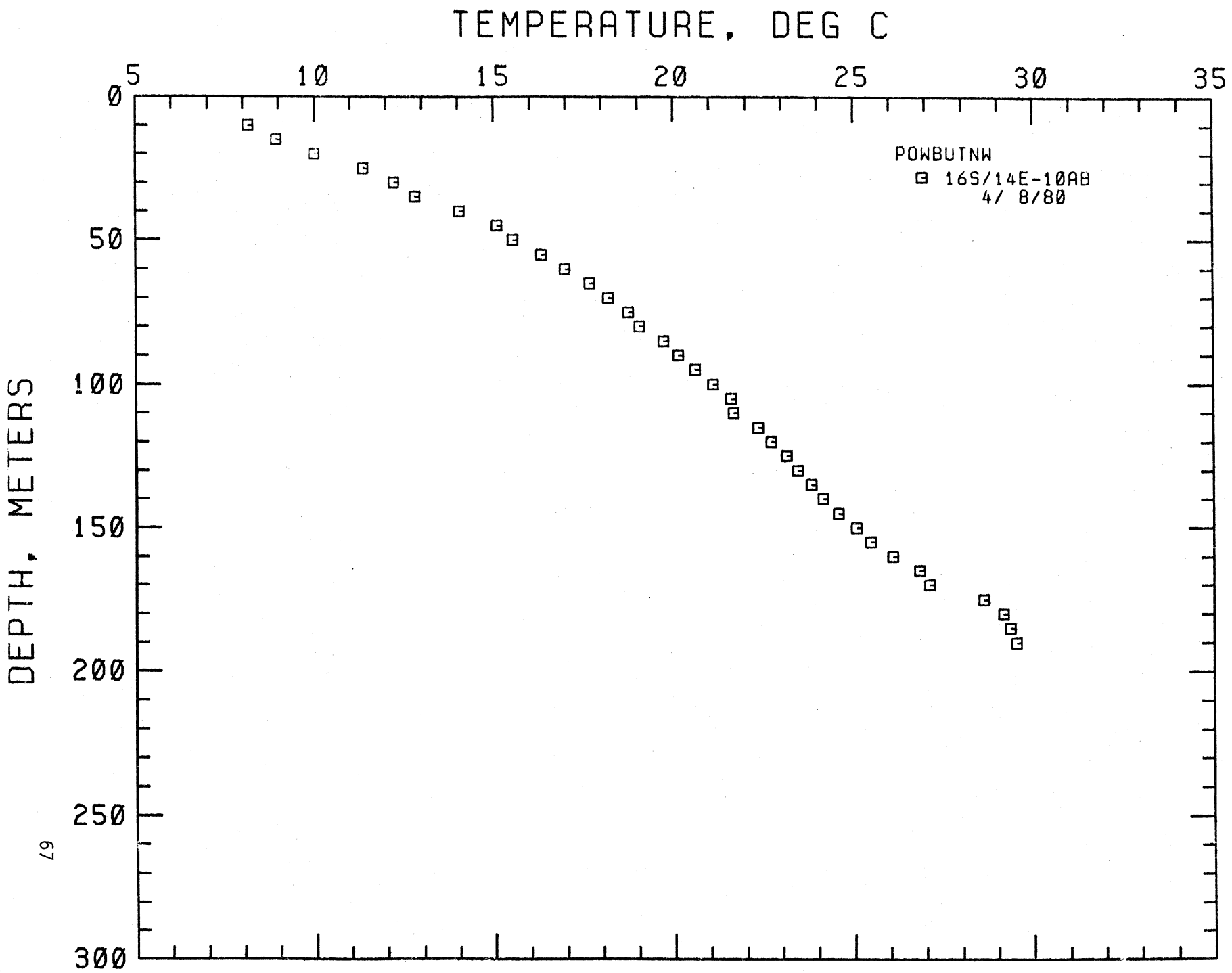
LOCATION: BEND AMS, OREGON
16S/14E- 3CC
HOLE NAME: MILLER
DATE MEASURED: 4/ 7/80

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	7.230	45.01	0.0	0.0
15.0	49.2	8.070	46.53	168.0	9.2
20.0	65.6	9.910	49.84	368.0	20.2
25.0	82.0	11.050	51.89	228.0	12.5
30.0	98.4	11.740	53.13	138.0	7.6
35.0	114.8	13.490	56.28	350.0	19.2
40.0	131.2	14.690	58.44	240.0	13.2
45.0	147.6	16.020	60.84	266.0	14.6
50.0	164.0	16.520	61.74	100.0	5.5
55.0	180.4	17.240	63.03	144.0	7.9
60.0	196.8	17.680	63.82	88.0	4.8
65.0	213.2	18.410	65.14	146.0	8.0
70.0	229.6	19.050	66.29	128.0	7.0
75.0	246.0	19.610	67.30	112.0	6.1
80.0	262.4	20.280	68.50	134.0	7.4
85.0	278.8	21.090	69.96	162.0	8.9
90.0	295.2	21.580	70.84	98.0	5.4
95.0	311.6	22.270	72.09	138.0	7.6
100.0	328.0	22.990	73.38	144.0	7.9
105.0	344.4	23.550	74.39	112.0	6.1
110.0	360.8	24.260	75.67	142.0	7.8
115.0	377.2	24.780	76.60	104.0	5.7
120.0	393.6	25.360	77.65	116.0	6.4
125.0	410.0	26.060	78.91	140.0	7.7
130.0	426.4	26.550	79.79	98.0	5.4
135.0	442.8	26.930	80.47	76.0	4.2
140.0	459.2	27.500	81.50	114.0	6.3
145.0	475.6	28.120	82.62	124.0	6.8
150.0	492.0	28.370	83.07	50.0	2.7
155.0	508.4	28.720	83.70	70.0	3.8
160.0	524.8	29.110	84.40	78.0	4.3
165.0	541.2	29.760	85.57	130.0	7.1
170.0	557.6	30.070	86.13	62.0	3.4
175.0	574.0	30.310	86.56	48.0	2.6
179.0	587.1	30.680	87.22	92.5	5.1


TEMPERATURE, DEG C
5
10
15
20
25
30
35
0
50
100
150
200
250
300
DEPTH, METERS
MILLER
16S/14E- 3CC
4/ 7/80

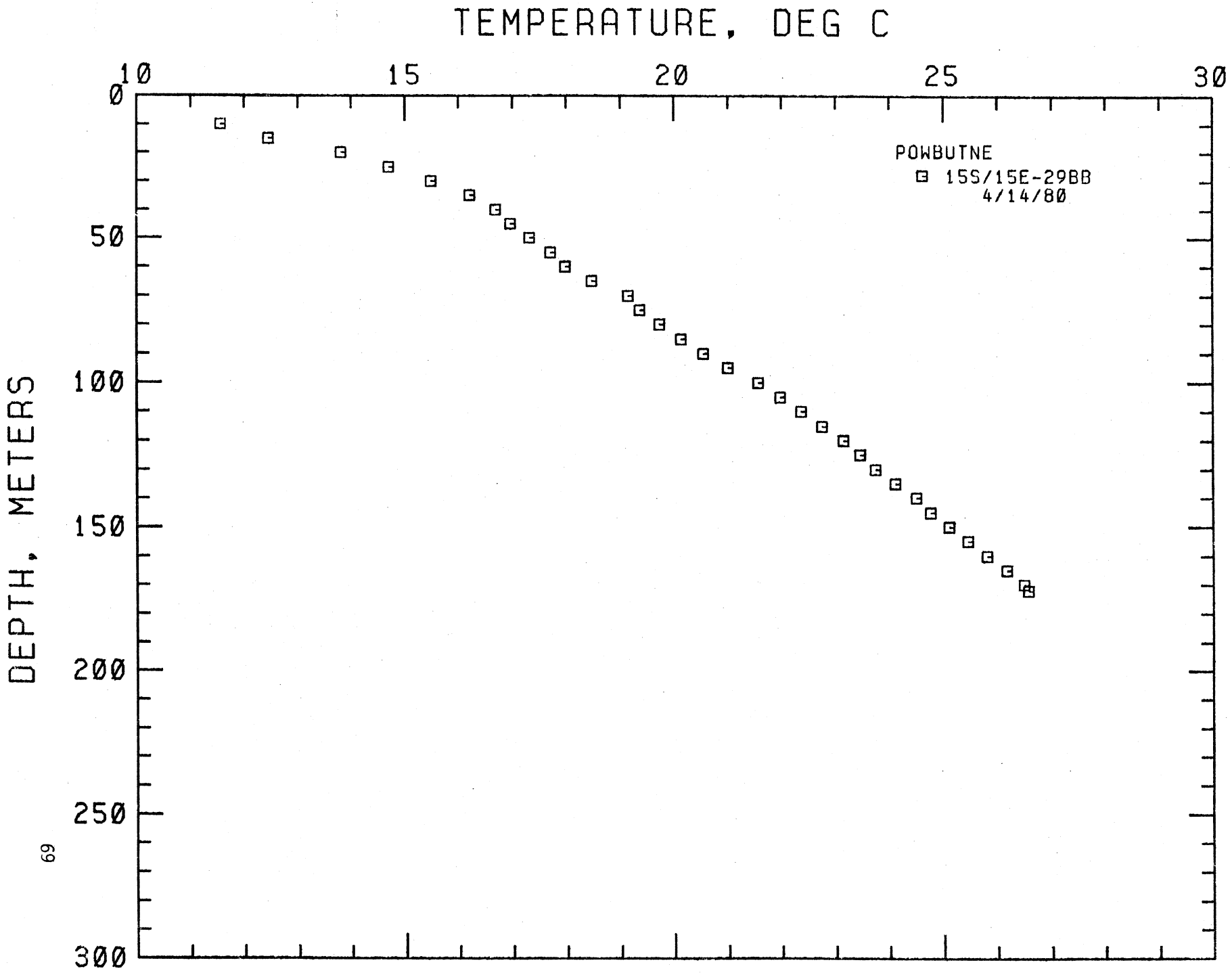
LOCATION: BEND AMS, OREGON
16S/14E-10AB
HOLE NAME: POWBUTNW
DATE MEASURED: 4/ 8/80

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	8.150	46.67	0.0	0.0
15.0	49.2	8.940	48.09	158.0	8.7
20.0	65.6	10.010	50.02	214.0	11.7
25.0	82.0	11.370	52.47	272.0	14.9
30.0	98.4	12.240	54.03	174.0	9.5
35.0	114.8	12.810	55.06	114.0	6.3
40.0	131.2	14.050	57.29	248.0	13.6
45.0	147.6	15.100	59.18	210.0	11.5
50.0	164.0	15.550	59.99	90.0	4.9
55.0	180.4	16.330	61.39	156.0	8.6
60.0	196.8	16.990	62.58	132.0	7.2
65.0	213.2	17.660	63.79	134.0	7.4
70.0	229.6	18.190	64.74	106.0	5.8
75.0	246.0	18.740	65.73	110.0	6.0
80.0	262.4	19.060	66.31	64.0	3.5
85.0	278.8	19.720	67.50	132.0	7.2
90.0	295.2	20.130	68.23	82.0	4.5
95.0	311.6	20.600	69.08	94.0	5.2
100.0	328.0	21.100	69.98	100.0	5.5
105.0	344.4	21.600	70.88	100.0	5.5
110.0	360.8	21.670	71.01	14.0	0.8
115.0	377.2	22.340	72.21	134.0	7.4
120.0	393.6	22.700	72.86	72.0	4.0
125.0	410.0	23.140	73.65	88.0	4.8
130.0	426.4	23.440	74.19	60.0	3.3
135.0	442.8	23.820	74.88	76.0	4.2
140.0	459.2	24.150	75.47	66.0	3.6
145.0	475.6	24.570	76.23	84.0	4.6
150.0	492.0	25.080	77.14	102.0	5.6
155.0	508.4	25.470	77.85	78.0	4.3
160.0	524.8	26.090	78.96	124.0	6.8
165.0	541.2	26.820	80.28	146.0	8.0
170.0	557.6	27.100	80.78	56.0	3.1
175.0	574.0	28.600	83.48	300.0	16.5
180.0	590.4	29.150	84.47	110.0	6.0
185.0	606.8	29.350	84.83	40.0	2.2
190.0	623.2	29.510	85.12	32.0	1.8


TEMPERATURE, DEG C
0
5
10
15
20
25
30
35
DEPTH, METERS
50
100
150
200
250
300
POWBUTNW
16S/14E-10AB
4/ 8/80

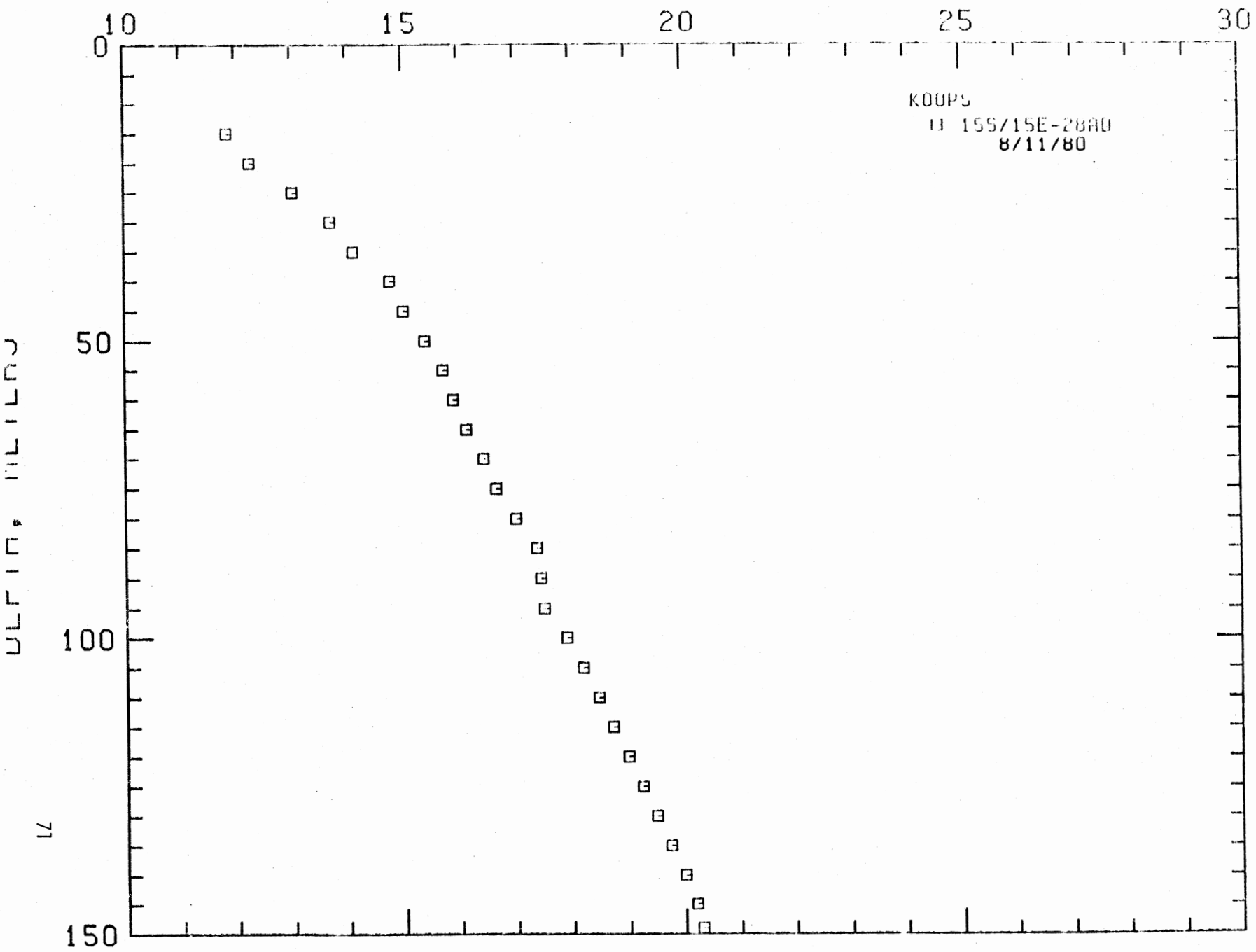
LOCATION: BEND AMS, OREGON
15S/15E-29BB
HOLE NAME: POWBUTNE
DATE MEASURED: 4/14/80

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	11.570	52.83	0.0	0.0
15.0	49.2	12.460	54.43	178.0	9.8
20.0	65.6	13.820	56.88	272.0	14.9
25.0	82.0	14.710	58.48	178.0	9.8
30.0	98.4	15.500	59.90	156.0	8.7
35.0	114.8	16.220	61.20	144.0	7.9
40.0	131.2	16.700	62.06	96.0	5.3
45.0	147.6	16.970	62.55	54.0	3.0
50.0	164.0	17.320	63.18	70.0	3.8
55.0	180.4	17.710	63.88	78.0	4.3
60.0	196.8	17.990	64.38	56.0	3.1
65.0	213.2	18.480	65.26	98.0	5.4
70.0	229.6	19.150	66.47	134.0	7.4
75.0	246.0	19.370	66.87	44.0	2.4
80.0	262.4	19.740	67.53	74.0	4.1
85.0	278.8	20.140	68.25	80.0	4.4
90.0	295.2	20.550	68.99	82.0	4.5
95.0	311.6	21.010	69.82	92.0	5.0
100.0	328.0	21.570	70.83	112.0	6.1
105.0	344.4	21.980	71.56	82.0	4.5
110.0	360.8	22.370	72.27	78.0	4.3
115.0	377.2	22.750	72.95	76.0	4.2
120.0	393.6	23.150	73.67	80.0	4.4
125.0	410.0	23.460	74.23	62.0	3.4
130.0	426.4	23.750	74.75	58.0	3.2
135.0	442.8	24.120	75.42	74.0	4.1
140.0	459.2	24.500	76.10	76.0	4.2
145.0	475.6	24.770	76.59	54.0	3.0
150.0	492.0	25.110	77.20	68.0	3.7
155.0	508.4	25.450	77.81	68.0	3.7
160.0	524.8	25.800	78.44	70.0	3.8
165.0	541.2	26.170	79.11	74.0	4.1
170.0	557.6	26.490	79.68	64.0	3.5
172.0	564.2	26.570	79.83	40.0	2.2


TEMPERATURE, DEG C
10
15
20
25
30
0
50
100
150
200
250
300
DEPTH, METERS
POWBUTNE
15S/15E-29BB
4/14/80

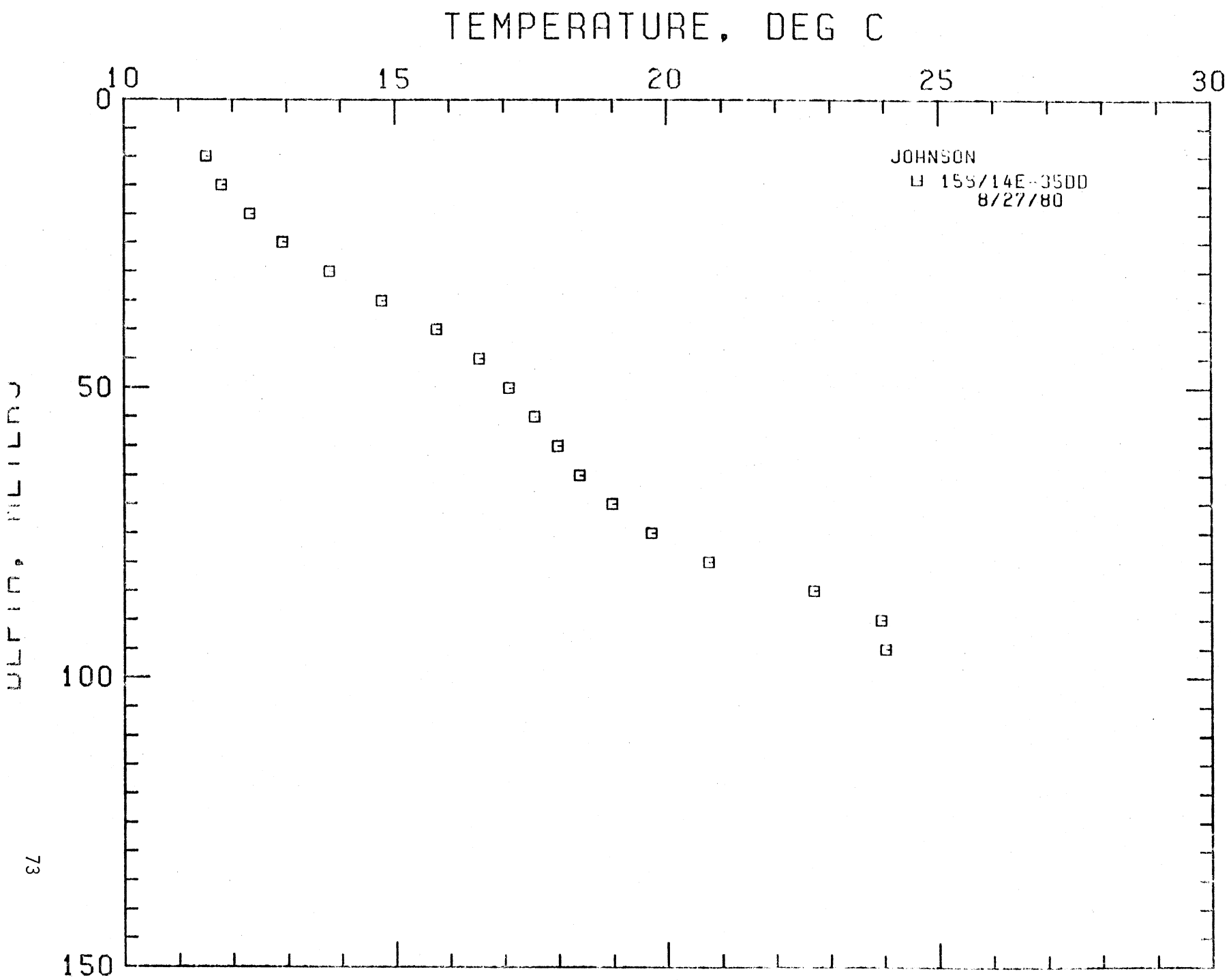
LOCATION: BEND AIR, OREGON
15S/15E-28AD
HOLE NAME: KOOPS
DATE MEASURED: 6/11/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
15.0	49.2	11.060	51.91	0.0	0.0
20.0	65.6	12.270	54.09	82.0	4.5
25.0	82.0	13.040	55.47	154.0	8.5
30.0	98.4	13.710	56.68	134.0	7.4
35.0	114.8	14.120	57.42	82.0	4.5
40.0	131.2	14.790	58.62	134.0	7.4
45.0	147.6	15.030	59.05	48.0	2.6
50.0	164.0	15.410	59.74	76.0	4.2
55.0	180.4	15.720	60.30	62.0	3.4
60.0	196.8	15.910	60.64	38.0	2.1
65.0	213.2	16.140	61.05	46.0	2.5
70.0	229.6	16.440	61.59	60.0	3.3
75.0	246.0	16.680	61.99	44.0	2.4
80.0	262.4	17.000	62.64	72.0	4.0
85.0	278.8	17.360	63.25	72.0	4.0
90.0	295.2	17.450	63.41	14.0	0.8
95.0	311.6	17.510	63.52	12.0	0.7
100.0	328.0	17.910	64.24	80.0	4.4
105.0	344.4	18.150	64.74	56.0	3.1
110.0	360.8	18.470	65.25	56.0	3.1
115.0	377.2	18.730	65.70	48.0	2.7
120.0	393.6	18.990	66.18	54.0	3.0
125.0	410.0	19.250	66.65	52.0	2.9
130.0	426.4	19.500	67.10	50.0	2.7
135.0	442.8	19.750	67.55	50.0	2.7
140.0	459.2	20.000	68.00	50.0	2.7
145.0	475.6	20.210	68.38	42.0	2.3
149.0	488.7	20.310	68.56	25.0	1.4


TEMPERATURE, DEG C
0
10
15
20
25
30
50
100
150
KOOPS
B 15S/15E-20AD
8/11/80

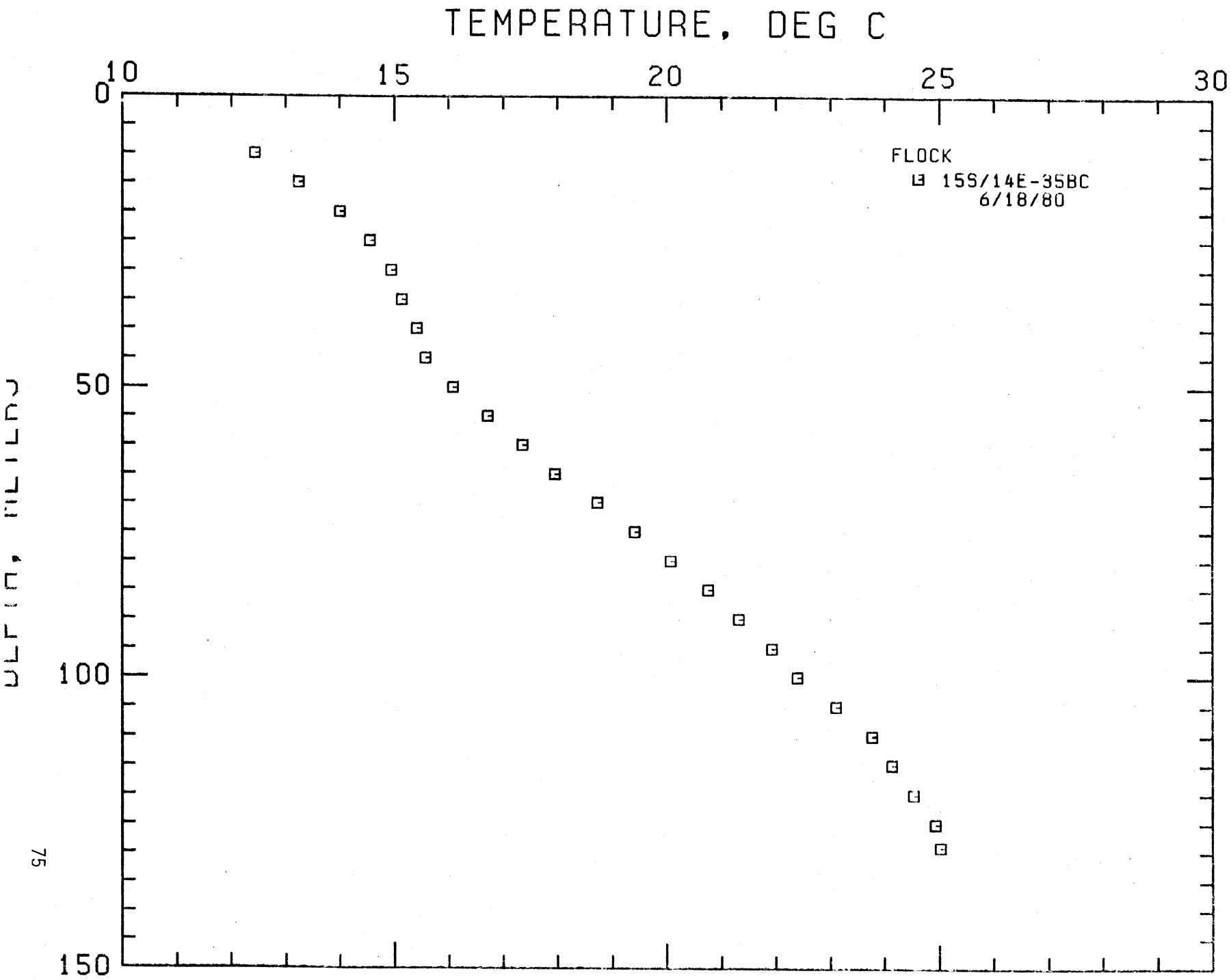
LOCATION: BEND AREA, OREGON
15S/14E [illegible]
HOLE NAME: JOHNSON
DATE MEASURED: [illegible]

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
10.0	[illegible]	11.5[illegible]0	[illegible]2.74	0.0	0.0
15.0	[illegible]	11.810	53.[illegible]	[illegible]	[illegible]
20.0	65.6	1[illegible].3[illegible]	[illegible]4.19	10[illegible].0	[illegible]
25.0	82.0	1[illegible].940	[illegible].29	1[illegible]	[illegible]
30.0	98.4	13.810	[illegible].86	1[illegible]	[illegible]
35.0	114.8	14.770	[illegible].59	[illegible]	10.[illegible]
40.0	131.2	15.770	[illegible]	[illegible]	11.[illegible]
45.0	147.6	1[illegible].5[illegible]	61.[illegible]	[illegible]	[illegible]
50.0	164.0	17.110	6[illegible]	1[illegible].0	[illegible]
55.0	180.4	17.[illegible]	63.[illegible]	[illegible]	[illegible]
60.0	196.8	18.0[illegible]	64.40	[illegible]	[illegible]
65.0	213.2	18.4[illegible]	65.1[illegible]	[illegible]	4.4
70.0	229.6	18.900	6[illegible].18	1[illegible]	[illegible]
75.0	246.0	19.710	67.48	1[illegible]	[illegible]
80.0	262.4	[illegible].7[illegible]	[illegible]	[illegible]	11.[illegible]
85.0	278.8	[illegible].700	72.8[illegible]	[illegible]	[illegible]
90.0	295.2	[illegible].940	7[illegible]	2[illegible].0	1[illegible]
95.0	311.6	24.020	7[illegible].24	1[illegible].0	[illegible].9


TEMPERATURE, DEG C
10
15
20
25
30
0
50
100
150
JOHNSON
155/14E-35DD
8/27/80

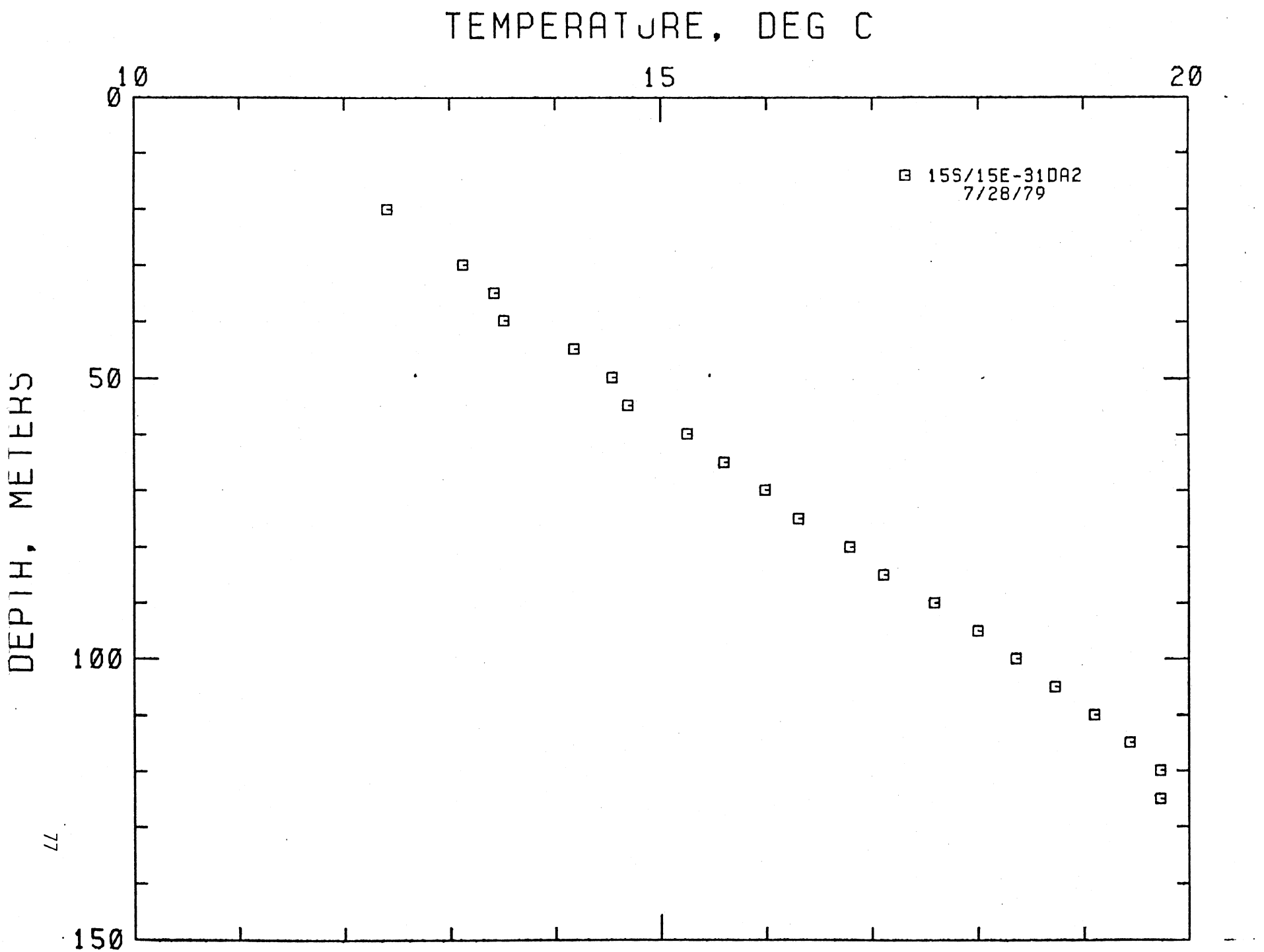
LOCATION: BEND AMS, OREGON
15S/14E-35BC
HOLE NAME: FLOCK
DATE MEASURED: 6/10/80

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	12.450	54.41	0.0	0.0
15.0	49.2	13.260	55.87	162.0	8.9
20.0	65.6	14.010	57.22	150.0	8.2
25.0	82.0	14.560	58.21	110.0	6.0
30.0	98.4	14.960	58.91	78.0	4.3
35.0	114.8	15.140	59.25	38.0	2.1
40.0	131.2	15.420	59.76	56.0	3.1
45.0	147.6	15.530	60.04	22.0	1.8
50.0	164.0	16.030	60.94	100.0	5.5
55.0	180.4	16.720	62.10	138.0	7.0
60.0	196.8	17.360	63.25	128.0	7.0
65.0	213.2	17.950	64.31	118.0	6.5
70.0	229.6	18.730	65.71	156.0	8.6
75.0	246.0	19.420	66.96	138.0	7.6
80.0	262.4	20.060	68.14	132.0	7.2
85.0	278.8	20.770	69.39	138.0	7.6
90.0	295.2	21.320	70.38	110.0	6.0
95.0	311.6	21.930	71.47	122.0	6.7
100.0	328.0	22.480	72.32	94.0	5.2
105.0	344.4	23.110	73.60	142.0	7.8
110.0	360.8	23.770	74.79	132.0	7.2
115.0	377.2	24.140	75.45	74.0	4.1
120.0	393.7	24.940	76.17	80.0	4.4
125.0	410.0	24.940	76.89	80.0	4.4
129.0	423.1	25.030	77.05	22.5	1.2


TEMPERATURE, DEG C
10
15
20
25
30
0
50
100
150
FLOCK
15S/14E-35BC
6/18/80

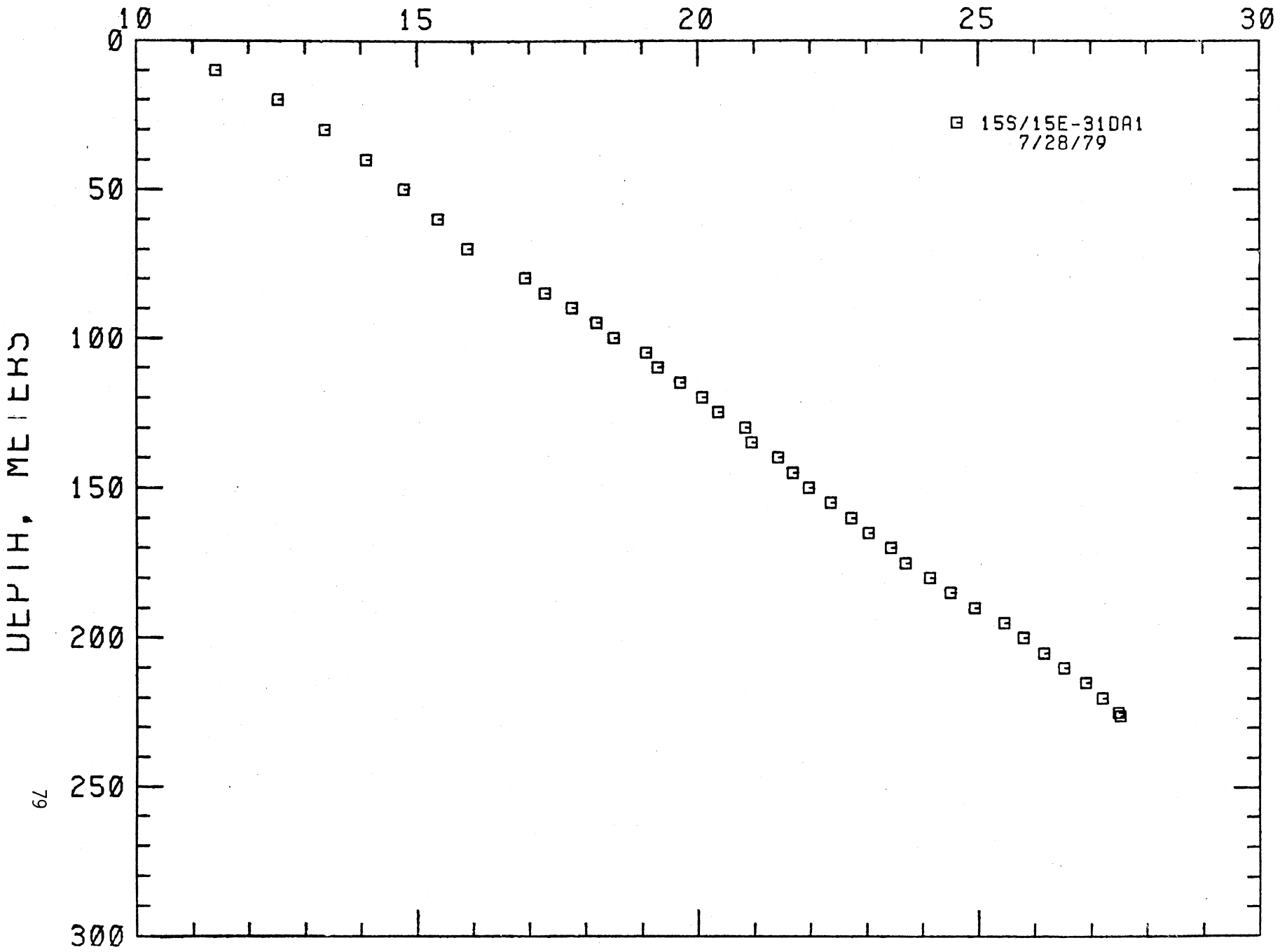
LOCATION: BEND AMS, OREGON
15S/15E-31DA2
HOLE NAME: KRANTH 2
DATE MEASURED: 7/28/79

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	12.410	54.34	0.0	0.0
30.0	98.4	13.130	55.63	72.0	4.0
35.0	114.8	13.430	56.17	60.0	3.3
40.0	131.2	13.520	56.34	18.0	1.0
45.0	147.6	14.180	57.52	132.0	7.2
50.0	164.0	14.540	58.17	72.0	4.0
55.0	180.4	14.690	58.44	30.0	1.6
60.0	196.8	15.250	59.45	112.0	6.1
65.0	213.2	15.600	60.08	70.0	3.8
70.0	229.6	15.990	60.78	78.0	4.3
75.0	246.0	16.300	61.34	62.0	3.4
80.0	262.4	16.790	62.22	98.0	5.4
85.0	278.8	17.110	62.80.	64.0	3.5
90.0	295.2	17.590	63.66	96.0	5.3
95.0	311.6	18.000	64.40	82.0	4.5
100.0	328.0	18.360	65.05	72.0	4.0
105.0	344.4	18.730	65.71	74.0	4.1
110.0	360.8	19.100	66.38	74.0	4.1
115.0	377.2	19.440	66.99	68.0	3.7
120.0	393.6	19.730	67.51	58.0	3.2
125.0	410.0	19.730	67.51	0.0	0.0


TEMPERATURE, DEG C
10
15
20
0
50
100
150
DEPTH, METERS
15S/15E-31DA2
7/28/79

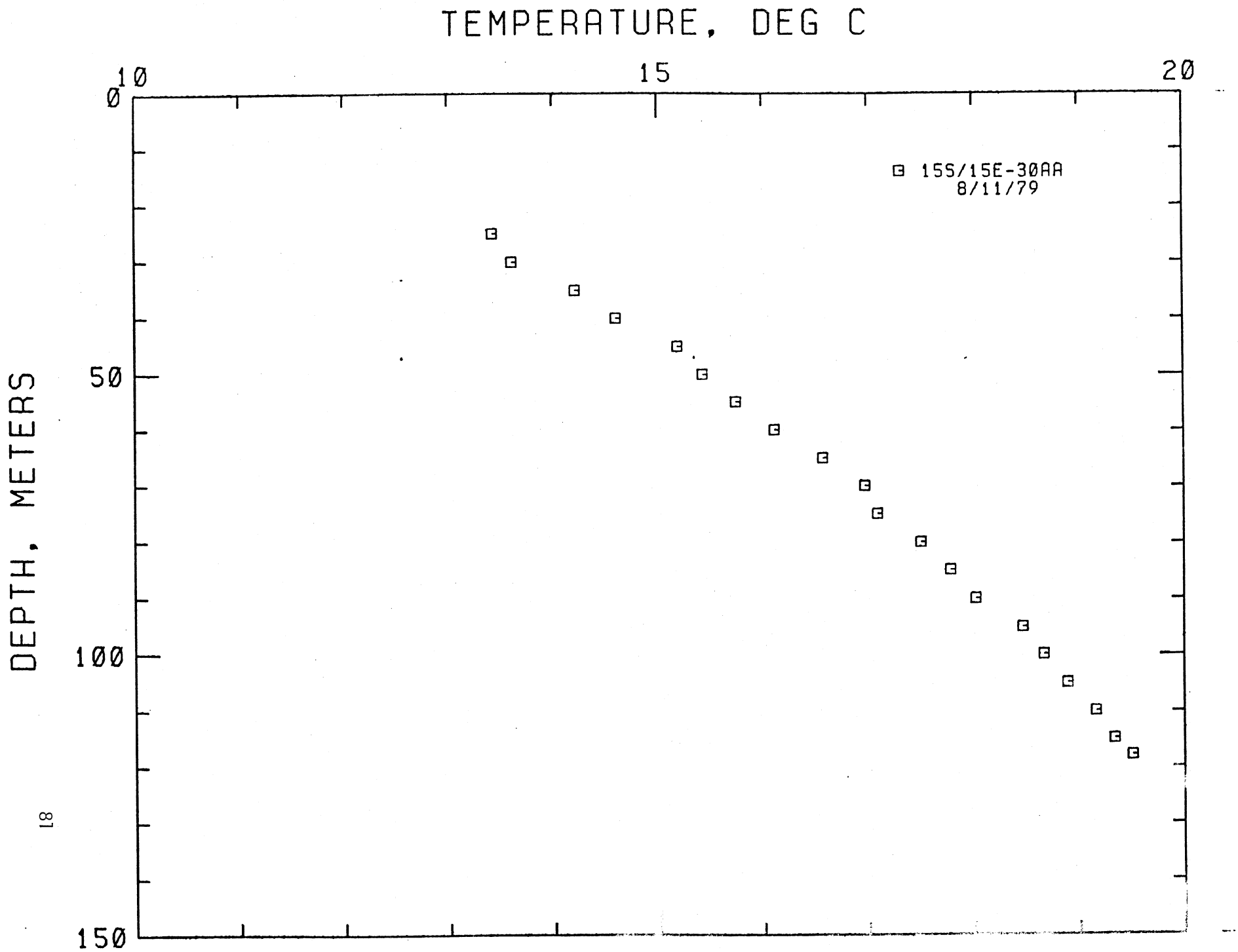
LOCATION: BEND AMS, OREGON
15S/15E-31DA1
HOLE NAME: KRANTH 1
DATE MEASURED: 7/28/79

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	11.420	52.56	0.0	0.0
20.0	65.6	12.530	54.55	111.0	6.1
30.0	98.4	13.360	56.05	83.0	4.6
40.0	131.2	14.100	57.38	74.0	4.1
50.0	164.0	14.780	58.60	68.0	3.7
60.0	196.8	15.380	59.68	60.0	3.3
70.0	229.6	15.910	60.64	53.0	2.9
80.0	262.4	16.940	62.49	103.0	5.7
85.0	278.8	17.290	63.12	70.0	3.8
90.0	295.2	17.770	63.99	96.0	5.3
95.0	311.6	18.200	64.76	86.0	4.7
100.0	328.0	18.510	65.32	62.0	3.4
105.0	344.4	19.090	66.36	116.0	6.4
110.0	360.8	19.290	66.72	40.0	2.2
115.0	377.2	19.690	67.44	80.0	4.4
120.0	393.6	20.080	68.14	78.0	4.3
125.0	410.0	20.360	68.65	56.0	3.1
130.0	426.4	20.850	69.53	98.0	5.4
135.0	442.8	20.960	69.73	22.0	1.2
140.0	459.2	21.430	70.57	94.0	5.2
145.0	475.6	21.690	71.04	52.0	2.9
150.0	492.0	21.980	71.56	58.0	3.2
155.0	508.4	22.360	72.25	76.0	4.2
160.0	524.8	22.730	72.91	74.0	4.1
165.0	541.2	23.040	73.47	62.0	3.4
170.0	557.6	23.440	74.19	80.0	4.4
175.0	574.0	23.700	74.66	52.0	2.9
180.0	590.4	24.140	75.45	88.0	4.8
185.0	606.8	24.500	76.10	72.0	4.0
190.0	623.2	24.940	76.89	88.0	4.8
195.0	639.6	25.460	77.83	104.0	5.7
200.0	656.0	25.800	78.44	68.0	3.7
205.0	672.4	26.170	79.11	74.0	4.1
210.0	688.8	26.530	79.75	72.0	4.0
215.0	705.2	26.910	80.44	76.0	4.2
220.0	721.6	27.210	80.98	60.0	3.3
225.0	738.0	27.500	81.50	58.0	3.2
226.0	741.3	27.530	81.55	30.0	1.6


TEMPERATURE, DEG C
10
15
20
25
30
0
50
100
150
200
250
300
DEPTH, METERS
15S/15E-31DA1
7/28/79

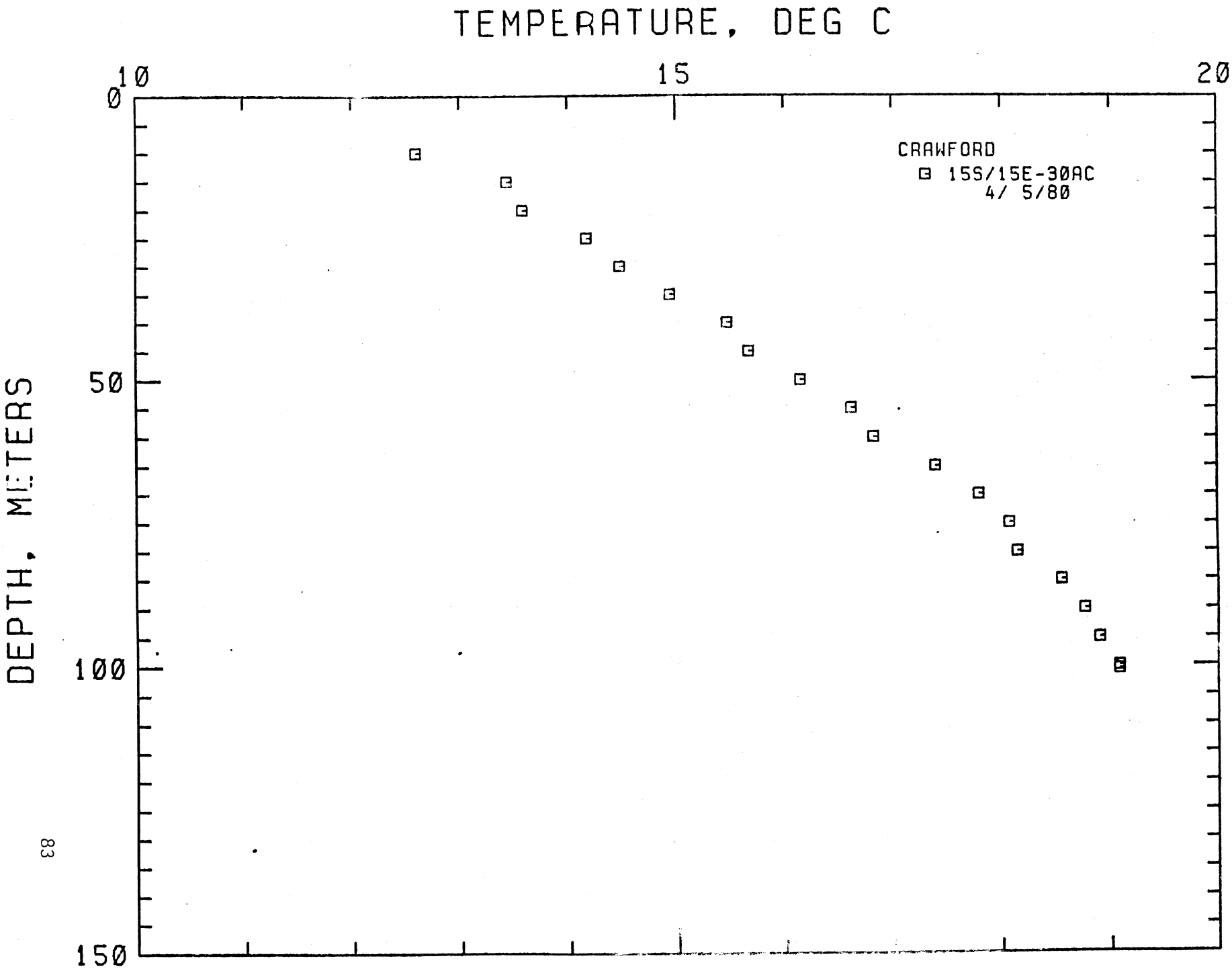
LOCATION: BEND AMS, OREGON
15S/15E-30AA
HOLE NAME: HOUSHOUR
DATE MEASURED: 8/11/79

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
25.0	82.0	13.430	56.17	0.0	0.0
30.0	98.4	13.610	56.50	36.0	2.0
35.0	114.8	14.210	57.58	120.0	6.6
40.0	131.2	14.600	58.28	78.0	4.3
45.0	147.6	15.190	59.34	118.0	6.5
50.0	164.0	15.430	59.77	48.0	2.6
55.0	180.4	15.740	60.33	62.0	3.4
60.0	196.8	16.110	61.00	74.0	4.1
65.0	213.2	16.570	61.83	92.0	5.0
70.0	229.6	16.970	62.55	80.0	4.4
75.0	246.0	17.090	62.76	24.0	1.3
80.0	262.4	17.500	63.50	82.0	4.5
85.0	278.8	17.780	64.00	56.0	3.1
90.0	295.2	18.020	64.44	48.0	2.6
95.0	311.6	18.470	65.25	90.0	4.9
100.0	328.0	18.670	65.61	40.0	2.2
105.0	344.4	18.890	66.00	44.0	2.4
110.0	360.8	19.160	66.49	54.0	3.0
115.0	377.2	19.340	66.81	36.0	2.0
118.0	387.0	19.510	67.12	56.7	3.1


TEMPERATURE, DEG C
10
15
20
0
50
100
150
DEPTH, METERS
15S/15E-30AA
8/11/79

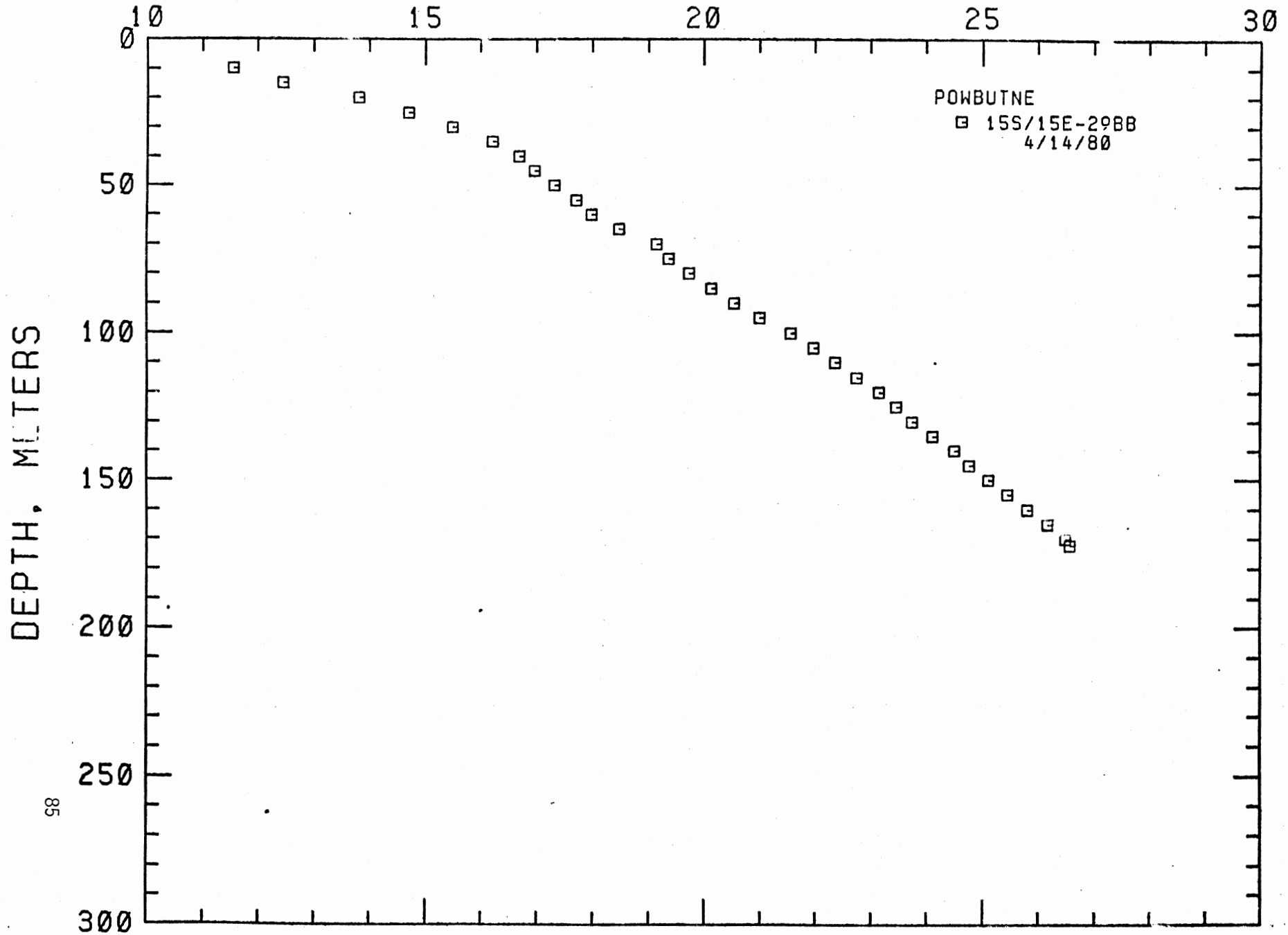
LOCATION: BEND AMS, OREGON
15S/15E-30AC
HOLE NAME: CRAWFORD
DATE MEASURED: 4/ 5/80

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	12.600	54.68	0.0	0.0
15.0	49.2	13.440	56.19	168.0	9.2
20.0	65.6	13.580	56.44	28.0	1.5
25.0	82.0	14.170	57.51	118.0	6.5
30.0	98.4	14.480	58.06	62.0	3.4
35.0	114.8	14.940	58.89	92.0	5.0
40.0	131.2	15.470	59.85	106.0	5.8
45.0	147.6	15.670	60.21	40.0	2.2
50.0	164.0	16.150	61.07	96.0	5.3
55.0	180.4	16.620	61.92	94.0	5.2
60.0	196.8	16.820	62.28	40.0	2.2
65.0	213.2	17.390	63.30	114.0	6.3
70.0	229.6	17.790	64.02	80.0	4.4
75.0	246.0	18.070	64.53	56.0	3.1
80.0	262.4	18.140	64.65	14.0	0.8
85.0	278.8	18.550	65.39	82.0	4.5
90.0	295.2	18.760	65.77	42.0	2.3
95.0	311.6	18.900	66.02	28.0	1.5
100.0	328.0	19.080	66.34	36.0	2.0
100.5	329.6	19.080	66.34	0.0	0.0


TEMPERATURE, DEG C
10
15
20
0
50
100
150
DEPTH, METERS
CRAWFORD
15S/15E-30AC
4/ 5/80

LOCATION: BEND AMS, OREGON
15S/15E-29BB
HOLE NAME: POWBUTNE
DATE MEASURED: 4/14/80

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	11.570	52.83	0.0	0.0
15.0	49.2	12.460	54.43	178.0	9.8
20.0	65.6	13.820	56.88	272.0	14.9
25.0	82.0	14.710	58.48	178.0	9.8
30.0	98.4	15.500	59.90	158.0	8.7
35.0	114.8	16.220	61.20	144.0	7.9
40.0	131.2	16.700	62.06	96.0	5.3
45.0	147.6	16.970	62.55	54.0	3.0
50.0	164.0	17.320	63.18	70.0	3.8
55.0	180.4	17.710	63.88	78.0	4.3
60.0	196.8	17.990	64.38	56.0	3.1
65.0	213.2	18.480	65.26	98.0	5.4
70.0	229.6	19.150	66.47	134.0	7.4
75.0	246.0	19.370	66.87	44.0	2.4
80.0	262.4	19.740	67.53	74.0	4.1
85.0	278.8	20.140	68.25	80.0	4.4
90.0	295.2	20.550	68.99	82.0	4.5
95.0	311.6	21.010	69.82	92.0	5.0
100.0	328.0	21.570	70.83	112.0	6.1
105.0	344.4	21.980	71.56	82.0	4.5
110.0	360.8	22.370	72.27	78.0	4.3
115.0	377.2	22.750	72.95	76.0	4.2
120.0	393.6	23.150	73.67	80.0	4.4
125.0	410.0	23.460	74.23	62.0	3.4
130.0	426.4	23.750	74.75	58.0	3.2
135.0	442.8	24.120	75.42	74.0	4.1
140.0	459.2	24.500	76.10	76.0	4.2
145.0	475.6	24.770	76.59	54.0	3.0
150.0	492.0	25.110	77.20	68.0	3.7
155.0	508.4	25.450	77.81	68.0	3.7
160.0	524.8	25.800	78.44	70.0	3.8
165.0	541.2	26.170	79.11	74.0	4.1
170.0	557.6	26.490	79.68	64.0	3.5
172.0	564.2	26.570	79.83	40.0	2.2


TEMPE..ATURE, DEG C
10
15
20
25
30
0
50
100
150
200
250
300
DEPTH, METERS
POWBUTNE
15S/15E-29BB
4/14/80

LOCATION: BEND AMS, OREGON
15S/15E-31AC
HOLE NAME: DEASON
DATE MEASURED: 4/ 6/80

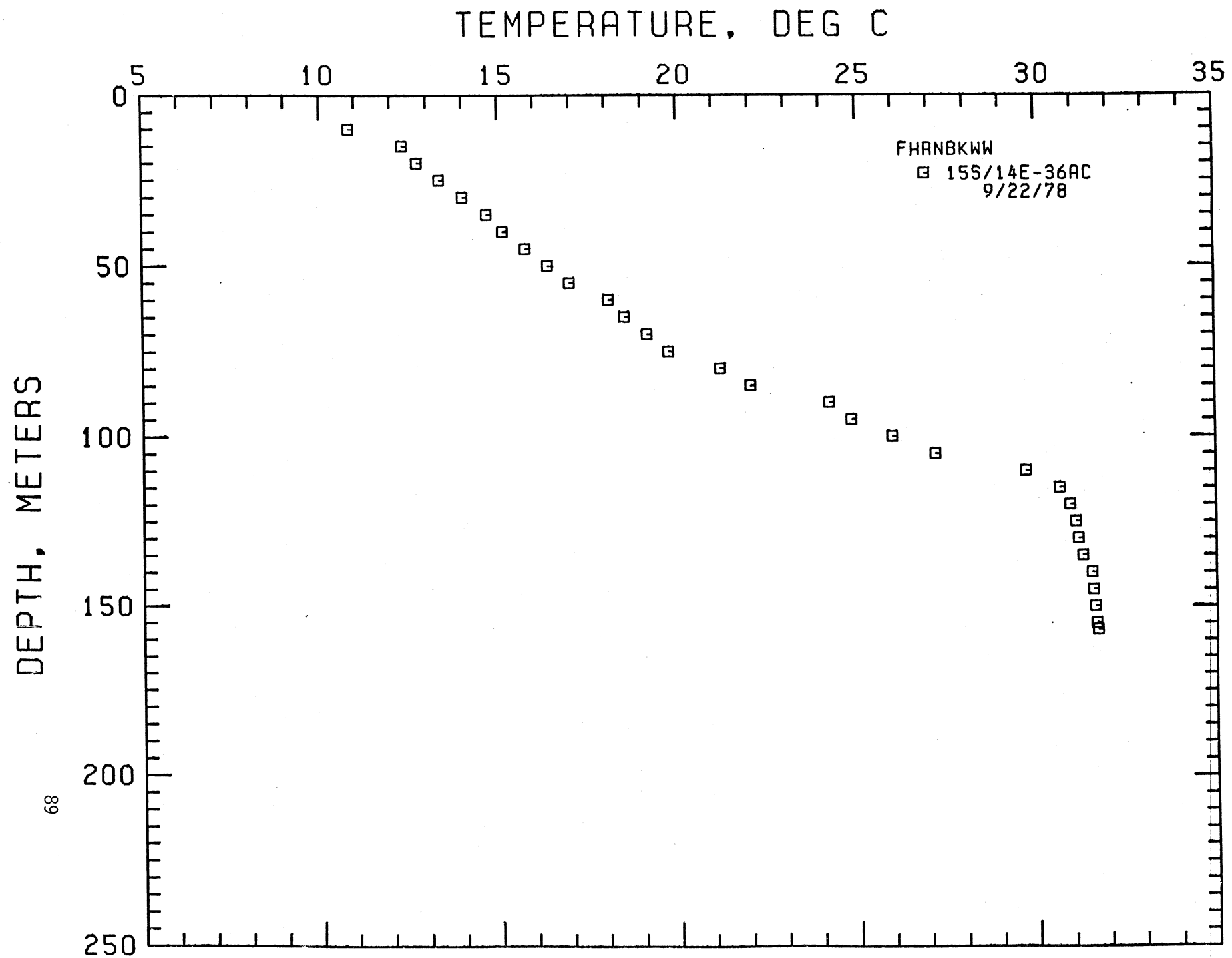
DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
10.0	32.8	7.940	46.29	0.0	0.0
15.0	49.2	10.100	50.18	432.0	23.7
20.0	65.6	11.000	51.80	180.0	9.9
25.0	82.0	12.090	53.76	218.0	12.0
30.0	98.4	14.060	57.31	394.0	21.6
35.0	114.8	14.860	58.75	160.0	8.8
40.0	131.2	16.190	61.14	266.0	14.6
45.0	147.6	16.590	61.86	80.0	4.4
50.0	164.0	17.000	62.60	82.0	4.5
55.0	180.4	17.150	62.87	30.0	1.6
60.0	196.8	17.550	63.59	80.0	4.4
65.0	213.2	17.730	63.91	36.0	2.0
70.0	229.6	17.690	63.84	-8.0	-0.4
75.0	246.0	18.410	65.14	144.0	7.9
80.0	262.4	18.560	65.41	30.0	1.6
85.0	278.8	18.870	65.97	62.0	3.4
90.0	295.2	19.640	67.35	154.0	8.5
95.0	311.6	19.980	67.96	68.0	3.7
100.0	328.0	20.490	68.88	102.0	5.6
105.0	344.4	21.050	69.89	112.0	6.1
110.0	360.8	21.210	70.18	32.0	1.8
115.0	377.2	21.640	70.95	86.0	4.7
120.0	393.6	22.340	72.21	140.0	7.7
125.0	410.0	22.730	72.91	78.0	4.3
130.0	426.4	23.040	73.47	62.0	3.4
135.0	442.8	23.230	73.81	38.0	2.1
140.0	459.2	24.100	75.38	174.0	9.5
145.0	475.6	24.210	75.58	22.0	1.2
150.0	492.0	24.610	76.30	80.0	4.4
155.0	508.4	24.990	76.98	76.0	4.2
160.0	524.8	25.070	77.13	16.0	0.9
165.0	541.2	25.460	77.83	78.0	4.3
170.0	557.6	25.560	78.01	20.0	1.1
175.0	574.0	26.030	78.85	94.0	5.2
180.0	590.4	26.200	79.16	34.0	1.9
185.0	606.8	26.810	80.26	122.0	6.7
190.0	623.2	26.840	80.31	6.0	0.3
195.0	639.6	27.350	81.23	102.0	5.6
200.0	656.0	27.620	81.72	54.0	3.0
205.0	672.4	27.690	81.84	14.0	0.8
210.0	688.8	28.010	82.42	64.0	3.5

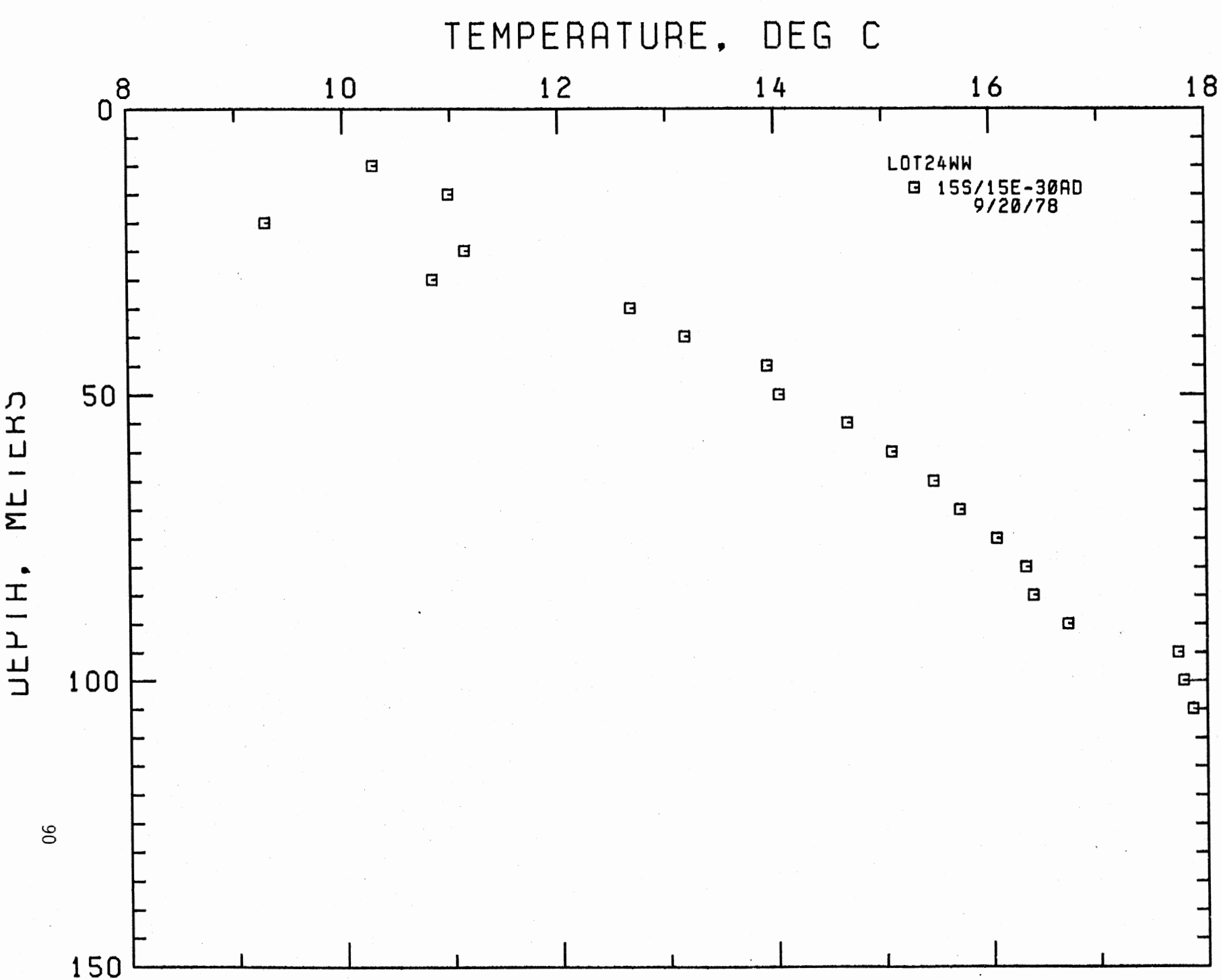
LOCATION: BEND AMS, OREGON
15S/15E-31AC
HOLE NAME: DEASON
DATE MEASURED: 4/ 6/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
215.0	705.2	28.230	82.81	44.0	2.4
220.0	721.6	28.290	82.92	12.0	0.7
225.0	738.0	28.430	83.17	28.0	1.5
230.0	754.4	28.270	82.89	-32.0	-1.8
235.0	770.8	29.200	84.56	186.0	10.2
240.0	787.2	29.730	85.51	106.0	5.8
244.3	801.3	29.960	85.93	53.5	2.9

LOCATION: BEND AMS, OREGON
15S/14E-36AC
HOLE NAME: FHRNBKWW
DATE MEASURED: 9/22/78

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	10.840	51.51	0.0	0.0
15.0	49.2	12.340	54.21	300.0	16.5
20.0	65.6	12.740	54.93	80.0	4.4
25.0	82.0	13.370	56.07	126.0	6.9
30.0	98.4	14.020	57.24	130.0	7.1
35.0	114.8	14.680	58.42	132.0	7.2
40.0	131.2	15.130	59.23	90.0	4.9
45.0	147.6	15.760	60.37	126.0	6.9
50.0	164.0	16.390	61.50	126.0	6.9
55.0	180.4	16.990	62.58	120.0	6.6
60.0	196.8	18.060	64.51	214.0	11.7
65.0	213.2	18.500	65.30	88.0	4.8
70.0	229.6	19.150	66.47	130.0	7.1
75.0	246.0	19.750	67.55	120.0	6.6
80.0	262.4	21.190	70.14	288.0	15.8
85.0	278.8	22.030	71.65	168.0	9.2
90.0	295.2	24.210	75.58	436.0	23.9
95.0	311.6	24.840	76.71	126.0	6.9
100.0	328.0	25.960	78.73	224.0	12.3
105.0	344.4	27.170	80.91	242.0	13.3
110.0	360.8	29.680	85.42	502.0	27.5
115.0	377.2	30.630	87.13	190.0	10.4
120.0	393.6	30.920	87.66	58.0	3.2
125.0	410.0	31.070	87.93	30.0	1.6
130.0	426.4	31.140	88.05	14.0	0.8
135.0	442.8	31.260	88.27	24.0	1.3
140.0	459.2	31.520	88.74	52.0	2.9
145.0	475.6	31.560	88.81	8.0	0.4
150.0	492.0	31.600	88.88	8.0	0.4
155.0	508.4	31.640	88.95	8.0	0.4
157.0	515.0	31.670	89.01	15.0	0.8


TEMPERATURE, DEG C
0
5
10
15
20
25
30
35
DEPTH, METERS
50
100
150
200
250
FHRNBKWW
15S/14E-36AC
9/22/78

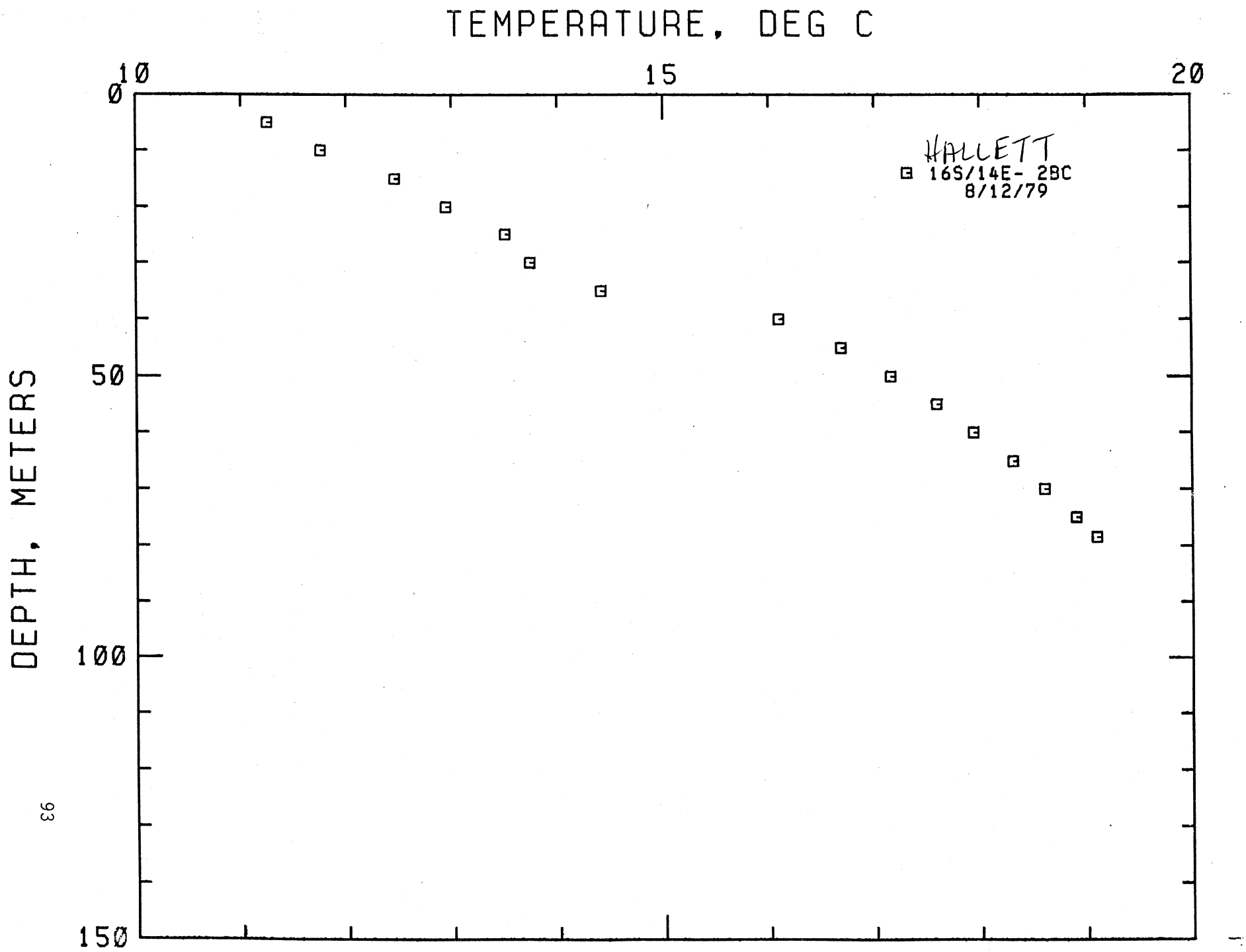

TEMPERATURE, DEG C
8
10
12
14
16
18
0
50
100
150
DEPTH, METERS
LOT24WW
15S/15E-30AD
9/20/78

LOCATION: BEND AMS, OREGON
15S/15E-30AD
HOLE NAME: LOT24WW
DATE MEASURED: 9/20/78

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	10.280	50.50	0.0	0.0
15.0	49.2	10.980	51.76	140.0	7.7
20.0	65.6	9.280	48.70	-340.0	-18.7
25.0	82.0	11.130	52.03	370.0	20.3
30.0	98.4	10.830	51.49	-60.0	-3.3
35.0	114.8	12.670	54.81	368.0	20.2
40.0	131.2	13.170	55.71	100.0	5.5
45.0	147.6	13.930	57.07	152.0	8.3
50.0	164.0	14.040	57.27	22.0	1.2
55.0	180.4	14.670	58.41	126.0	6.9
60.0	196.8	15.080	59.14	82.0	4.5
65.0	213.2	15.470	59.85	78.0	4.3
70.0	229.6	15.710	60.28	48.0	2.6
75.0	246.0	16.050	60.89	68.0	3.7
80.0	262.4	16.320	61.38	54.0	3.0
85.0	278.8	16.390	61.50	14.0	0.8
90.0	295.2	16.710	62.08	64.0	3.5
95.0	311.6	17.730	63.91	204.0	11.2
100.0	328.0	17.780	64.00	10.0	0.5
105.0	344.4	17.870	64.17	18.0	1.0

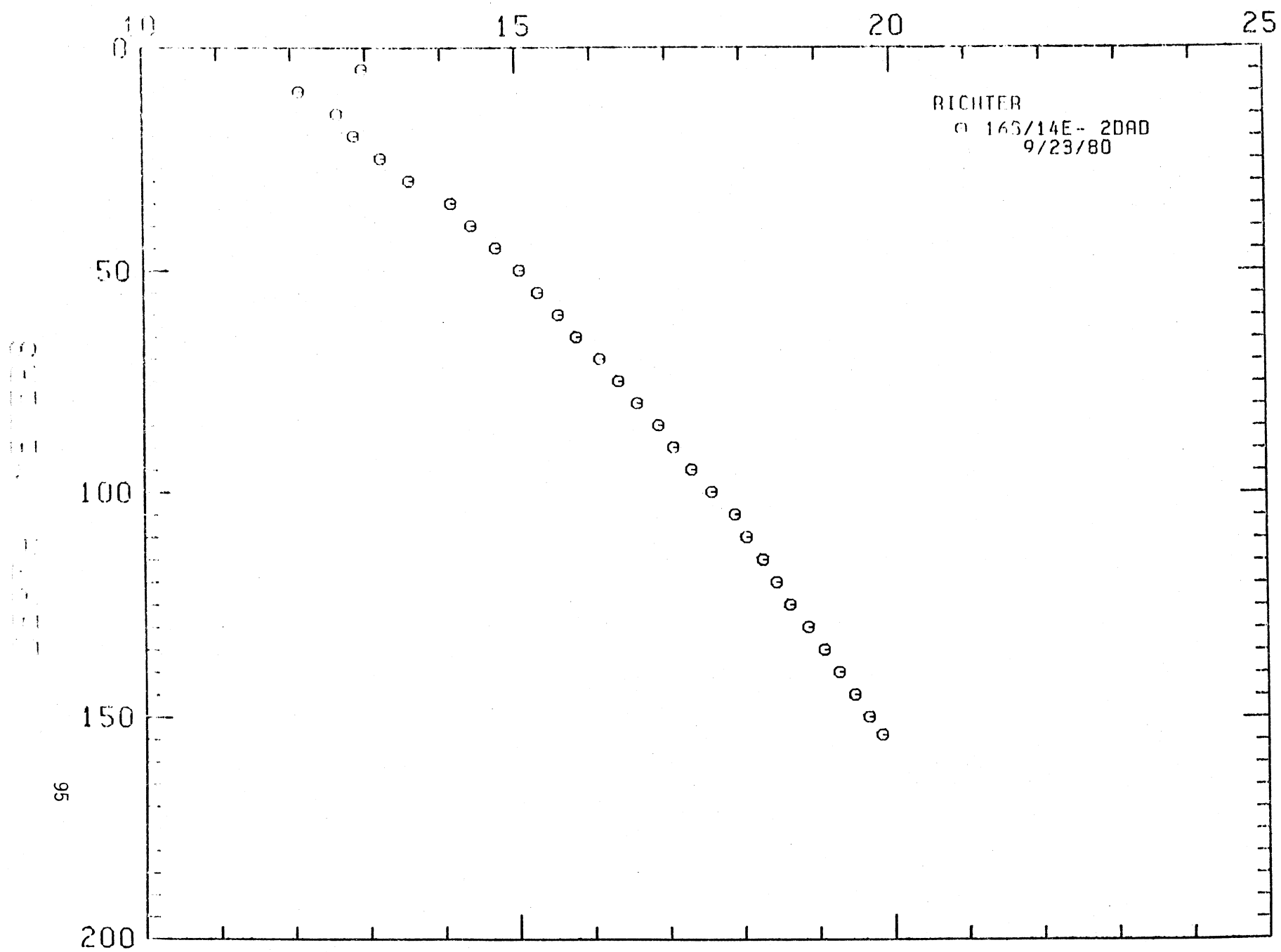
LOCATION: BEND AMS, OREGON
16S/14E- 2BC
HOLE NAME: HALLETT
DATE MEASURED: 8/12/79

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	11.250	52.25	0.0	0.0
10.0	32.8	11.760	53.17	102.0	5.6
15.0	49.2	12.460	54.43	140.0	7.7
20.0	65.6	12.950	55.31	98.0	5.4
25.0	82.0	13.510	56.32	112.0	6.1
30.0	98.4	13.740	56.73	46.0	2.5
35.0	114.8	14.410	57.94	134.0	7.4
40.0	131.2	16.090	60.96	336.0	18.4
45.0	147.6	16.680	62.02	118.0	6.5
50.0	164.0	17.150	62.87	94.0	5.2
55.0	180.4	17.580	63.64	86.0	4.7
60.0	196.8	17.930	64.27	70.0	3.8
65.0	213.2	18.300	64.94	74.0	4.1
70.0	229.6	18.600	65.48	60.0	3.3
75.0	246.0	18.900	66.02	60.0	3.3
78.5	257.5	19.090	66.36	54.3	3.0


TEMPERATURE, DEG C
10
15
20
0
50
100
150
DEPTH, METERS
HALLETT
16S/14E- 28C
8/12/79

LOCATION: BEND AMS, OREGON
16S/14E- 2DAD
HOLE NAME: RICHTER
DATE MEASURED: 9/23/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	12.960	55.33	0.0	0.0
10.0	32.8	12.110	53.80	-170.0	-9.3
15.0	49.2	12.610	54.70	100.0	5.5
20.0	65.6	12.840	55.11	46.0	2.5
25.0	82.0	13.200	55.76	72.0	4.0
30.0	98.4	13.570	56.43	74.0	4.1
35.0	114.8	14.130	57.43	112.0	6.1
40.0	131.2	14.400	57.92	54.0	3.0
45.0	147.6	14.720	58.50	64.0	3.5
50.0	164.0	15.040	59.07	64.0	3.5
55.0	180.4	15.280	59.50	48.0	2.6
60.0	196.8	15.550	59.99	54.0	3.0
65.0	213.2	15.790	60.42	48.0	2.6
70.0	229.6	16.100	60.98	62.0	3.4
75.0	246.0	16.350	61.43	50.0	2.7
80.0	262.4	16.600	61.88	50.0	2.7
85.0	278.8	16.880	62.38	56.0	3.1
90.0	295.2	17.080	62.74	40.0	2.2
95.0	311.6	17.320	63.18	48.0	2.6
100.0	328.0	17.590	63.66	54.0	3.0
105.0	344.4	17.890	64.20	60.0	3.3
110.0	360.8	18.050	64.49	32.0	1.8
115.0	377.2	18.260	64.87	42.0	2.3
120.0	393.6	18.440	65.19	36.0	2.0
125.0	410.0	18.620	65.52	36.0	2.0
130.0	426.4	18.860	65.95	48.0	2.6
135.0	442.8	19.080	66.34	44.0	2.4
140.0	459.2	19.270	66.69	38.0	2.1
145.0	475.6	19.480	67.06	42.0	2.3
150.0	492.0	19.670	67.41	38.0	2.1
154.0	505.1	19.840	67.71	42.5	2.3

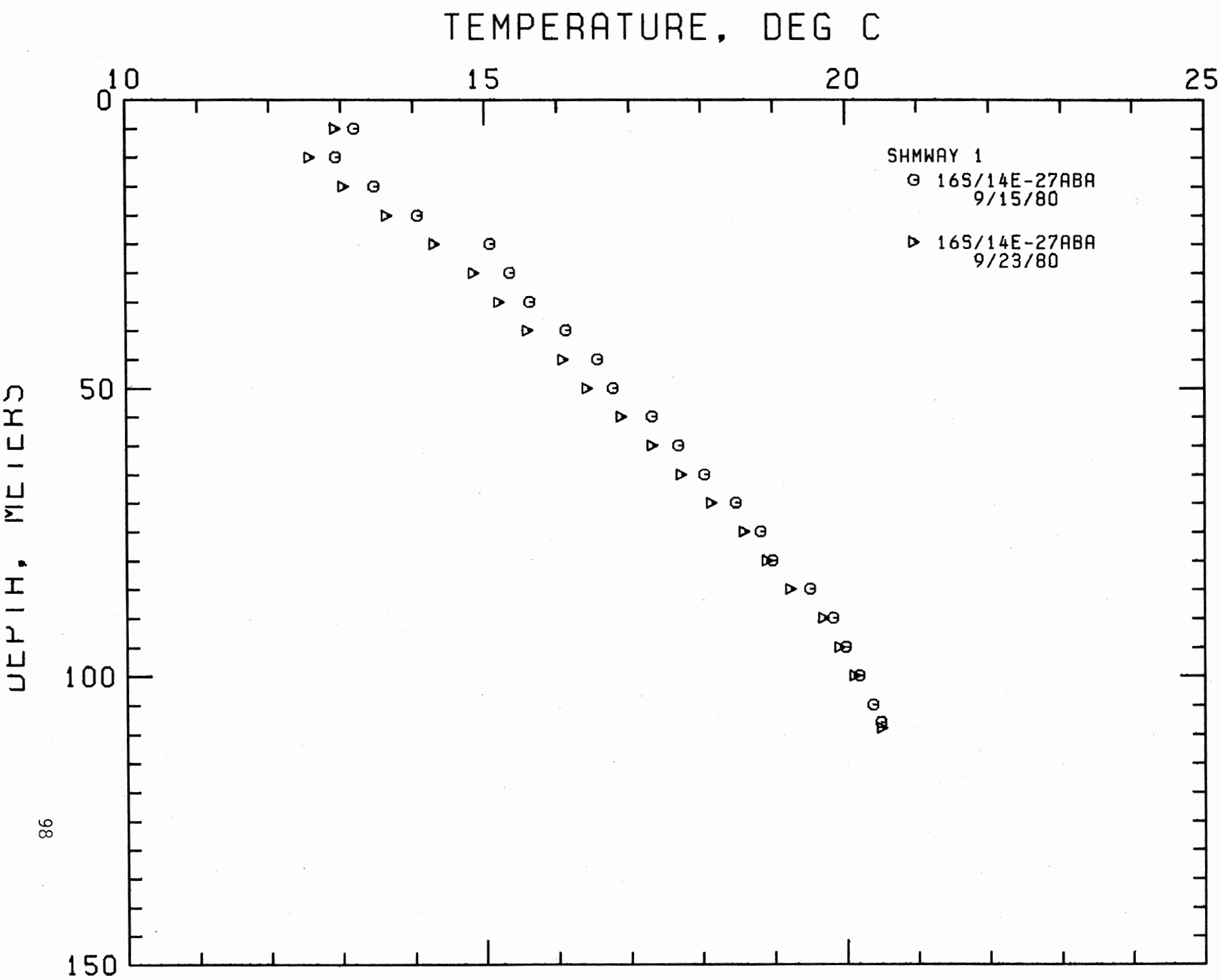

TEMPERATURE, DEG C
10
15
20
25
0
50
100
150
200
RICHTER
165/14E- 2DAD
9/23/80

LOCATION: BEND AMS, OREGON
16S/14E-27ABA
HOLE NAME: SHMWAY 1
DATE MEASURED: 9/15/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	13.190	55.74	0.0	0.0
10.0	32.8	12.930	55.27	-52.0	-2.9
15.0	49.2	13.460	56.23	106.0	5.8
20.0	65.6	14.060	57.31	120.0	6.6
25.0	82.0	15.070	59.13	202.0	11.1
30.0	98.4	15.350	59.63	56.0	3.1
35.0	114.8	15.620	60.12	54.0	3.0
40.0	131.2	16.120	61.02	100.0	5.5
45.0	147.6	16.560	61.81	88.0	4.8
50.0	164.0	16.770	62.19	42.0	2.3
55.0	180.4	17.310	63.16	108.0	5.9
60.0	196.8	17.680	63.82	74.0	4.1
65.0	213.2	18.040	64.47	72.0	4.0
70.0	229.6	18.480	65.26	88.0	4.8
75.0	246.0	18.820	65.88	68.0	3.7
80.0	262.4	18.980	66.16	32.0	1.8
85.0	278.8	19.510	67.12	106.0	5.8
90.0	295.2	19.820	67.68	62.0	3.4
95.0	311.6	19.990	67.98	34.0	1.9
100.0	328.0	20.180	68.32	38.0	2.1
105.0	344.4	20.370	68.67	38.0	2.1
108.0	354.2	20.480	68.86	36.7	2.0

LOCATION: BEND AMS, OREGON
16S/14E-27ABA
HOLE NAME: SHMWAY 1
DATE MEASURED: 9/23/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	12.930	55.27	0.0	0.0
10.0	32.8	12.570	54.63	-72.0	-4.0
15.0	49.2	13.040	55.47	94.0	5.2
20.0	65.6	13.640	56.55	120.0	6.6
25.0	82.0	14.300	57.74	132.0	7.2
30.0	98.4	14.850	58.73	110.0	6.0
35.0	114.8	15.200	59.36	70.0	3.8
40.0	131.2	15.600	60.08	80.0	4.4
45.0	147.6	16.090	60.96	98.0	5.4
50.0	164.0	16.420	61.56	66.0	3.6
55.0	180.4	16.890	62.40	94.0	5.2
60.0	196.8	17.320	63.18	86.0	4.7
65.0	213.2	17.720	63.90	80.0	4.4
70.0	229.6	18.140	64.65	84.0	4.6
75.0	246.0	18.600	65.48	92.0	5.0
80.0	262.4	18.910	66.04	62.0	3.4
85.0	278.8	19.240	66.63	66.0	3.6
90.0	295.2	19.690	67.44	90.0	4.9
95.0	311.6	19.920	67.86	46.0	2.5
100.0	328.0	20.120	68.22	40.0	2.2
109.0	357.5	20.500	68.90	42.2	2.3

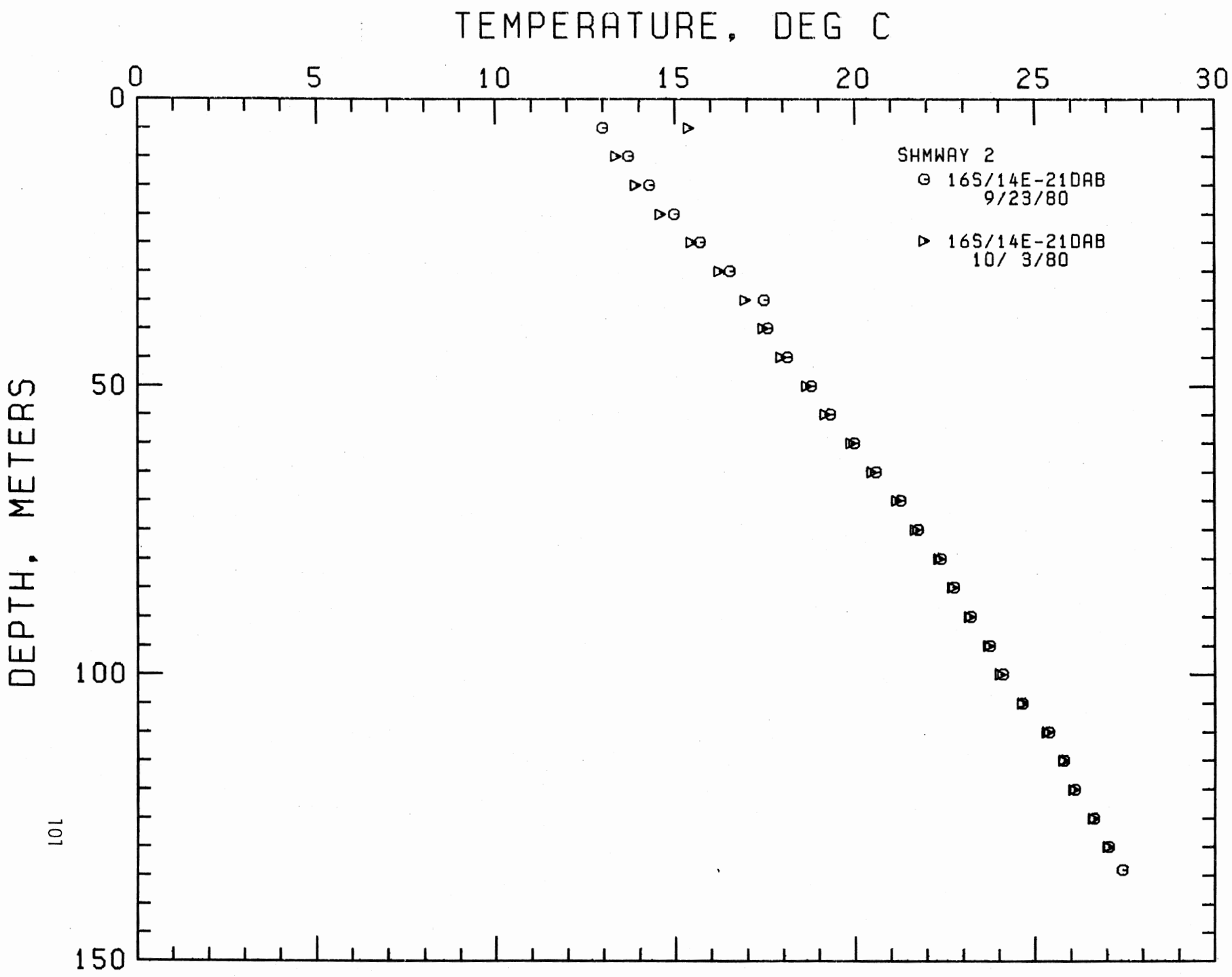

TEMPERATURE, DEG C
10
15
20
25
0
50
100
150
DEPTH, METERS
SHMWAY 1
16S/14E-27ABA
9/15/80
16S/14E-27ABA
9/23/80

LOCATION: BEND AMS, OREGON
16S/14E-21DAB
HOLE NAME: SHMWAY 2
DATE MEASURED: 9/23/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	13.000	55.40	0.0	0.0
10.0	32.8	13.710	56.68	142.0	7.8
15.0	49.2	14.290	57.72	116.0	6.4
20.0	65.6	14.980	58.96	138.0	7.6
25.0	82.0	15.700	60.26	144.0	7.9
30.0	98.4	16.530	61.75	166.0	9.1
35.0	114.8	17.470	63.45	188.0	10.3
40.0	131.2	17.570	63.63	20.0	1.1
45.0	147.6	18.120	64.62	110.0	6.0
50.0	164.0	18.790	65.82	134.0	7.4
55.0	180.4	19.320	66.78	106.0	5.8
60.0	196.8	19.990	67.98	134.0	7.4
65.0	213.2	20.580	69.04	118.0	6.5
70.0	229.6	21.270	70.29	138.0	7.6
75.0	246.0	21.760	71.17	98.0	5.4
80.0	262.4	22.380	72.28	124.0	6.8
85.0	278.8	22.750	72.95	74.0	4.1
90.0	295.2	23.210	73.78	92.0	5.0
95.0	311.6	23.740	74.73	106.0	5.8
100.0	328.0	24.110	75.40	74.0	4.1
105.0	344.4	24.650	76.37	108.0	5.9
110.0	360.8	25.380	77.68	146.0	8.0
115.0	377.2	25.800	78.44	84.0	4.6
120.0	393.6	26.100	78.98	60.0	3.3
125.0	410.0	26.640	79.95	108.0	5.9
130.0	426.4	27.050	80.69	82.0	4.5
134.0	439.5	27.420	81.36	92.5	5.1

LOCATION: BEND AMS, OREGON
16S/14E-21DAB
HOLE NAME: SHMWAY 2
DATE MEASURED: 10/ 3/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	15.400	59.72	0.0	0.0
10.0	32.8	13.370	56.07	-406.0	-22.3
15.0	49.2	13.920	57.06	110.0	6.0
20.0	65.6	14.600	58.28	136.0	7.5
25.0	82.0	15.470	59.85	174.0	9.5
30.0	98.4	16.240	61.23	154.0	8.5
35.0	114.8	16.960	62.53	144.0	7.9
40.0	131.2	17.450	63.41	98.0	5.4
45.0	147.6	17.950	64.31	100.0	5.5
50.0	164.0	18.670	65.61	144.0	7.9
55.0	180.4	19.190	66.54	104.0	5.7
60.0	196.8	19.900	67.82	142.0	7.8
65.0	213.2	20.480	68.86	116.0	6.4
70.0	229.6	21.170	70.11	138.0	7.6
75.0	246.0	21.690	71.04	104.0	5.7
80.0	262.4	22.340	72.21	130.0	7.1
85.0	278.8	22.710	72.88	74.0	4.1
90.0	295.2	23.180	73.72	94.0	5.2
95.0	311.6	23.700	74.66	104.0	5.7
100.0	328.0	24.030	75.25	66.0	3.6
105.0	344.4	24.650	76.37	124.0	6.8
110.0	360.8	25.340	77.61	138.0	7.6
115.0	377.2	25.800	78.44	92.0	5.0
120.0	393.6	26.080	78.94	56.0	3.1
125.0	410.0	26.620	79.92	108.0	5.9
130.0	426.4	27.030	80.65	82.0	4.5

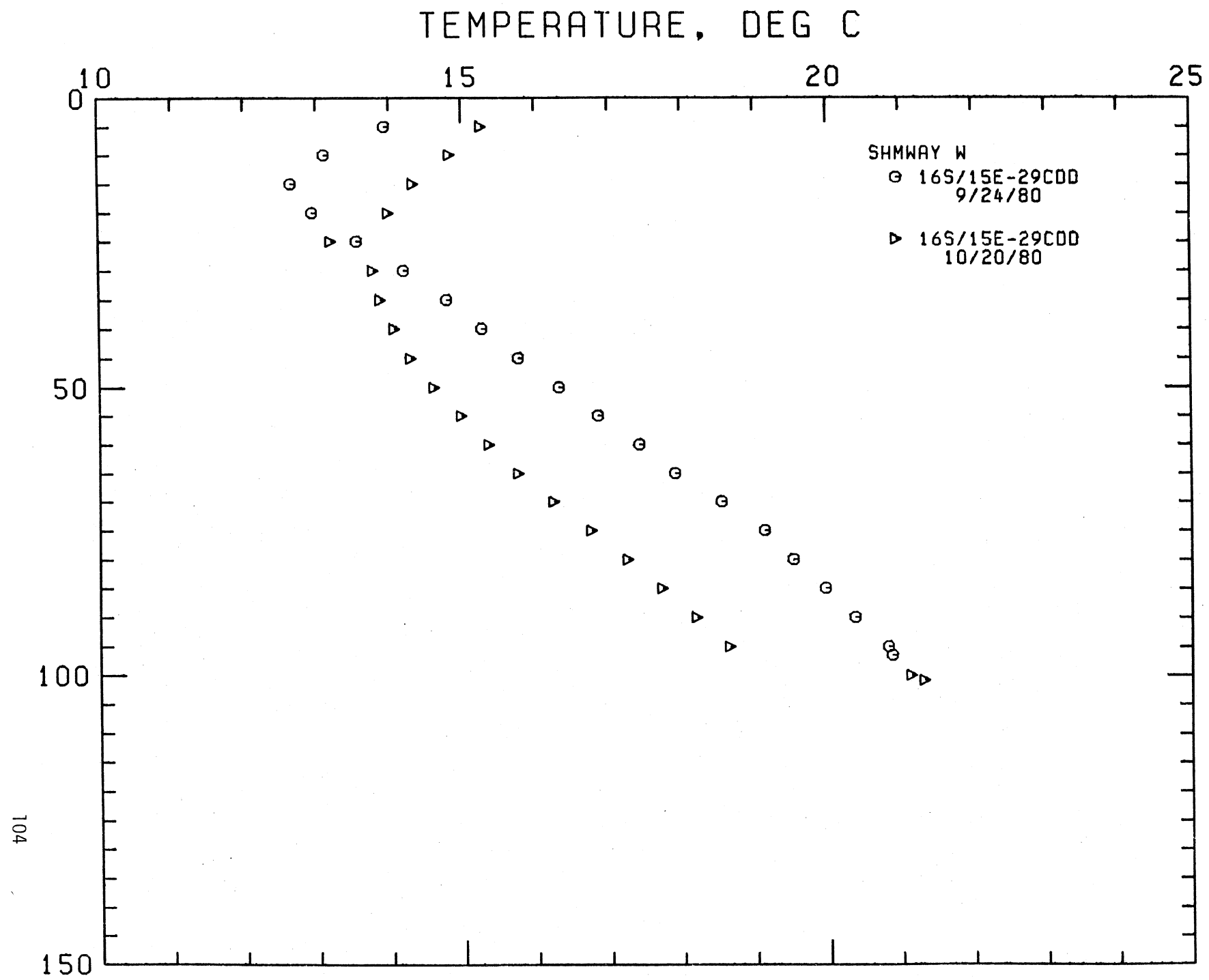

TEMPERATURE, DEG C
0
5
10
15
20
25
30
DEPTH, METERS
0
50
100
150
SHMWAY 2
16S/14E-21DAB
9/23/80
16S/14E-21DAB
10/ 3/80

LOCATION: BEND AMS, OREGON
16S/15E-29CDD
HOLE NAME: SHMWAY W
DATE MEASURED: 9/24/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	13.940	57.09	0.0	0.0
10.0	32.8	13.110	55.60	-166.0	-9.1
15.0	49.2	12.650	54.77	-92.0	-5.0
20.0	65.6	12.940	55.29	58.0	3.2
25.0	82.0	13.550	56.39	122.0	6.7
30.0	98.4	14.190	57.54	128.0	7.0
35.0	114.8	14.780	58.60	118.0	6.5
40.0	131.2	15.260	59.47	96.0	5.3
45.0	147.6	15.760	60.37	100.0	5.5
50.0	164.0	16.320	61.38	112.0	6.1
55.0	180.4	16.850	62.33	106.0	5.8
60.0	196.8	17.410	63.34	112.0	6.1
65.0	213.2	17.900	64.22	98.0	5.4
70.0	229.6	18.540	65.37	128.0	7.0
75.0	246.0	19.130	66.43	118.0	6.5
80.0	262.4	19.520	67.14	78.0	4.3
85.0	278.8	19.960	67.93	88.0	4.8
90.0	295.2	20.360	68.65	80.0	4.4
95.0	311.6	20.820	69.48	92.0	5.0
96.5	316.5	20.870	69.57	33.3	1.8

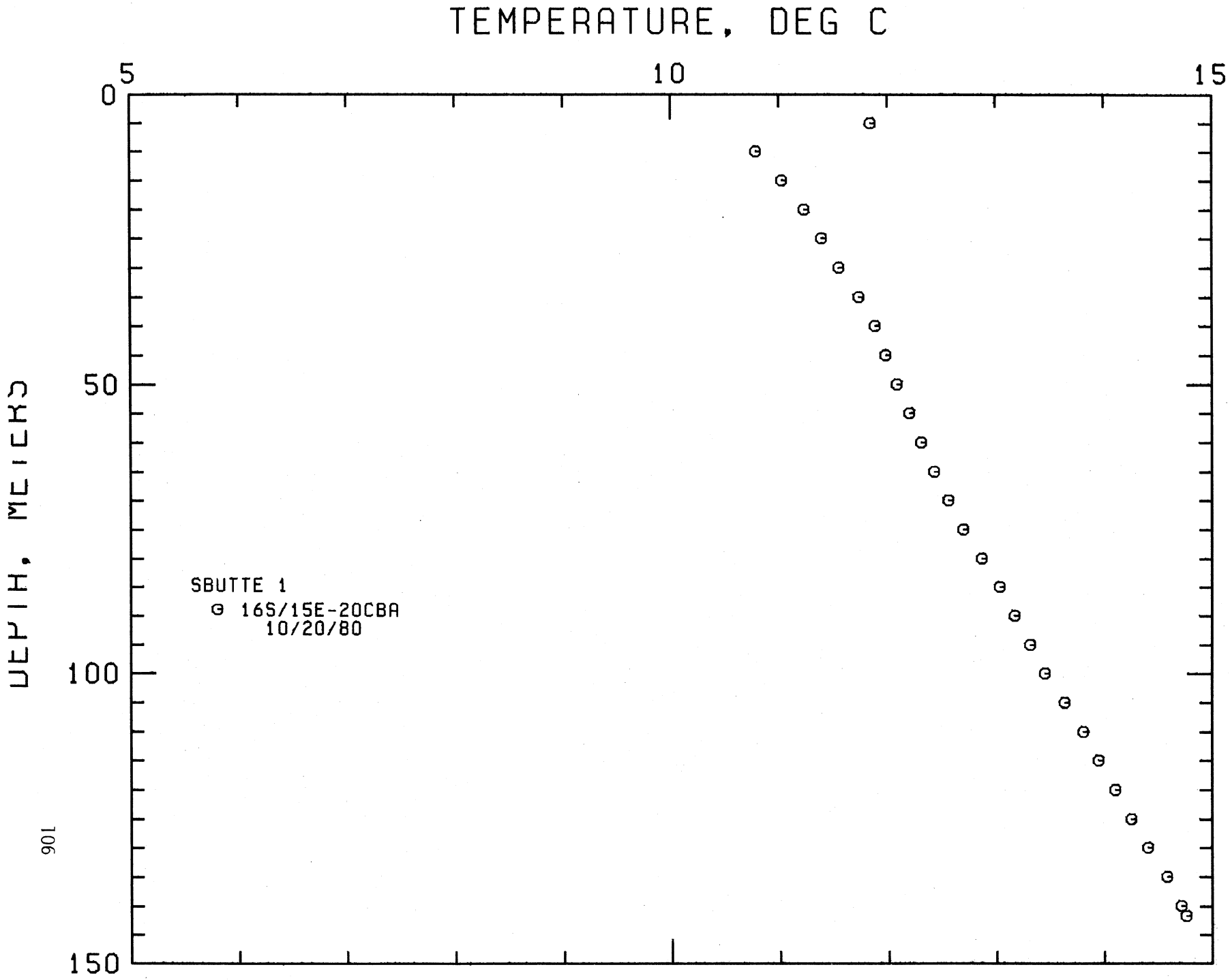
LOCATION: BEND AMS, OREGON
16S/15E-29CDD
HOLE NAME: SHMWAY W
DATE MEASURED: 10/20/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	15.276	59.50	0.0	0.0
10.0	32.8	14.839	58.71	-87.4	-4.8
15.0	49.2	14.339	57.81	-100.0	-5.5
20.0	65.6	13.993	57.19	-69.2	-3.8
25.0	82.0	13.200	55.76	-158.6	-8.7
30.0	98.4	13.780	56.80	116.0	6.4
35.0	114.8	13.877	56.98	19.4	1.1
40.0	131.2	14.060	57.31	36.6	2.0
45.0	147.6	14.288	57.72	45.6	2.5
50.0	164.0	14.605	58.29	63.4	3.5
55.0	180.4	14.977	58.96	74.4	4.1
60.0	196.8	15.357	59.64	76.0	4.2
65.0	213.2	15.760	60.37	80.6	4.4
70.0	229.6	16.236	61.22	95.2	5.2
75.0	246.0	16.750	62.15	102.8	5.6
80.0	262.4	17.249	63.05	99.8	5.5
85.0	278.8	17.723	63.90	94.8	5.2
90.0	295.2	18.194	64.75	94.2	5.2
95.0	311.6	18.649	65.57	91.0	5.0
100.0	328.0	21.132	70.04	496.6	27.3
100.8	330.6	21.314	70.37	227.5	12.5


TEMPERATURE, DEG C
10
15
20
25
0
50
100
150
SHMWAY W
16S/15E-29CDD
9/24/80
16S/15E-29CDD
10/20/80

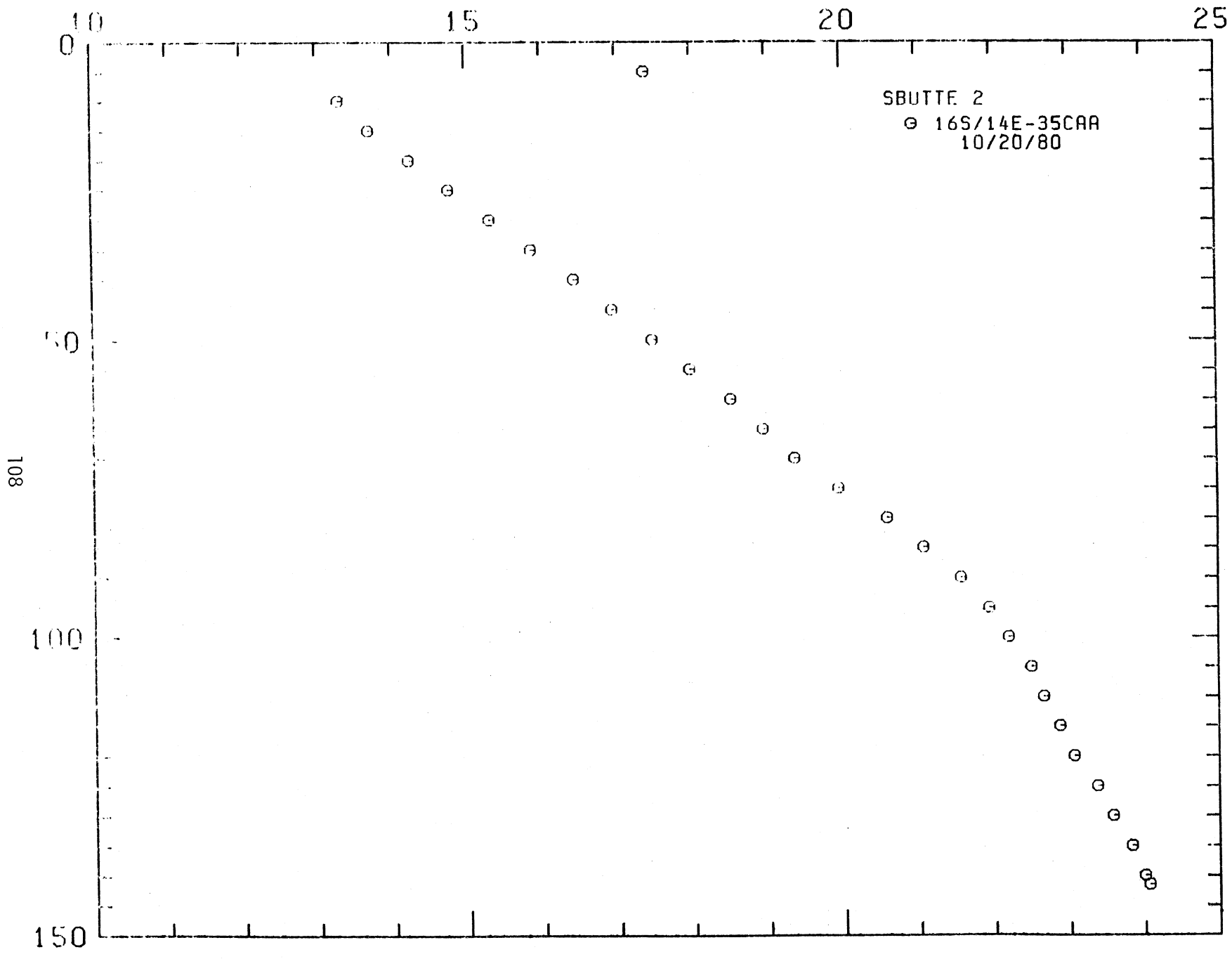
LOCATION: BEND AMS, OREGON
16S/15E-20CBA
HOLE NAME: SBUTTE 1
DATE MEASURED: 10/20/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	11.843	53.32	0.0	0.0
10.0	32.8	10.790	51.42	-210.6	-11.6
15.0	49.2	11.031	51.86	48.2	2.6
20.0	65.6	11.234	52.22	40.6	2.2
25.0	82.0	11.397	52.51	32.6	1.8
30.0	98.4	11.554	52.80	31.4	1.7
35.0	114.8	11.736	53.12	36.4	2.0
40.0	131.2	11.888	53.40	30.4	1.7
45.0	147.6	11.982	53.57	18.8	1.0
50.0	164.0	12.088	53.76	21.2	1.2
55.0	180.4	12.201	53.96	22.6	1.2
60.0	196.8	12.309	54.16	21.6	1.2
65.0	213.2	12.428	54.37	23.8	1.3
70.0	229.6	12.559	54.61	26.2	1.4
75.0	246.0	12.699	54.86	28.0	1.5
80.0	262.4	12.870	55.17	34.2	1.9
85.0	278.8	13.034	55.46	32.8	1.8
90.0	295.2	13.172	55.71	27.6	1.5
95.0	311.6	13.312	55.96	28.0	1.5
100.0	328.0	13.453	56.22	28.2	1.5
105.0	344.4	13.633	56.54	36.0	2.0
110.0	360.8	13.808	56.85	35.0	1.9
115.0	377.2	13.949	57.11	28.2	1.5
120.0	393.6	14.102	57.38	30.6	1.7
125.0	410.0	14.251	57.65	29.8	1.6
130.0	426.4	14.408	57.93	31.4	1.7
135.0	442.8	14.580	58.24	34.4	1.9
140.0	459.2	14.717	58.49	27.4	1.5
141.7	464.8	14.759	58.57	24.7	1.4


TEMPERATURE, DEG C
0
5
10
15
50
100
150
DEPTH, METERS
SBUTTE 1
16S/15E-20CBA
10/20/80

LOCATION: BEND AMS, OREGON
16S/14E-35CAA
HOLE NAME: SBUTTE 2
DATE MEASURED: 10/20/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	17.394	63.31	0.0	0.0
10.0	32.8	13.310	55.96	-816.8	-44.8
15.0	49.2	13.708	56.67	79.6	4.4
20.0	65.6	14.253	57.66	109.0	6.0
25.0	82.0	14.778	58.60	105.0	5.8
30.0	98.4	15.323	59.58	109.0	6.0
35.0	114.8	15.875	60.57	110.4	6.1
40.0	131.2	16.438	61.59	112.6	6.2
45.0	147.6	16.941	62.49	100.6	5.5
50.0	164.0	17.478	63.46	107.4	5.9
55.0	180.4	17.971	64.35	98.6	5.4
60.0	196.8	18.513	65.32	108.4	5.9
65.0	213.2	18.943	66.10	86.0	4.7
70.0	229.6	19.358	66.84	83.0	4.6
75.0	246.0	19.943	67.90	117.0	6.4
80.0	262.4	20.587	69.06	128.8	7.1
85.0	278.8	21.062	69.91	95.0	5.2
90.0	295.2	21.566	70.82	100.8	5.5
95.0	311.6	21.939	71.49	74.6	4.1
100.0	328.0	22.197	71.95	51.6	2.8
105.0	344.4	22.495	72.49	59.6	3.3
110.0	360.8	22.663	72.79	33.6	1.8
115.0	377.2	22.878	73.18	43.0	2.4
120.0	393.6	23.064	73.52	37.2	2.0
125.0	410.0	23.375	74.07	62.2	3.4
130.0	426.4	23.579	74.44	40.8	2.2
135.0	442.8	23.828	74.89	49.8	2.7
140.0	459.2	23.997	75.19	33.8	1.9
141.5	464.1	24.057	75.30	40.0	2.2

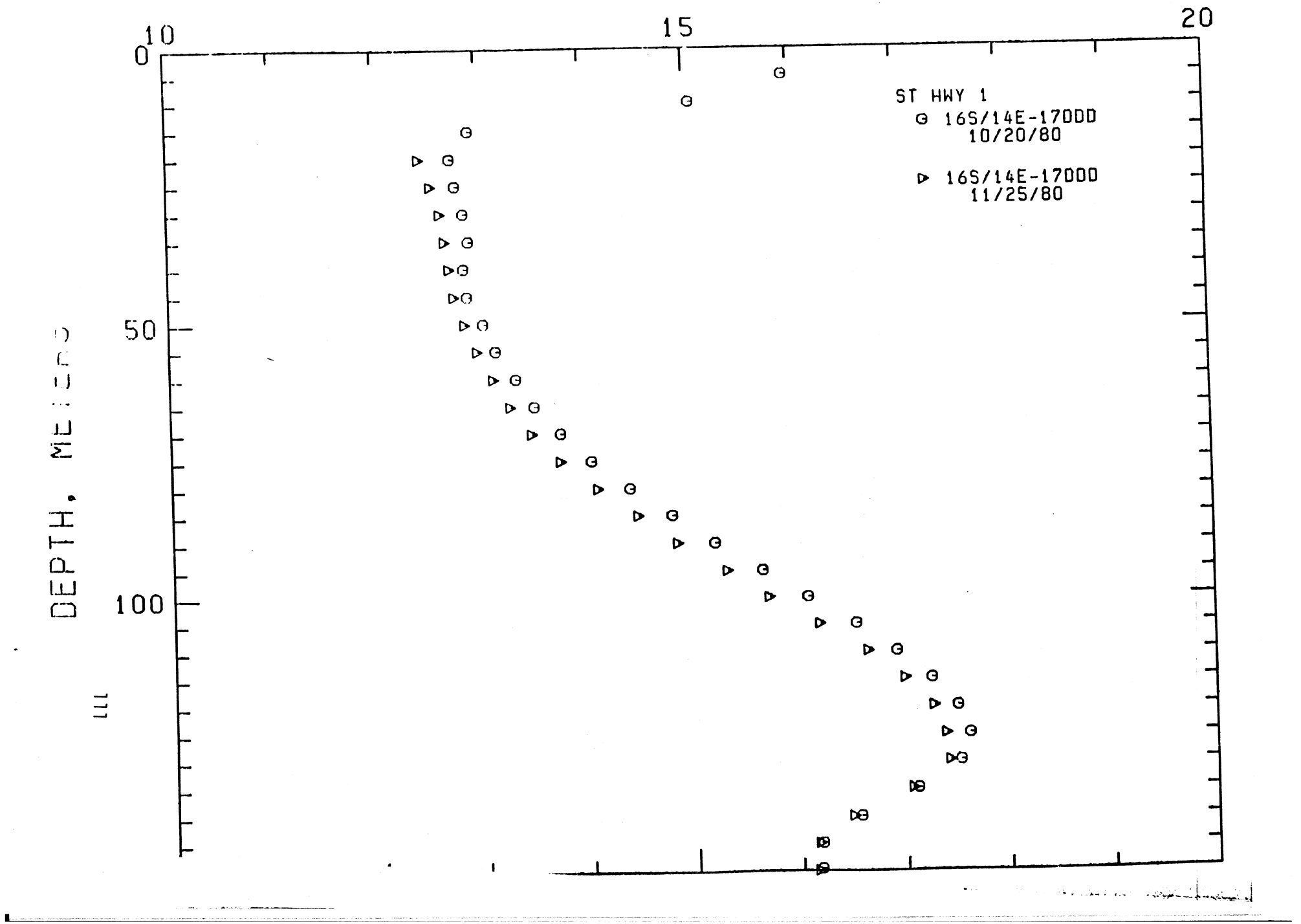

TEMPERATURE, DEG C
10
15
20
25
0
50
100
150
108
SBUTTE 2
Θ 16S/14E-35CAA
10/20/80

LOCATION: BEND AMS, OREGON
16S/14E-17DDD
HOLE NAME: ST HWY 1
DATE MEASURED: 10/20/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	15.959	60.73	0.0	0.0
10.0	32.8	15.062	59.11	-179.4	-9.8
15.0	49.2	12.924	55.26	-427.6	-23.5
20.0	65.6	12.742	54.94	-36.4	-2.0
25.0	82.0	12.787	55.02	9.0	0.5
30.0	98.4	12.865	55.16	15.6	0.9
35.0	114.8	12.906	55.23	8.2	0.5
40.0	131.2	12.855	55.14	-10.2	-0.6
45.0	147.6	12.884	55.19	5.8	0.3
50.0	164.0	13.036	55.46	30.4	1.7
55.0	180.4	13.150	55.67	22.8	1.3
60.0	196.8	13.337	56.01	37.4	2.1
65.0	213.2	13.508	56.31	34.2	1.9
70.0	229.6	13.752	56.75	48.8	2.7
75.0	246.0	14.045	57.28	58.6	3.2
80.0	262.4	14.409	57.94	72.8	4.0
85.0	278.8	14.809	58.66	80.0	4.4
90.0	295.2	15.212	59.38	80.6	4.4
95.0	311.6	15.663	60.19	90.2	5.0
100.0	328.0	16.090	60.96	85.4	4.7
105.0	344.4	16.550	61.79	92.0	5.0
110.0	360.8	16.931	62.48	76.2	4.2
115.0	377.2	17.262	63.07	66.2	3.6
120.0	393.6	17.506	63.51	48.8	2.7
125.0	410.0	17.625	63.73	23.8	1.3
130.0	426.4	17.531	63.56	-18.8	-1.0
135.0	442.8	17.116	62.81	-83.0	-4.6
140.0	459.2	16.559	61.81	-111.4	-6.1
145.0	475.6	16.186	61.13	-74.6	-4.1
149.7	491.0	16.177	61.12	-1.9	-0.1

LOCATION: BEND AMS, OREGON
16S/14E-17DDD
HOLE NAME: ST HWY 1
DATE MEASURED: 11/25/80

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	12.450	54.41	0.0	0.0
25.0	82.0	12.560	54.61	22.0	1.2
30.0	98.4	12.645	54.76	17.0	0.9
35.0	114.8	12.685	54.83	8.0	0.4
40.0	131.2	12.725	54.90	8.0	0.4
45.0	147.6	12.765	54.98	8.0	0.4
50.0	164.0	12.865	55.16	20.0	1.1
55.0	180.4	12.975	55.35	22.0	1.2
60.0	196.8	13.125	55.62	30.0	1.6
65.0	213.2	13.285	55.91	32.0	1.8
70.0	229.6	13.485	56.27	40.0	2.2
75.0	246.0	13.755	56.76	54.0	3.0
80.0	262.4	14.110	57.40	71.0	3.9
85.0	278.8	14.490	58.08	76.0	4.2
90.0	295.2	14.860	58.75	74.0	4.1
95.0	311.6	15.330	59.59	94.0	5.2
100.0	328.0	15.725	60.31	79.0	4.3
105.0	344.4	16.205	61.17	96.0	5.3
110.0	360.8	16.665	62.00	92.0	5.0
115.0	377.2	17.010	62.62	69.0	3.8
120.0	393.6	17.285	63.11	55.0	3.0
125.0	410.0	17.400	63.32	23.0	1.3
130.0	426.4	17.435	63.38	7.0	0.4
135.0	442.8	17.075	62.74	-72.0	-4.0
140.0	459.2	16.495	61.69	-116.0	-6.4
145.0	475.6	16.170	61.11	-65.0	-3.6
150.0	492.0	16.160	61.09	-2.0	-0.1

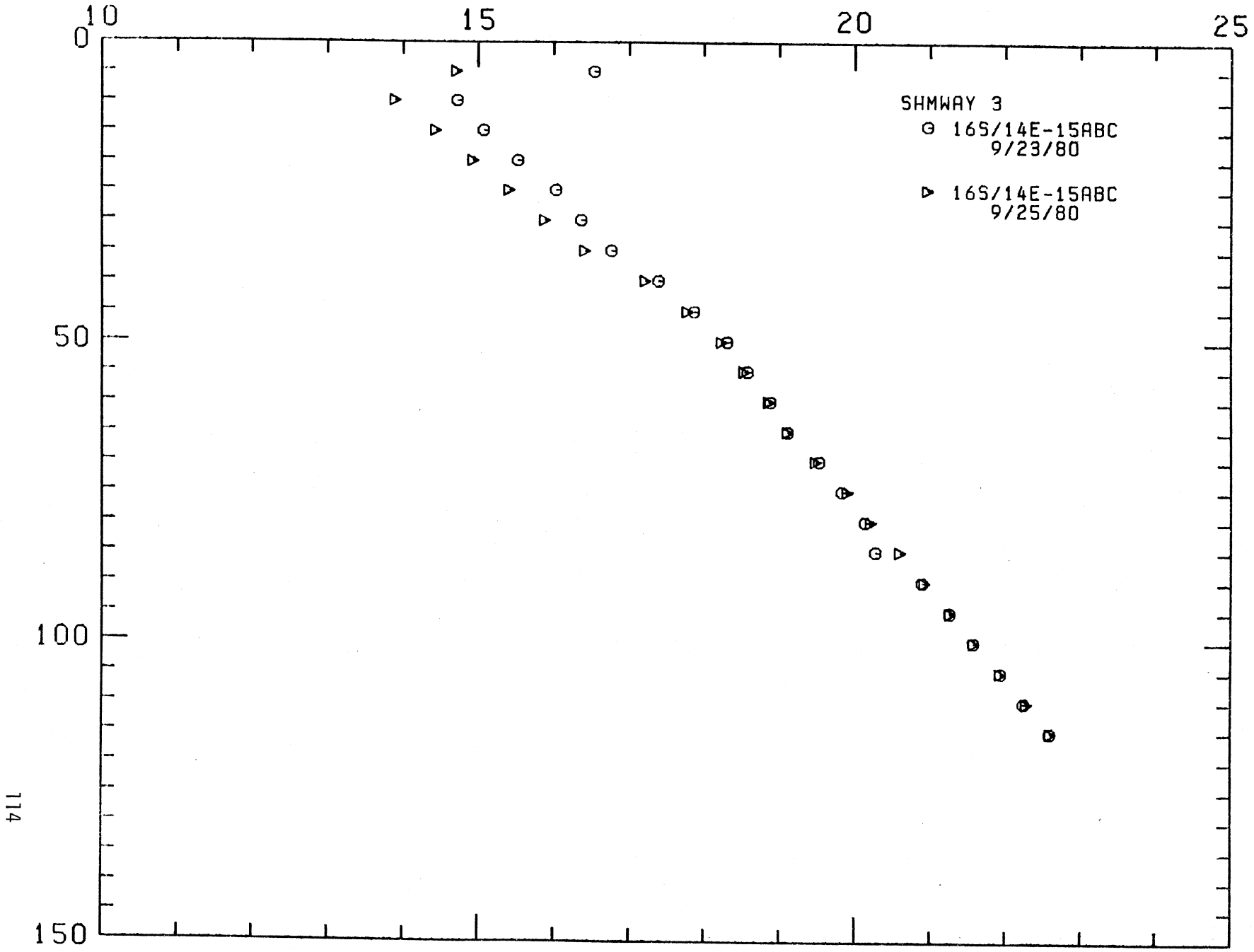

TEMPERATURE, DEG C
0
10
15
20
50
100
DEPTH, METERS
ST HWY 1
16S/14E-17DDD
10/20/80
16S/14E-17DDD
11/25/80

LOCATION: BEND AMS, OREGON
16S/14E-15ABC
HOLE NAME: SHMWAY 3
DATE MEASURED: 9/23/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	16.540	61.77	0.0	0.0
10.0	32.8	14.720	58.50	-364.0	-20.0
15.0	49.2	15.070	59.13	70.0	3.8
20.0	65.6	15.530	59.95	92.0	5.0
25.0	82.0	16.030	60.85	100.0	5.5
30.0	98.4	16.370	61.47	68.0	3.7
35.0	114.8	16.770	62.19	80.0	4.4
40.0	131.2	17.400	63.32	126.0	6.9
45.0	147.6	17.870	64.17	94.0	5.2
50.0	164.0	18.310	64.96	88.0	4.8
55.0	180.4	18.580	65.44	54.0	3.0
60.0	196.8	18.880	65.98	60.0	3.3
65.0	213.2	19.110	66.40	46.0	2.5
70.0	229.6	19.530	67.15	84.0	4.6
75.0	246.0	19.830	67.69	60.0	3.3
80.0	262.4	20.140	68.25	62.0	3.4
85.0	278.8	20.280	68.50	28.0	1.5
90.0	295.2	20.890	69.60	122.0	6.7
95.0	311.6	21.260	70.27	74.0	4.1
100.0	328.0	21.580	70.84	64.0	3.5
105.0	344.4	21.940	71.49	72.0	4.0
110.0	360.8	22.250	72.05	62.0	3.4
115.0	377.2	22.600	72.68	70.0	3.8

LOCATION: BEND AMS, OREGON
16S/14E-15ABC
HOLE NAME: SHMWAY 3
DATE MEASURED: 9/25/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	14.710	58.48	0.0	0.0
10.0	32.8	13.900	57.02	-162.0	-8.9
15.0	49.2	14.440	57.99	108.0	5.9
20.0	65.6	14.940	58.89	100.0	5.5
25.0	82.0	15.420	59.76	96.0	5.3
30.0	98.4	15.890	60.60	94.0	5.2
35.0	114.8	16.420	61.56	106.0	5.8
40.0	131.2	17.230	63.01	162.0	8.9
45.0	147.6	17.780	64.00	110.0	6.0
50.0	164.0	18.240	64.83	92.0	5.0
55.0	180.4	18.540	65.37	60.0	3.3
60.0	196.8	18.860	65.95	64.0	3.5
65.0	213.2	19.110	66.40	50.0	2.7
70.0	229.6	19.490	67.08	76.0	4.2
75.0	246.0	19.910	67.84	84.0	4.6
80.0	262.4	20.220	68.40	62.0	3.4
85.0	278.8	20.600	69.08	76.0	4.2
90.0	295.2	20.930	69.67	66.0	3.6
95.0	311.6	21.270	70.29	68.0	3.7
100.0	328.0	21.590	70.86	64.0	3.5
105.0	344.4	21.940	71.49	70.0	3.8
110.0	360.8	22.290	72.12	70.0	3.8
115.0	377.2	22.610	72.70	64.0	3.5

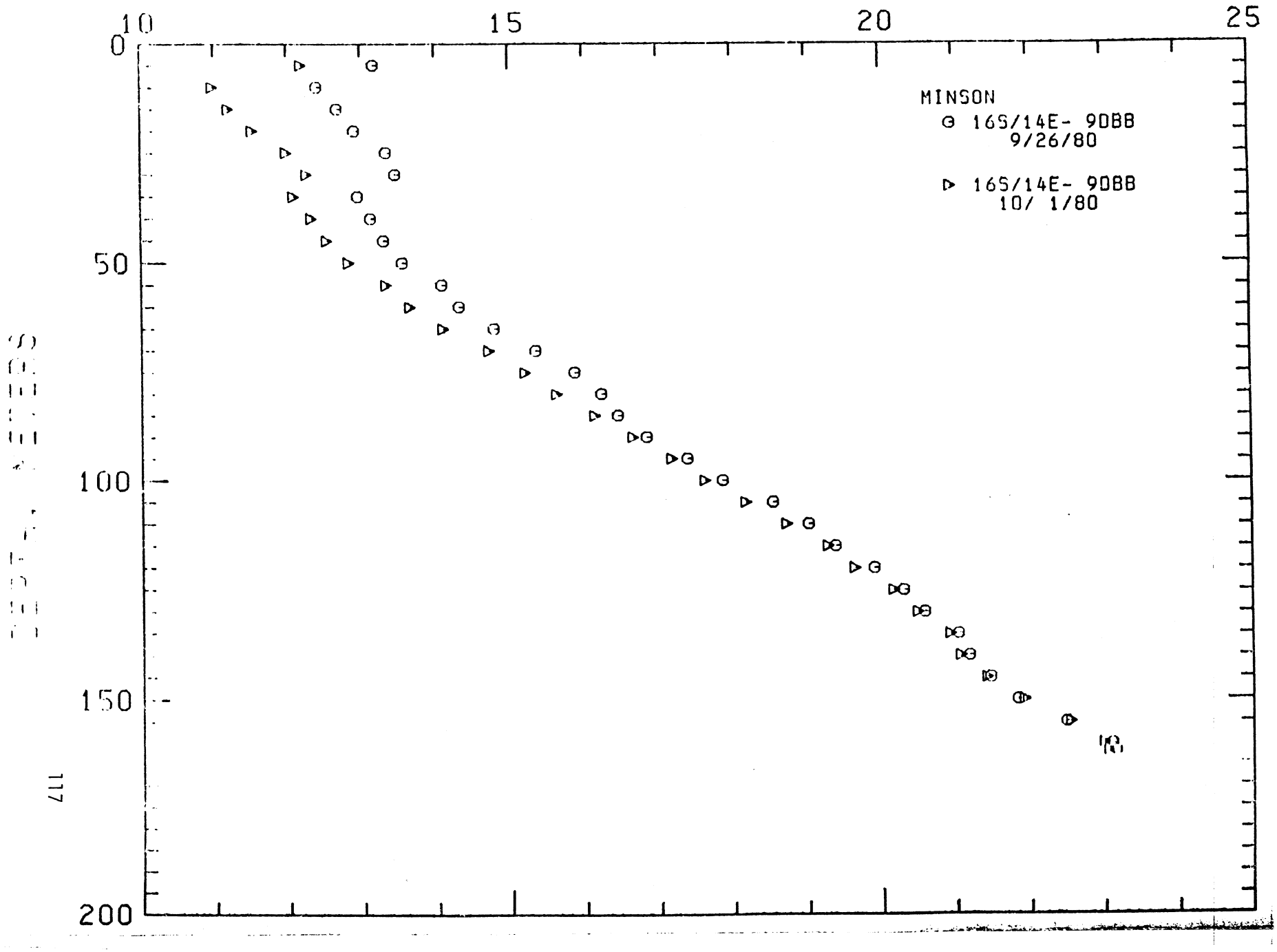

TEMPERATURE, DEG C
10
15
20
25
0
50
100
150
SHMWAY 3
16S/14E-15ABC
9/23/80
16S/14E-15ABC
9/25/80

LOCATION: BEND AMS, OREGON
16S/14E- 9DBB
HOLE NAME: MINSON
DATE MEASURED: 9/26/80

DEPTH METEPS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	13.180	55.72	0.0	0.0
10.0	32.8	12.410	54.34	-154.0	-8.5
15.0	49.2	12.680	54.82	54.0	3.0
20.0	65.6	12.910	55.24	46.0	2.5
25.0	82.0	13.340	56.01	86.0	4.7
30.0	98.4	13.460	56.23	24.0	1.3
35.0	114.8	12.960	55.33	-100.0	-5.5
40.0	131.2	13.130	55.63	34.0	1.9
45.0	147.6	13.300	55.94	34.0	1.9
50.0	164.0	13.550	56.39	50.0	2.7
55.0	180.4	14.080	57.34	106.0	5.8
60.0	196.8	14.310	57.76	46.0	2.5
65.0	213.2	14.780	58.60	94.0	5.2
70.0	229.6	15.340	59.61	112.0	6.1
75.0	246.0	15.860	60.55	104.0	5.7
80.0	262.4	16.220	61.20	72.0	4.0
85.0	278.8	16.450	61.61	46.0	2.5
90.0	295.2	16.830	62.29	76.0	4.2
95.0	311.6	17.380	63.28	110.0	6.0
100.0	328.0	17.850	64.13	94.0	5.2
105.0	344.4	18.530	65.35	136.0	7.5
110.0	360.8	19.010	66.22	96.0	5.3
115.0	377.2	19.370	66.87	72.0	4.0
120.0	393.6	19.890	67.80	104.0	5.7
125.0	410.0	20.290	68.52	80.0	4.4
130.0	426.4	20.570	69.03	56.0	3.1
135.0	442.8	21.020	69.84	90.0	4.9
140.0	459.2	21.170	70.11	30.0	1.6
145.0	475.6	21.450	70.61	56.0	3.1
150.0	492.0	21.820	71.28	74.0	4.1
155.0	508.4	22.480	72.46	132.0	7.2
160.0	524.8	23.090	73.56	122.0	6.7
162.0	531.4	23.140	73.65	25.0	1.4

LOCATION: BEND AMS, OREGON
16S/14E- 9DBB
HOLE NAME: MINSON
DATE MEASURED: 10/ 1/80

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
5.0	16.4	12.200	53.96	0.0	0.0
10.0	32.8	10.990	51.78	-242.0	-13.3
15.0	49.2	11.210	52.18	44.0	2.4
20.0	65.6	11.530	52.75	64.0	3.5
25.0	82.0	12.000	53.60	94.0	5.2
30.0	98.4	12.270	54.09	54.0	3.0
35.0	114.8	12.090	53.76	-36.0	-2.0
40.0	131.2	12.330	54.19	48.0	2.6
45.0	147.6	12.540	54.57	42.0	2.3
50.0	164.0	12.830	55.09	58.0	3.2
55.0	180.4	13.330	55.99	100.0	5.5
60.0	196.8	13.650	56.57	64.0	3.5
65.0	213.2	14.100	57.38	90.0	4.9
70.0	229.6	14.710	58.48	122.0	6.7
75.0	246.0	15.200	59.36	98.0	5.4
80.0	262.4	15.620	60.12	84.0	4.6
85.0	278.8	16.140	61.05	104.0	5.7
90.0	295.2	16.650	61.97	102.0	5.6
95.0	311.6	17.170	62.91	104.0	5.7
100.0	328.0	17.620	63.72	90.0	4.9
105.0	344.4	18.170	64.71	110.0	6.0
110.0	360.8	18.720	65.70	110.0	6.0
115.0	377.2	19.270	66.69	110.0	6.0
120.0	393.6	19.630	67.33	72.0	4.0
125.0	410.0	20.160	68.29	106.0	5.8
130.0	426.4	20.480	68.86	64.0	3.5
135.0	442.8	20.920	69.66	88.0	4.8
140.0	459.2	21.060	69.91	28.0	1.5
145.0	475.6	21.420	70.56	72.0	4.0
150.0	492.0	21.910	71.44	98.0	5.4
155.0	508.4	22.540	72.57	126.0	6.9
160.0	524.8	22.990	73.38	90.0	4.9
162.0	531.4	23.050	73.49	30.0	1.6


TEMPERATURE, DEG C
10
15
20
25
0
50
100
150
200
MINSON
16S/14E- 9DBB
9/26/80
16S/14E- 9DBB
10/ 1/80