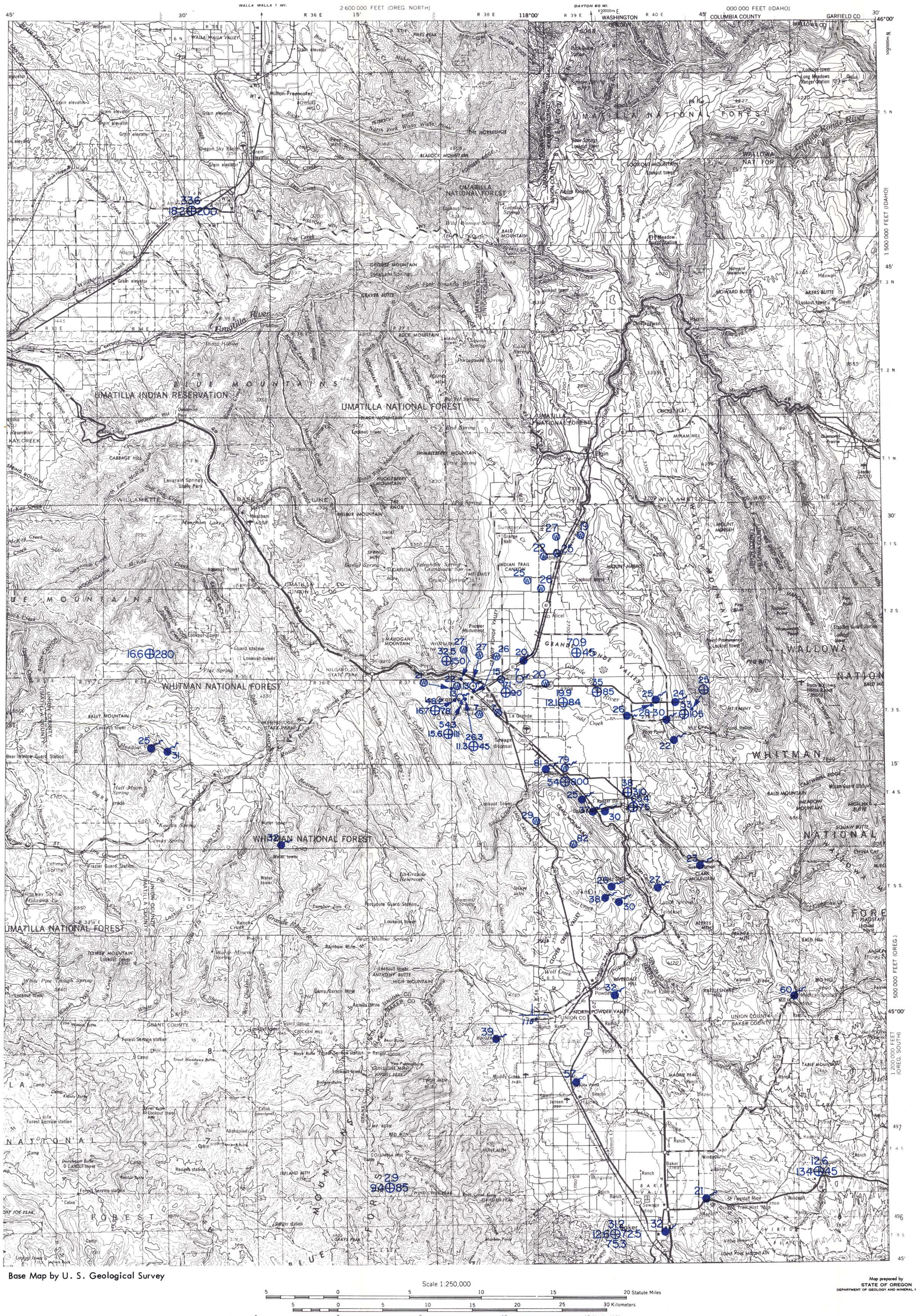
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

OPEN FILE REPORT #0-80-4

PRELIMINARY GEOTHERMAL RESOURCE MAP OF THE CRAIG MOUNTAIN - COVE AREA, OREGON

Compiled by John R. Petros



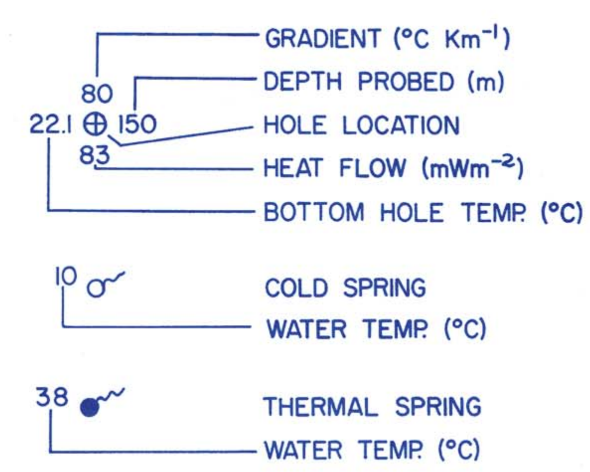
Base Map by U. S. Geological Survey

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

Scale 1:250,000

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

E X P L A N A T I O N



STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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OPEN-FILE REPORT O-80-4

PRELIMINARY GEOLOGY AND GEOTHERMAL RESOURCE POTENTIAL OF THE CRAIG MOUNTAIN-COVE AREA, OREGON

by

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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.

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INTRODUCTION

This reconnaissance study of the Craig Mountain-Cove Area is part of a statewide low-temperature geothermal assessment program funded by U. S. Department of Energy Cooperative Agreement No. DE-FC07-79ET27220 and was initiated to assess the potential for direct-use low-temperature geothermal resources (Figure 1).

The Craig Mountain-Cove Area comprises that part of the Grande Ronde River Basin surrounding the cities of La Grande (pop. 11,140), Union (pop. 2,160), and Cove (pop. 500) which are the main population centers in the study area. The cities are served by a well-developed transportation network which includes U. S. Highway I-84, State Highways 203 and 237, and the Union Pacific main line, which runs southeastward from La Grande toward Baker. Presence of significant transportation facilities and population centers makes this area a logical choice for direct-use geothermal applications.

The topography and climate is typical of the Basin and Range province of eastern Oregon. The area is dominated by the Grande Ronde River Valley which lies at an elevation of 2,700 feet above sea level. Northwest-trending mountain ranges rise abruptly from the Valley floor along steeply dipping fault zones. The climate is semi-arid with annual precipitation between about 13.2 and 22.9 inches and temperature lows of 0^{o} to 20^{o}F in winter and $85^{o}$to 100^{o} F highs in summer.

This study focused on heat flow, geochemistry of ground water, and geological controls of geothermal resources. Heat flow determinations were made by measuring temperature gradients in wells and three shallow exploration holes drilled as part of this study. Geochemical analyses of water samples from springs and wells were utilized to calculate reservoir temperatures. Analysis of the geology yielded information on controls of the geothermal systems at depth.

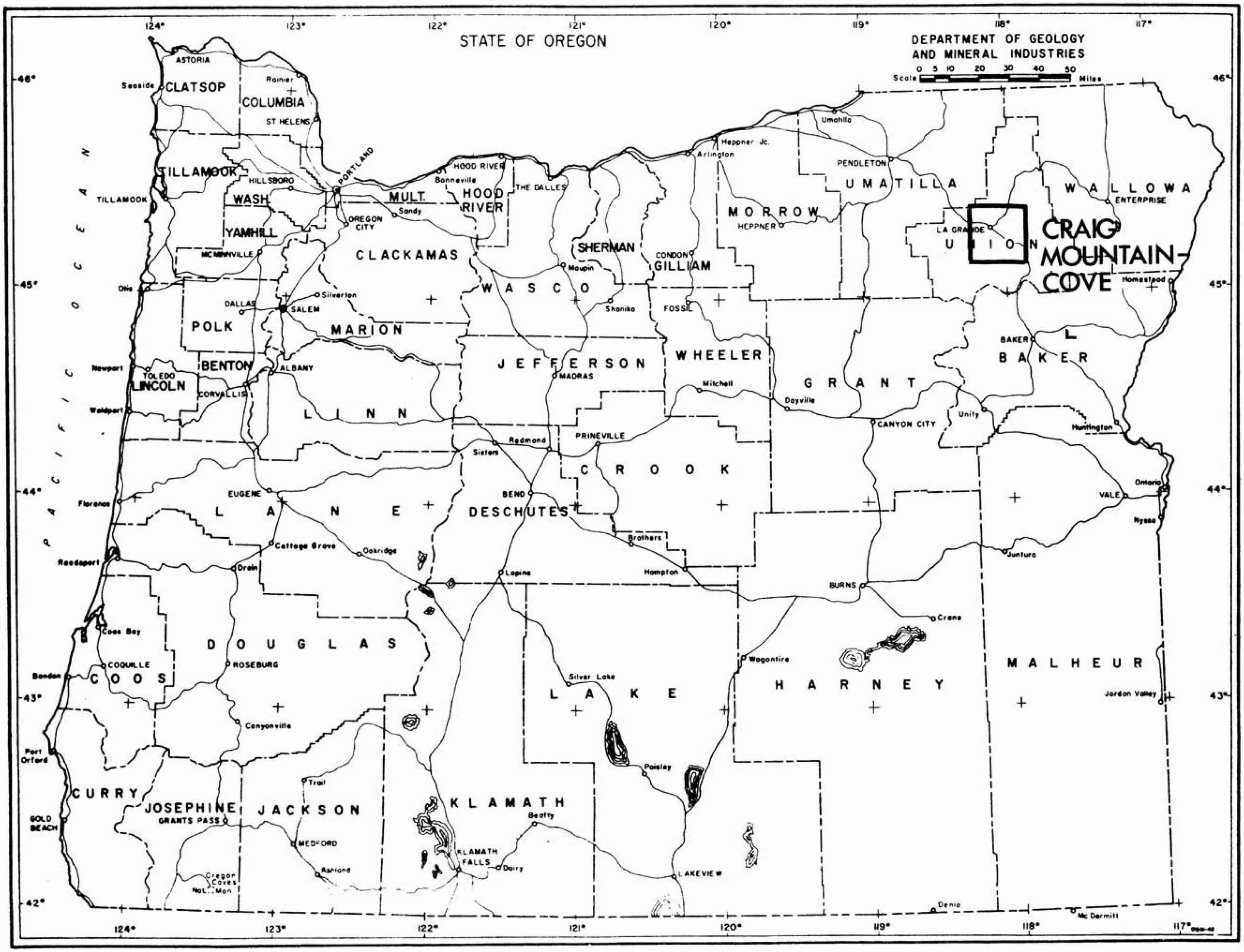

Figure 1: Map showing location of study area.

GEOLOGY

Introduction

The reader is referred to the DOGAMI publication Special Paper 6 by Barrash and others (1980) for a detailed treatment of the geology of the La Grande area. A brief summary of their data is presented herein, and a generalized geologic map from Walker (1977) is presented in Figure 2.

Volcanic stratigraphy

The Grande Ronde Valley graben and adjacent horst blocks are composed of Miocene-age Grande Ronde Basalt of the Columbia River Basalt Group and overlying lavas equivalent in age to the Miocene Wanapum Basalt and Saddle Mountains Basalt. Units above the Grande Ronde Basalt are assigned to the Columbia River Basalt Group but are not invariably basaltic in composition. The Basalt of Glass Hill is composed of glassy andesite (57.28-61.80% SiO_2) and diktytaxitic basalt (50.74-52.13% SiO_2) which directly overlie the Grande Ronde Basalt. The Basalt of Glass Hill is overlain by two roughly time-equivalent andesitic units--the andesite of Mahogany Mountain (66.48% SiO_2) and the andesite of Craig Mountain (61.08% SiO_2).

Structural geology

For a complete summary of the structure and lineaments of the study area, the reader is referred to Barrash and others (1980). Their data are briefly summarized here.

The Craig Mountain-Cove area has undergone broad synclinal folding since the Miocene on a northeasterly trend parallel to the adjacent Blue Mountains anticline. Normal faults cut the broadly folded rocks on a northwesterly trend and generally account for most of the lineaments in the area. The northwest-trending normal faults may be the result of tension developed at right angles to N.35^{O}W. compression which may have created the broad northeasterly folds in

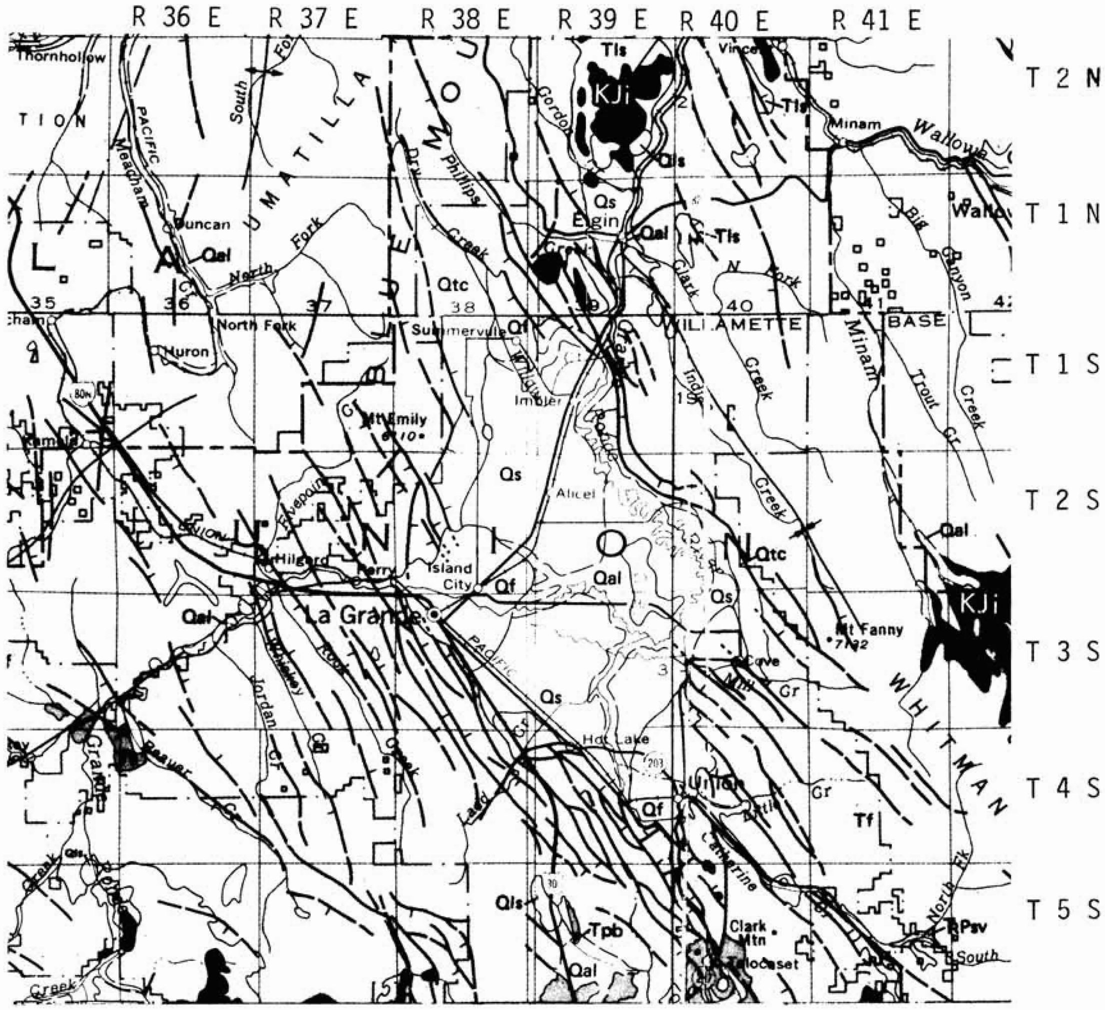

Figure 2. GENERALIZED GEOLOGY OF THE LA GRANDE AREA, OREGON (From G. W. Walker, 1977)

EXPLANATION

Holo.	Qal	Alluvium
Pleist. & Holo.	Qf	Fanglomerate
	Qls	Landslide and debris-flow deposits
	Qtc	Talus and colluvium
Pleist.	Qs	Lacustrine sedimentary
Plio.	Tob	Olivine basalt
	Ts	Tuffaceous sedimentary rocks and tuff
Mio. & Plio.	Tpb	Pyroclastic rocks of basaltic cinder cones
Mio.	Tf	Basalt and andesite flows and breccia
Jur.& Cret.	KJi	Intrusive rocks
Perm. & Tri.	ȣPsv	Sedimentary and volcanic rocks partly metamorphosed
	ȣPv	Volcanic rocks

GEOLOGIC SYMBOLS

Contact
Dashed where approximately located

Syncline

Fault
Dashed where approximately located; dotted where concealed or inferred; bar on downthrown side

SCALE 1:500,000

the area.

Relation of structures to geothermal systems

Barrash and others (1980) point out that currently active geothermal systems are probably controlled by range-front faults bordering the Grande Ronde Valley. Plate I illustrates this relationship very clearly. Nearly all of the thermal wells and springs are located near the break in slope between the Valley and surrounding horst block mountains. Shatter zones adjacent to the faults within both the horst and graben blocks should be attractive geothermal targets.

The Craig Mountain fault system is the most important single structure controlling hot springs. The largest, hottest spring in the area, located at the Hot Lake Resort hot spring, is along the Craig Mountain fault. This spring has a temperature of 85^{o}C (185^{o}F) and a flow of 6435 lpm (1700 gpm) (Barrash and others, 1980). One of the goals of this study was to check Huggins' (1978) hypothesis that faults similar to the Craig Mountain fault may lie under the Valley alluvium at the city of La Grande. Unfortunately, drilling for this study did not conclusively show that a geothermal system equivalent to that at Hot Lake exists at La Grande. The chief reason for this was the shallow depth (55 to 120 m) of holes drilled for this project. Extreme drilling problems associated with broken bedrock and loose alluvium caused all holes to be halted short of their projected 152 m depth. The La Grande Hospital well (3S/38E-7Acc) did, however, intercept highly fractured basalt bedrock under about 32.6 m (107') of alluvium. This highly fractured basalt is probably the shatter zone of the major range front fault on the west side of town. A high (90.7 ^{o}CKm^{-1}) gradient and highly permeable bedrock at the Hospital site were very encouraging. In addition, the hole contained a low temperature (15-21^{o}C, 60-70^{o}F) geothermal aquifer which flowed about 114 lpm (30 gpm). This site and other sites along known and projected extensions of faults should be investigated with intermediate depth (2,000') holes and special drilling techniques to overcome the caving problems.

GEOPHYSICS

No geophysical studies are available in the public domain to delineate subsurface structures in this highly important area. Specific recommendations are made under the Conclusions and Recommendations section of this report.

WATER CHEMISTRY

During the period of this study, twenty-five thermal wells and springs were sampled and their waters analyzed, bringing to seventy-five the number of analyses available for evaluation (Table 1). These analyses were then used to calculate minimum reservoir temperatures (Table 2). The methodology used in these calculations is presented, together with references used, in Appendix A.

Several studies have been performed on the thermal waters of the Craig Mountain-Cove Area (Dellechaie, 1975, and Huggins, 1978) and the reader is directed to them for a detailed discussion. A generalized summary of these studies is as follows:

1. The thermal waters tend to be neutral to basic, low in total dissolved solids, with sodium and chloride as principal ions ($Cl>HCO_3>SO_4$;$NA>Ca>K>Mg$).
2. Silica content (SiO_2) is probably controlled by chalcedony, since no major amounts of silicic quartz-bearing rocks are known in the area. Chalcedony veins are, however, common.
3. Chalcedony and 4/3 β Na:K:Ca (probably best estimations) geothermometers indicate reservoir temperatures probably do not exceed the 100^{o}-$125^{o}C$ range. The highest calculated reservoir temperatures are for springs and wells situated near the graben-bounding faults.

Table 1. Spring and well chemistry of the Craig Mountain-Cove area. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	DOGAMI Drill Hole #2	Island City Well	Union Pacific RR Well #1	Union Pacific RR Well #2	Union Pacific RR Well #1
Location	3S/38E/ 7Ad	3S/38E/ 3Ab	3S/38E/ 5Cb	3S/38E/ 5Cb	3S/38E/ 5Cb
Date sampled	12/79	12/79	/77	/77	12/79
Temp. (^{o} C)	7.2	15	27	26	25.5
pH	8.5	7.9	6.2	nt	8.2
Conductance μmhos/cm	172	156	nt	nt	129
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	83_c	72_c	nt	nt	60_c
Hardness as mg/l $CaCO_3$	53	45	nt	nt	15
Total dissolved solids	821	140	nt	nt	160
SiO_2	48.4	56.6	61	60	84
Na	14.6	13.7	10.4	17.0	19.4
K	6.4	5.0	3.2	3.2	5.7
Ca	22.6	10.5	5.7	5.4	5.4
Mg	6.77	4.56	0.40	0.60	0.39
Cl	1.2	1.1	12.5	50.0	0.9
As	<0.005	<0.005	nt	nt	<0.005
B	<0.20	<0.20	nt	nt	<0.20
Li	0.02	<0.01	nt	nt	0.01
F	0.3	0.2	nt	nt	0.1
Fe (total)	15.5	<0.05	nt	nt	<0.05
Al	13.60	<0.05	nt	nt	<0.05
HCO_3	nt	nt	70	80	nt
PO_4	0.044	0.128	nt	nt	0.016
SO_4	2.9	3.8	1	1	3.9
NO_3	0.16	0.06	nt	nt	0.02
NH_3	0.07	0.03	nt	nt	0.05

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Union Pacific RR Well #2	Starkey Warm Spring	Cooper Warm Spring	Meadow Creek Warm Spring	Flagstaff Point Springs
Location	3S/38E/ 5Cb	4S/36E/ 31Cb	5S/40E/ 12Ba	3S/34E/ 27Cd	9S/40E/ 1Ac
Date sampled	12/79	/77	/77	/77	/77
Temp. (^{o} C)	26.1	32	23	25	21
pH	8.4	9.2	6.8	6.2	7.5
Conductance µmhos/cm	143	nt	nt	nt	nt
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	67_c	nt	nt	nt	nt
Hardness as mg/l $CaCO_3$	11	nt	nt	nt	nt
Total dissolved solids	154	nt	nt	nt	nt
SiO_2	80.4	56	53	50	50
Na	23.6	17.0	42.0	22.0	169.6
K	6.1	10.0	1.6	1.1	2.9
Ca	5.0	2.5	1.8	4.5	4.8
Mg	0.62	0.25	0.20	0.20	4.4
Cl	0.9	25.0	25.0	12.5	37.5
As	<0.005	nt	nt	nt	nt
B	<0.20	nt	nt	nt	nt
Li	0.01	nt	nt	nt	nt
F	0.7	nt	nt	nt	nt
Fe (total)	<0.05	nt	nt	nt	nt
Al	<0.05	nt	nt	nt	nt
HCO_3	nt	20	15	80	300
PO_4	0.026	nt	nt	nt	nt
SO_4	2.4	3	17	1	1
NO_3	0.03	nt	nt	nt	nt
NH_3	0.11	nt	nt	nt	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Unnamed spring	Unnamed spring	Wagner Well	Wagner Well	Wagner Well	City well #2
Location	3S/38E/ 7Ac	3S/38E/ 5	4S/38E/ 24Dd	1S/38E/ 24Dd	1S/38E/ 24Dd	3S/38E/ 6Ad
Date sampled	12/79	12/79	8/50	/77	4/80	/77
Temp. (^{o} C)	13.3	13.3	29	32	31	22
pH	7.8	7.7	8.0	6.0	8.5	6.4
Conductance µmhos/cm	149	182	148	nt	145	nt
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	70_c	86_c	nt	nt	55_c	nt
Hardness as mg/l $CaCO_3$	47	30	nt	nt	10	nt
Total dissolved solids	294	222	nt	nt	154	nt
SiO_2	46.6	74	nt	46	88	44
Na	13.0	28.2	28	16	24.8	10.4
K	4.7	5.7	4.0	3.0	5.4	2.8
Ca	12.3	5.9	3.6	3.6	2.2	9.0
Mg	3.88	2.79	0.8	0.20	<0.1	0.50
Cl	1.1	2.0	3.1	12.5	1.4	12.5
As	<0.005	0.007	nt	nt	<0.005	nt
B	<0.20	<0.20	0.1	nt	<0.2	nt
Li	<0.01	<0.01	nt	nt	<0.1	nt
F	0.2	0.4	2.0	nt	1.5	nt
Fe (total)	13.9	1.5	nt	nt	<0.05	nt
Al	8.20	1.5	nt	nt	<0.1	nt
HCO_3	nt	nt	62	40	nt	60
PO_4	0.022	0.217	nt	nt	0.017	nt
SO_4	2.1	2.4	8.3	5	6.1	2
NO_3	0.05	0.04	0.2	nt	<0.02	nt
NH_3	0.03	0.16	nt	nt	0.05	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	City well south of La Grande	City well La Grande	Girdner Warm Spring	Girdner Warm Spring	Cropp Hot Spring	Cropp Hot Spring
Location	NE corner of 20th & Leckler		3S/40E/ 27Ac	3S/40E/ 27Bc	6S/39E/ 25Ba	6S/39E/ 25Ba
Date sampled	12/79	12/79	/77	4/80	11/72	/77
Temp. (^{o} C)	5.5	22.2	22	22.2	43	32
pH	7.8	8.3	7.0	9.0	7.3	nt
Conductance µmhos/cm	181	140	nt	133	445	nt
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	89_c	67_c	nt	54_c	43_c	nt
Hardness as mg/l $CaCO_3$	61	24	nt	<1	nt	nt
Total dissolved solids	137	161	nt	121	392	nt
SiO_2	57	72.2	33	58.7	58	59
Na	13.3	18.7	27	27	93	107.2
K	4.0	5.1	2.7	2.0	1.5	1.9
Ca	14.0	8.5	1.3	0.5	1.1	4.6
Mg	6.5	0.55	0.2	<0.1	0.1	0.2
Cl	1.1	0.9	25.0	3.1	81	12.5
As	<0.005	<0.005	nt	<0.006	<0.005	nt
B	nt	<0.2	nt	<0.2	3.3	nt
Li	<0.01	<0.01	nt	<0.1	<0.1	nt
F	0.3	0.4	nt	0.2	1.2	nt
Fe (total)	0.09	0.06	nt	<0.05	<0.03	nt
Al	<0.05	<0.05	nt	<0.1	0.04	nt
HCO_3	nt	nt	30	nt	nt	20
PO_4	0.113	0.018	nt	0.043	nt	nt
SO_4	3.7	3.8	4	6.6	32	11
NO_3	0.03	0.02	nt	<0.02	nt	nt
NH_3	0.04	0.06	nt	0.02	0.15	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Warm Creek Springs	Warm Creek Springs	Cove Bath House Warm Spring	Cove (Swimming Pool) Hot Spring	Cove (Swimming Pool) Hot Spring
Location	9S/40E/ 9Ca	3S/40E/ 9Ca	3S/40E/22Bb	3S/40E/22Bb	3S/40E/22Bb
Date sampled	/77	4/80	6/57	/77	4/80
Temp. (^{o} C)	27	25	29.4	29	30
pH	6.0	9.3	9.8	9.8	9.7
Conductance µmhos/cm	nt	121	150	nt	157
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	45_c	nt	nt	55_c
Hardness as mg/l $CaCO_3$	nt	12	nt	nt	5
Total dissolved solids	nt	95	109	nt	114
SiO_2	50	34.7	29	10	38.7
Na	107.2	21.8	30	66	28.8
K	1.0	0.8	0.5	0.4	0.6
Ca	2.0	2.4	1.6	1.4	1.9
Mg	0.25	0.2	nt	0.2	<0.1
Cl	50	3.8	5.0	25.0	4.5
As	nt	<0.005	nt	nt	0.006
B	nt	<0.2	0.08	nt	<0.2
Li	nt	<0.1	nt	nt	<0.1
F	nt	0.1	0.3	nt	0.1
Fe (total)	nt	0.09	nt	nt	0.05
Al	nt	0.22	nt	nt	0.16
HCO_3	nt	nt	5	20	nt
PO_4	nt	0.012	nt	nt	0.008
SO_4	9	5.5	8.8	5	8.3
NO_3	nt	0.06	nt	nt	<0.02
NH_3	nt	0.02	nt	nt	0.03

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Cove Bath House Spring	Cove Bath House Spring	Unnamed spring	Medical Hot Springs	Medical Hot Springs
Location	3S/40E/ 22Bb	3S/40E/ 22Bb	3S/38E/ 2Aa	6S/41E/ 25Ad	6S/41E/ 25Ad
Date sampled	/77	4/80	1/80	/73	/74
Temp. (^{o} C)	29	28.8	7.2	60	60
pH	6.2	9.6	7.8	8.23	nt
Conductance µmhos/cm	nt	149	124	1173	nt
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	50_c	59_c	nt	nt
Hardness as mg/l $CaCO_3$	nt	6	40	nt	nt
Total dissolved solids	nt	110	129	nt	896
SiO_2	47	35.3	56.2	80	97
Na	22.4	28	10.4	190	191
K	0.7	0.5	3.4	7.0	3.4
Ca	3.4	1.7	9.6	72	62
Mg	0.1	<0.1	2.7	0.2	1.2
Cl	12.5	4.3	0.7	77	77
As	nt	0.005	<0.005	nt	nt
B	nt	<0.2	<0.2	2.2	nt
Li	nt	<0.1	<0.01	0.05	nt
F	nt	0.1	0.2	1.2	nt
Fe (total)	nt	0.12	0.08	<0.02	nt
Al	nt	0.24	0.09	nt	nt
HCO_3	nt	nt	nt	26	nt
PO_4	nt	0.014	0.033	nt	nt
SO_4	5	8.1	2.3	400	432
NO_3	nt	<0.02	0.4	nt	nt
NH_3	nt	0.02	0.02	nt	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Medical Hot Springs	Radium Hot Springs	Radium Hot Springs	Radium Hot Springs	Creston Shaw Well	Boise Cascade Well
Location	6S/41E/ 25Ad	7S/39E/ 28A	7S/39E/ 28A	7S/39E/ 28A	1S/39E/ 31Dd	2S/38E/ 26Dd
Date sampled	/77	5/55	/72	/77	/77	/77
Temp. (^{o} C)	60	57.2	58	57	26	20
pH	6.2	9.7	9.56	7.0	6.2	6.2
Conductance µmhos/cm	nt	290	290	nt	nt	nt
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 $CaCO_3$	nt	nt	nt	nt	nt	nt
Total dissolved solids	nt	244	nt	nt	nt	nt
SiO_2	61	80	78	48	46	46
Na	200	63	58	56	20	22
K	3.9	2.0	1.1	0.8	3.1	2.5
Ca	56	1.6	1.5	3.1	1.5	5.5
Mg	0.25	nt	0.1	0.2	0.3	0.45
Cl	150	17	17	12.5	12.5	12.5
As	nt	nt	<0.01	nt	nt	nt
B	nt	nt	0.42	nt	nt	nt
Li	0.06	nt	0.01	nt	nt	nt
F	nt	1	1.3	nt	nt	nt
Fe (total)	nt	nt	<0.02	nt	nt	nt
Al	nt	nt	nt	nt	nt	nt
HCO_3	25	5	86	25	40	50
PO_4	nt	nt	0.092	nt	nt	nt
SO_4	385	31	34	23	1	1
NO_3	nt	0.2	nt	nt	nt	nt
NH_3	nt	nt	nt	nt	nt	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Elwyn Bingaman Well	Clayton Fox Well	Norm Woodell Well	Hunters Spring	Unnamed well	Unnamed well
Location	1S/39E/ 20Bd	1S/39E/ 20Bd	1S/38E/ 36Aa	3S/34E/ 35Ab	3S/38E/ 5Ca	3S/38E/ 5Ca
Date sampled	/77	/77	/77	/77	1/55	1/55
Temp. (^{o} C)	24.5	26	24.6	31	27	25
pH	6.4	6.2	6.2	6.4	7.9	7.9
Conductance µmhos/cm	nt	nt	nt	nt	nt	nt
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	nt	nt	nt	nt	63_h
Hardness as mg/l $CaCO_3$	nt	nt	nt	nt	nt	nt
Total dissolved solids	nt	nt	nt	nt	nt	nt
SiO_2	46	63	60	93	84	72
Na	24	26	20	14	27	30
K	2.7	5.6	3.1	1	5	5
Ca	1.3	2.5	1.3	2.5	5	4.8
Mg	0.5	0.1	0.2	0.1	0.3	1.3
Cl	12.5	12.5	12.5	25	3.2	2.1
As	nt	nt	nt	nt	nt	nt
B	nt	nt	nt	nt	nt	nt
Li	nt	nt	nt	nt	nt	nt
F	nt	nt	nt	nt	0.5	0.5
Fe (total)	nt	nt	nt	nt	nt	nt
Al	nt	nt	nt	nt	nt	nt
HCO_3	70	50	55	60	nt	nt
PO_4	nt	nt	nt	nt	nt	nt
SO_4	1	1	1	1	3.3	4.8
NO_3	nt	nt	nt	nt	nt	nt
NH_3	nt	nt	nt	nt	nt	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Unnamed well	Unnamed well	Unnamed well	Doyle Eisminger Well	Hot Lake Resort Spring
Location	3S/38E/ 6Ac	3S/38E/ 15Ca	3S/38E/ 16Cb	1S/39E/ 9Cc	4S/39E/ 5Db
Date sampled	5/57	1/80	1/80	4/80	/72
Temp. (^{o} C)	27	7.2	7.2	19	80
pH	nt	7.7	8.2	8.1	9.21
Conductance µmhos/cm	146	349	326	145	688
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	84_c	183_c	156	62_c	nt
Hardness as mg/l $CaCO_3$	nt	1	134	20	nt
Total dissolved solids	nt	263	237	130	nt
SiO_2	71	53.4	60.6	70.1	48
Na	19	86.1	16.4	21.8	130
K	5	1.2	5.3	5.3	2.7
Ca	10	0.81	35.3	5.8	4.9
Mg	0.2	0.18	9.35	0.1	<0.1
Cl	1	1.8	2.6	0.7	140
As	nt	<0.005	<0.005	<0.005	0.01
B	nt	<0.2	nt	<0.2	2.9
Li	nt	<0.01	<0.01	<0.1	0.03
F	0.5	0.2	0.2	0.6	1.7
Fe (total)	nt	0.21	0.11	<0.05	<0.02
Al	nt	<0.05	<0.05	<0.1	nt
HCO_3	nt	nt	nt	nt	75
PO_4	nt	0.131	0.035	0.012	0.09
SO_4	4.5	1.1	4.4	4.8	56
NO_3	nt	<0.02	2	<0.02	nt
NH_3	nt	0.02	<0.02	0.04	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Hot Lake Resort Spring	Hot Lake Resort Spring	Hot Lake Courtwright Well	Hot Lake Courtwright Well	Royce Well
Location	4S/39E/ 5Db	4S/39E/ 5Db	4S/39E/ 4Cc	4S/39E/ 4Cc	1S/39E/ 17Bb
Date sampled	/77	4/80	/77	/77	4/80
Temp. (^{o} C)	85	81	79	67	26.6
pH	9.8	9.3	9.8	9.4	8.6
Conductance µmhos/cm	nt	703	nt	725	148
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	61_c	nt	65_c	60_c
Hardness as mg/l $CaCO_3$	nt	15	nt	18	12
Total dissolved solids	nt	450	nt	473	142
SiO_2	11	84	61	82.9	71.5
Na	130	142.4	119	145.6	122
K	2.1	2.8	1.6	2.6	5.4
Ca	4.7	4.9	4.2	4.4	3.3
Mg	0.2	<0.1	0.2	<0.1	<0.1
Cl	237.5	132	237.5	135	1
As	nt	0.009	nt	0.009	<0.005
B	2.9	nt	2.8	nt	<0.2
Li	0.06	<0.1	0.03	<0.1	<0.1
F	nt	1.5	nt	1.6	1.1
Fe (total)	nt	<0.05	nt	<0.05	<0.05
Al	nt	0.13	nt	0.14	<0.1
HCO_3	20	nt	5	nt	nt
PO_4	nt	0.009	nt	0.009	0.021
SO_4	49	1.4	35	47.5	5.5
NO_3	nt	<0.36	nt	<0.15	<0.05

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Grange Hall Spring	Grange Hall Spring	Hoofnagle Warm Spring	Hoofnagle Spring	Duck Pond Spring	Duck Pond Spring
Location	3S/40E/ 9Cc	3S/40E/ 9Cc	3S/40E/ 10Dc	3S/40E/ 10Dc	4S/39E/ 15Db	4S/39E/ 15Db
Date sampled	/77	4/80	/77	4/80	/77	4/80
Temp. (^{o} C)	26	26	24	24	26	25
pH	6	8.7	6.2	9.1	6.4	8.5
Conductance µmhos/cm	nt	114	nt	121	nt	232
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	46_c	nt	45_c	nt	66_c
Hardness as mg/l $CaCO_3$	nt	16	nt	10	nt	15
Total dissolved solids	nt	95	nt	96	nt	177
SiO_2	61	37.9	44	37.5	44	55.7
Na	22	22.8	14.4	22.6	42	39.2
K	3	0.8	1.5	1.2	2.2	2.3
Ca	2.5	2.2	3.9	2.5	4	3.9
Mg	0.2	<0.1	0.2	<0.1	0.25	0.2
Cl	25	3.5	25	3.6	37.5	14.9
As	nt	<0.005	nt	0.005	nt	0.015
B	nt	<0.2	nt	<0.2	nt	0.5
Li	nt	<0.1	nt	<0.1	nt	<0.1
F	nt	0.1	nt	0.1	nt	0.6
Fe (total)	nt	<0.05	nt	<0.05	nt	<0.05
Al	nt	<0.1	nt	<0.1	nt	0.12
HCO_3	15	nt	35	nt	50	nt
PO_4	nt	0.014	nt	0.018	nt	0.017
SO_4	3	5.8	2	5.5	12	14.4
NO_3	nt	0.03	nt	0.09	nt	0.34
NH_3	nt	0.02	nt	0.03	nt	0.02

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Sam -O- Spring	Sam -O- Spring	Fisher Hot Spring	Fisher Hot Spring	Union Junction Warm Spring #1
Location	9S/40E/ 16Da	9S/40E/ 16Da	7S/38E/ 10Ba	7S/38E/ 10Ba	4S/39E/22Da
Date sampled	/77	2/77	6/72	/77	/77
Temp. (^{o} C)	32	27	37	39	37
pH	6.5	8.1	9.8(?)	6.8	6.2
Conductance μmhos/cm	nt	891	197	nt	nt
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	nt	425_c	68_c	nt	nt
Hardness as mg/l $CaCO_3$	nt	nt	nt	nt	nt
Total dissolved solids	nt	595	143	nt	nt
SiO_2	50	68	39	42	44
Na	209.6	171	40	28.8	105
K	6	12	nt	0.5	2.2
Ca	17	16	1.4	3.1	4.2
Mg	10.7	6	<0.1	0.1	1.2
Cl	37.5	16	1.8	12.5	125
As	nt	<0.005	<0.005	nt	nt
B	nt	1.6	2.8	nt	nt
Li	0.06	0.06	1	nt	0.03
F	nt	1.2	0.4	nt	nt
Fe (total)	nt	<0.1	<0.03	nt	nt
Al	nt	0.43	0.07	nt	nt
HCO_3	435	nt	nt	15	60
PO_4	nt	0.09	nt	nt	nt
SO_4	3	0.7	12	11	38
NO_3	nt	nt	nt	nt	nt
NH_3	nt	0.5	nt	nt	nt

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Union Junction Warm Spring #1	Union Junction Warm Spring #2	Union Junction Warm Spring #2	Barstad Hot Well
Location	4S/39E/22Da	4S/39E/23Ca	4S/39E/23Ca	4S/39E/33Dc
Date sampled	4/80	/77	4/80	6/74
Temp. (^{o} C)	37	29	30	81.5
pH	8.1	6.8	8.4	9.6
Conductance µmhos/cm	465	nt	464	nt
Alkalinity X_h as mg/l HCO_3 X_c as mg/l $CaCO_3$	58_c	nt	64c	nt
Hardness as mg/l $CaCO_3$	21	nt	21	nt
Total dissolved solids	311	nt	306	511
SiO_2	77.8	44	64.8	107
Na	74.6	95	74.2	136
K	3.5	1.9	2.6	2.5
Ca	5	6	6	3
Mg	1.1	1	0.8	<0.1
Cl	59	112.5	59	137
As	0.063	nt	0.057	nt
B	1.5	nt	1.5	3
Li	<0.1	0.06	0.1	0.03
F	1.2	nt	1.1	2.39
Fe (total)	<0.05	nt	0.05	<0.1
Al	<0.1	nt	0.13	nt
HCO_3	nt	50	nt	6
PO_4	0.055	nt	0.040	nt
SO_4	41.4	37	40	60
NO_3	0.42	nt	0.35	nt
NH_3	0.02	nt	0.03	1.2

Table 1. Spring and well chemistry of the Craig Mountain-Cove area--Continued. All measurements are in mg/l, except for pH or as indicated. nt = not tested; tr = trace.

	Sweet Water Warm Spring	Oasis Warm Spring	Bennett Warm Spring	Baker Warm Spring	Haystack Warm Spring	Cemetary Artesian Well
Location	5S/39E/23A	5S/39E 24D	5S/40E/ 16E	5S/40E/ 16Ca	5S/39E/ 13Dd	1S/39E/ 19
Date sampled	6/74	6/74	6/74	6/74	6/74	6/74
Temp. (^{o} C)	38	29.5	27	26	25.5	21.5
pH	8.6	8.7	9.7	7.89	9.1	9.5
Conductance μmhos/cm	nt	nt	nt	nt	nt	nt
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 $CaCO_3$	nt	nt	nt	nt	nt	nt
Total dissolved solids	nt	337	233	243	217	151
SiO_2	84	78	61	54	70	20
Na	84	80	56	62	45	41
K	3.4	2.7	0.9	0.3	3	1.4
Ca	4	4	0.8	2	2	1
Mg	1	1	<0.1	<0.1	0.2	0.1
Cl	64	62	36.1	26.9	19.2	2.6
As	nt	nt	nt	nt	nt	nt
B	1.8	<1	<1	<1	<1	<1
Li	0.04	0.05	0.01	<0.01	0.01	0.01
F	2.62	2.07	0.43	0.47	1.2	0.65
Fe (total)	<0.1	0.4	0.2	0.2	<0.1	<0.1
Al	nt	nt	nt	nt	nt	nt
HCO_3	56	64	19	85	65	78
PO_4	nt	nt	nt	nt	nt	nt
SO_4	46	42	15	10	11	5
NO_3	nt	nt	nt	nt	nt	nt
NH_3	nt	nt	0.21	nt	nt	nt

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area.

	DOGAMI Drill Hole #2 '79	Island City Well '79	Union Pacific RR Well #1 '77	Union Pacific RR Well #2 '77	Union Pacific RR Well #1 '79
Flow rate liters/min.	nc	nc	379	284	379
Measured temperature °C	7.2	15	27	26	25.5
Na:K °C	314	292	274	226	269
Na:K:Ca 1/3 β °C	218	213	203	185	214
Na:K:Ca 4/3 β °C	61	68	64	71	91
Na:K:Ca Mg corrected °C	93	70	194	151	210
SiO_2 conductive °C	100	108	111	110	128
SiO_2 adiabatic °C	101	108	111	110	125
SiO_2 chalcedony °C	70	78	82	81	100
SiO_2 opal °C	-15	-9	-6	-6	8

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Union Pacific RR Well #2 '79	Starkey Warm Spring '77	Cooper Warm Spring '77	Meadow Creek Warm Spring '77	Flagstaff Point Spring '77
Flow rate liters/min.	284	30	19	68	19
Measured temperature °C	26.1	32	23	25	21
Na:K °C	256	352	115	131	76
Na:K:Ca 1/3 β °C	211	268	131	127	110
Na:K:Ca 4/3 β °C	98	131	82	46	96
Na:K:Ca Mg corrected °C	168	302	110	107	77
SiO_2 conductive °C	125	107	104	102	102
SiO_2 adiabatic °C	123	107	105	103	103
SiO_2 chalcedony °C	97	78	75	72	72
SiO_2 opal °C	6	-9	-12	-14	-14

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Unnamed spring '79	Unnamed spring '79	Wagner Well '50	Wagner Well (Artesian) '77	Wagner Well '80
Flow rate liters/min.	nc	nc	pumped	380	pumped
Measured temperature °C	13.3	13.3	29	32	31
Na:K °C	291	232	202	225	239
Na:K:Ca 1/3 β °C	210	198	183	187	210
Na:K:Ca 4/3 β °C	63	93	92	76	114
Na:K:Ca Mg corrected °C	84	63	102	190	nc
SiO_2 conductive °C	98	121	nc	98	130
SiO_2 adiabatic °C	100	119	nc	99	127
SiO_2 chalcedony °C	68	93	nc	68	103
SiO_2 opal °C	-17	3	nc	-17	11

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	City Well #2 '77	City well south of La Grande '79	City Well La Grande '79	Girdner Warm Spring '77	Girdner Warm Spring '80
Flow rate liters/min.	1050	nc	1400	76	76
Measured temperature °C	22	5.5	22.2	22	22.2
Na:K °C	260	271	261	175	155
Na:K:Ca 1/3 β °C	191	198	204	172	165
Na:K:Ca 4/3 β °C	52	56	77	102	115
Na:K:Ca Mg corrected °C	207	50	201	125	nc
SiO_2 conductive °C	96	108	120	83	109
SiO_2 adiabatic °C	97	108	118	86	109
SiO_2 chalcedony °C	66	79	91	52	80
SiO_2 opal °C	-19	-7	1	-30	-7

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Cropp Hot Spring '72	Cropp Hot Spring '77	Warm Creek Spring '77	Warm Creek Spring '80	Cove Warm Spring '57
Flow rate liters/min.	19	19	950	950	1137
Measured temperature ^{o}C	43	32	27	25	29.4
Na:K ^{o}C	74	78	52	113	75
Na:K:Ca 1/3 β ^{o}C	110	106	88	118	95
Na:K:Ca 4/3 β ^{o}C	100	77	74	48	46
Na:K:Ca Mg corrected ^{o}C	nc	nc	nc	110	nc
SiO_2 conductive ^{o}C	109	110	102	85	78
SiO_2 adiabatic ^{o}C	109	109	103	88	82
SiO_2 chalcedony ^{o}C	79	80	72	54	47
SiO_2 opal ^{o}C	-8	-7	-14	-28	-34

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

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Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Radium Hot Spring '72	Radium Hot Spring '77	Creston Shaw Well '77	Boise Cascade Well '77	Elwyn Bingamin Well '77	Clayton Fox Well '77
Flow rate liters/min.	1136	1136	>10,000	1136	>190	4732
Measured temperature ^oC	58	57	26	20	24.5	26
Na:K ^oC	81	69	209	185	184	238
Na:K:Ca 1/3 β ^oC	108	93	189	163	176	209
Na:K:Ca 4/3 β ^oC	77	52	100	65	101	113
Na:K:Ca Mg corrected ^oC	nc	nc	125	139	84	224
SiO_2 conductive ^oC	124	100	98	98	98	113
SiO_2 adiabatic ^oC	121	101	99	99	99	112
SiO_2 chalcedony ^oC	96	70	68	68	68	84
SiO_2 opal ^oC	5	-16	-17	-17	-17	-4

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Norman Woodell Well '77	Hunter's Spring '77	Unnamed well '55	Unnamed well '55	Unnamed well '57	Unnamed well '80
Flow rate liters/min.	3400	>38	nc	nc	nc	nc
Measured temperature °C	24.6	31	27	25	27	7.2
Na:K °C	209	152	224	215	257	68
Na:K:Ca 1/3 β °C	190	140	193	190	200	105
Na:K:Ca 4/3 β °C	104	50	92	94	73	98
Na:K:Ca Mg corrected °C	149	149	192	93	247	nc
SiO_2 conductive °C	110	133	128	120	119	105
SiO_2 adiabatic °C	110	129	125	118	117	105
SiO_2 chalcedony °C	81	106	100	91	90	75
SiO_2 opal °C	-6	13	8	1	1	-11

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

Table 2. Geothermetric caluculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Unnamed well '80	Doyle Eisminger Well '80	Hot Lake Resort Spring '72	Hot Lake Resort Spring '77	Hot Lake Resort Spring '80
Flow rate liters/min.	nc	190	>6000	>6000	>6000
Measured temperature ^oC	7.2	19	80	85	81
Na:K ^oC	279	250	85	70	91
Na:K:Ca 1/3 β ^oC	197	189	114	103	118
Na:K:Ca 4/3 β ^oC	48	93	89	83	90
Na:K:Ca Mg corrrected ^oC	89	245	nc	nc	nc
SiO_2 conductive ^oC	111	118	100	42	128
SiO_2 adiabatic ^oC	110	117	101	50	125
SiO_2 chalcedony ^oC	82	90	70	10	100
SiO_2 opal ^oC	-6	0	-16	-63	8

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Hot Lake Courtwright Well '77	Hot Lake Courtwright Well '80	Royce Well '80	Grange Hall Spring '77	Grange Hall Spring '80
Flow rate liters/min.	114	114	5	57	57
Measured temperature °C	79	67	26.6	26	26
Na:K °C	58	86	238	199	111
Na:K:Ca 1/3 β °C	93	115	205	179	117
Na:K:Ca 4/3 β °C	77	90	104	88	50
Na:K:Ca Mg corrected °C	nc	nc	nc	161	nc
SiO_2 conductive °C	111	125	119	111	89
SiO_2 adiabatic °C	111	124	117	111	92
SiO_2 chalcedony °C	82	99	91	82	58
SiO_2 opal °C	-6	8	1	-6	-25

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Hoofnagle Warm Spring '77	Hoofnagle Warm Spring '80	Duck Pond Spring '77	Duck Pond Spring '80	Sam -0- Spring '77
Flow rate liters/min.	19	19	57	57	1000+
Measured temperature °C	24	24	26	25	32
Na:K °C	178	134	133	152	100
Na:K:Ca 1/3 β °C	154	134	139	152	125
Na:K:Ca 4/3 β °C	53	59	75	82	94
Na:K:Ca Mg corrected °C	158	nc	123	149	33
SiO_2 conductive °C	96	89	96	107	102
SiO_2 adiabatic °C	97	91	97	107	103
SiO_2 chalcedony °C	66	58	66	77	72
SiO_2 opal °C	-19	-25	-19	-10	-14

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Sam -O- Spring '77	Fisher Hot Spring '77	Union Junction Warm Spring #1 '77	Union Junction Warm Spring #1 '80
Flow rate liters/min.	1000+	284	57	57
Measured temperature °C	27	39	37	37
Na:K °C	151	77	86	276
Na:K:Ca 1/3 β °C	164	92	113	141
Na:K:Ca 4/3 β °C	119	34	83	92
Na:K:Ca Mg corrected °C	59	nc	66	126
SiO_2 conductive °C	117	94	96	124
SiO_2 adiabatic °C	115	96	97	121
SiO_2 chalcedony °C	88	63	66	95
SiO_2 opal °C	-1	-21	-19	-5

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Union Junction Warm Spring #2 '77	Union Junction Warm Spring #2 '80	Barstad Hot Well '74	Sweetwater Warm Spring '74	Oasis Warm Spring '74
Flow rate liters/min.	95	95	380	57	220
Measured temperature °C	29	30	81.5	38	29.5
Na:K °C	83	111	80	119	109
Na:K:Ca 1/3 β °C	107	127	113	138	129
Na:K:Ca 4/3 β °C	70	77	99	97	88
Na:K:Ca Mg corrected °C	nc	101	nc	86	87
SiO_2 conductive °C	96	114	141	28	124
SiO_2 adiabatic °C	97	113	136	25	121
SiO_2 chalcedony °C	66	85	115	00	96
SiO_2 opal °C	-19	-3	20	8	5

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

Table 2. Geothermetric calculations* of minimum reservoir temperatures for selected thermal waters of the Craig Mountain-Cove area--Continued.

	Bennett Warm Spring '74	Baker Warm Spring '74	Haystack Warm Spring '74	Cemetary Artesian Well '74
Flow rate liters/min.	38	11	57	190
Measured temperature ^{o}C	27	26	255	21.5
Na:K ^{o}C	74	29	148	109
Na:K:Ca 1/3 β ^{o}C	105	61	157	130
Na:K:Ca 4/3 β ^{o}C	84	35	102	90
Na:K:Ca Mg corrected ^{o}C	nc	nc	nc	nc
SiO_2 conductive ^{o}C	111	105	118	63
SiO_2 adiabatic ^{o}C	111	106	117	69
SiO_2 chalcedony ^{o}C	82	76	90	31
SiO_2 opal ^{o}C	-6	-11	0	-46

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

GEOTHERMAL-GRADIENT AND HEAT-FLOW DATA; CRAIG MOUNTAIN-COVE AREA*

The temperature-gradient and heat-flow results for the La Grande area are shown in Table 3. Included in the table are the township/range-section and latitude and longitude location of each hole. In addition, the hole name, date of logging used and collar elevation are included for each hole. Plate I shows the bottom hole temperature, maximum depth, corrected temperature gradient and (where available) corrected heat flow. These values are also listed in the table, as are the depth interval and average thermal conductivity used for calculation of the 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}K^{-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 open-filed at the DOGAMI office in Portland, and are presented in Appendix B. Corrected gradient and corrected heat flow are values for which the topographic effects have been removed. These are significant for several of the sites studied.

The holes are ranked in terms of the 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 directly on cutting samples. Three of the holes in the town of La Grande were drilled specifically for heat flow measurements. These are discussed in more detail below. The remainder of the measurements have been made in available water wells, and the data quality is, in general, very poor. Estimates of heat flow are problematical, because we have no satisfactory samples of the rocks, and gradients seem to vary over a wide range, with no apparent correlation to rock type or thermal conductivity. The best estimate for a

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*Text is by Dr. David D. Blackwell, Southern Methodist University, Dallas, Texas.

heat-flow value for the Grande Ronde Valley would appear to be between 60 and 80 mWm^{-2}, and the best gradient $50\pm20^{o}C/km$.

As part of the low-temperature geothermal program, three holes were drilled by DOGAMI in the town of La Grande, Oregon, for determinations of geothermal gradient and heat flow (wells 3S/38E-7Acc, 3S/38E-7Acd and 3S/38E-7Adc, see Table 3). Severe drilling problems were encountered in all three holes, because the drilling was done in gravel, sands and rubbly basalts.

The temperature-depth curve observed in 3S/38E-7Acd is linear, with a change in slope at 75 m which might correspond to a change from overburden to lava flows. The gradient decreases from $41.9\pm$ to $1.3^{o}C/km$ to $21.9\pm0.8^{o}C/km$ at that point. If the upper material is assumed to have a porosity of 30%, and the material below the contact is assumed to have a porosity of 5%, then thermal conductivities above and below the contact would be 1.25 $Wm^{-1}K^{-1}$ and 1.73 $Wm^{-1}K^{-1}$, respectively. The thermal conductivity change is not as great as is observed in the gradients, so there is an apparent change in heat flow with depth in the hole. The hole is at the foot of a very steep hill, and the terrain correction decreases the heat flow by approximately 20%. If the two intervals are averaged, the best estimate of gradient is $27.9^{o}C/km$, and the best estimate of heat flow is 42 mWm^{-2}.

The final observed temperature-depth data from hole 3S/38E-7Acc indicate a very low gradient and a high surface temperature; however, temperatures measured before the drill hole reached the major aquifer indicate a linear _in situ_ temperature-depth curve beginning at the surface temperature of approximately $11^{o}C$, with a slope of approximately $90^{o}C/km$. Using a terrain-corrected heat flow is 84 mWm^{-2}. No heat flow was calculated for hole 3S/38E-7Ada, as it has a negative temperature versus depth curve.

Table 3. Geothermal-gradient data, Craig Mountain-Cove 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
2S/37E- 25DB	45-21.80	118- 7.27	THOMAS 8/23/77	1143	11.98	20.0 150.0			32.5 .6			B
						90.0 150.0	1.59		36.4 .6	46.0	71	B
3S/38E- 4BD	45-19.98	118- 4.08	HIGHDEPT 8/22/77	837	11.67	35.0 75.0						X
3S/38E- 3DC	45-19.72	118- 2.65	ISLCTYCM 8/23/77	829	11.81	10.0 90.0			17.1 1.0	17.0		C
						60.0 90.0			31.4 1.6	31.0		C
3S/39E- 2CD	45-19.70	117-54.18	HAMMAN 8/22/77	814	11.85	35.0 85.0			23.6 .6	23.6		B
3S/38E- 7ADA	45-19.29	118- 5.87	MID SCH 2/ 6/80	859	11.27	.0 55.0	1.33 .08	1				X
3S/38E- 7ACD	45-19.14	118- 6.17	CENT SCH 2/ 5/80	875	15.61	20.0 75.0	1.25 .13	1	41.9 1.3	34.2	43	C
						75.0 120.0	1.73		21.9 .8	17.5	30	C
						20.0 120.0	1.51 .17		33.5 3.2	27.9	42	C
3S/38E- 7ACC	45-19.13	118- 6.32	LGR HOSP 12/14/79	896	16.77	20.0 45.0	1.55	1	48.2 1.5			D
						.0 78.0	1.20 .12		82.2	68.5	82	C
3S/39E- 8DA	45-18.92	117-57.24	WEISHAAR 10/26/79	822	12.08	15.0 75.0			19.9 .5	19.9		D
3S/40E- 14CB 2	45-18.10	117-47.17	COVE 2 8/24/77	978	15.35	50.0 105.0			71.8 1.8	65.0		C
						20.0 105.0			53.0 2.6	48.0		C

Table 3. Geothermal-gradient data, Craig Mountain-Cove 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
3S/40E- 14CB 1	45-18.05	117-47.17	COVE 1 8/24/77	978	11.38	23.0 45.0			(25.0)			X
3S/39E- 28AC	45-16.53	117-56.46	B JONES 8/24/77	821	12.31	10.0 45.0			70.9 2.6	70.9		C
						27.5 45.0	> 1.17		55.9 1.1	56.0	> 67	B
4S/40E- 18BA	45-13.45	117-51.72	UNIONCTY 8/23/77	845	22.79	.0 310.0	1.59		38.0	36.0	59	B
4S/40E- 18CD	45-12.75	117-51.74	UNIONGRN 8/24/77	848	16.20	12.5 75.0	(1.26)		65.4 .8	65.0	(84)	B

CONCLUSIONS AND RECOMMENDATIONS

The area with the greatest potential resource base is the Craig Mountain-Hot Lake fault zone and extensions of that zone to the north and south. The La Grande area may lie on an extension of that zone, but these data are inadequate to evaluate this possibility. Shallow (152 m) drill holes for this study were inadequate to evaluate heat-flow patterns which might show thermal waters beneath La Grande. Intermediate-depth (2,000') wells should be drilled along extensions of the Craig Mountain fault and similar fault zones within the city of La Grande. Such wells should be drilled with techniques capable of overcoming caving and lost-circulation problems associated with loose basin sediments and shattered bedrock. Such techniques will inevitably lead to unusually high drilling costs, but are justified by the potential resources.

Direct utilization by La Grande of known resources at the Hot Lake should be investigated. The Hot Lake hot spring (measured temperature = $85^{O}C$; possible reservoir temperature = $100-125^{O}C$; flow = 1,700 gpm) lies only 11.7 km (7.3 mi) southeast of La Grande. Intermediate depth (2,000') holes should be drilled around the Hot Lake springs to define the details of that geothermal system for siting of possible production wells. A detailed engineering study of the cost effectiveness of direct utilization of the resources at Hot Lake should be made to guide decisions on the viability of exploitation.

Before drilling, however, geophysical studies should be carried out to determine the structure of bedrock beneath the basin fill to increase the likelihood of drilling success. Methods that should be considered are gravity traverses, aeromagnetic or hand-held magnetic surveys, deep-penetration electrical surveys (either wandering dipole, dipole-dipole, or telluric) and seismic surveys. One method, though expensive, that would undoubtedly give valuable results would be a number of vibro-seismic traverses. This method would easily "see" the interface between the valley fill and underlying bedrock. This would allow precise location of hidden faults, and calculation of their offsets.

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APPENDIX A

Formulas used in calculations

Na:K (revised):

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

Na:K:Ca:

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

where $F\ (T) = \log (Na/K) + [\ \beta \log (\sqrt{Ca}/Na)\ ]$,
β = 1/3 if $t > 100^{o}C$, and 4/3 if $t < 100^{o}C$,
$t^{o}C$ = 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 ^{o}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.

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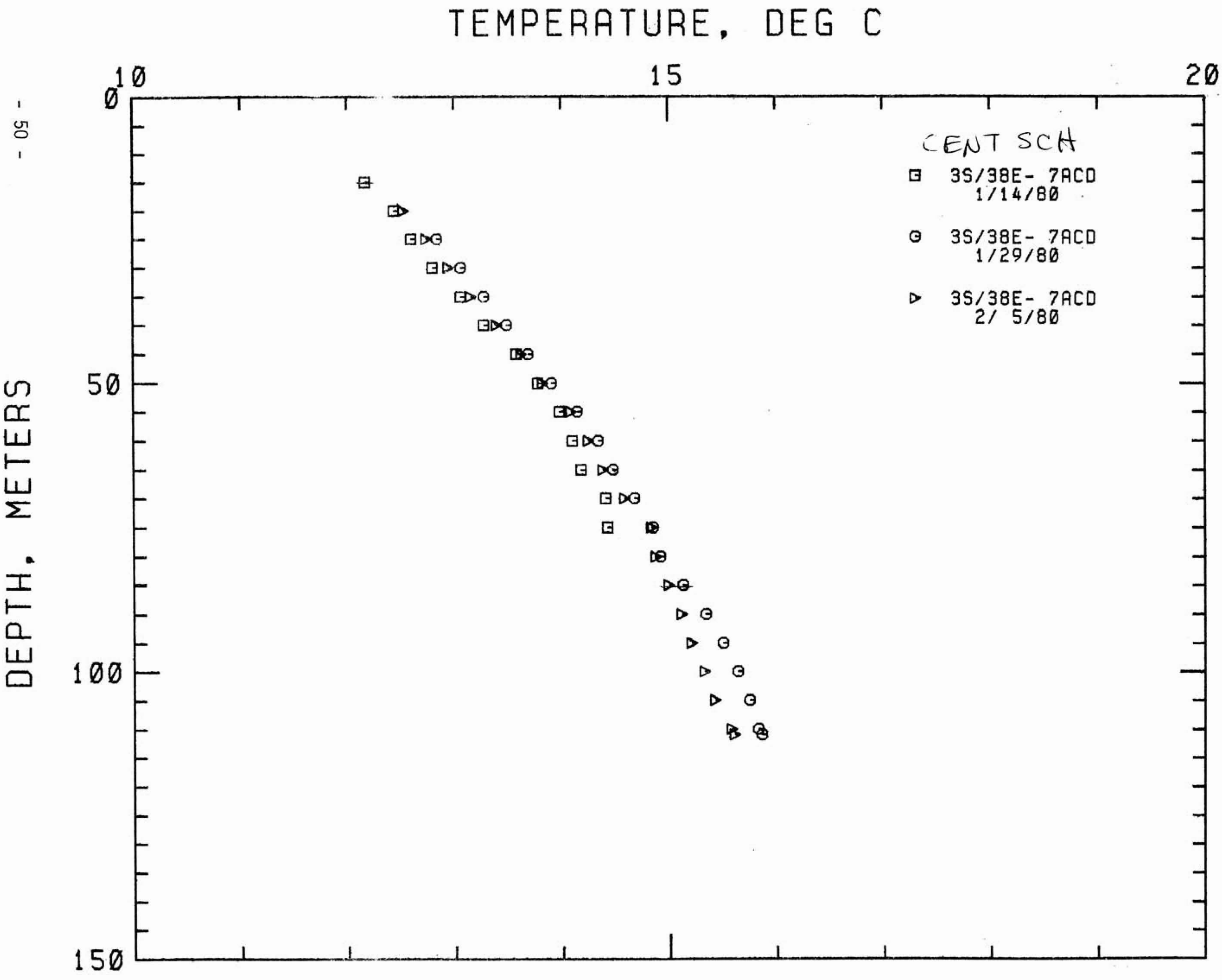
APPENDIX B

Geothermal-gradient data

LOCATION: PENDLETON AMS, OREGON
3S/38E- 7ACD
HOLE NAME: CENT SCH
DATE MEASURED: 2/ 5/80

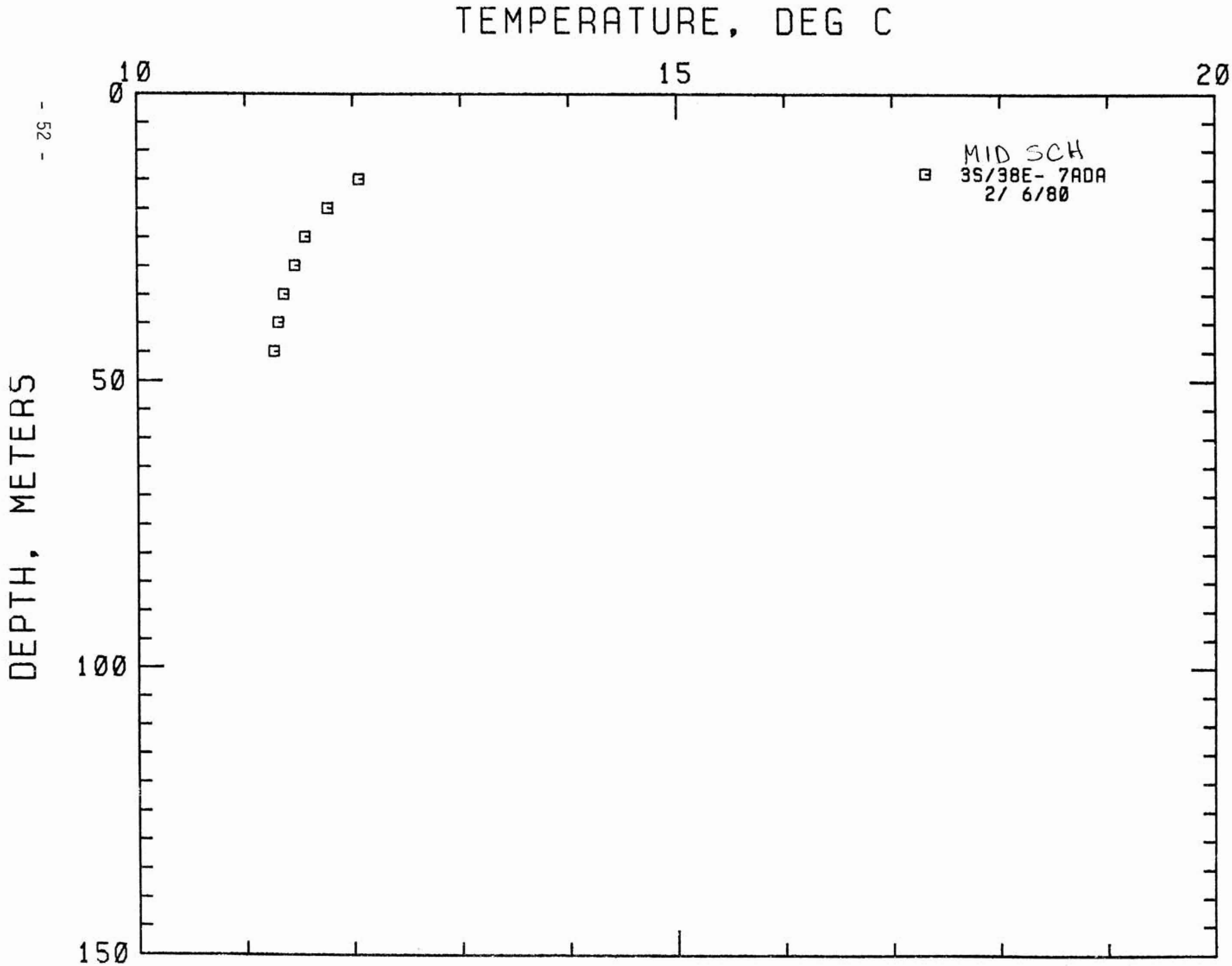
DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT DEG F/100 FT
20.0	65.6	12.530	54.55	0.0	0.0
25.0	82.0	12.740	54.93	42.0	2.3
30.0	98.4	12.950	55.31	42.0	2.3
35.0	114.8	13.160	55.69	42.0	2.3
40.0	131.2	13.400	56.12	48.0	2.6
45.0	147.6	13.630	56.53	46.0	2.5
50.0	164.0	13.830	56.89	40.0	2.2
55.0	180.4	14.090	57.36	52.0	2.9
60.0	196.8	14.250	57.65	32.0	1.8
65.0	213.2	14.390	57.90	28.0	1.5
70.0	229.6	14.590	58.26	40.0	2.2
75.0	246.0	14.840	58.71	50.0	2.7
80.0	262.4	14.880	58.78	8.0	0.4
85.0	278.8	15.000	59.00	24.0	1.3
90.0	295.2	15.120	59.22	24.0	1.3
95.0	311.6	15.210	59.38	18.0	1.0
100.0	328.0	15.330	59.59	24.0	1.3
105.0	344.4	15.430	59.77	20.0	1.1
110.0	360.8	15.580	60.04	30.0	1.6
111.0	364.1	15.610	60.10	30.0	1.6



TEMPERATURE, DEG C
10
15
20
0
50
100
150
DEPTH, METERS
CENT SCH
3S/38E- 7ACD 1/14/80
3S/38E- 7ACD 1/29/80
3S/38E- 7ACD 2/ 5/80

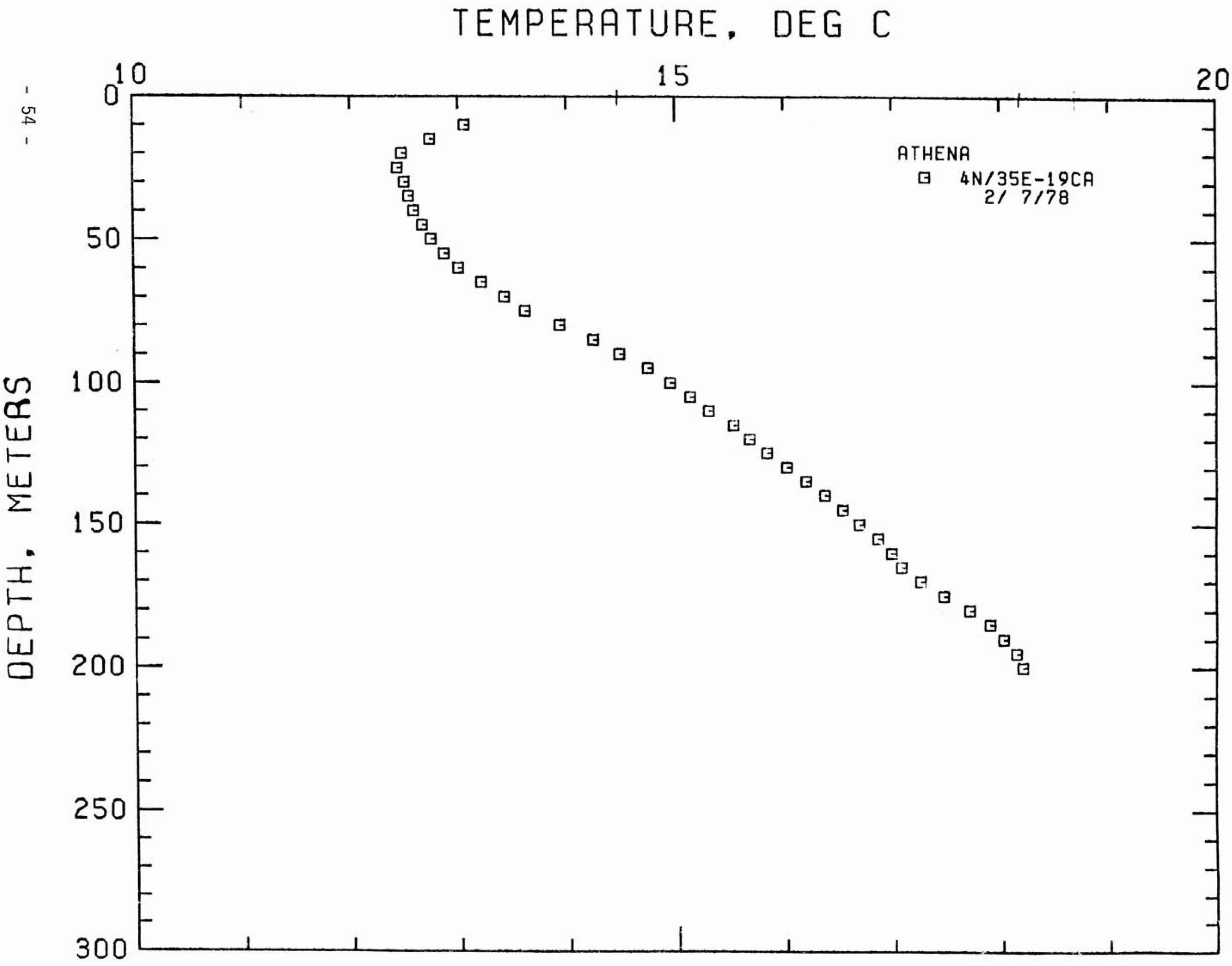
LOCATION: PENDLETON AMS, OREGON
3S/32E- 7ADA
HOLE NAME: MID SCH
DATE MEASURED: 2/ 6/80

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	12.060	53.71	0.0	0.0
20.0	65.6	11.770	53.19	-58.0	-3.2
25.0	82.0	11.560	52.81	-42.0	-2.3
30.0	98.4	11.460	52.63	-20.0	-1.1
35.0	114.8	11.360	52.45	-20.0	-1.1
40.0	131.2	11.310	52.36	-10.0	-0.5
45.0	147.6	11.270	52.29	-8.0	-0.4


TEMPERATURE, DEG C
10
15
20
0
50
100
150
DEPTH, METERS
MID SCH
3S/38E- 7ADA
2/ 6/80

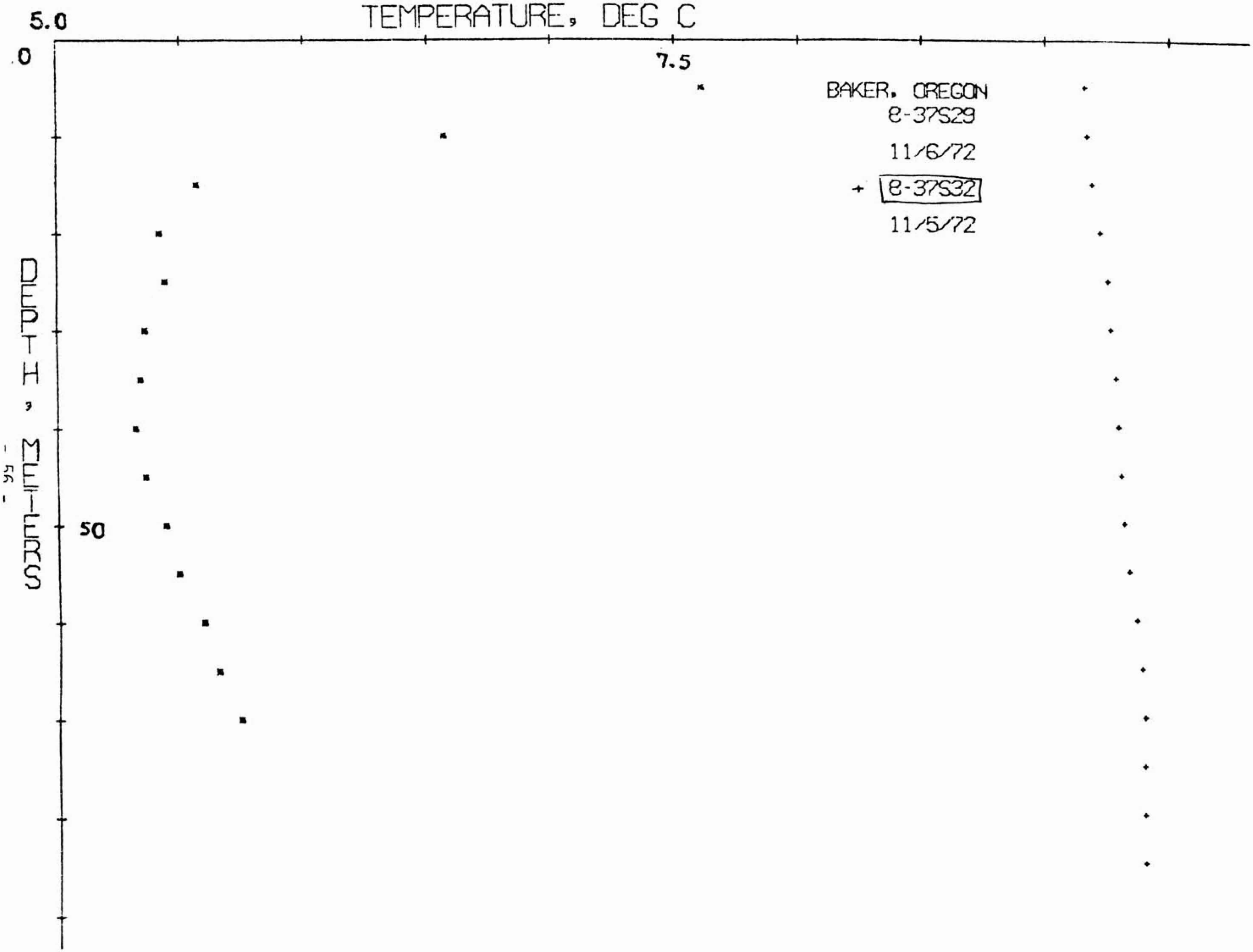
LOCATION: PENDLETON AMS, OREGON
4N/35E-19CA
HOLE NAME: ATHENA
DATE MEASURED: 2/ 7/78

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	13.060	55.51	0.0	0.0
15.0	49.2	12.740	54.93	-64.0	-3.5
20.0	65.6	12.480	54.46	-52.0	-2.9
25.0	82.0	12.440	54.39	-8.0	-0.4
30.0	98.4	12.500	54.50	12.0	0.7
35.0	114.8	12.540	54.57	8.0	0.4
40.0	131.2	12.590	54.66	10.0	0.5
45.0	147.6	12.670	54.81	16.0	0.9
50.0	164.0	12.750	54.95	16.0	0.9
55.0	180.4	12.870	55.17	24.0	1.3
60.0	196.8	13.000	55.40	26.0	1.4
65.0	213.2	13.210	55.78	42.0	2.3
70.0	229.6	13.420	56.16	42.0	2.3
75.0	246.0	13.610	56.50	38.0	2.1
80.0	262.4	13.930	57.07	64.0	3.5
85.0	278.8	14.240	57.63	62.0	3.4
90.0	295.2	14.480	58.06	48.0	2.6
95.0	311.6	14.740	58.53	52.0	2.9
100.0	328.0	14.950	58.91	42.0	2.3
105.0	344.4	15.130	59.23	36.0	2.0
110.0	360.8	15.300	59.54	34.0	1.9
115.0	377.2	15.530	59.95	46.0	2.5
120.0	393.6	15.680	60.22	30.0	1.6
125.0	410.0	15.840	60.51	32.0	1.8
130.0	426.4	16.020	60.84	36.0	2.0
135.0	442.8	16.200	61.16	36.0	2.0
140.0	459.2	16.370	61.47	34.0	1.9
145.0	475.6	16.540	61.77	34.0	1.9
150.0	492.0	16.690	62.04	30.0	1.6
155.0	508.4	16.860	62.35	34.0	1.9
160.0	524.8	16.990	62.58	26.0	1.4
165.0	541.2	17.080	62.74	18.0	1.0
170.0	557.6	17.260	63.07	36.0	2.0
175.0	574.0	17.470	63.45	42.0	2.3
180.0	590.4	17.710	63.88	48.0	2.6
185.0	606.8	17.900	64.22	38.0	2.1
190.0	623.2	18.020	64.44	24.0	1.3
195.0	639.6	18.140	64.65	24.0	1.3
200.0	656.0	18.200	64.76	12.0	0.7


TEMPERATURE, DEG C
10
15
20
0
50
100
150
200
250
300
DEPTH, METERS
ATHENA
4N/35E-19CA
2/ 7/78

LOCATION: BAKER, OREGON
HOLE NUMBER: 8-37S32
DATE MEASURED: 11/5/72

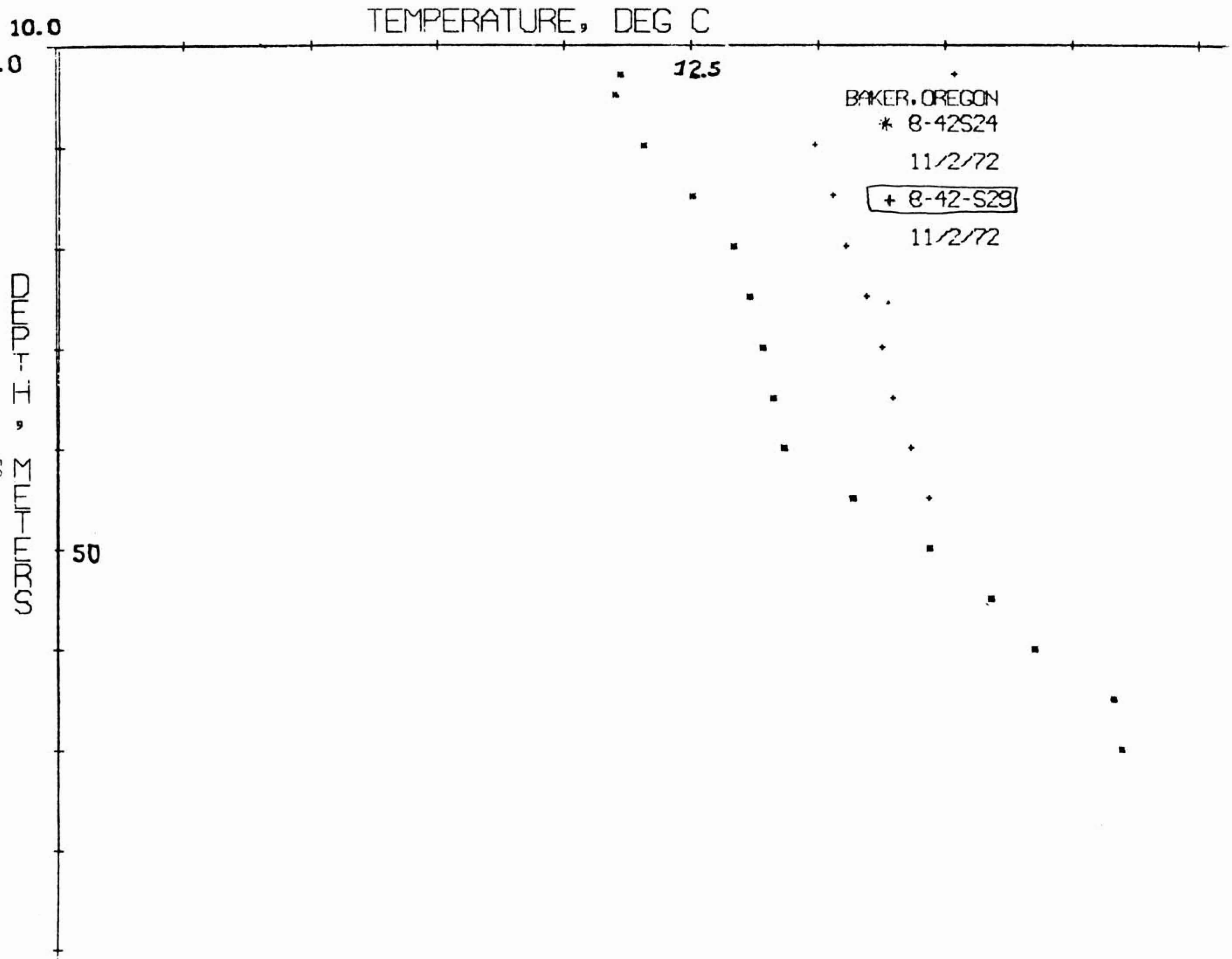
DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT FEET/DEG F
5.0	16.4	9.160	48.49	.0	.0
10.0	32.8	9.170	48.51	2.0	911.1
15.0	49.2	9.190	48.54	4.0	455.6
20.0	65.6	9.220	48.60	6.0	303.7
25.0	82.0	9.250	48.65	6.0	303.7
30.0	98.4	9.260	48.67	2.0	911.1
35.0	114.8	9.280	48.70	4.0	455.6
40.0	131.2	9.290	48.72	2.0	911.1
45.0	147.6	9.300	48.74	2.0	911.1
50.0	164.0	9.310	48.76	2.0	911.1
55.0	180.4	9.330	48.79	4.0	455.6
60.0	196.8	9.360	48.85	6.0	303.7
65.0	213.2	9.380	48.88	4.0	455.6
70.0	229.6	9.390	48.90	2.0	911.1
75.0	246.0	9.390	48.90	.000000000000.0	
80.0	262.4	9.390	48.90	.000000000000.0	
85.0	278.8	9.390	48.90	.000000000000.0	



TEMPERATURE, DEG C
5.0
7.5
.0
50
DEPTH, METERS
BAKER, OREGON
8-37S29
11/6/72
+ 8-37S32
11/5/72

LOCATION: BAKER, OREGON
HOLE NUMBER: 8-42-S29
DATE MEASURED: 11/2/72

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	DEG F	GEOTHERMAL GRADIENT DEG C/KM	FEET/DEG F
3.0	9.8	13.550	56.39	.0	.0
5.0	16.4	13.220	55.80	-165.0	-11.0
10.0	32.8	13.000	55.40	-44.0	-41.4
15.0	49.2	13.070	55.53	14.0	130.2
20.0	65.6	13.120	55.62	10.0	182.2
25.0	82.0	13.200	55.76	16.0	113.9
30.0	98.4	13.260	55.87	12.0	151.9
35.0	114.8	13.300	55.94	8.0	227.8
40.0	131.2	13.370	56.07	14.0	130.2
45.0	147.6	13.440	56.19	14.0	130.2



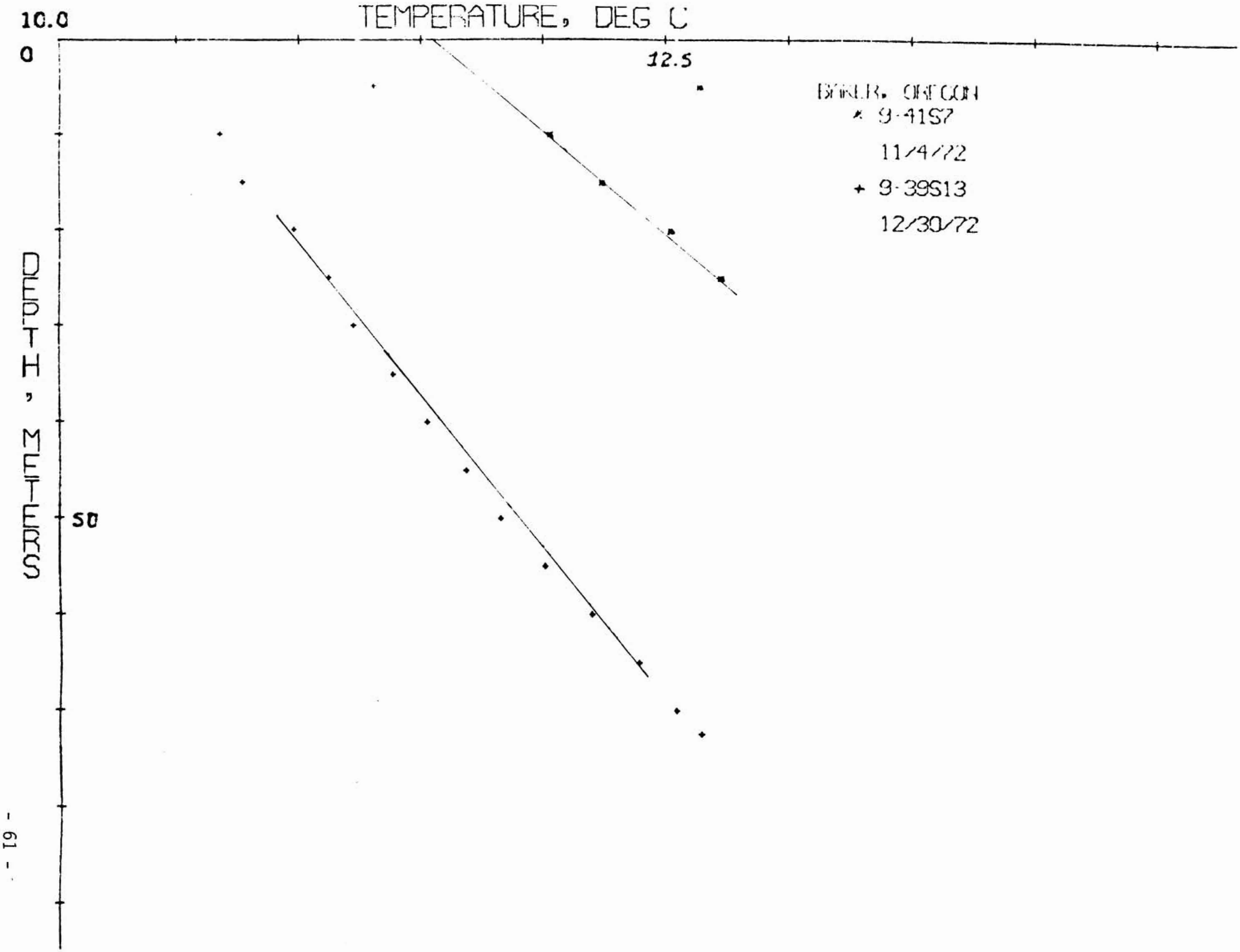
TEMPERATURE, DEG C
10.0
.0
12.5
50
DEPTH, METERS
BAKER, OREGON
* 8-42S24
11/2/72
+ 8-42-S29
11/2/72

LOCATION: BAKER, OREGON
HOLE NUMBER: 9-39S13
DATE MEASURED: 12/30/72

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	TEMPERATURE DEG F	GEOTHERMAL GRADIENT DEG C/KM	GEOTHERMAL GRADIENT FEET/DEG F
5.0	16.4	11.310	52.36	.0	.0
10.0	32.8	10.680	51.22	-126.0	-14.5
15.0	49.2	10.770	51.39	18.0	101.2
20.0	65.6	10.980	51.76	42.0	43.4
25.0	82.0	11.120	52.02	28.0	65.1
30.0	98.4	11.220	52.20	20.0	91.1
35.0	114.8	11.380	52.48	32.0	56.9
40.0	131.2	11.520	52.74	28.0	65.1
45.0	147.6	11.680	53.02	32.0	56.9
50.0	164.0	11.820	53.28	28.0	65.1
55.0	180.4	12.000	53.60	36.0	50.6
60.0	196.8	12.190	53.94	38.0	48.0
65.0	213.2	12.380	54.28	38.0	48.0
70.0	229.6	12.530	54.55	30.0	60.7
72.5	237.8	12.630	54.73	40.0	45.6

LOCATION: BAKER, OREGON
HOLE NUMBER: 9-41SS7
DATE MEASURED: 11/4/72

DEPTH METERS	DEPTH FEET	TEMPERATURE DEG C	DEG F	GEOTHERMAL GRADIENT DEG C/KM	FEET/DEG F
5.0	16.4	12.640	54.75	.0	.0
10.0	32.8	12.030	53.65	-122.0	-14.9
15.0	49.2	12.240	54.03	42.0	43.4
20.0	65.6	12.520	54.54	56.0	32.5
25.0	82.0	12.720	54.90	40.0	45.6


TEMPERATURE, DEG C
10.0
12.5
0
50
DEPTH, METERS
BAKER, OREGON
* 9-41S7
11/4/72
+ 9-39S13
12/30/72

LOCATION: PENDLETO. AMS,OREGON
02S/34E/27BD
HOLE NUMBER: IL-AA
DATE MEASURED: 06/01/76

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	6.590	43.86	.0	.0
40.0	131.2	7.480	45.46	44.5	2.4
60.0	196.8	8.010	46.42	26.5	1.5
80.0	262.4	8.980	48.16	48.5	2.7
100.0	328.0	10.120	50.22	57.0	3.1
120.0	393.6	11.130	52.03	50.5	2.8
140.0	459.2	11.530	52.75	20.0	1.1
160.0	524.8	12.430	54.37	45.0	2.5
175.0	574.0	12.850	55.13	28.0	1.5
180.0	590.4	13.000	55.40	30.0	1.6
185.0	606.8	13.300	55.94	60.0	3.3
190.0	623.2	13.440	56.19	28.0	1.5
195.0	639.6	13.530	56.35	18.0	1.0
200.0	656.0	13.660	56.59	26.0	1.4
205.0	672.4	13.850	56.93	38.0	2.1
210.0	688.8	14.130	57.43	56.0	3.1
215.0	705.2	14.280	57.70	30.0	1.6
220.0	721.6	14.480	58.06	40.0	2.2
225.0	738.0	14.730	58.51	50.0	2.7
230.0	754.4	14.820	58.68	18.0	1.0
235.0	770.8	14.970	58.95	30.0	1.6
240.0	787.2	15.550	59.99	116.0	6.4
245.0	803.6	15.840	60.51	58.0	3.2
250.0	820.0	16.240	61.23	80.0	4.4
255.0	836.4	16.290	61.32	10.0	.5
260.0	852.8	16.350	61.43	12.0	.7
265.0	869.2	16.400	61.52	10.0	.5
270.0	885.6	16.470	61.65	14.0	.8
275.0	902.0	16.540	61.77	14.0	.8
280.0	918.4	16.620	61.92	16.0	.9

LOCATION: PENDLETON AMS, OREGON
3S/38E- 7ACC
HOLE NAME: LGR HOSP
DATE MEASURED: 12/14/79

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	15.280	59.50	0.0	0.0
25.0	82.0	15.610	60.10	66.0	3.6
30.0	98.4	15.890	60.60	56.0	3.1
35.0	114.8	16.110	61.00	44.0	2.4
40.0	131.2	16.350	61.43	48.0	2.6
45.0	147.6	16.480	61.66	26.0	1.4
50.0	164.0	16.540	61.77	12.0	0.7
55.0	180.4	16.590	61.86	10.0	0.5
60.0	196.8	16.620	61.92	6.0	0.3
65.0	213.2	16.650	61.97	6.0	0.3
70.0	229.6	16.680	62.02	6.0	0.3
75.0	246.0	16.740	62.13	12.0	0.7
78.0	255.8	16.770	62.19	10.0	0.5

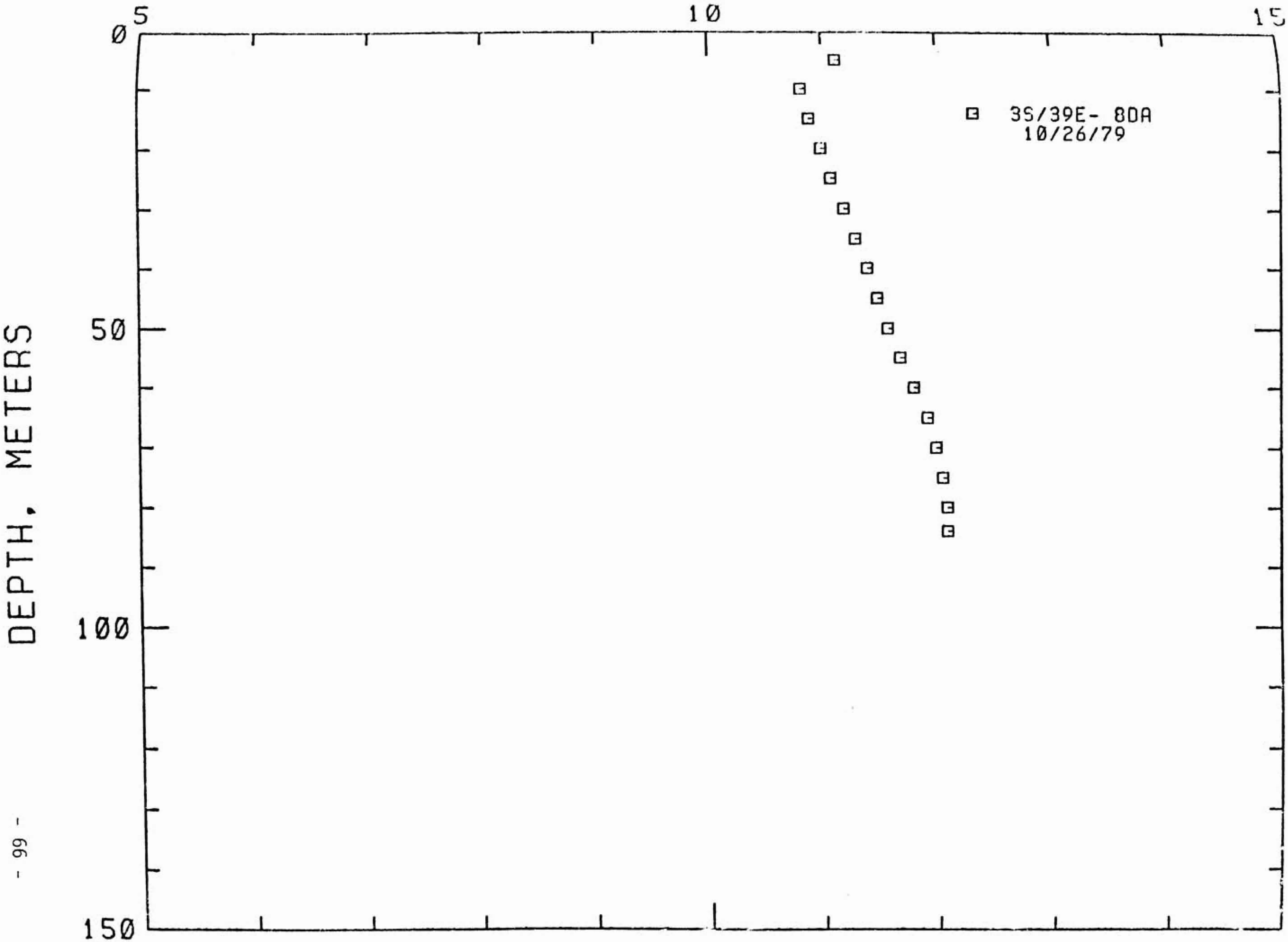
LOCATION: PENDLETON AMS, OREGON
3S/38E- 7ACC
HOLE NAME: LGR HOSP
DATE MEASURED: 12/10/79

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	12.740	54.93	0.0	0.0
25.0	82.0	13.340	56.01	120.0	6.6
30.0	98.4	13.560	56.41	44.0	2.4
35.0	114.8	13.760	56.77	40.0	2.2
40.0	131.2	14.600	58.28	168.0	9.2
45.0	147.6	15.120	59.22	104.0	5.7

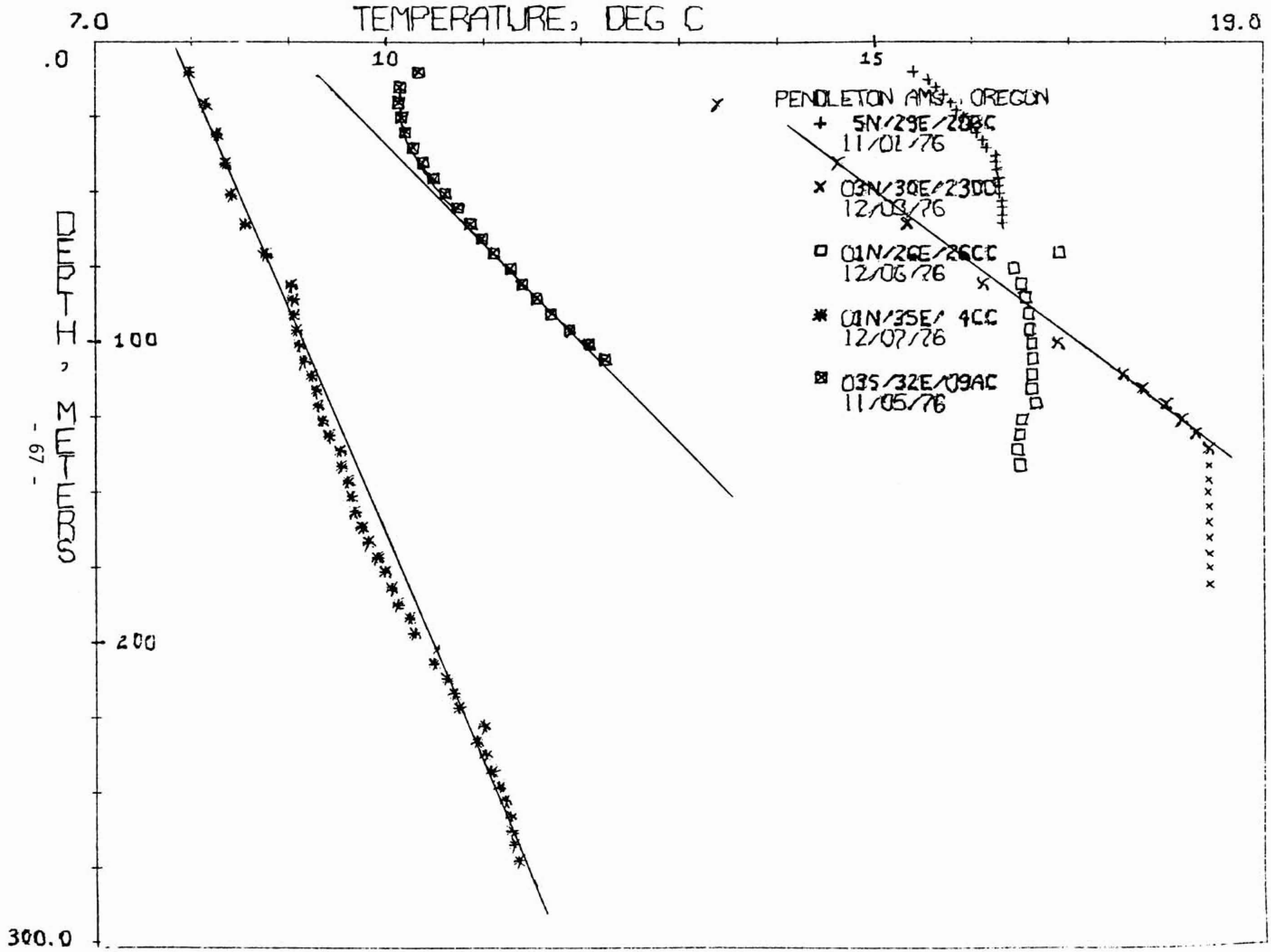
LOCATION: GRANGEVILLE AMS. OREGON
3S/39E- 8DA
HOLE NAME: WEISHAAR
DATE MEASURED: 10/26/79

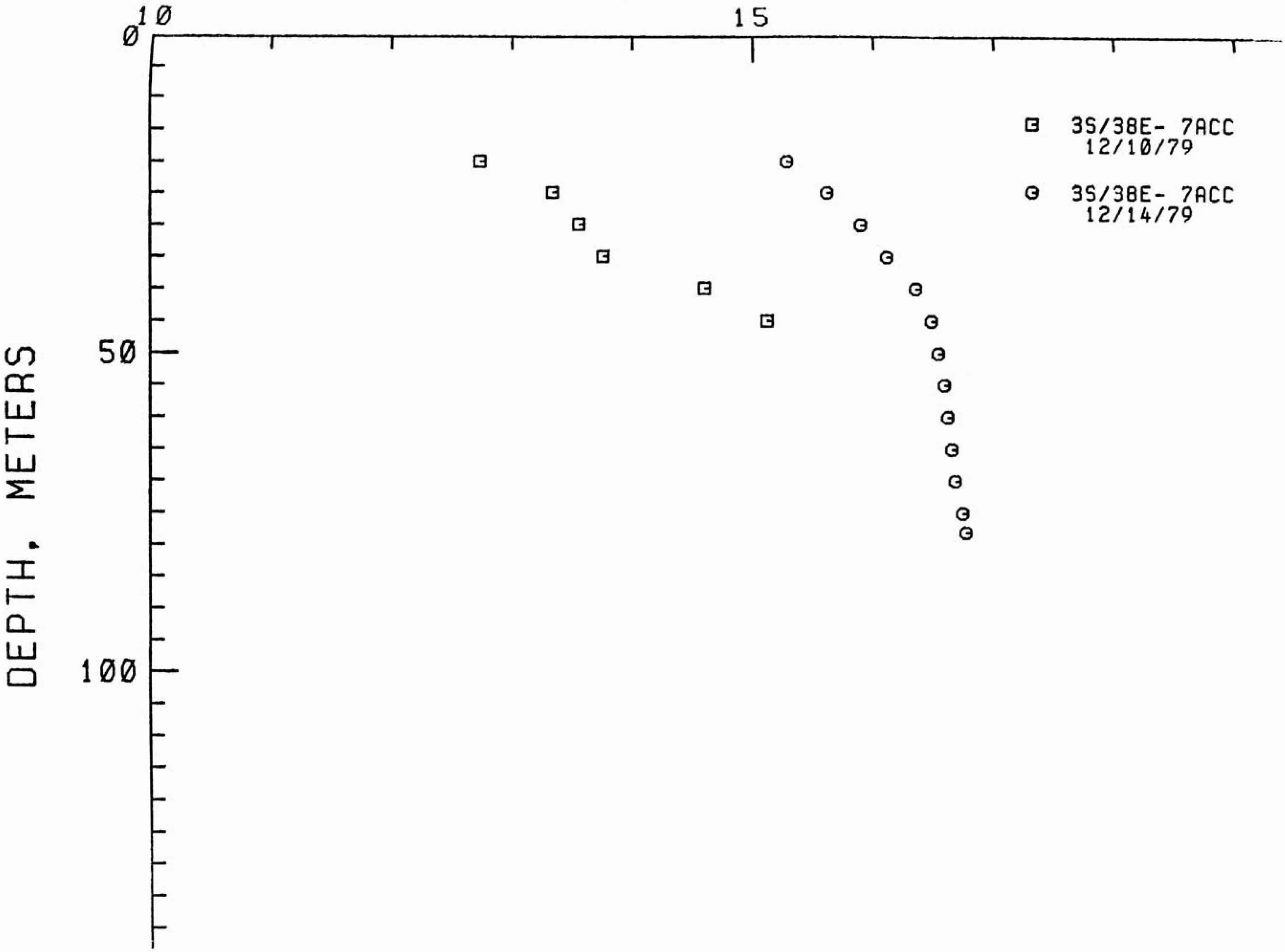
Plotted 1/14/81 RP

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	11.120	52.02	0.0	0.0
10.0	32.8	10.810	51.46	-62.0	-3.4
15.0	49.2	10.880	51.58	14.0	0.8
20.0	65.6	10.980	51.76	20.0	1.1
25.0	82.0	11.070	51.93	18.0	1.0
30.0	98.4	11.180	52.12	22.0	1.2
35.0	114.8	11.280	52.30	20.0	1.1
40.0	131.2	11.380	52.48	20.0	1.1
45.0	147.6	11.470	52.65	18.0	1.0
50.0	164.0	11.560	52.81	18.0	1.0
55.0	180.4	11.670	53.01	22.0	1.2
60.0	196.8	11.790	53.22	24.0	1.3
65.0	213.2	11.910	53.44	24.0	1.3
70.0	229.6	11.980	53.56	14.0	0.8
75.0	246.0	12.040	53.67	12.0	0.7
80.0	262.4	12.080	53.74	8.0	0.4
84.0	275.5	12.080	53.74	0.0	0.0



5
10
15
0
50
100
150
DEPTH, METERS
3S/39E- 8DA
10/26/79


TEMPERATURE, DEG C
7.0
10
15
19.0
DEPTH, METERS
.0
100
200
300.0
PENDLETON AMS, OREGON
+ 5N/29E/20BC
11/01/76
× 03N/30E/23DD
12/03/76
□ 01N/26E/26CC
12/06/76
✱ 01N/35E/ 4CC
12/07/76
⊠ 03S/32E/09AC
11/05/76


10
15
0
50
100
DEPTH, METERS
3S/38E- 7ACC 12/10/79
3S/38E- 7ACC 12/14/79