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Geothermal Data From Test Wells Drilled In Grass Valley And Buffalo Valley, Nevada

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GEOTHERMAL DATA FROM TEST WELLS DRILLED IN GRASS VALLEY AND BUFFALO VALLEY, NEVADA

by

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

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INTRODUCTION

A systematic evaluation of several geothermal prospects in northern Nevada has been carried out by the Lawrence Berkeley Laboratory (LBL) of the University of California during the past two years (Beyer and Morrison, 1976; Bowman and others, 1976; Corwin, 1975; Wollenberg and others, 1975; Majer and others, 1975). Concurrently the U.S. Geological Survey (USGS) has been making a hydrogeologic appraisal and a regional heat-flow study of these and other areas in northern and central Nevada (Hose and Taylor, 1974; Olmsted and others, 1975; Sass and others, 1975; White and Williams, 1975). This report presents heat-flow data obtained during a cooperative LBL-USGS study of the heat flow and hydrology of two of these prospects, Leach Hot Springs and Buffalo Valley Hot Springs. Figure 1 shows the areas studied in relation to the major towns in the region (Winnemucca and Battle Mountain) together with previously published heat-flow values from this portion of the Battle Mountain heat-flow high (Sass and others, 1971; Diment and others, 1975).

Four types of measurement are considered in this report:

1) Regional background heat flows: For the area shown in Figure 1, all of these data were obtained from crystalline rocks in holes drilled for mineral exploration (Roy and others, 1968; Sass and others, 1971).

2) Shallow hydrologic test wells: These have been drilled in the sedimentary formations surrounding several of the hot springs of northern and central Nevada (Olmsted and others, 1975) in patterns similar to that of sites H-1 through H-15 (Figure 2). The wells typically are in

the range of from 20 to 50 m in depth within a radius of ∿3 km of the observed surface hydrothermal phenomenon.

3) Heat-flow test wells: Three have been drilled in each of the study areas (Figure 1). These wells are typically in the depth range 100 to 200 m, are cored at two or more intervals of from 1 to 3 m, and have a 32 mm I.D. access pipe (capped at the bottom) grouted in place to total depth to facilitate temperature measurements.

4) Heat flow - hydrologic test wells: This type of construction has been designated as Q-H in Figure 2 and other tables and figures in this report. They differ from type 3 (above) only in that a parallel pipe with a well screen on the bottom is also emplaced. The annulus of the lowermost 10 m or so of the wells is packed off with gravel to allow access of formation water. Above the screen, the annulus between the parallel casings and borehole wall is sealed off with cement grout.

The results of the study are shown as a series of graphs and tables along with our preliminary interpretation of the results. Figures 2 through 10 and Tables 1 through 10 present the results from Grass Valley (Leach Hot Springs). Thermal data from the Buffalo Valley Hot Springs are given in Figures 11 through 15 and Tables 11 and 12.

Temperatures and thermal conductivities were determined by the methods described by Sass and others (1971). Most thermal conductivities were measured using the needle probe (Von Herzen and Maxwell, 1959), but for competent rocks, steady-state measurements using cylindrical disks and the divided bar (see e.g., Birch, 1950) were made. The divided-bar measurements (Tables 6, 7, and 12) are those which include estimates of density and porosity (ρ, ϕ).

The following symbols and units are used:

K, thermal conductivity mcal/cm sec °C

<K>, harmonic mean thermal conductivity

N, number of thermal conductivity measurements

q, heat flow (HFU) = μcal/cm^2 sec

ρ, density g/cm^3

ϕ, porosity (% voids)

Acknowledgments. Drilling was done by a crew from the U.S. Bureau of Reclamation under the supervision of Ted Darrow. Shirley Crossland and Marcello Lippman helped monitor drilling operations for Grass Valley. We thank Tom Moses and Glen Blevens for technical assistance in well completion. Geophysical logs other than temperature logs were made by Richard McCullough, and needle-probe determinations of thermal conductivity by Eugene Smith.

LEACH HOT SPRINGS (GRASS VALLEY)

The major effort to date has been in the vicinity of Leach Hot Springs (Figure 2). Table 1 presents a summary of the heat-flow data obtained from the seven relatively deep wells drilled as part of this study. Table 2 summarizes the results from shallow hydrologic wells (sites H-1 through H-15, Figure 2); it is an updating of thermal data from the hydrogeologic appraisal first presented by Olmsted and others (1975). The measurements at different times in each test well indicate small changes in temperature at depths of 15 and 30 meters and also small differences in temperature gradient. Because these changes occur at depths beneath the annual conductive temperature wave, they must be attributed to some combination of:

1) Longer period conductive variations,

2) Heat transfer by moving water, and

3) Instrumental error. The relative magnitude of each source of variation is not known. The depth intervals for which the temperature gradients are tabulated are those in which the gradients are nearly linear and presumed to be chiefly conductive and steady.

Tables 3 through 9 contain details of lithology and individual thermal conductivity measurements for the various heat-flow test holes. Table 10 shows the stratigraphy based on examination of drill cuttings.

Figure 3 is a graph showing temperature profiles from all seven of the heat flow (Q) and heat flow - hydrologic wells (Q-H) drilled between April and June 1975. This figure and the heat-flow determinations

(Table 1) demonstrate a large variation in conductive heat flows over a relatively small area. Temperature profiles for individual wells obtained in June and October 1975 (Figures 4 through 10) show that the thermal regime in the upper 200 m is primarily conductive with the annual wave being attenuated between about 12 and 15 m below the surface.

The large range of heat flows (1.4 to 9 HFU) suggests that a hydrothermal convective system influences the temperatures at depths greater than a few hundred meters below the surface. Combining gradients in the shallow holes near Leach Hot Springs (Table 2) with the relatively high thermal conductivities determined from QH-1 results in conductive heat flows ranging from 1.4 to greater than 60 HFU. The gradients further indicate a general pattern of decreasing heat flow out to a radial distance of 2 km from the springs (see also Olmsted and others, 1975). This reinforces the presumption of a relatively local hydrothermal upflow enclosed by impermeable sedimentary rocks surrounding Leach Hot Springs. The high value at site Q-3 (4.87 HFU) confirms the high heat flows reported earlier by Sass and others (1971) from crystalline rocks at the Big Mike Mine, south of Panther Canyon. This heat flow, together with the high value at site QH-3 (5.11 HFU), flanked by considerably lower heat flows at QH-4 and Q-2, indicate the presence of complex upward and downward flow at depth in Grass Valley, in addition to the flow beneath the orifice at Leach Hot Springs.

BUFFALO VALLEY HOT SPRINGS

Three heat-flow holes were drilled near the Buffalo Valley Hot Springs (Figure 11). Hole #1 was drilled approximately 500 m east of the easternmost pool of Buffalo Valley Hot Springs, in an area known to be anomalous by previous shallow temperature measurements (Olmsted and others, 1975). Hole #2 was drilled ∿2 km west of the hot springs thermal anomaly, to observe "background" heat flow in valley alluvium away from the springs. Hole #3 was drilled on a low mound in the northwestern portion of the valley playa, on the northern projection of a mid-valley fault zone, considered possibly thermally active (Wollenberg and others, 1975). Temperature profiles from all three holes are shown in Figure 12 and individual profiles obtained on two different dates are plotted in Figures 13 through 15. Unfortunately, the casing could not be lowered below about 37 m in hole 1 so that the only available temperature log is one obtained on 10-12-74, a few hours after completion of drilling (Figures 12 and 13). There appears to be a hydrologic effect between depths of about 30 and 40 m in hole 3 (Figure 15). Apart from this, however, temperature gradients reflect a conductive regime. This, in turn, suggests that relatively impermeable rocks enclose or "cap" the hydrothermal system. Not shown in Figure 11 are the 9 shallow test wells (of the "H" type, Figure 2) drilled near the springs and previously reported by Olmsted and others, 1975. From observations in these wells, Olmsted and others (1975) estimated that within a radius of 1 or 2 km heat flows increase sharply to >50 HFU near the springs. The high heat flow from BV-1 about 1/2 km from the springs and the normal value from BV-2 (Figure 11, Table 11) about ∿2 km west of the springs generally confirm this view. However, the value of 6.5 HFU at BV-1 is less by a factor of 3 or more than the heat flow estimated for the same region from the shallower wells.

SUMMARY AND CONCLUSIONS

Subsurface thermal observations indicate that Leach Hot Springs in Grass Valley, and Buffalo Hot Springs in Buffalo Valley, overlie localized upflows of hot water enclosed by relatively impermeable sediments. Upward and downward flows occur elsewhere in Grass Valley, probably indicating a complex system of hydrothermal circulation. The thermal data are inadequate to determine whether a comparable condition exists in Buffalo Valley.

Deeper test drilling is being planned for both the Leach and Buffalo Hot Spring areas to find the depth to which the conductive regime extends and to provide further sub-surface data for an evaluation of the geothermal energy potential of the prospects.

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TABLE 1. Summary of temperature gradients, conductivities, and heat flows for holes near Leach Hot Springs

Hole	Gradient °C/km	N*	K** mcal/cm sec °C	q HFU
Q1	65.5	12	3.42	2.24
Q2	55.5	10	3.68	2.04
Q3	120	16	4.06	4.87
QH-1	224	12	4.03	9.03
QH-2	52	17	2.88	1.50
QH-3	118	9	4.33	5.11
QH-4	42	11	3.25	1.36

*Number of conductivity determinations.
**Harmonic mean thermal conductivity (see Tables 3 through 9 for individual determinations).

TABLE 2. Shallow temperatures and temperature gradients for U.S. Geological Survey shallow test holes, Grass Valley, Nevada

Test hole*	Date of measurement year	mo	day	Depth to saturated zone (m)	Temperature (°C) 15 m	30 m	Depth interval measured (m)	Temperature gradient (°C/km)
H-1	73	06	14		13.82	14.80	12.98-44.84	64
P, Sc	73	12	14	12.6[N]	13.42	14.38	13.59-44.68	70
	74	08	07		13.70	14.46	13.85-44.85	63
	75	06	21		13.40	14.31	17.00-45.00	69
H-2	73	06	15		15.38	15.73	15.12-50.14	20
P, C	73	12	14	>50	14.26	14.98	13.90-40.72	50
							40.72-50.05	32
	74	08	06		14.15	14.97	15.54-40.54	49
							40.54-49.54	36
	75	04	24		14.15	14.85	14.00-40.00	49
							40.00-50.03	37
	74	06	23		14.06	14.87	14.00-30.00	52
							34.00-42.00	44
H-3	73	06	15		24.95	32.92	11.31-23.50	550
P, C							23.50-49.87	490
	73	12	14	22-26[N]	25.07	33.35	12.53-23.50	610
							23.50-49.96	480
	75	04	24		25.04	33.45	14.00-23.00	610
							23.00-50.09	480
	75	06	22		25.00	33.35	14.00-22.00	650
							22.00-46.00	490

TABLE 2. Shallow temperatures and temperature gradients for U.S. Geological Survey shallow test holes, Grass Valley, Nevada (continued)

Test hole*	Date of measurement year	mo	day	Depth to saturated zone (m)	Temperature (°C) 15 m	30 m	Depth interval measured (m)	Temperature gradient (°C/km)
H-4	73	06	19		20.81	25.48	14.97-23.50	330
P, C							23.50-47.88	260
	73	12	14	23.6[N]	20.61	25.36	13.75-24.72	380
							24.72-38.25	210
							33.25-45.45	270
	75	04	24		20.63	25.35	14.00-18.00	340
							18.00-24.00	370
							24.00-44.00	260
	75	06	13	23.9[N]	20.75	25.35	14.00-26.00	350
							26.00-34.00	200
							34.00-49.90	260
H-5	73	07	08		16.02	18.5[e]	13.44-19.54	180
P, C							19.54-27.16	160
	73	12	14	>27	15.63	18.1[e]	13.44-19.54	180
							19.54-27.13	150
	75	06	14		15.55		14.00-22.00	190
							22.00-27.13	160
H-6	73	07	09		17.9[e]	20.45	29.90-40.26	180
St,Sc	73	12	14	16.7[N]	17.7[e]	20.18	29.29-40.26	180
	74	08	07		17.7[e]	20.27	30.09-40.09	170
	75	04	24		17.8[e]	20.20	30.00-40.00	170
	75	06	21			20.25	30.00-41.00	170

TABLE 2. Shallow temperatures and temperature gradients for U.S. Geological Survey shallow test holes, Grass Valley, Nevada (continued)

Test hole*	Date of measurement year	mo	day	Depth to saturated zone (m)	Temperature (°C) 15 m	30 m	Depth interval measured (m)	Temperature gradient (°C/km)
H-7	73	07	09			17.83	27.13-50.90	100
P, Sc	73	12	15	26.4[N]		17.54	33.22-50.29	110
	74	08	07			17.58	33.45-48.45	100
	75	06	21			17.63	30.00-50.88	110
H-8	73	10	31		12.66	13.70	19.02-44.32	67
P, Sc	73	11	09	22.9[N]		13.77	27.55-44.01	69
	73	12	13			13.86	24.51-44.62	68
	74	08	06			13.84	26.79-44.79	66
	74	12	10			13.65	28.00-45.00	67
	75	06	21			13.68	28.00-44.95	68
H-9	73	11	01	36.2[N]		37.50	28.07-35.39	710
St,Sc							35.39-42.70	660
	73	11	09			38.62	28.07-35.39	680
							35.39-41.48	610
	73	12	15			38.80	28.07-35.39	720
							35.39-42.09	630
	74	08	07			39.2[e]	31.09-36.09	630
							36.09-42.61	640
	75	06	21			38.7[e]	35.00-41.00	640

TABLE 2. Shallow temperatures and temperature gradients for U.S. Geological Survey shallow test holes, Grass Valley, Nevada (continued)

Test hole*	Date of measurement: year	mo	day	Depth to saturated zone (m)	Temperature (°C): 15 m	30 m	Depth interval measured (m)	Temperature gradient (°C/km)
H-10	73	11	09	5.8[c]	82.41	108.0[e]	5.82- 9.48	1,400
St,Sc							9.48-16.79	1,800
	73	12	15	5.8[c]	85.10	110.0[e]	5.82- 8.87	1,300
							8.87-16.79	1,800
	74	08	07	5.8[c]	86.55	111.7[e]	6.39- 9.39	1,700
							9.39-16.76	1,900
	75	06	22	5.8[c]	85.50		6.00-16.79	1,700
H-11	73	11	09	29.5[N]		21.1[e]	32.40-44.59	250
St,Sc	73	12	15			21.22	31.18-44.59	240
	74	08	07			21.34	35.09-43.65	240
	75	06	21			21.51	36.00-44.00	230
H-12	75	06	21	25.1[c]		14.11	29.00-42.73	87
P, Sc	75	07	20	25.1[c]		13.90	29.00-43.00	100
H-13A	75	06	22			37.66	19.00-52.00	710
St,Sc	75	09	30	17.3[c]		37.63	20.00-52.00	670
H-13B	75	06	22		26.70	38.01	33.00-41.44	700
St,C,g	75	09	30	17.3[c]	26.35	37.90	20.00-41.41	720
H-14A	75	06	22	31.4		25.2[e]	33.00-42.00	260
P, Sc	75	10	01	31.9		25.1[e]	33.00-42.00	260

TABLE 2. Shallow temperatures and temperature gradients for U.S. Geological Survey shallow test holes, Grass Valley, Nevada (continued)

Test hole	Date of measurement year	mo	day	Depth to saturated zone (m)	Temperature (°C) 15 m	30 m	Depth interval measured (m)	Temperature gradient (°C/km)
H-14B	75	06	22	31.4	20.35	25.04	10.00-18.00	390
P, C							18.00-30.00	300
	75	09	30	31.9	20.11	25.01	10.00-16.00	420
							22.00-30.00	300
H-15	75	06	21		21.37	26.30	15.00-44.00	300
P, C	75	07	20		21.10	26.21	15.00-44.00	310
	75	09	07	33.8(?)[N]	21.07	26.29	16.00-30.00	340
							30.00-44.39	280
	75	09	30	33.8(?)[N]	20.93	26.25	34.00-44.00	270

[N]determined from neutron logs.

[c]confined water level.

[e]extrapolated linearly downward from lowest depth shown in depth interval, or upward from highest depth.

*Letters beneath hole number denote type of casing and completion:

- P, plastic (PVC) casing.
- St, steel casing.
- C, casing capped at bottom.
- Sc, screen at bottom of casing.
- g, indicates that the casing was grouted in (all other wells have the annulus backfilled with cuttings and/or dry surface materials).

TABLE 3. Thermal conductivity and lithology of cores from test hole Q-1, Grass Valley, Nevada

Core depth (meters)	Lithology	K sample depth (meters)	K (mcal/cm sec °C)
62.48 to 64.01	Tan clay and silt; small pebble sized chert and quartzite clasts rare	62.73	3.86
		63.03	4.09
		63.31	3.48
121.92 to 123.44	Tan clay and silt; 20%± medium sand	122.13	3.55
		122.22	3.84
123.44 to 124.97	Tan clay and silt; 2-5% very coarse sand; calcite cement	123.54	2.67
		123.75	3.38
		123.96	3.07
		124.15	3.38
167.64 to 168.07	Tan clay to very fine sand	167.79	3.33
		167.94	3.26
		168.01	3.56

TABLE 4. Thermal conductivity and lithology of cores from test hole Q-2, Grass Valley, Nevada

Core depth (meters)	Lithology	K sample depth (meters)	K (mcal/cm sec °C)
62.48 to 62.84	Conglomerate; quartzite, chert, basalt, and metavolcanic clasts, average clast size 5-10 mm (maximum size 80 mm), poor sorting, 20-30% tan clay and silt matrix	62.79	6.22
62.84 to 63.63	Conglomerate; average clast size 2-6 mm (maximum size 30 mm), poor sorting, 50-60% tan clay and silt matrix	63.15 63.43	4.43 4.28
122.53 to 123.09	Tan clay and silt; 5-20% poorly sorted clasts of quartzite, chert, and metavolcanics	122.80 123.08	2.91 3.09
123.09 to 124.05	Conglomerate; quartzite, chert, and metavolcanic clasts, 60-70% tan silt and clay matrix	123.20	3.54
124.05 to 124.46	Tan clay to very coarse sand; 10-20% chert clasts (maximum size 10 mm), poor sorting	124.36	3.28
124.46 to 124.66	Conglomerate; average clast size 3-7 mm (maximum size 10 mm), clasts predominantly of chert, 50%± tan clay to coarse sand matrix	124.66	3.85
124.66 to 125.22	Conglomerate; chert clasts predominate, average clast size 10-15 mm (maximum size 25 cm), poor sorting, 50%± tan clay to coarse sand matrix	124.97 125.21	3.27 3.64

TABLE 5. Thermal conductivity and lithology of cores from test hole Q-3, Grass Valley, Nevada

Core depth (meters)	Lithology	K sample depth (meters)	K (mcal/cm sec °C)
64.62 to 65.99	Conglomerate; clasts subrounded to angular chert, average clast size 5-15 mm (maximum size 50 mm), poor sorting, 40-60% tan clay and silt matrix	64.83 65.07 65.26 65.59	4.31 5.02 4.75 4.95
128.02 to 128.63	Conglomerate; chert, quartzite and rhyolitic clasts as large as 30 mm; 50%± tan clay to medium sand size matrix	128.14 128.47	3.21 5.17
128.63 to 129.11	Tan clay and silt; 5%± coarse sand	128.78 129.05	2.88 3.24
129.11 to 129.74	Conglomerate	129.45	6.05
129.74 to 129.97	Tan clay and silt	129.88	3.50
129.97 to 130.63	Conglomerate	130.36	3.69
164.59 to 165.91	Conglomerate; clasts of chert, quartzite, and andesite, average clast size 1-5 mm (maximum size 70 mm), poor sorting	164.71 165.02 165.29 165.63 165.90	4.42 4.03 4.81 3.79 3.73

TABLE 6. Lithology and conductivity of cores from test well QH-1, Grass Valley, Nevada

Core depth (meters)	Lithology	K sample depth (meters)	K (mcal/cm sec °C)
58.22 to 58.46	Conglomerate; clasts subrounded to angular chert and quartzite, average clast size 10-30 mm, poor sorting, 30%± light green clay and silt matrix	58.37	5.45
58.46 to 59.74	Light green silt and clay; pervasively sheared, moderately indurated, 1-5% sub-rounded to angular chert and quartzite clasts	58.77 59.10 59.59	4.18 3.85 3.20
119.48 to 119.88	Fine sand; poor sorting, clayey matrix	119.60	3.97
119.88 to 120.30	Medium to fine sand; poor sorting, clayey matrix		
120.30 to 121.31	Medium sand; poor sorting, clayey matrix	120.43 120.76	3.78 3.98
152.70 to 152.89	Brown silt and clay; poor sorting, 5-30% very coarse sand		
152.89 to 153.13	Brown silt and clay; 5-20% medium to coarse pebble-sized chert and quartzite clasts	153.07	5.13
153.13 to 153.22	Brown silt and clay	153.19	4.61
153.22 to 154.23	Brown clay and coarse silt; thin indistinct interbeds with as much as 10% very coarse sand	153.38 153.56 154.23	4.40 2.98 4.13*

*density: 2.32; porosity: 16.6%

TABLE 7. Lithology and conductivity of cores from test well QH-2, Grass Valley, Nevada

Core depth (meters)	Lithology	K sample depth (meters)	K (mcal/cm sec °C)
60.96 to 62.79	Light green clay and silt; thin indistinct coarse silt to very fine sand interbeds, evidence of minor shearing, trace of secondary pyrite along fractures	61.60	2.55
		61.78	2.61
		61.94	2.79
		61.96	2.75
		62.06	2.91
		62.36	2.77
		62.51	2.79
		62.73	2.79
121.92 to 122.41	Light green clay to coarse silt; 1-2% chert clasts, average clast size 2-6 mm	122.16	2.61
122.41 to 124.00	Light green clay to medium silt	122.53	2.90
		122.70	3.06
		122.90	2.46
152.70 to 154.53	Light green silt to very fine sand; evidence of minor shearing, trace of secondary calcite as veining	153.04	3.32
		153.22	2.92
		153.86	3.26
		154.14	3.48
		154.53	3.51*

*density: 2.04; porosity: 27.1%

TABLE 8. Lithology and conductivity of cores from test well QH-3, Grass Valley, Nevada

Core depth (meters)	Lithology	K sample depth (meters)	K (mcal/cm sec °C)
60.96 to 61.87	Conglomerate; clasts subrounded to angular quartzite, average clast size 15-25 mm (maximum size 65 mm), poor sorting, 20%± tan silt and clay matrix	61.11 61.17	4.98 5.33
118.87 to 120.40	Conglomerate; clasts subrounded to angular quartzite, chert, and meta-volcanics, maximum clast size 70-80 mm, 20-50% tan silt and clay matrix	119.02 119.18 119.36 119.48	3.81 5.59 3.11 4.32
152.70 to 152.86	Tan clay and silt; <10% pebble-sized clasts		
152.86 to 153.01	Conglomerate; average clast size 3-8 mm (maximum size 40 mm), 20%± tan clay and silt matrix	152.89 152.98	4.70 4.90
153.01 to 153.40	Conglomerate; average clast size 20-40 mm (maximum 85 mm), predominantly chert, quartzite, and meta-volcanic clasts, with some schistose and granitic fragments, 20%± clay and silt matrix	153.19	3.60

TABLE 9. Lithology and conductivity of cores from test well QH-4, Grass Valley, Nevada

Core depth (meters)	Lithology	K sample depth (meters)	K (mcal/cm sec °C)
58.22 to 58.83	Conglomerate; chert and quartzite clasts predominate, 30%± tan clay and silt matrix	58.43 58.49	4.01 4.06
58.83 to 59.15	Conglomerate; clasts subrounded to angular, 75% of clasts are chert and quartzite, remainder are metavolcanic and andesitic, 20%± tan clay and silt matrix	59.04	4.22
59.15 to 59.45	Tan clay and silt; 2-5% very coarse sand	59.22	2.84
59.45 to 59.85	Tan clay and silt; 20-40% clasts as large as 20 mm	59.50 59.59	3.04 3.04
122.00 to 123.00	Conglomerate; quartzite, chert and graywacke clasts as large as 100 mm, 10%± brick-red clay matrix	122.59	4.19
154.53 to 156.06	Brick-red clay; high angle (80°) shear planes	154.69 154.96 155.51 155.97	2.68 2.94 2.80 3.01

TABLE 10. Generalized lithology of Grass Valley test holes (based on examination of drill cuttings)

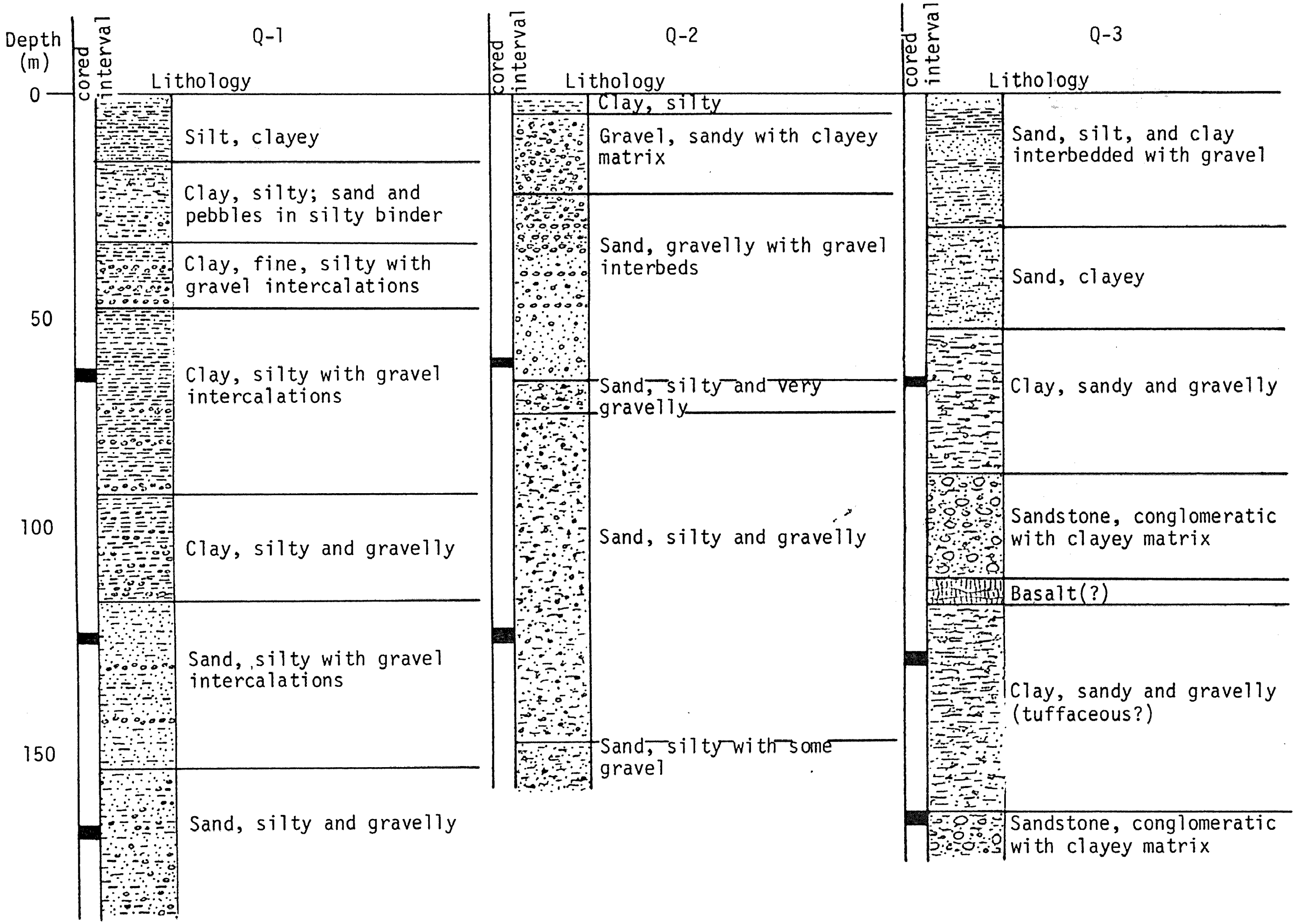


TABLE 10. (continued)

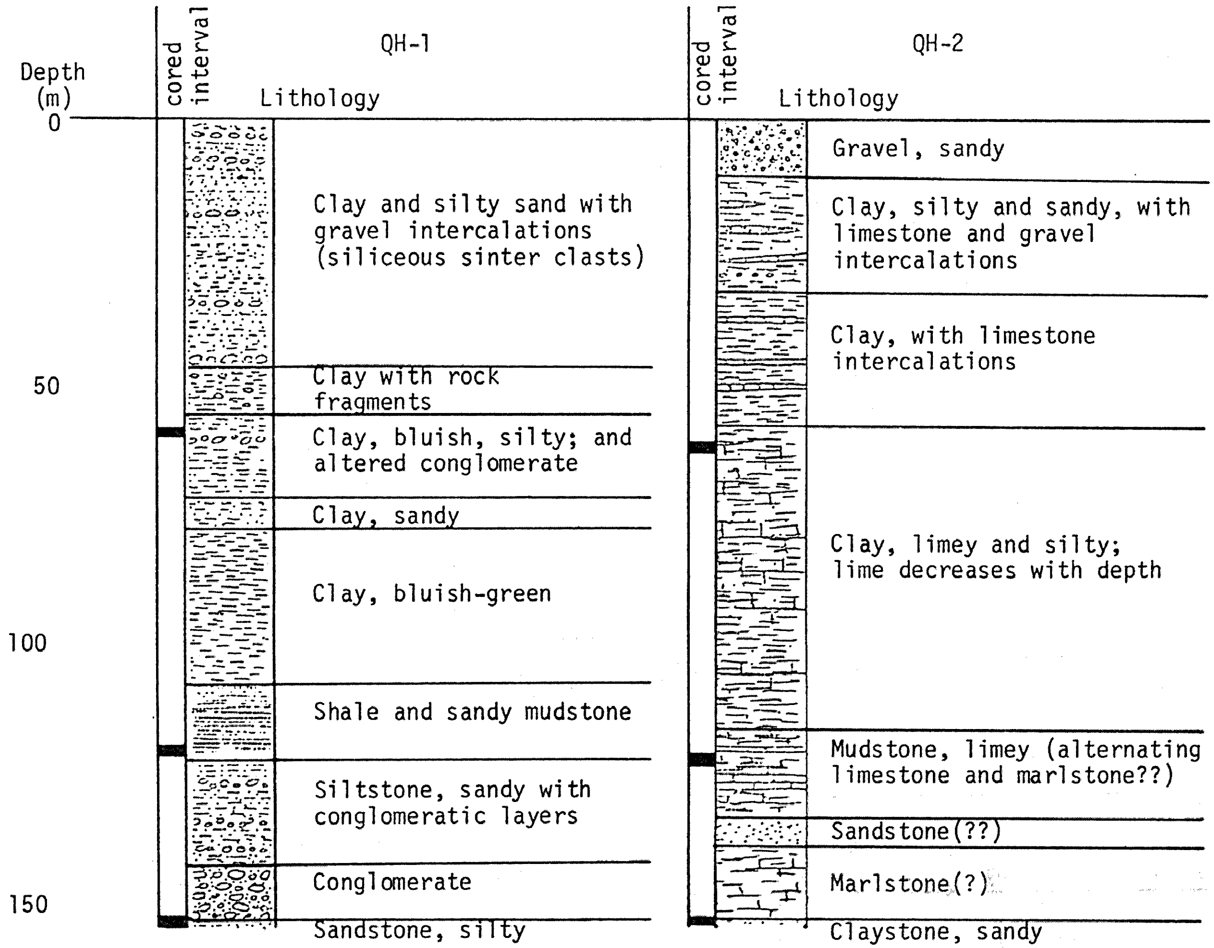


TABLE 10. (continued)

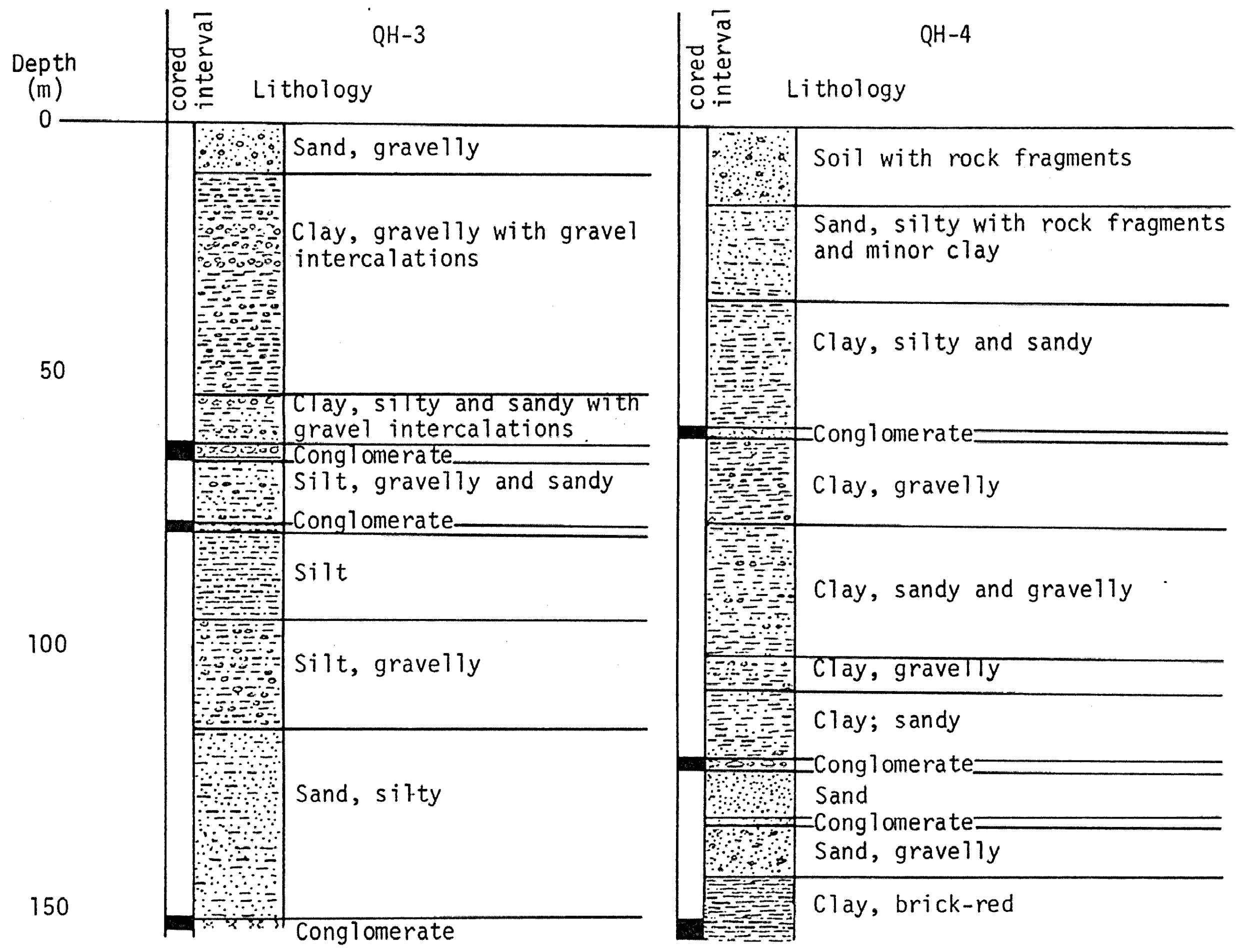


TABLE 11. Summary of temperature gradients, conductivities, and heat flows for holes near Buffalo Valley Hot Springs, Nevada

Hole	Interval	Grad °C/km	<K> mcal/cm sec °C	q HFU
1	30-37	147	3.7*	5.5
	45-60	280†	2.65	7.4
			average	6.5±1
2	45-116	79	2.48	2.0
3	40-97	107.5	2.57	2.8

*Mean of the two extreme outcrop specimen values for basalt (3.08 and 4.36).

†Based on a temperature log made only a few hours after cessation of drilling.

TABLE 12. Lithology and thermal conductivity for conductivity samples from Buffalo Valley heat-flow holes

Hole #	Depth	Lithology*	K mcal/cm sec °C
1	0†	basalt $\rho = 2.12$, $\phi = 20.6$	3.08
	0†	basalt $\rho = 2.69$, $\phi = 7.8$	4.10
	0†	basalt $\rho = 2.71$, $\phi = 7.0$	4.36
	67.7	silty sand	2.65
2	92.6	clayey sand	2.36
	93.0	clayey sand	2.36
	113.7	gritty sand	2.52
	114.0	gritty sand	2.66
	114.3	gritty sand	2.54
3	61.6	silty sand	2.62
	61.9	silty sand	2.42
	62.2	silty sand	2.34
	62.5	silty sand	2.36
	78.3	silty sand	2.39
	95.1	silty clay	2.70
	96.0	silty clay	2.59
	96.6	silty clay	3.38

*For basalts ρ = density g/cm^3, ϕ = apparent porosity %.

†Nearby outcrop samples of basalt flow intersected between ∿30 and ∿37 meters.

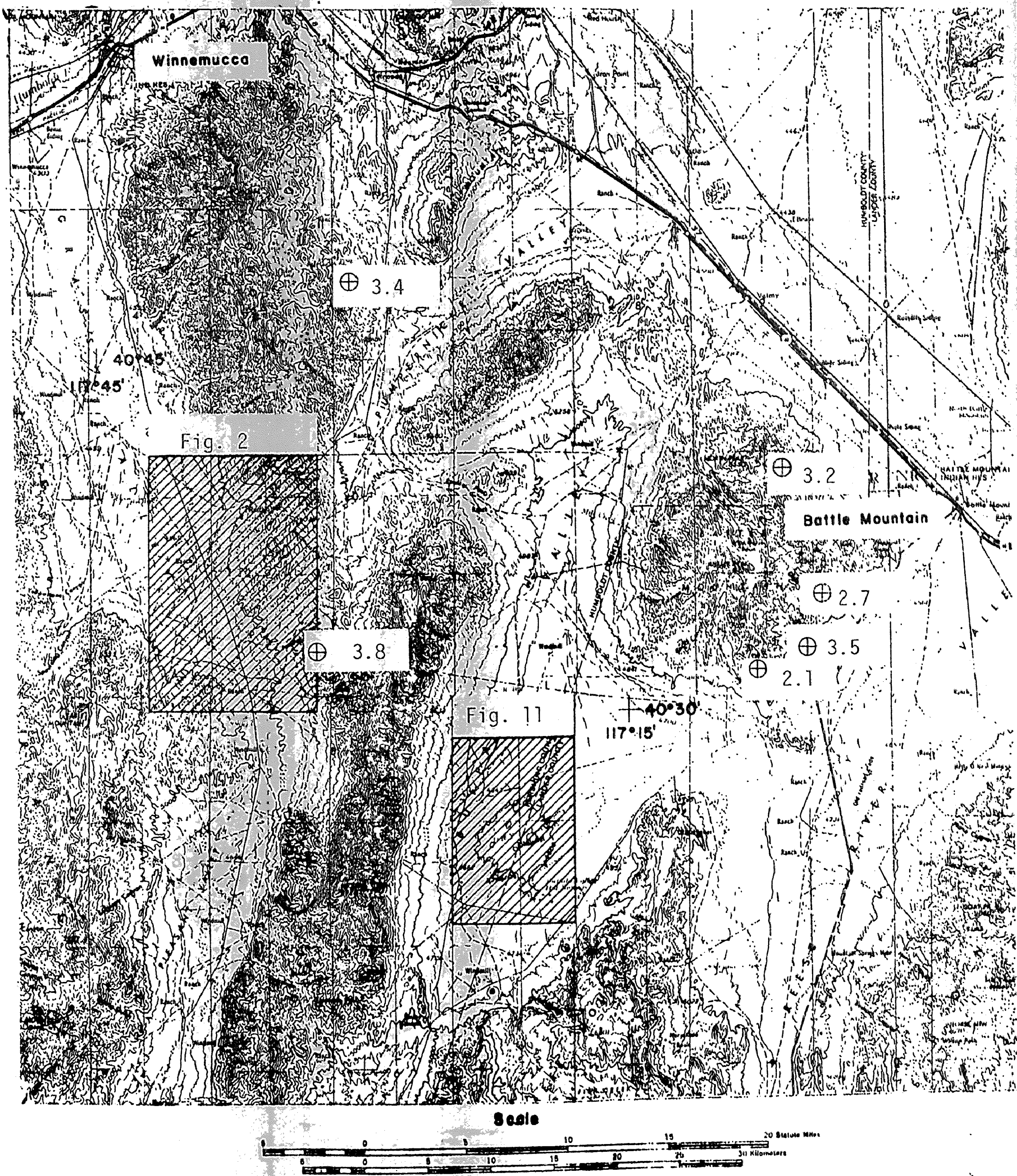


Figure 1. Location map showing areas of more detailed maps together with previously published heat-flow values ⊕

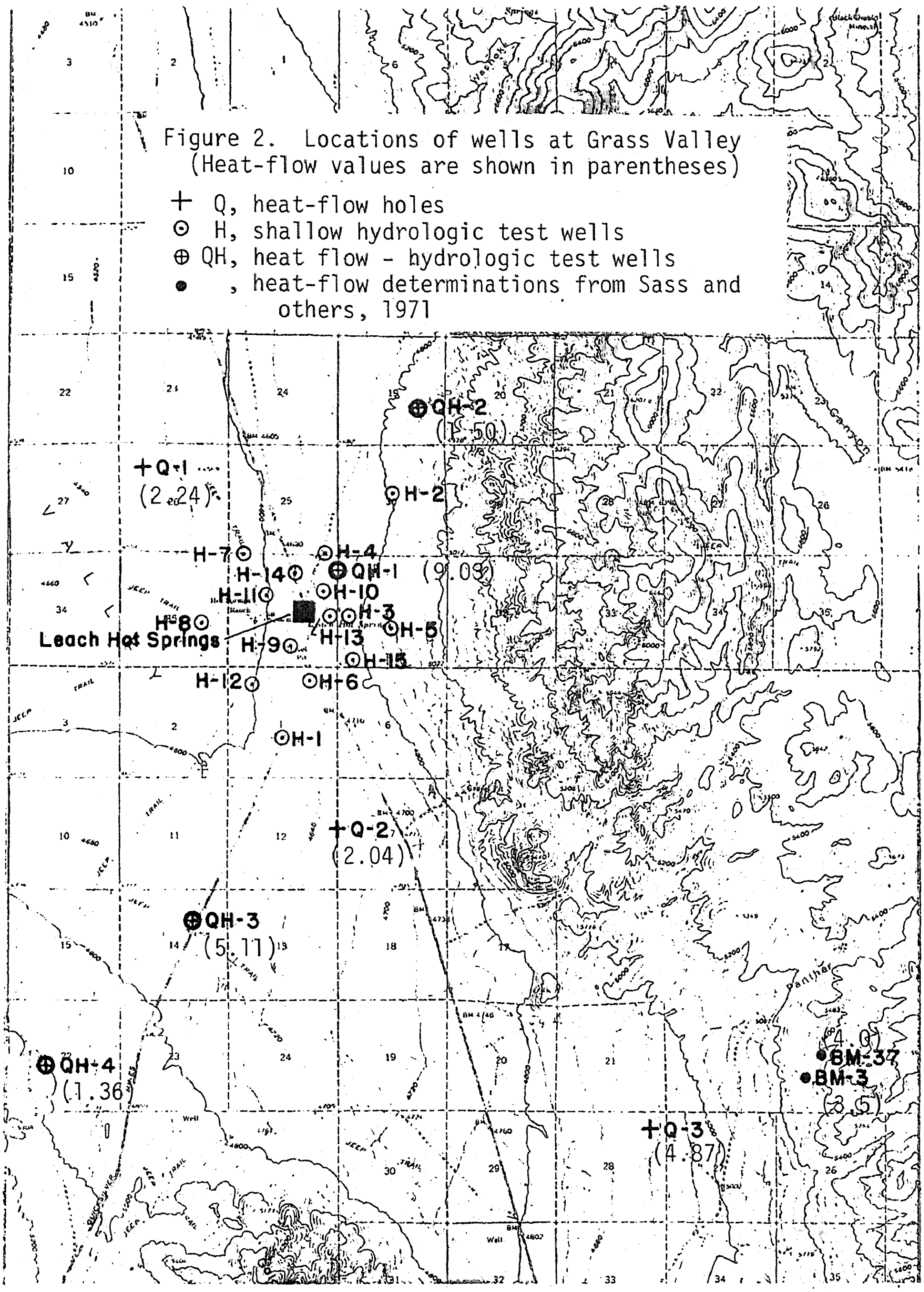
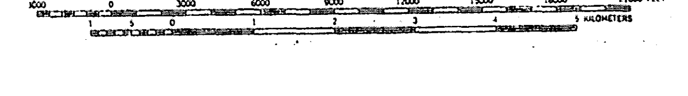


Figure 2. Locations of wells at Grass Valley (Heat-flow values are shown in parentheses)

+ Q, heat-flow holes
⊙ H, shallow hydrologic test wells
⊕ QH, heat flow - hydrologic test wells
● , heat-flow determinations from Sass and others, 1971

Scale



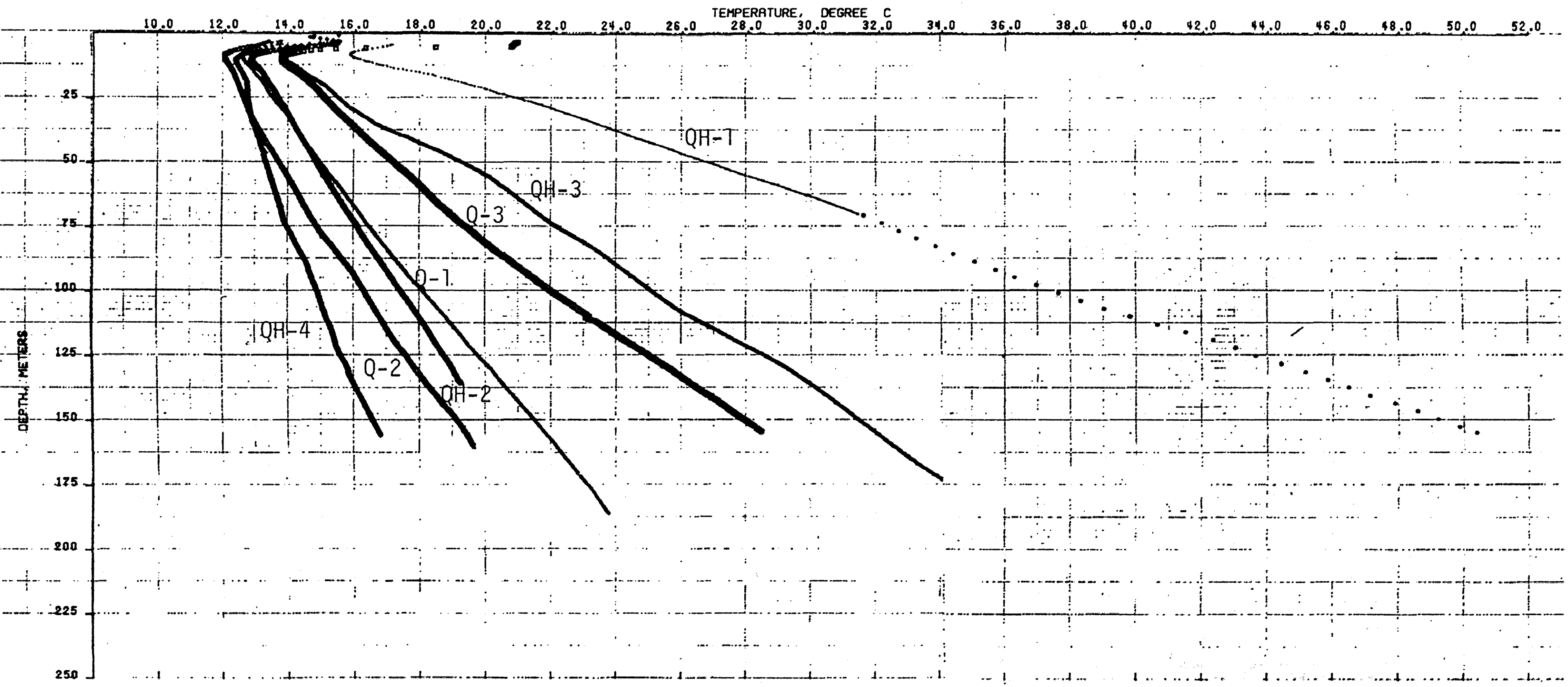


Figure 3. Temperature profiles for holes Q-1 through Q-3 and QH-1 through QH-4, Grass Valley, Nevada.
All temperatures measured on 10-21-75.

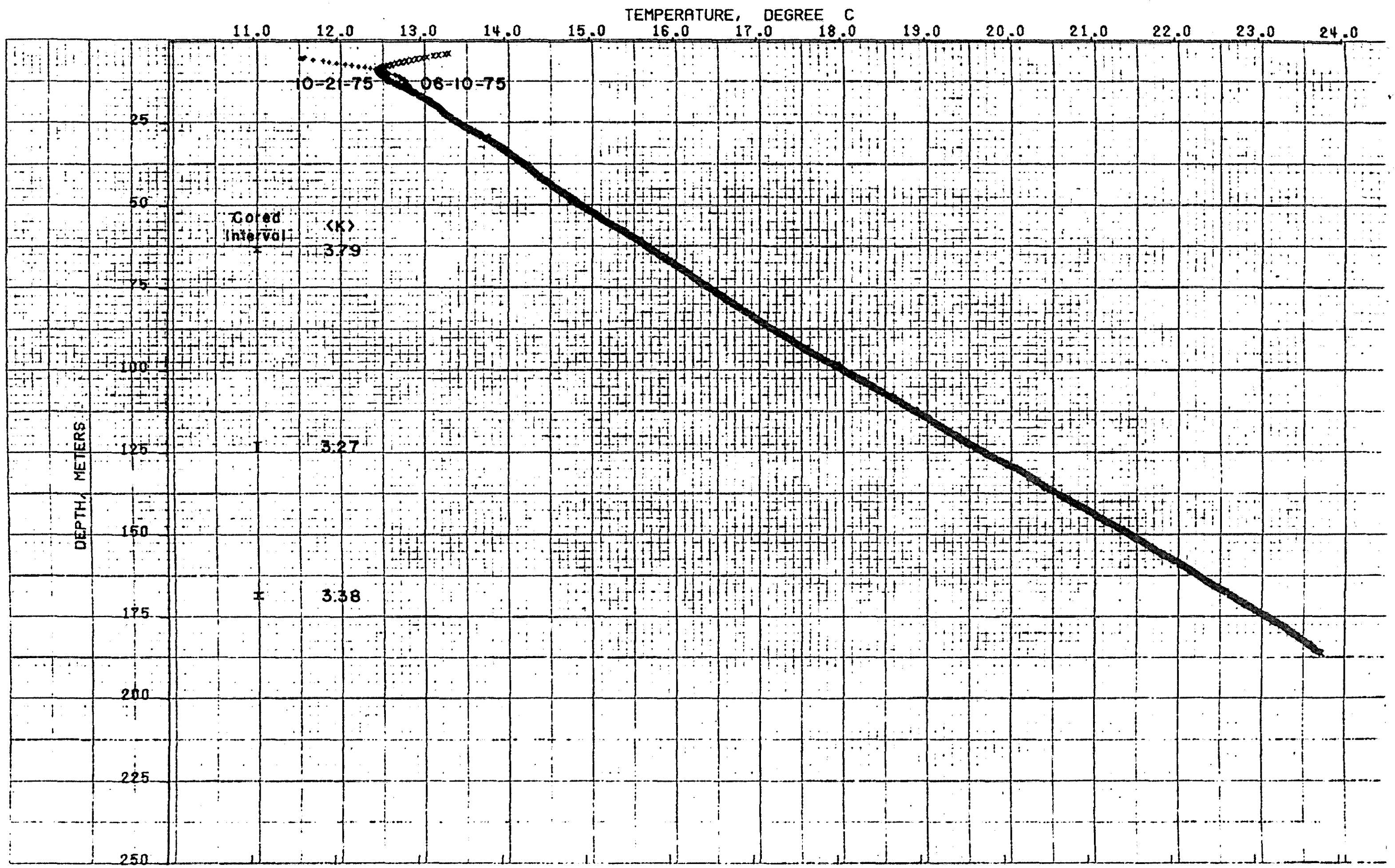


Figure 4. Temperature profiles from hole Q-1, Grass Valley, drilled 4-5 to 4-8, 1975.

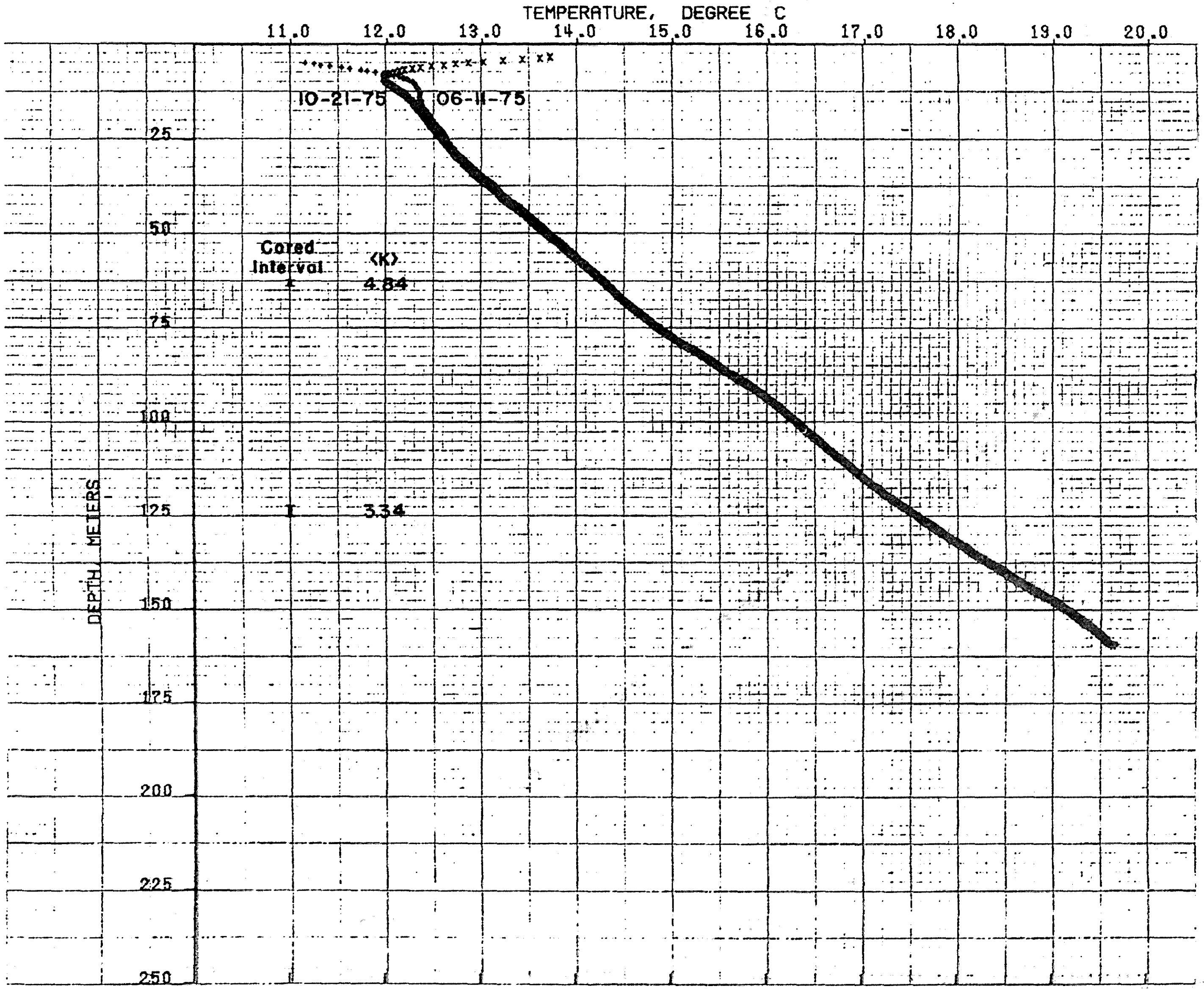


Figure 5. Temperature profiles from hole Q-2, Grass Valley, drilled 4-9 to 4-17, 1975 (includes 4-day break).

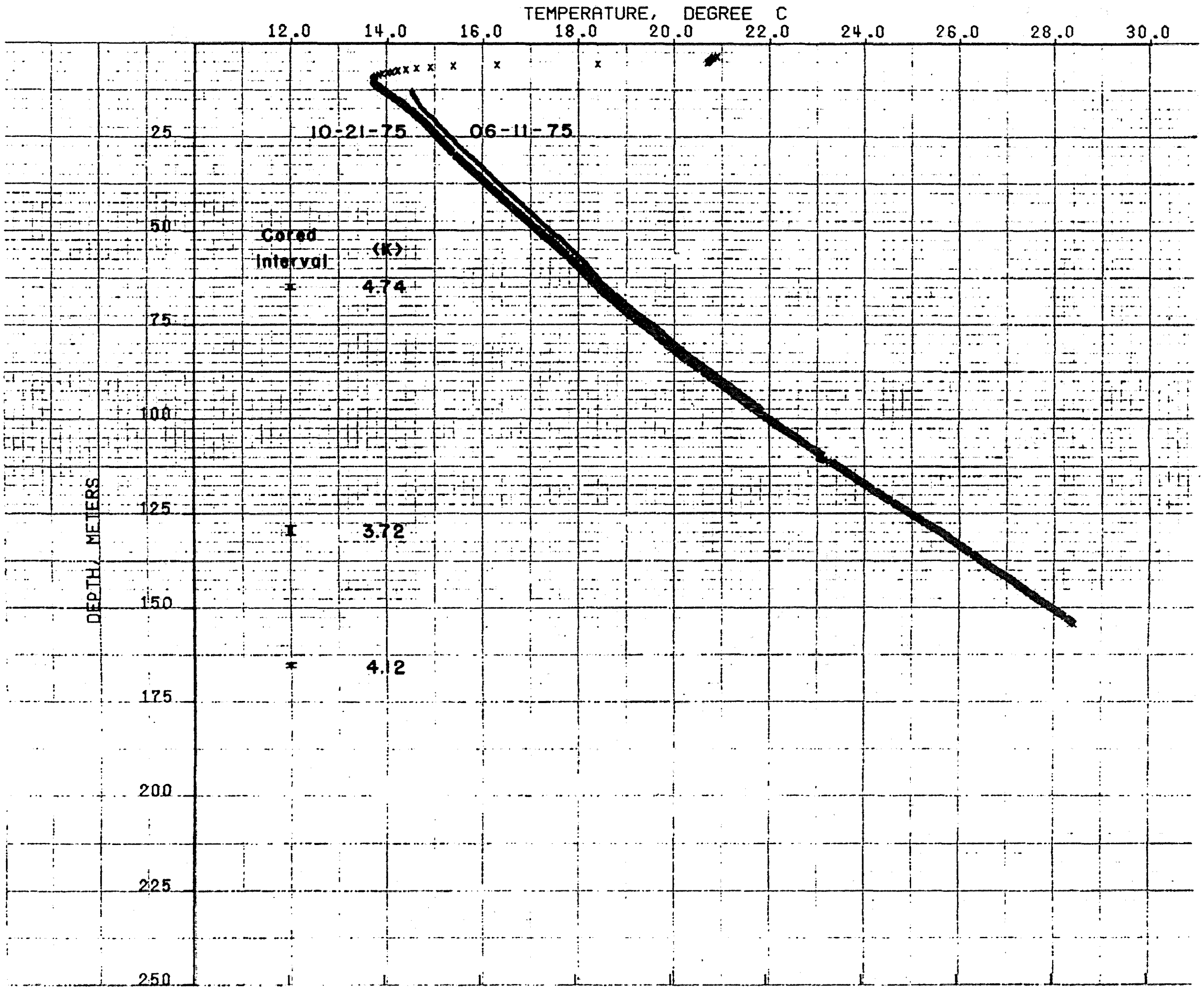


Figure 6. Temperature profiles from hole Q-3, Grass Valley, drilled 4-18 to 4-22, 1975.

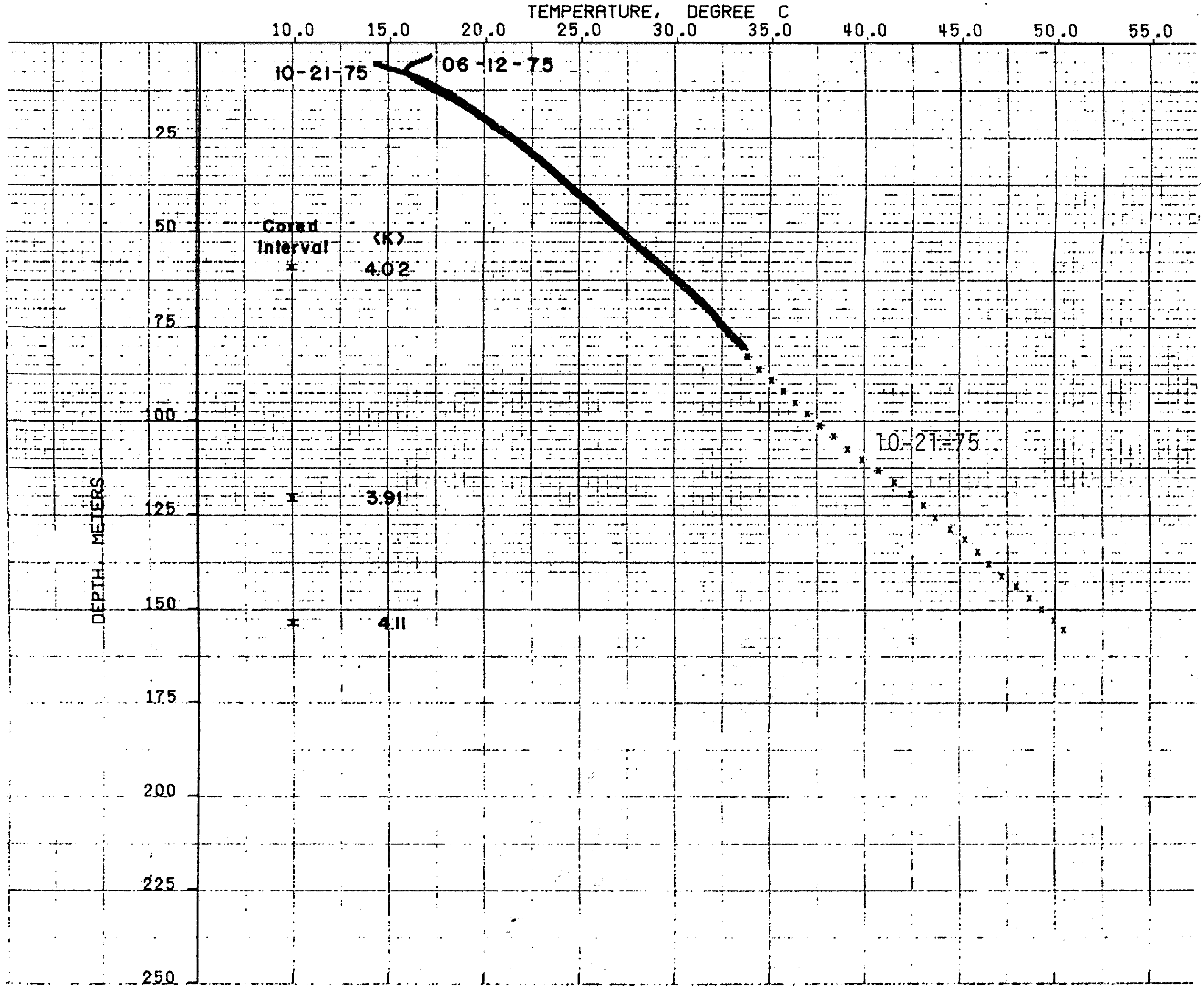


Figure 7. Temperatures from hole QH-1, Grass Valley, drilled 4-23 to 5-3, 1975 (includes 4-day break).

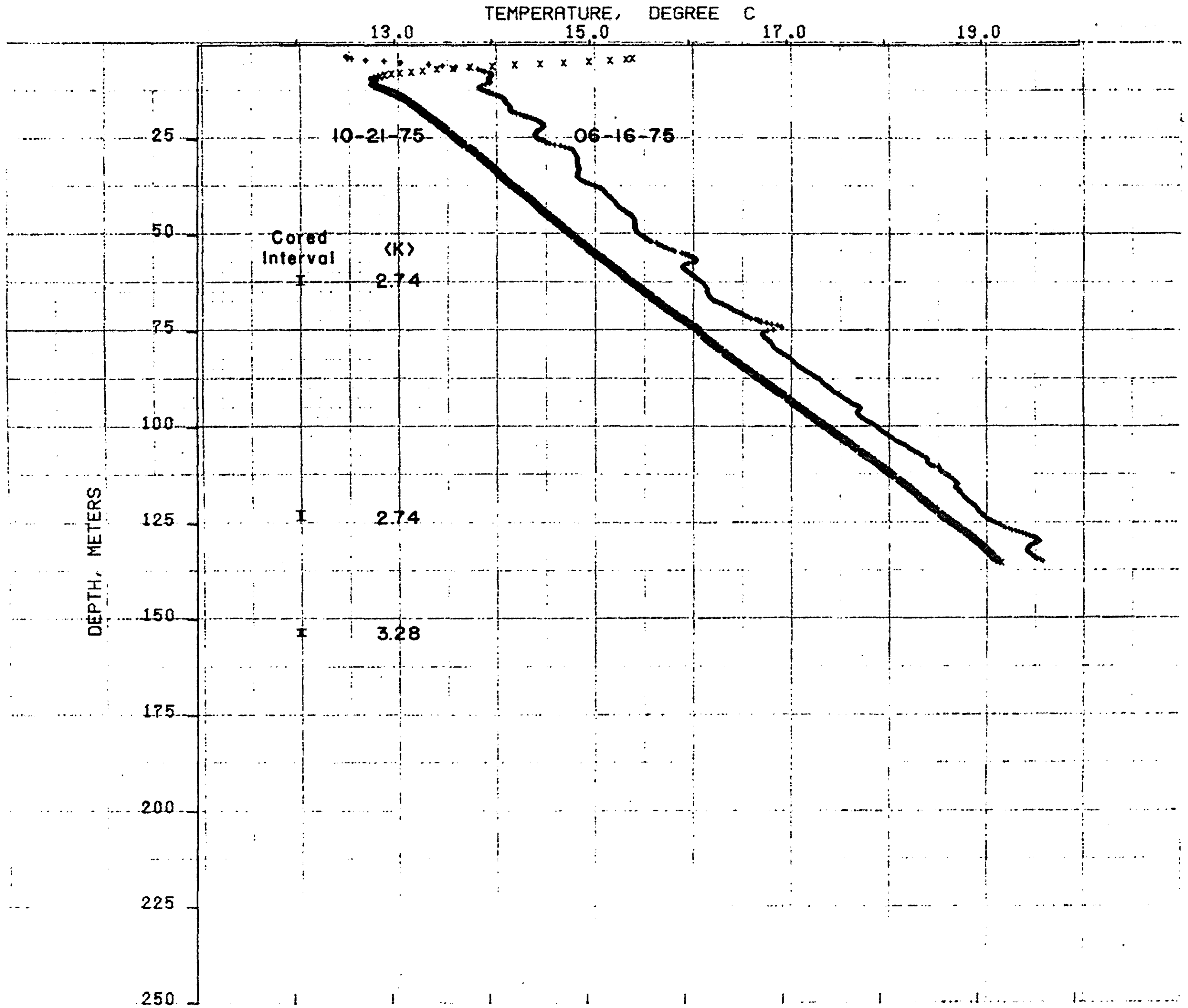


Figure 8. Temperatures from hole QH-2, Grass Valley, drilled 6-1 to 6-4, 1975.

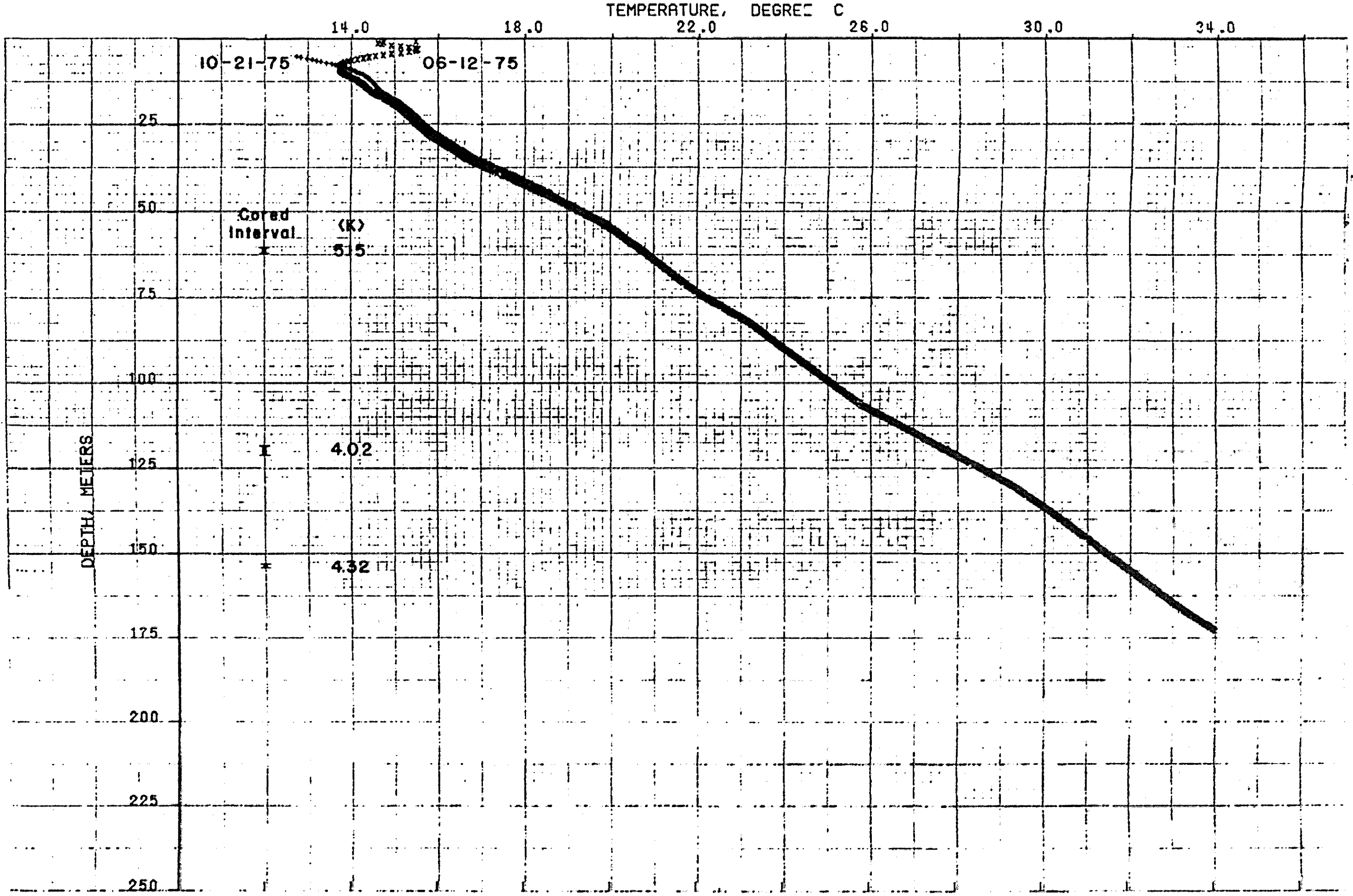


Figure 9. Temperatures from hole QH-3, Grass Valley, drilled 5-5 to 5-16, 1975 (includes 4-day break).

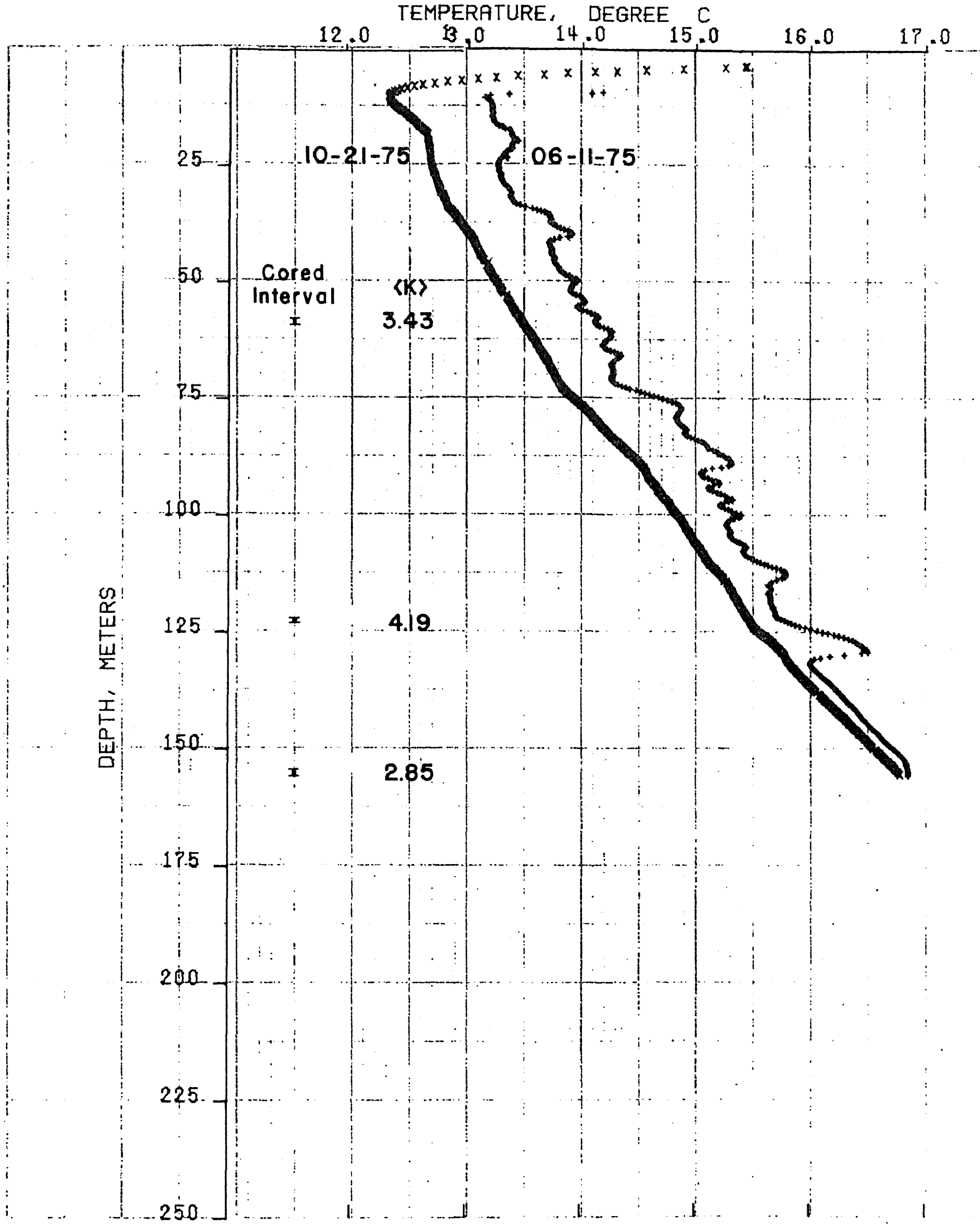


Figure 10. Temperatures from hole QH-4, Grass Valley, drilled 5-20 to 5-30, 1975 (includes 5-day break).

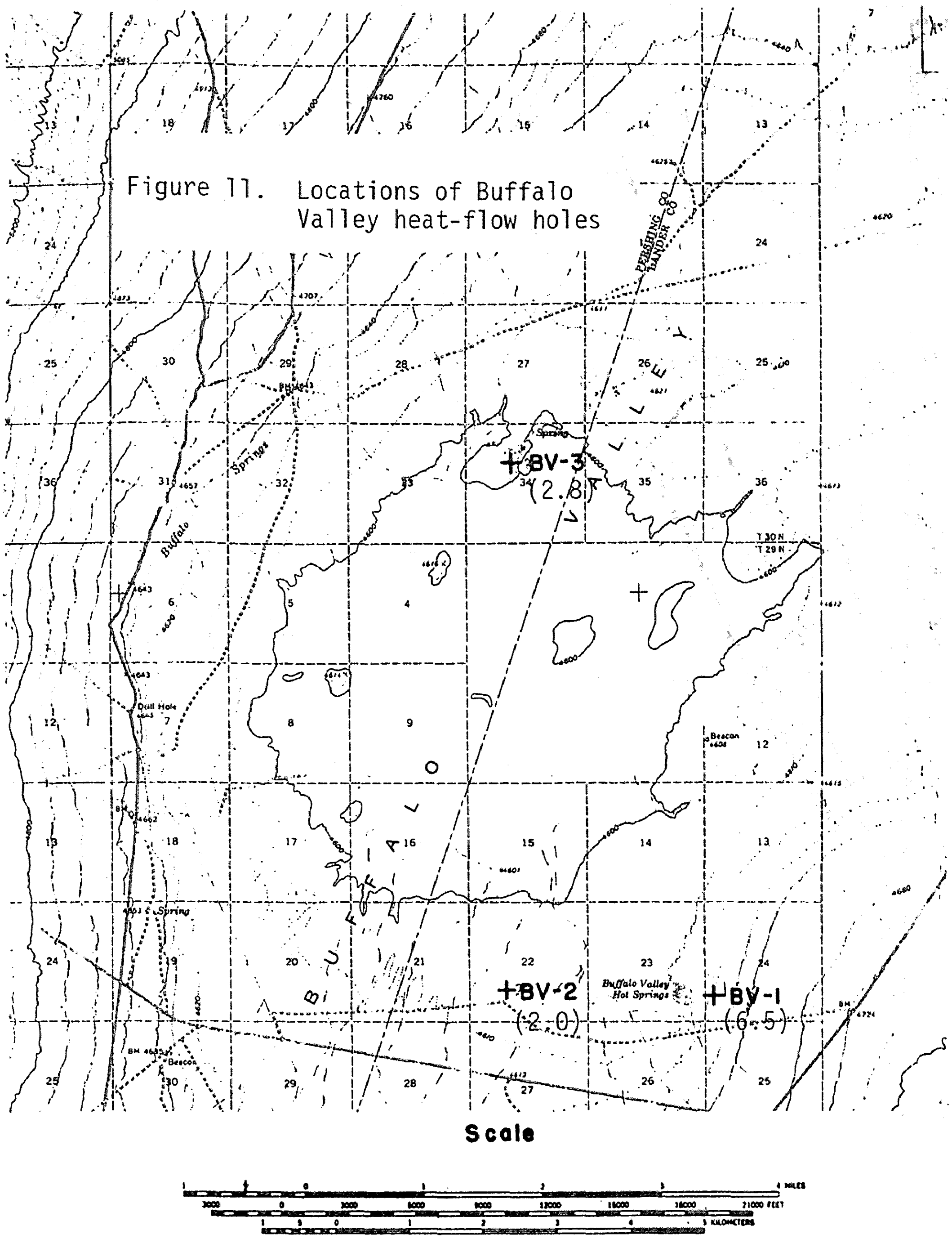


Figure 11. Locations of Buffalo Valley heat-flow holes

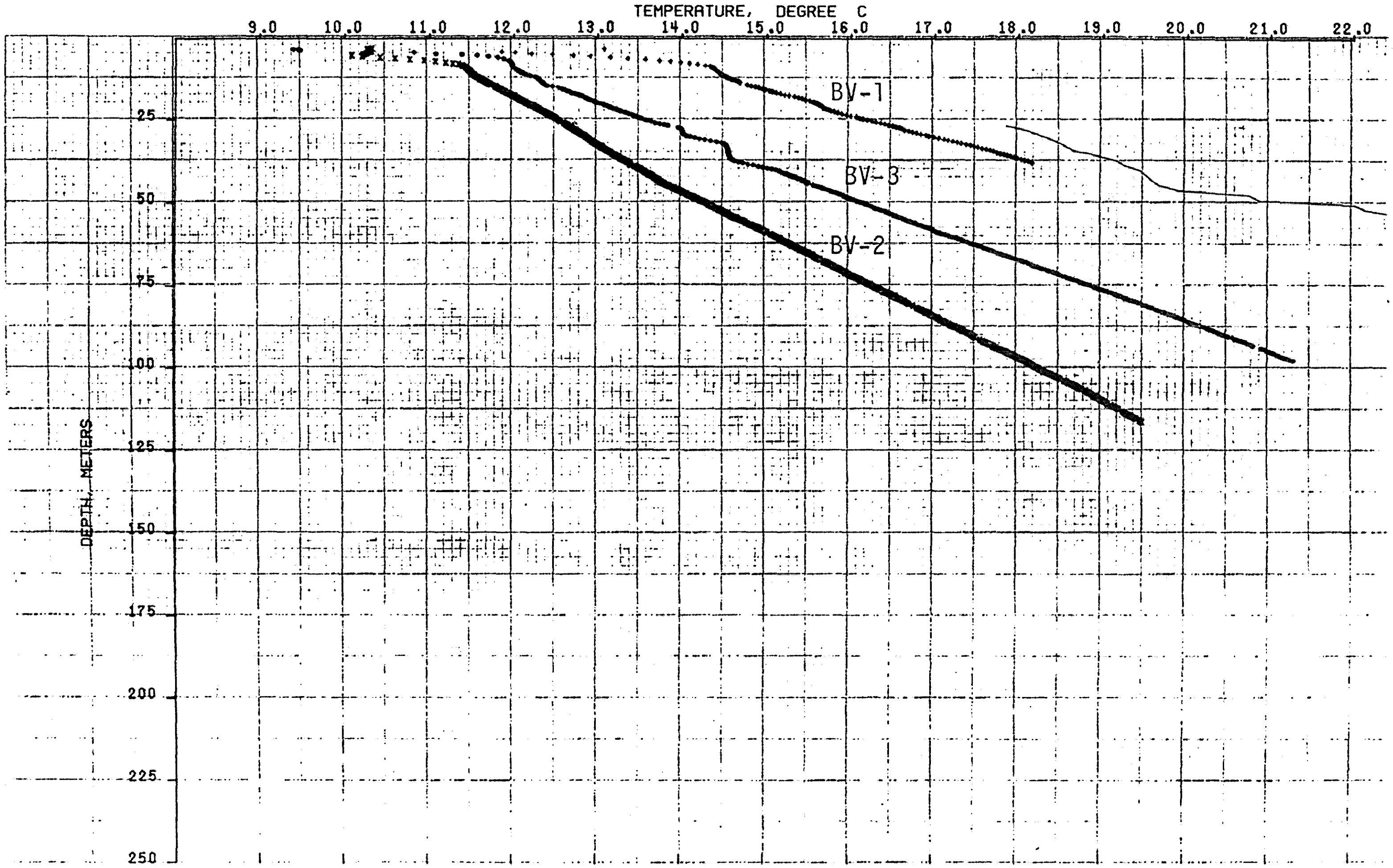


Figure 12. Temperature profiles for all Buffalo Valley heat-flow holes.

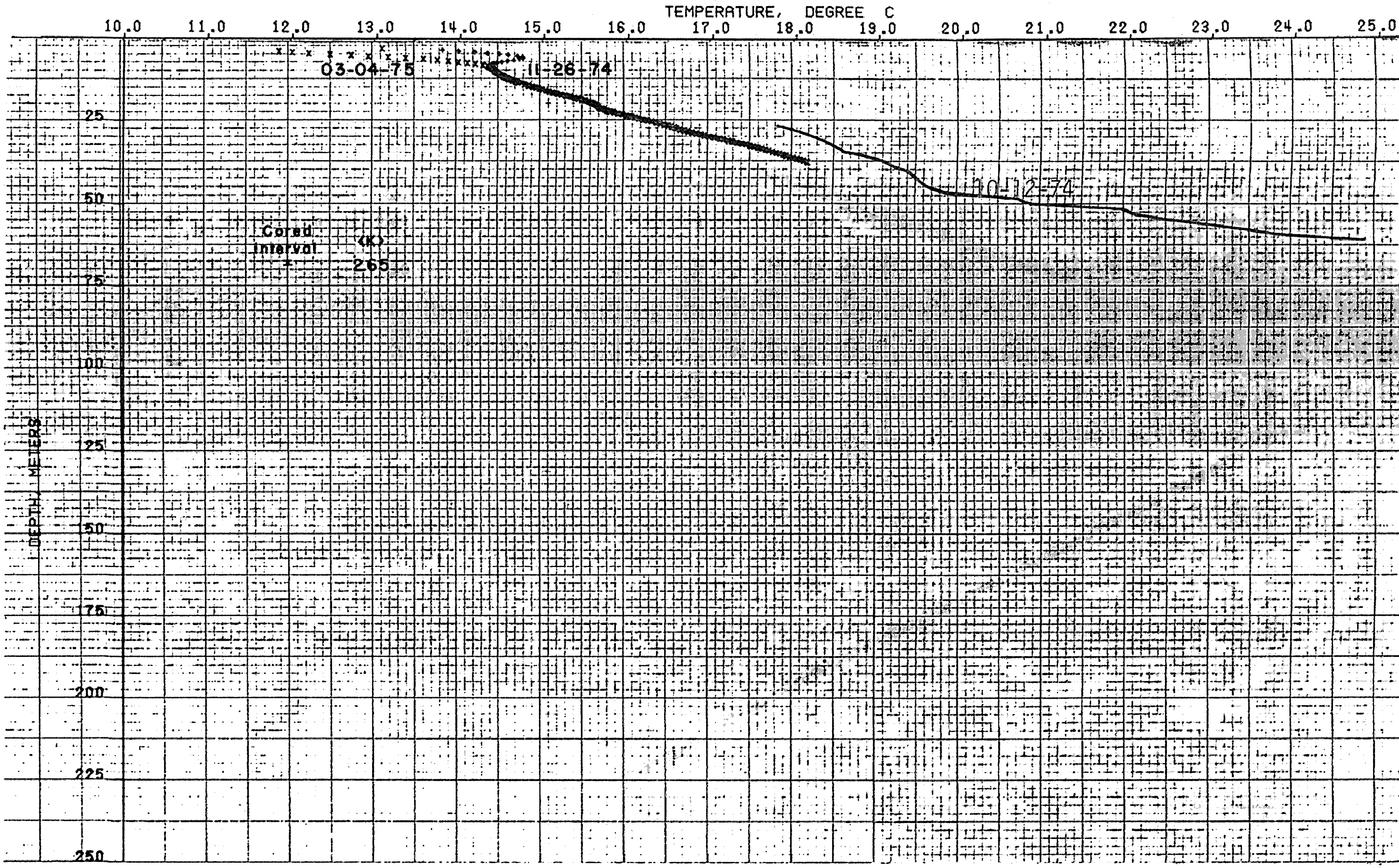


Figure 13. Temperature profiles for heat-flow hole BV-1, Buffalo Valley, drilled 10-9 to 10-13, 1974.

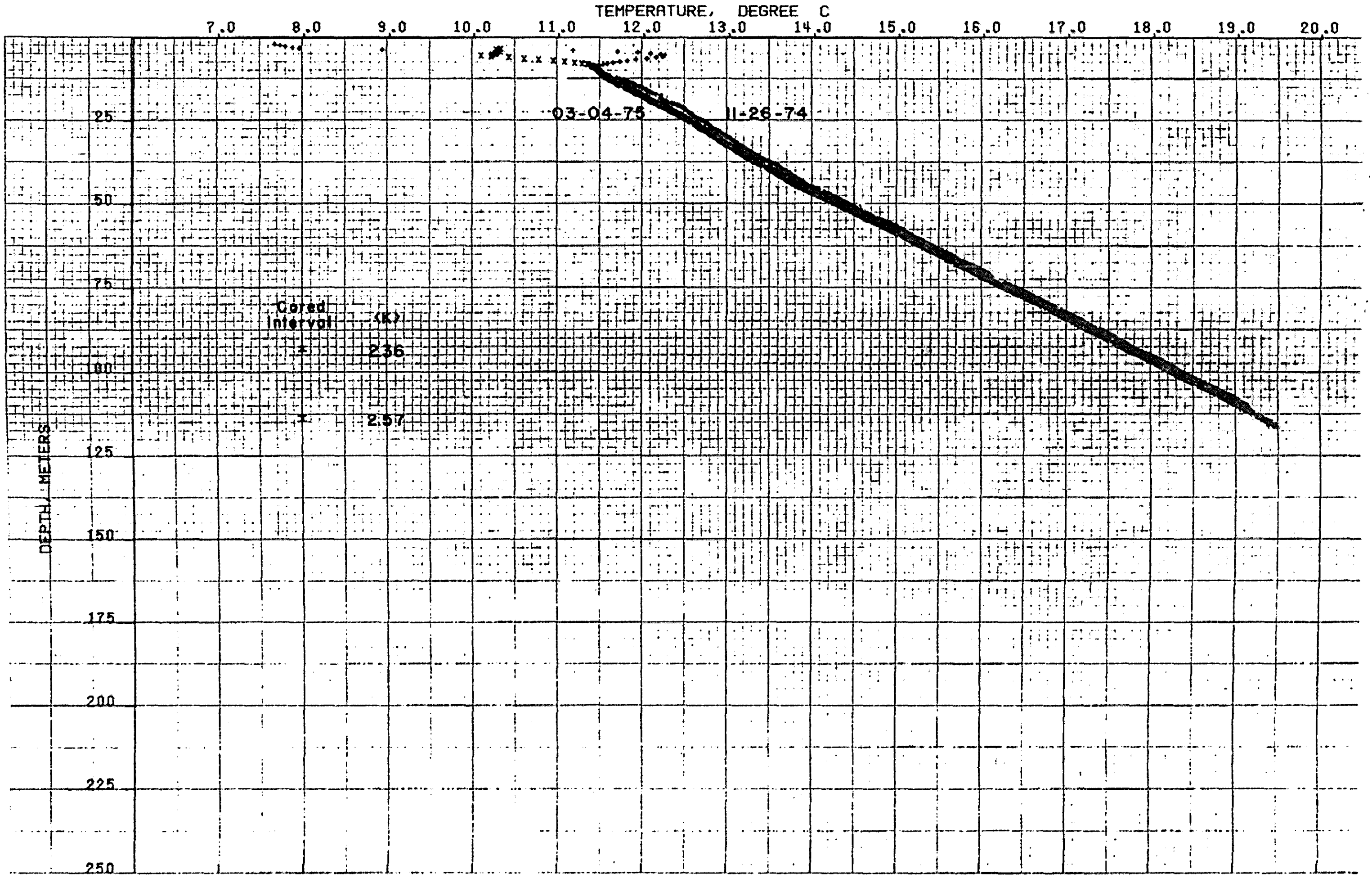


Figure 14. Temperature profiles for heat-flow hole BV-2, Buffalo Valley, drilled 10-14 to 10-16, 1974.

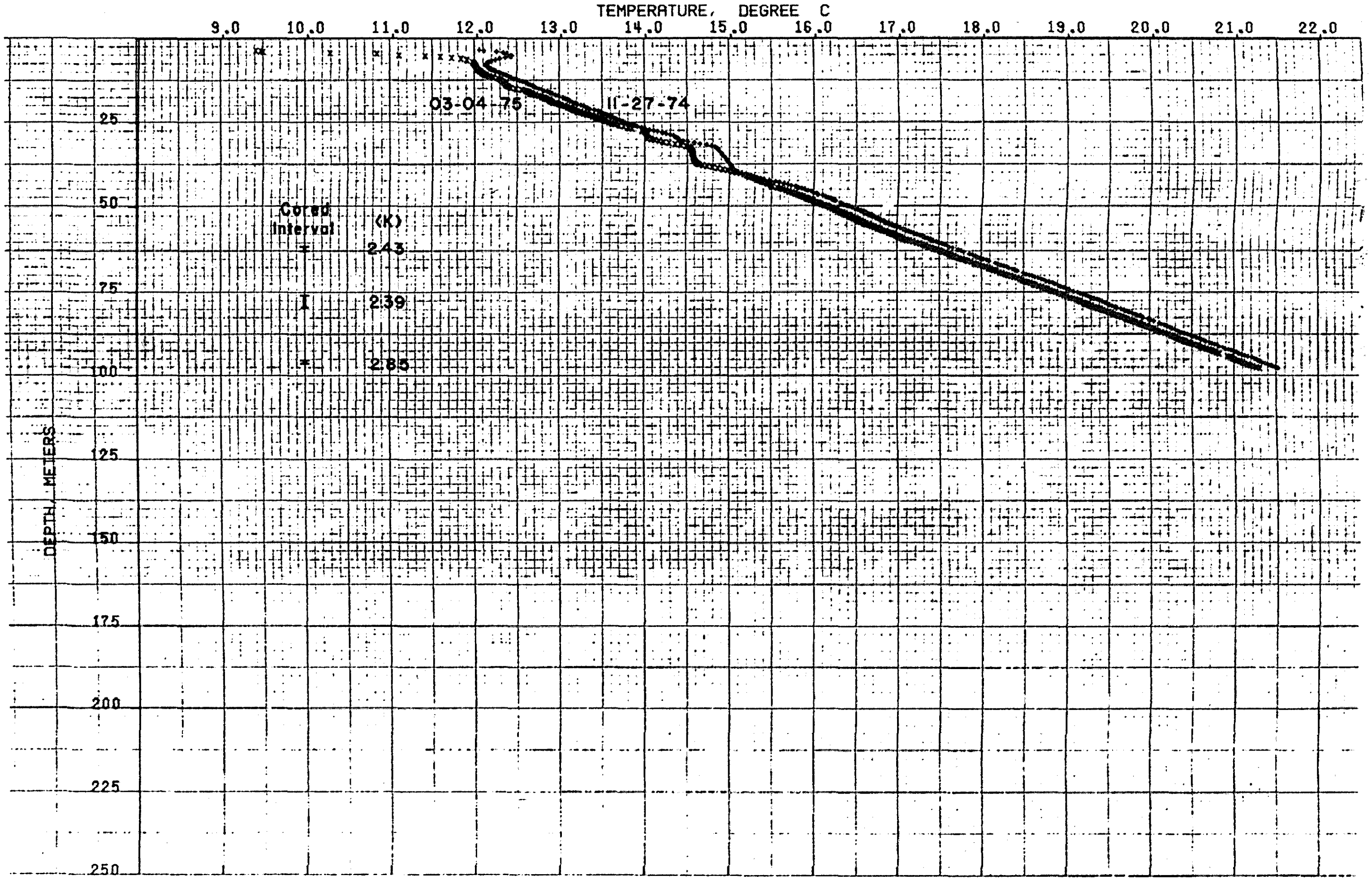


Figure 15. Temperature profiles for heat-flow hole BV-3, Buffalo Valley, drilled 10-17 to 10-18, 1974.