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UTAH GEOLOGICAL AND MINERAL SURVEY

REPORT OF INVESTIGATION

No. 142

Preliminary Report

GEOLOGY, CHARACTERISTICS, AND RESOURCE POTENTIAL OF THE LOW-TEMPERATURE GEOTHERMAL SYSTEM NEAR MIDWAY, WASATCH COUNTY, UTAH

by
James F. Kohler,
June 1, 1979

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PREFACE

by J. Wallace Gwynn
Chief, Research Section, UGMS

Under contract with the U. S. Department of Energy (DOE), the Utah Geological and Mineral Survey (UGMS) has been conducting research to advance the utilization of low temperature geothermal heat in the state of Utah. Activities related to the contract (originally EG-77-S-07-1679 but later changed to DE-AS07-77ET28393) began on July 1, 1977 and will continue into 1980.

This work, on the Midway Hot Springs area, was done by James F. Kohler, in partial fulfillment of the requirements for a Master of Science degree in Geology, at Utah State University at Logan, Utah. Mr. Kohler is presently with the Conservation Division of the U. S. G. S. in Salt Lake City, Utah. The four geothermal gradient wells drilled for this investigation were financed by the U. S. Department of Energy through the Utah Geological and Mineral Survey contract.

ABSTRACT

Recent awareness of the finite nature of fossil-fuel resources has resulted in an increased interest in alternate sources of energy such as geothermal. To evaluate the geothermal energy potential of the hot springs system near Midway, Wasatch Co., Utah, consideration was given to heat flow, water chemistry, and structural controls.

Abnormal heat flow was indicated qualitatively by snow-melt patterns and quantitatively by heat-flow measurements that were obtained from two of four temperature-gradient wells drilled in the area. These measurements indicated that the area north of the town of Midway is characterized by heat flow equal to 321.75 mW/m^2, which is over four times the value generally considered as "normal" heat flow.

Chemical analyses of water from six selected thermal springs and wells were used in conjunction with the silica and Na-K-Ca geothermometers to estimate the reservoir temperature of the thermal system. Because the calculated temperature was more than 25°C above the maximum observed temperature, a mixing model calculation was used to project an upper limit for the reservoir temperature. Based on these calculations, the system has a reservoir temperature ranging from 46 to 125°C.

Structural information obtained from published geologic maps of the area and from an unpublished gravity survey, enabled two models to be developed for the system. The first model, based on geologic relationships in the mountains to the north and west of Midway, assumes that the heat for the thermal system comes from a relatively young intrusive or related hydrothermal convection system in the vicinity of the Mayflower mine. Meteoric waters would be heated as they approach the heat source and then move laterally to the south through faults and fractures in the rocks. These thermal waters then rise to the surface through fractures in the crest of an anticline underneath the Midway area. The second model, based on the gravity survey, assumes an igneous intrusion directly beneath Midway as the heat source. The first model is considered more likely.

The Midway geothermal system is a low temperature resource, suitable for space-heating and other direct-use applications.

INTRODUCTION

In recent years, there has been an increased awareness of the finite nature of fossil-fuel resources. Therefore, much research has been directed towards developing alternate sources of energy. One of these sources of energy is the natural heat of the earth. This energy (commonly referred to as geothermal energy) can be exploited when heat from within the earth is brought to the earth's surface, generally either by deeply-circulating meteoric waters or by near-surface magma chambers.

In Utah, there are a number of hot spring systems, areas of high heat flow, and other manifestations of possible geothermal energy. Near the town of Midway, Wasatch County, Utah, one such system of hot springs is found. Although a fairly complete study was made of the hydrology of this system (Baker, 1968), questions relating to the geothermal potential of this system remain.

The purpose of this investigation is to evaluate the geothermal potential of the area. To accomplish this, consideration will be given to heat flow, chemistry of the thermal waters, expected reservoir temperature, structural controls, and the possible sources of heat for the system.

Geographic and Geologic Setting

The Midway Hot Springs are located in and around the town of Midway, Utah, in the northwest corner of Heber Valley (figure 1). The springs are surrounded by deposits of calcareous tufa with an areal extent of 8 to 10 square kilometers. The tufa deposits are locally more than 30 meters thick, and are underlain by alluvium.

Two types of thermal springs occur in the area: (1) pools that occupy craters in conical or hemispherical mounds of tufa (known locally as "hot pots"), and (2) springs that flow from cracks or openings in the tufa. Baker (1968) described these thermal springs in some detail.

The generalized geology of the area surrounding the Midway Hot Springs is shown in figure 2. The hot springs are situated on the east flank of the Wasatch Mountains, south of the east-west trending Uinta Arch, and on the axis of the Park City Anticline. The Charleston thrust fault is the major structural feature south of the study area. The geology of the area is relatively complex, with Paleozoic and Mesozoic sedimentary rocks in the Wasatch Range to the west, Tertiary intrusive stocks to

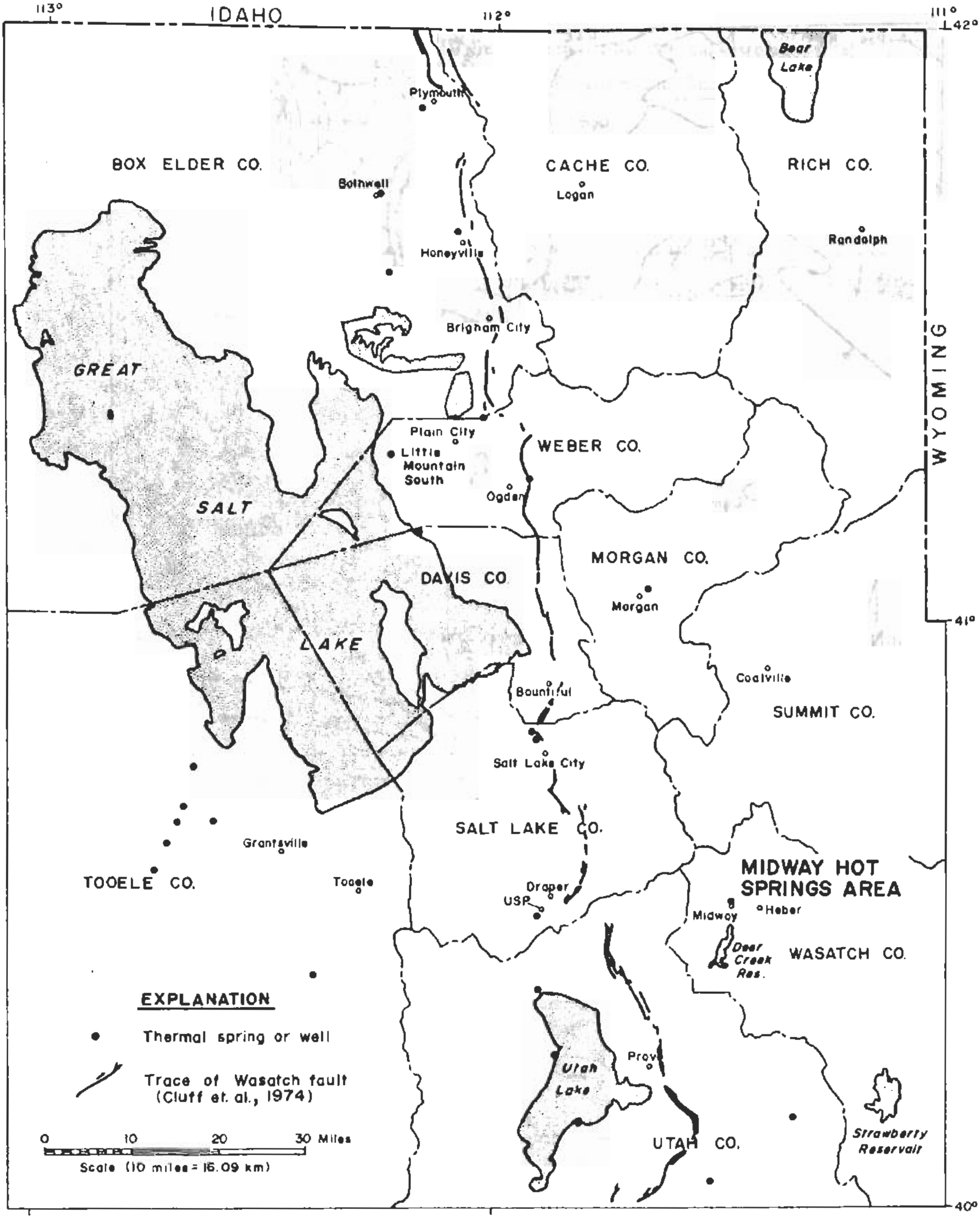


Figure 1. Location of the Midway Hot Springs near Midway, Wasatch County, Utah

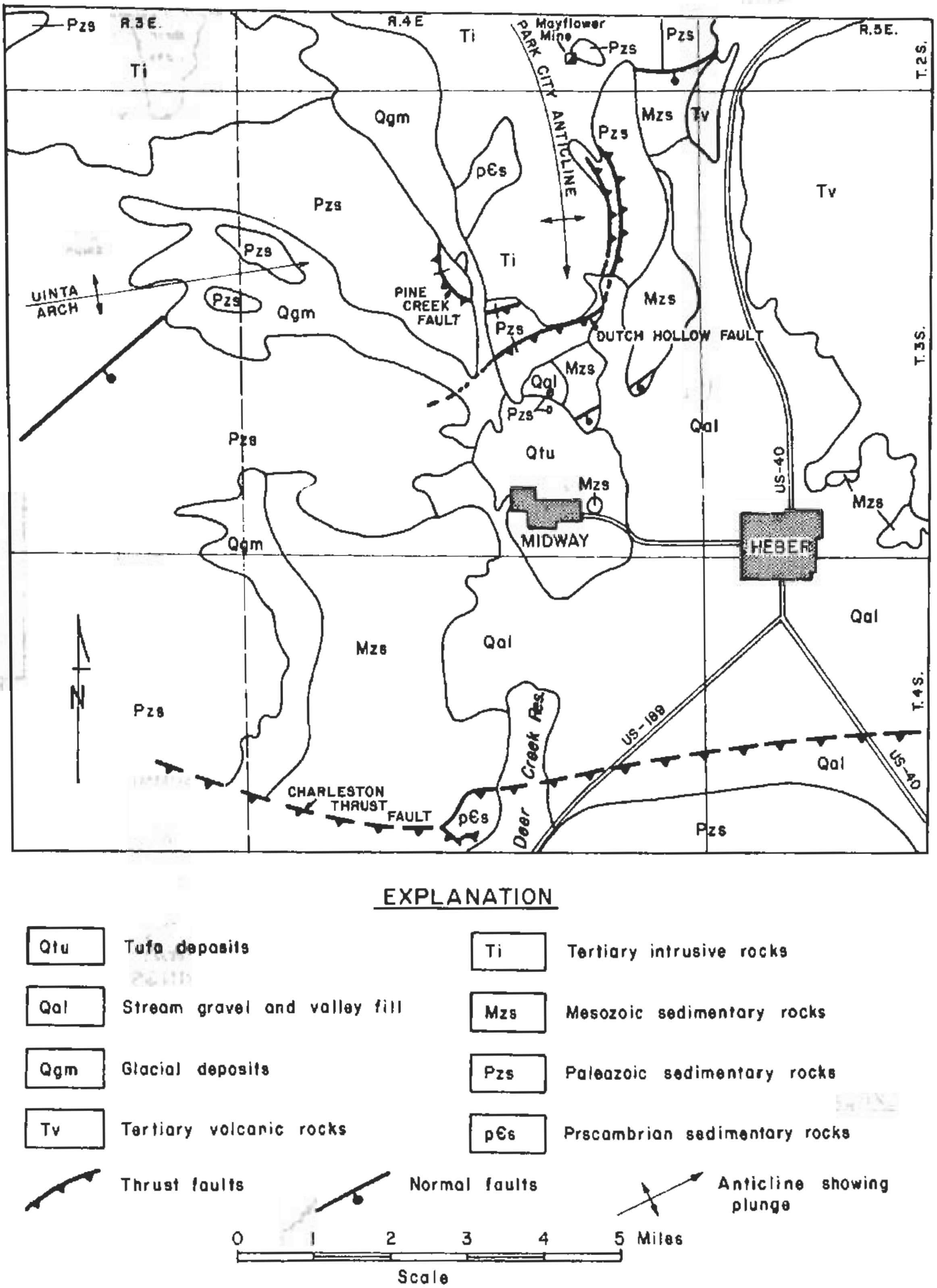


Figure 2. Generalized Geology of the Midway Hot Springs Area (adapted from Bromfield, 1968; Bromfield, et al., 1970; and Baker, 1976)

the north, and Tertiary volcanic rocks to the northeast. Unlike most thermal systems in Utah, the Midway Hot Springs are not located in the Basin and Range Province, and their origin cannot be directly linked to deep-seated normal faulting.

Previous Work

Earliest mention of the Midway Hot Springs is in conjunction with regional reconnaissance surveys in the 19th century (Howell, 1875, p. 256-257; Hague and Emmons, 1877, p. 317-319). Both of these early reports give a general description of the hot springs.

Heylmun (1966, p. 13) mentioned the hot springs as a potential source of geothermal energy and suggested that if the Midway Hot Springs waters contains gases of magmatic origin, then the area would be of prime interest as a souce of geothermal power. He further suggested that the source of heat for the system is "volcanic or tectonic" (1966, p. 15). Milligan, Marsell, and Bagley (1966, p. 36) speculated that the hot-springs system could be controlled by a zone of faulting beneath the alluvium from which they issue.

Baker, (1968, p. D63-D70) described the hydrology of the hot-springs system in some detail. He suggested that the system is fed by deeply circulating meteoric waters that descend through fractures and solution openings in carbonate rocks in the Wasatch Mountains, gain heat at depth, and return to the surface under artesian pressure through fractures in the rocks. Goode (1978, p. 37) used the geologic map of the Heber quadrangle (Bromfield, Baker, and Crittendon, 1970) to expand Baker's inferred origin of the hot springs and to suggest that the meteoric water descends along the planes of the Dutch Hollow and the Pine Creek thrust faults (figure 2), and returns to the surface through normal faults or fractures along the crest of an anticline that underlies Midway.

The area surrounding the Midway Hot Springs has been classified by the United States Geological Survey as prospectively valuable for geothermal resources (Godwin et. al., 1971). The area is considered to be a low-temperature geothermal system with an average reservoir temperature of less than 100°C. (National Geophysical and Solar-Terrestial Data Center, 1977).

Uses of the Hot Spring Waters

The thermal waters form the Midway Hot Springs have been used for bathing purposes at resorts for many years. In addition, some of the thermal springs have been used for space-heating purposes, and at least two homes are presently (1980) heated by thermal waters. The limited use of the thermal waters in the Midway area has been confined to existing natural springs. No wells have been drilled in the area specifically for the purpose of developing the thermal waters.

PHYSICAL CHARACTERISTICS OF THE THERMAL SYSTEM

Heat Flow

General Statement

The term heat flow refers to the amount of heat leaving the earth. Heat flow is discharged as radiation, either by warming ambient air or water, or by convection in water vapor produced by flashing or evaporation at the water table. Heat flow at any given location is a product of the geothermal gradient and the thermal conductivity of the rocks. The heat flow equation is expressed as:

$$Q = (T_1 - T_2)\, K/L$$

where Q = heat flow,
$(T_1 - T_2)$ = temperature difference between two points
L = the vertical distance between them
K = the thermal conductivity of the rocks.

Heat flow measurements are generally expressed in terms of heat flow units (HFU), and 1 HFU = 1 μcal/cm^2/sec or 41.84 milliwatts/meter^2 (mW/m^2). In this report, the thermal conductivities of the rocks were measured in terms of Watts per meter per °C. Consequently, the heat-flow measurements are expressed as mW/m^2. Areas of normal heat flow cover about 99% of the earth's surface and exhibit a heat flux of about 1.5 HFU (Elder, 1965). Near hot springs, hydrothermal convection can complicate interpretation of heat flow measurements.

Indications of abnormal heat flow

In the Midway area, regions of possible abnormal heat flow are indicated qualitatively by snowmelt patterns and the geographical concentrations of thermal springs. Areas of suspected higher-than-normal heat flow based on snow melt patterns were identified during initial field reconnaissance of the area. Oblique aerial photos were taken of the area in the spring, and the snow-melt patterns evident on these photographs were plotted on a topographic map of the area (figure 3). The patterned areas were devoid of snow while the surrounding areas were still covered by snow about 0.25 meters deep. As was later proved by drilling, the snow-melt patterns indicated areas where the thermal waters were near the surface due to free circulation of the ground water.

Temperature-gradient wells

In order to obtain quantitative heat flow measurements from the area, four shallow temperature-gradient wells were drilled in the spring of 1978, at the locations shown on figure 3. The wells were drilled to depths between 58 and 85 meters by a standard rotary rig. Generalized lithologic logs of these four wells, based on samples taken at about 3 meter intervals, are shown in figure 4, and more detailed lithologic logs are found in Appendix I. The wells were completed as temperature observation wells by installing 1 inch I. D. steel tubing to the total depth. The tubing was capped on the bottom and filled with water. Temperatures were measured at 2.5 meter intervals within the tubing by a thermistor probe attached to a digital multimeter. Resistance readings were converted to temperature (°C) from tables calibrated for the thermistor probe, and if calibrated properly, are accurate to 0.01°C. Three temperature logs were run on each well over a period of about six months to ensure that the temperature profiles of each well exhibited no disturbance from drilling. Except for an apparent temperature shift for G. W. 1, G. W. 2, and G. W. 4 between the readings taken early in May and the later surveys, no significant temperature variations were noted. This shift can be attributed to improper calibration of the probe used for these early readings. Temperature profiles representative of each well are shown in figure 5; more complete profiles and the data upon which these temperature profiles are based are found in Appendix II. The results of the drilling and the temperatures observed in each of the four gradient wells are summarized as follows:

G. W. 1 – This well is sited in an area suspected of having abnormal heat flow based on the distribution of snow-melt patterns. Except for tufa in the top 3-4 meters, the well was drilled in alluvial deposits that appeared to be totally saturated with water. Because of this saturation and the apparent free circulation of the water in the alluvial deposits, this well exhibits an essentially isothermal temperature profile. The maximum temperature of 24.27°C was observed at a depth of 20 meters and remained fairly constant throughout the remainder of the well.

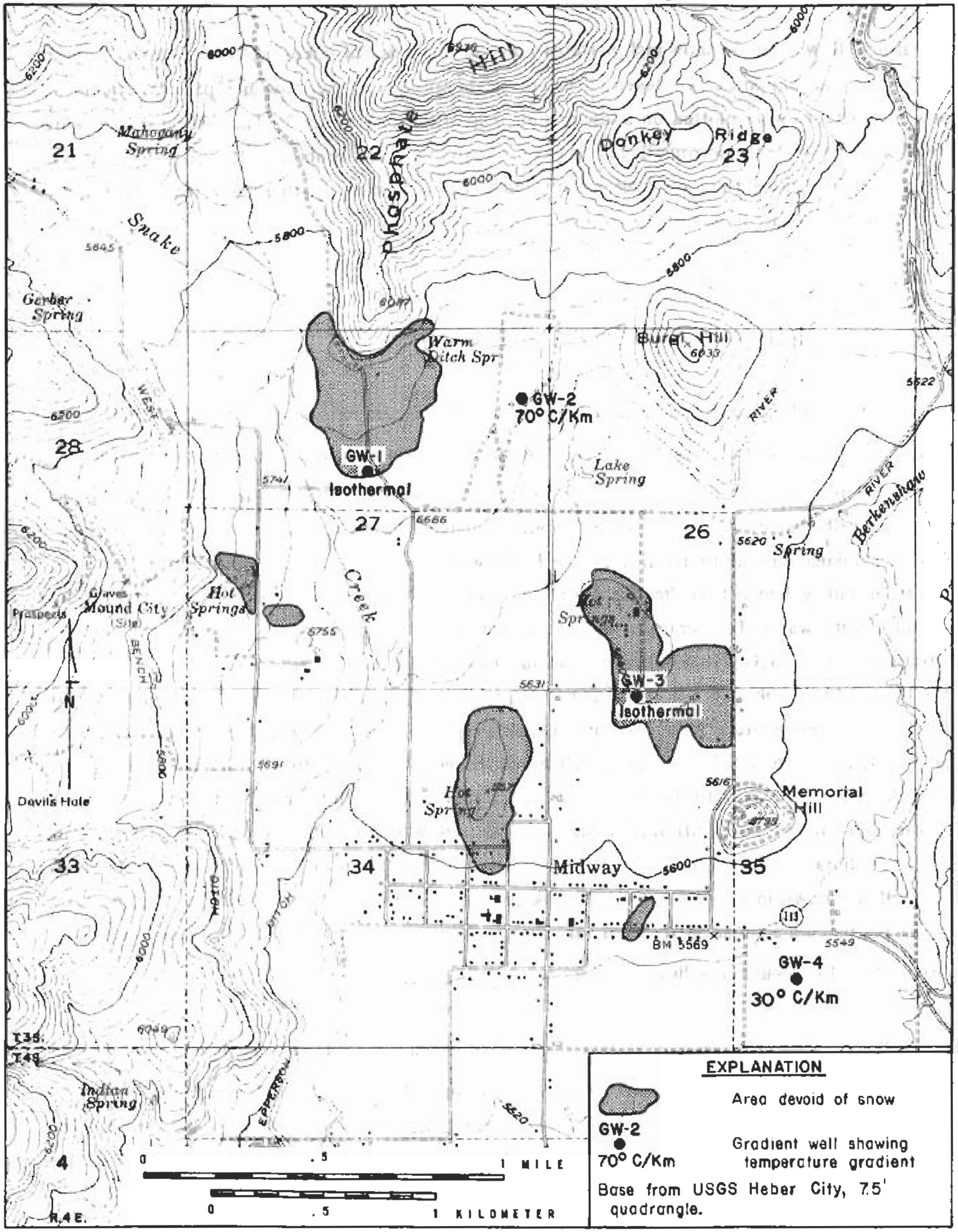


Figure 3. Indications of high heat flow in the vicinity of Midway, Utah

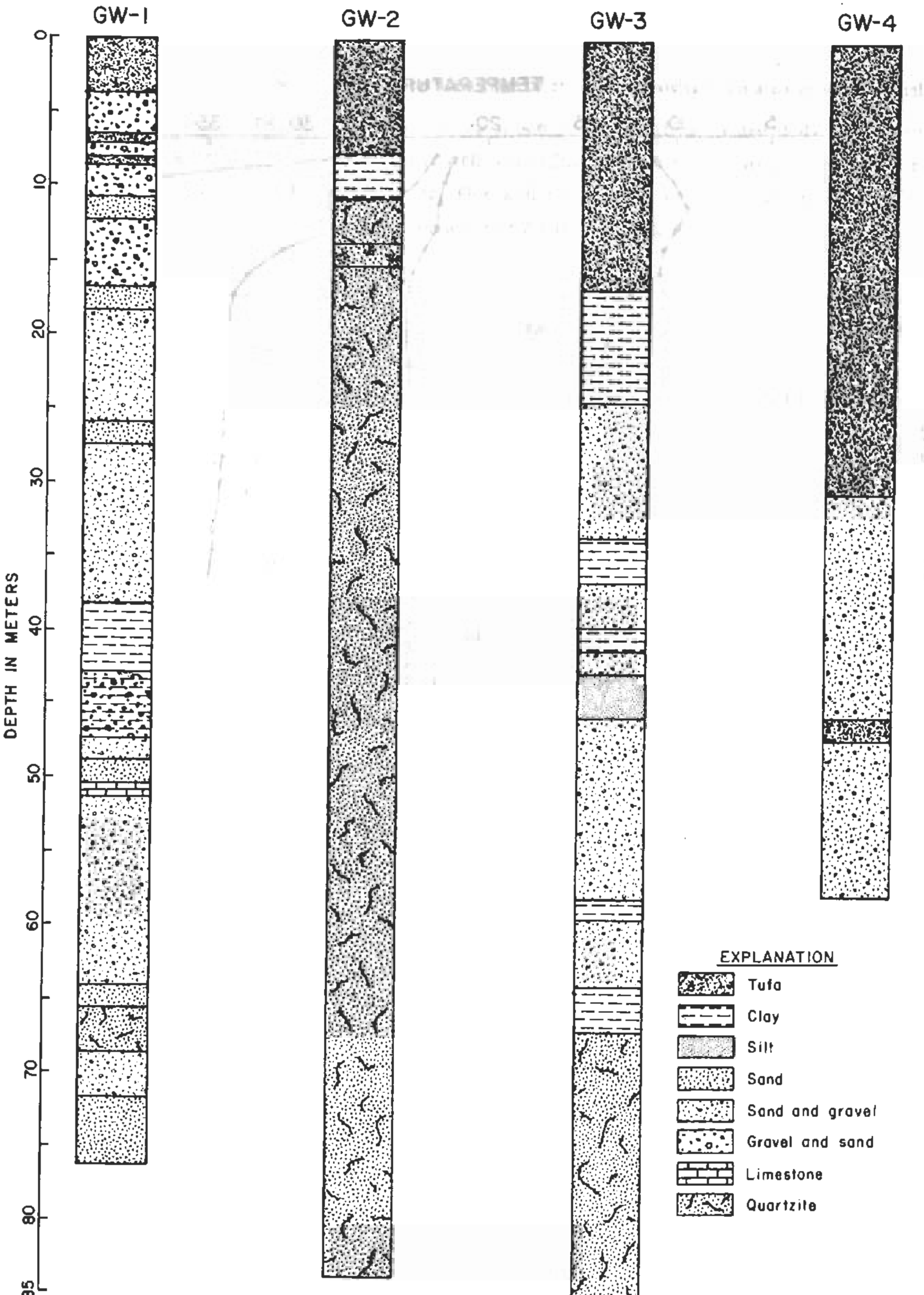


Figure 4. Lithologic logs of temperature gradient wells GW No. 1 - GW No. 4, Midway, Wasatch County, Utah

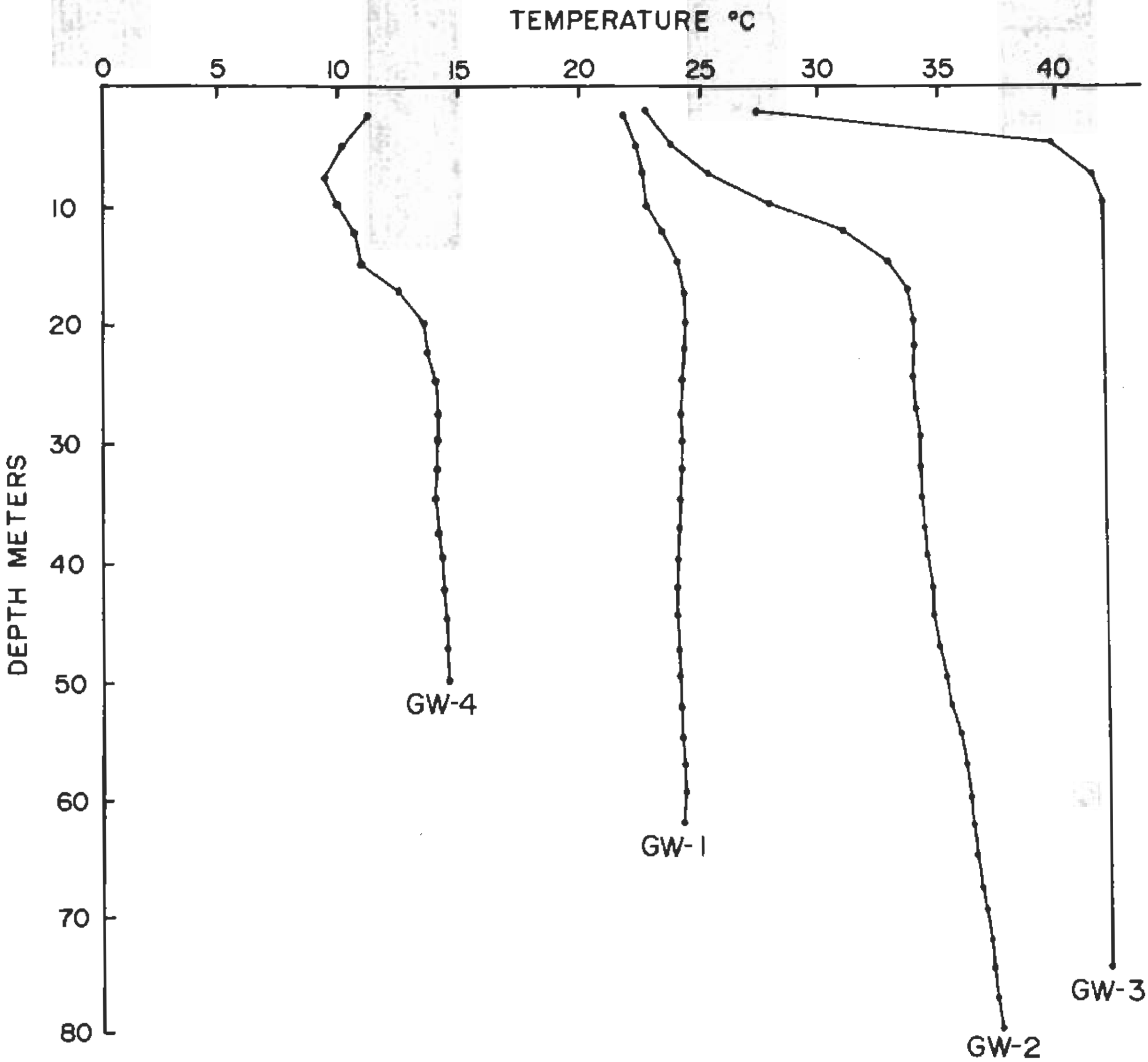


Figure 5. Temperature profiles of temperature gradient wells GW No. 1 - GW No. 4, near Midway, Wasatch County, Utah.

G. W. 2 – This well is located at the northern edge of the tufa deposits in an area where thermal spring activity has ceased. This location was selected in part because of the expected shallow depth to bedrock. Except for the upper 10 meters, the well was drilled in a fairly monotonous and uniform section of the Pennsylvanian Weber Quartzite. This well has a maximum temperature of 37.35°C at the bottom of the hole, and an average temperature gradient of 70°C/km.

G. W. 3 – As with G. W. 1, this well site was selected because of suspected abnormal heat flow based on differential melting of the snow. The well was started in porous, locally cavernous, tufa that contained thermal (>30°C) water at a depth of about 8 meters. The base of the tufa was penetrated at 18 meters, and the tufa was underlain by alluvium to the top of the Weber Quartzite at a depth of 60 meters. In this well, the quartzite was very highly fractured and contained hot water under artesian pressure. Because of the abundant flow (estimated at about 700 gpm) encountered in this well, drilling was stopped at a depth of 85 meters. During the almost 3 days that the well was allowed to flow before it could be plugged, the water level in a "hot pot" about 500 meters to the north dropped 20 centimeters, demonstrating a connection between the well and the spring. The water level in the "hot pot" returned to its original level within 5 days after the well was plugged. Because of the relatively shallow thermal water encountered in this well and the apparent free circulation of water in the alluvium and tufa, the temperature profile of this well is essentially isothermal. The maximum temperature observed, slightly over 42°C, was encountered at about 10 meters. This temperature remained fairly constant throughout the rest of the well.

G. W. 4 – This well is located on the southern edge of the tufa deposits away from any indication of thermal anomalies, and was intended to provide an indication of the "normal" heat flow for the area. Drilling in this well was stopped at 58 meters due to a slow drilling rate and circulation problems, and the steel tubing could only by installed to a depth of 50 meters. In this well, the tufa at the surface was thicker than in any other well (30 meters), and a thin layer of possible tufa was encountered in the alluvial deposits at about 45 meters. The temperatures in G. W. 4 were somewhat lower than in the other wells. This well exhibits a relatively consistant temperature gradient of about 30°C/km from a depth of 20 meters to the bottom. The maximum temperature observed in the well was 14.38°C at the bottom (50 meters).

The average temperature gradients for G.W. 2 and G.W. 4 were calculated by performing a linear regression analysis on the data obtained from the temperature logs run on these wells. To eliminate the possible disruptive effect of climate and near-surface ground water, the analysis was performed on the temperature vs. depth data below a depth of 15-20 meters. Visual examination of the temperature profiles showed a reasonably straight-line relationship beyond this point. The slope of the line that fits these data points is the temperature gradient. Thermal conductivities of tufa and of the Weber Quartzite were determined from outcrop samples and drill cuttings to be about 1.4 and 4.5 Watts/ meter/°C respectively (Chapman, 1979, oral communication). By using the thermal conductivity of the quartzite and the temperature gradient from G.W. 2 in the standard heat flow equation, the heat flow for the northern part of the Midway area is calculated to be 321.75 mW/m^2, or about 7 HFU. In contrast, the heat flow calculated for G.W. 4 is equal to 44.1 mW/m^2m or slightly over 1 HFU.

Water Chemistry

General statement

The locations of thermal and non-thermal springs and wells in the Midway area are shown in figure 6. Because many of these springs were sampled and analyzed previously (Baker, 1968), sampling for this investigation was limited to the springs and wells shown in figure 7. These were selected to provide a representative sampling of the area. The analyses from some of the springs previously sampled by Baker were used as a check on the sampling and analytical procedures used in this report.

Sampling procedures

The procedures used for sample collection were modified from those of Presser and Barnes (1974). Three 250 ml samples were taken from each spring or well and filtered into a polyethylyne bottle through 0.45 micron Millipore filters. One sample was left untreated, one sample was acidified to a pH less than 2 with 1 ml of spectrographic grade nitric acid to preserve the unstable constituents, and the third sample was diluted 1:9 with deionized water to preserve silica. Specific conductance, pH, HCO_3 and alkalinity were determined in the field.

Analytical procedures

Analyses were performed on a Perkin-Elmer Model 303 atomic absorption spectrophotometer using standard methods. Chloride was determined using an Orion chloride-specific ion electrode. No difference was noted in the silica content of the acidified and the diluted samples, so all values reported are from the acidified sample. The results of these analyses are shown in table 1.

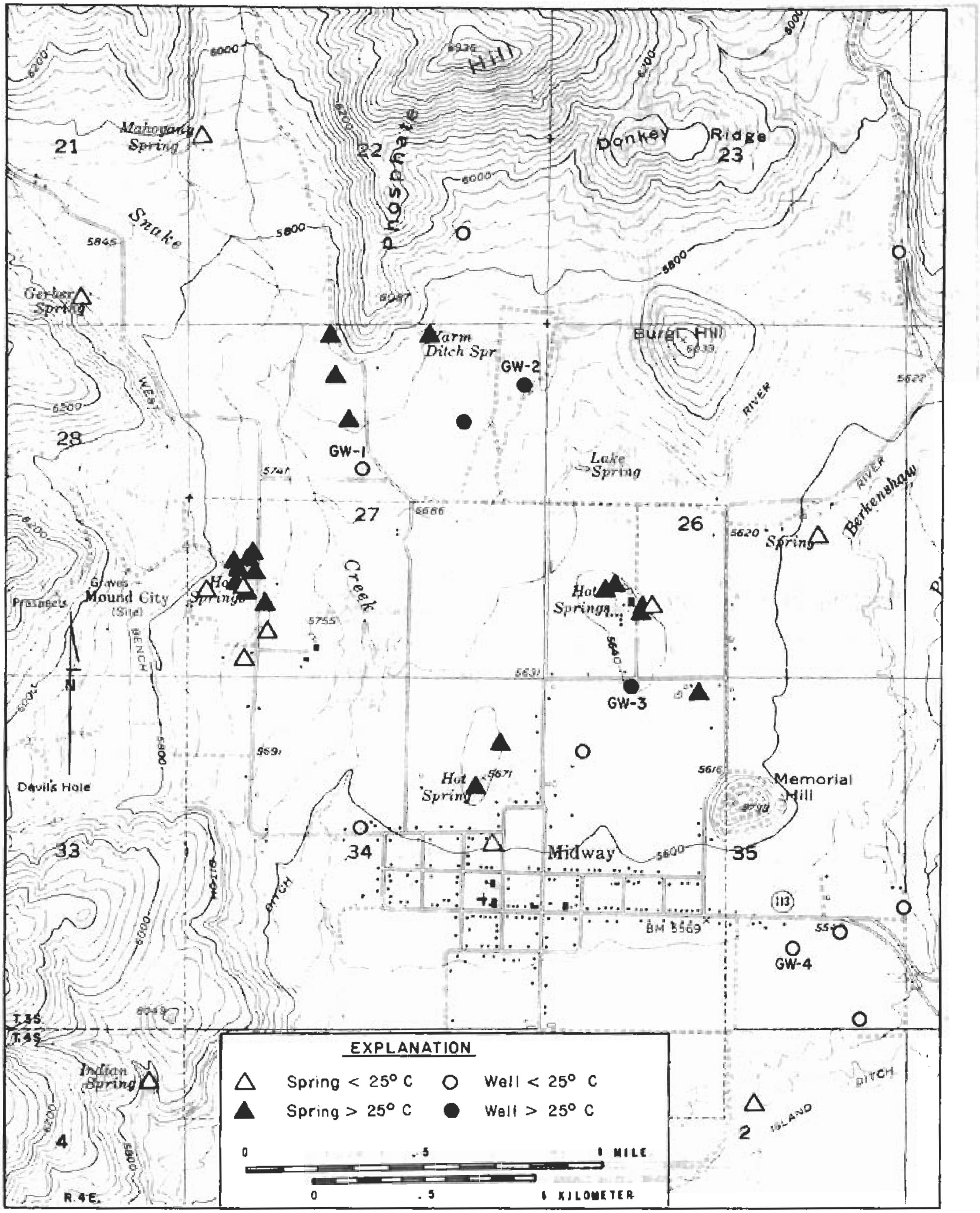


Figure 6. Some thermal and non-thermal wells and springs near Midway, Wasatch County, Utah

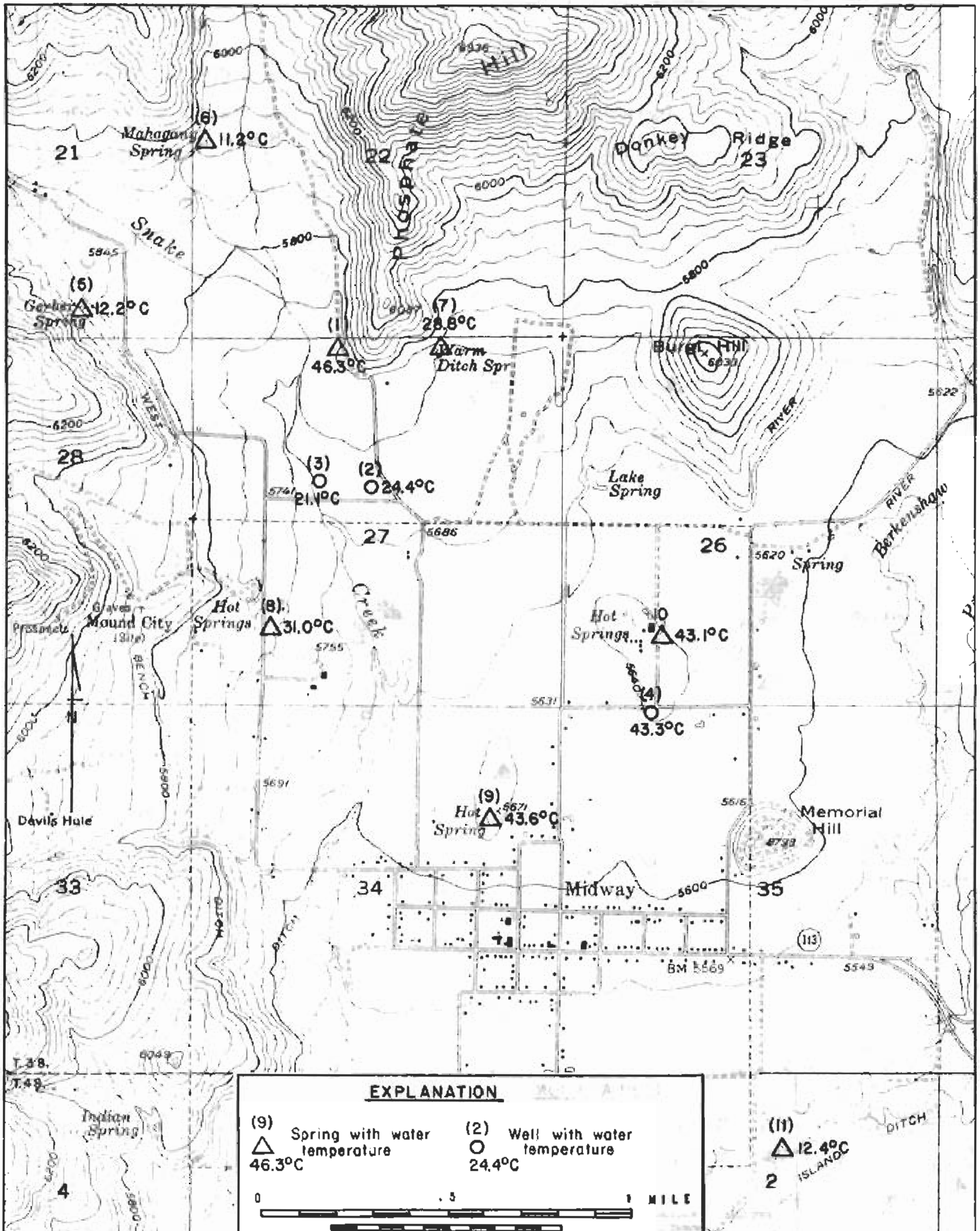


Figure 7. Springs and wells from which water samples were analyzed (chemical analyses are shown in Table 1)

Table 1. Chemical Analyses from selected springs and wells in the vicinity of Midway, Utah

Source	Location on fig 7.	Temp. °C	pH	Spec. Cond.	Alka-inity.	HCO_3	Ca ppm	K ppm	Na ppm	SiO_2 ppm	Cl^- ppm
Coleman Hot Spring	1	46.3	6.4	2200	632	770	371	32	128	30	180
		*(46)	(6.4)	(2410)		(644)	(345)	(16)	(148)	(27)	(132)
GW No. 1	2	24.4	6.5	1700	812	990	383	22	120	62	165
Johnson Well	3	21.1					336	22	102	30	
GW No. 3	4	43.3					336	25	98	26	125
Gerber Spring	5	12.2	7.5	470	162	198	64	1	10	6	9.6
Mahogany Spring	6	11.2	7.2	420	174	212	58	1	6	11	6.5
Warm Ditch Spring	7	28.8	6.9	675	331	404	145	10	34	19	39
Unnamed Spring	8	31.0	6.5	1400	518	632	310	27	94	24	120
Whitaker Hot Spring	9	43.6	6.5	2000	545	664	312	28	93	26	126
Mt. Spa "Hot Pot"	10	43.1	6.5	2000	571	696	329	33	117	28	163
		*(40.0)	(6.5)	(2200)		(674)	(331)	(25)	(114)	(23)	(108)
Fox Den Spring	11	12.4	7.1	850	305	372	166	12	38	19	46

*(from Baker, 1968)

Geothermometers

Theory

Chemical analyses of thermal waters can be used to predict a minimum temperature for the geothermal system by use of chemical geothermometers. These geothermometers operate on the theory that the chemical composition of the thermal waters reflects the temperature at which the water was last in equilibrium with the surrounding rock. This temperature is generally assumed to represent the reservoir temperature for the thermal system.

The two most widely used geothermometers are the silica geothermometer (Fournier and Rowe, 1966), and the Na-K-Ca geothermometer (Fournier and Truesdell, 1973). These geothermometers should be used with a certain degree of caution because they both depend on a number of assumptions which may limit their application. The following assumptions, taken from Fournier et al. (1974), apply to both the silica and Na-K-Ca geothermometers:

1. Temperature-dependent reactions occur at depth.
2. The supply of all constituents involved in a temperature-dependent reaction is not a limiting factor.
3. Water-rock equilibrium occurs at the reservoir temperature.
4. Little or no re-equilibration occurs at lower temperatures as the water flows from the reservoir to the surface.
5. No mixing of hot water with cooler, shallow ground water occurs.

The last two assumptions are not likely to be valid for most systems, so the temperature calculated will usually represent a minimum temperature for the system.

The silica geothermometer is based on the fact that mineral solubilities generally are dependent on temperature and pressure. The solubilities of most silicates increase with increasing temperature, so the silica content of the waters may provide the temperature at which the thermal waters were last in equilibrium with the surrounding rocks. This geothermometer uses the silica content of the spring waters, measured in parts per million, in an equation that depends on the form of silica available to the system. The silica temperatures for the Midway Hot Springs were calculated using both the quartz and chalcedony conductive cooling models. The equations used are as follows:

Quartz $$t^\circ C = \frac{1315}{5.295 - \log SiO_2} - 273.15$$

Chalcedony $$t^\circ C = \frac{1015.1}{4.655 - \log SiO_2} - 273.15$$

The Na-K-Ca geothermometer is based on the equilibrium constants for exchange and alteration reactions that are also temperature dependent. With the Na-K-Ca geothermometer, water composition in moles per liter, is related to temperature by the equation:

$$t^\circ C = \frac{1647}{\log (Na/K) + \beta \log (\sqrt{Ca}/Na) + 2.24} - 273.15$$

where $\beta = 4/3$ for water equilibrated below 100°C and 1/3 for water equilibrated at 100°C or greater.

Springs which flow in excess of 200 liters/minute can be assumed to have lost little heat to the surrounding rock during upward movement. Unless the thermal waters are mixed with near-surface cold waters, the temperatures calculated using geothermometers based on chemical equilibrium should be within about 25°C of the spring water. Marked disagreement between measured and calculated temperatures suggests a mixed water (Fournier and Truesdell, 1974).

Estimated reservoir temperature

The chemical analyses of the Midway thermal waters were used to calculate a minimum temperature using the Na-K-Ca and silica geothermometers. The results of these calculations are shown in table 2.

A good agreement exists between the Na-K-Ca temperature and the quartz-silica temperature, whereas the chalcedony-silica temperature is nearly the same as the measured temperature. If the Na-K-Ca geothermometer indicates a temperature <100 °C, it is sometimes assumed that the silica content of the water is a function of chalcedony solubility and the chalcedony equation is used (Kolsar and DeGraff, 1978). In the Midway area, however, drilling information indicates that the Weber Quartzite (which consists primarily of crystalline quartz) may serve as a reservoir for the thermal waters. This observation, and the obvious agreement between the Na-K-Ca and the quartz-silica geothermometers (table 2), supports the idea that the silica content of the Midway thermal waters is a result of quartz solubility. If the quartz-silica geothermometer is valid for this area, the reservoir temperature for the Midway Hot Springs system may be about 70°C.

Table 2. Projected Maximum Reservoir Temperature of the Midway Hot Springs Geothermal System using the silica and Na-K-Ca Geothermometers

Source	Location on fig. 7	Water temp. °C	Na-K-Ca temp. °C	Quartz silica temp. °C	Chalcedony silica temp. °C
Coleman Hot Spring	1	46.3	76	80	48
GW No. 3	4	43.3	68	74	42
Warm Ditch Spring	7	28.8	47	62	28
Unnamed Spring	8	31.0	71	71	39
Whitaker Spring	9	43.6	72	74	42
Mt Spa "hot pot"	10	43.1	78	77	45

The calculated temperature for the Coleman Hot Spring which flows in excess of 4800 liters per minute (Baker, 1968) is more than 25 °C greater than the observed temperature. This suggests that the spring represents a mixed water. To evaluate this possibility, the mixing models developed by Fournier and Truesdell (1974) were applied to the Coleman Hot Spring and the Warm Ditch Spring (both of which flow in excess of 200 liters/minute). These procedures enable both the probable maximum subsurface temperature obtained by the hot-water component, and the cold water fraction, to be estimated by using the following relationships:

$$(H_{cold})(X) + (H_{hot})(1-X) = H_{spring}$$

and

$$(Si_{cold})\ (X) + (Si_{hot})\ (1\text{-}X) = Si_{spring}$$

where

H = Enthalpy (taken from standard steam tables)

Si = Silica content (ppm, converted to temperature °C using the quartz-silica geothermometer)

X = fraction of cold water.

For each spring, a plot is made of the fraction of cold water vs. temperature for both the enthalpy and the silica considerations. The point of intersection of these curves represents the temperature and cold-water fraction estimated for the system. The plots for the Coleman and Warm Ditch Springs are shown in figure 8. In both cases, the mixing model suggests a maximum reservoir temperature of about 125°C.

Structural Geology

The exact structure of the bedrock underneath the Midway area is difficult to determine with certainty, because the bedrock is covered by alluvial deposits which are in turn overlain by tufa. The tufa deposits are quite extensive and thicken southward, where a thickness of about 30 meters was penetrated in drill hole G.W. 4. In addition to the four temperature-gradient wells drilled in conjunction with this investigation, a number of water wells penetrating the tufa have been drilled in the area. The locations of these wells and the thickness and extent of the tufa deposits are shown in figure 9.

The geology in the mountains to the north and west of Midway suggests the possibility of an anticlinal structure under the area. This anticline is illustrated in a northwest-southeast structure section across the area (figure 10).

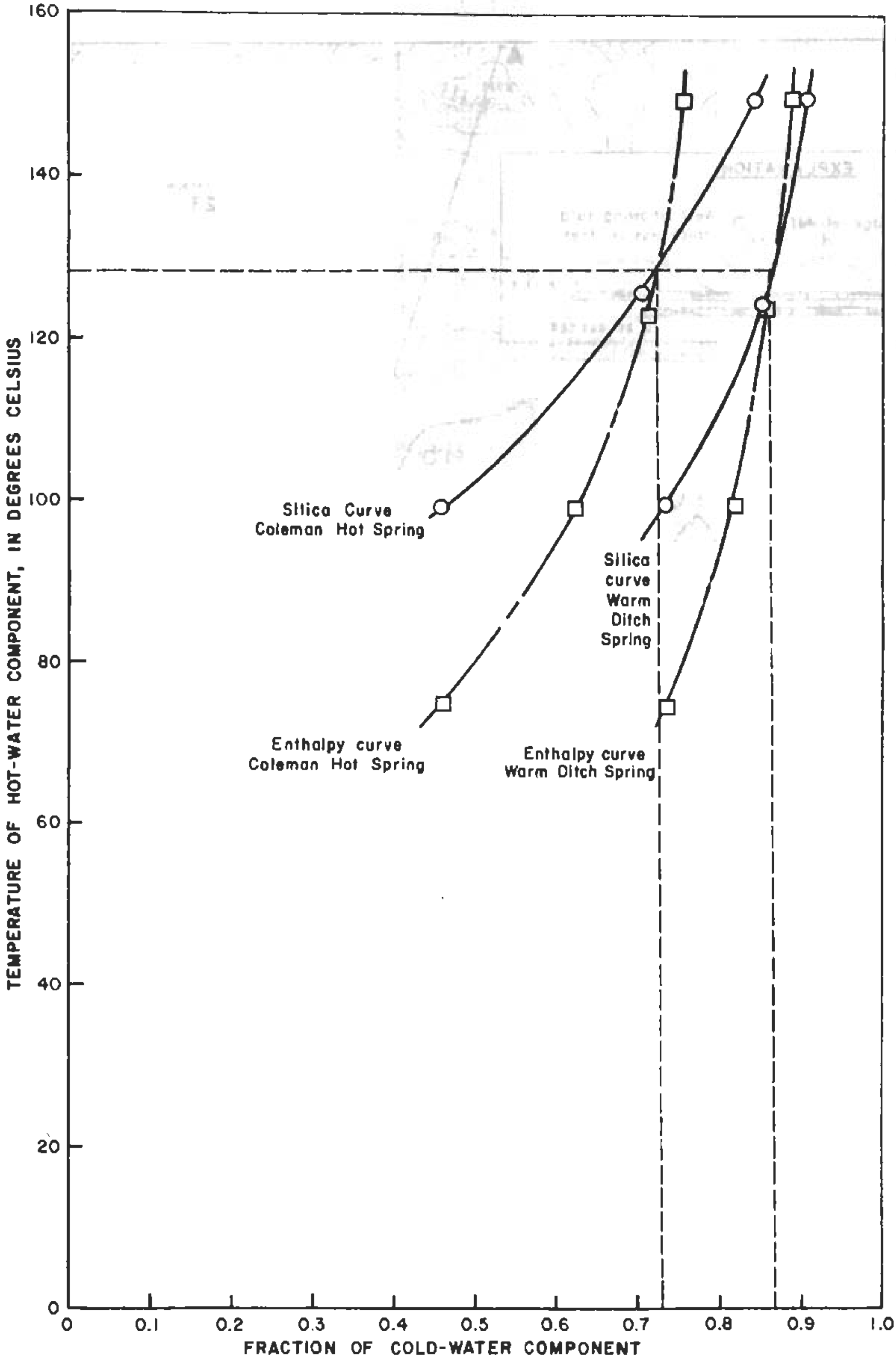


Figure 8. Mixing models for the Coleman and Warm Ditch Springs

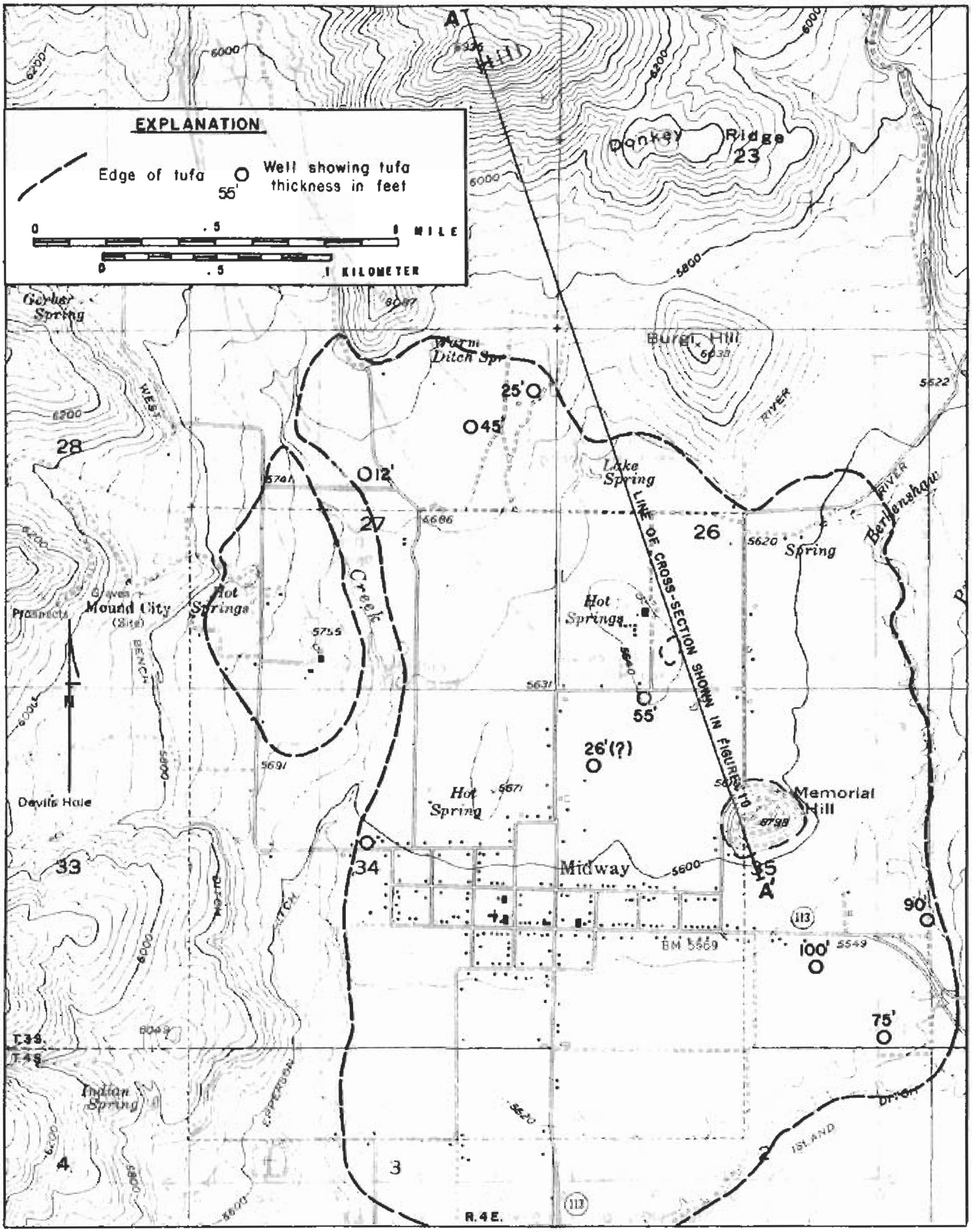


Figure 9. Thickness and distribution of the tufa deposits near Midway, Wasatch County, Utah

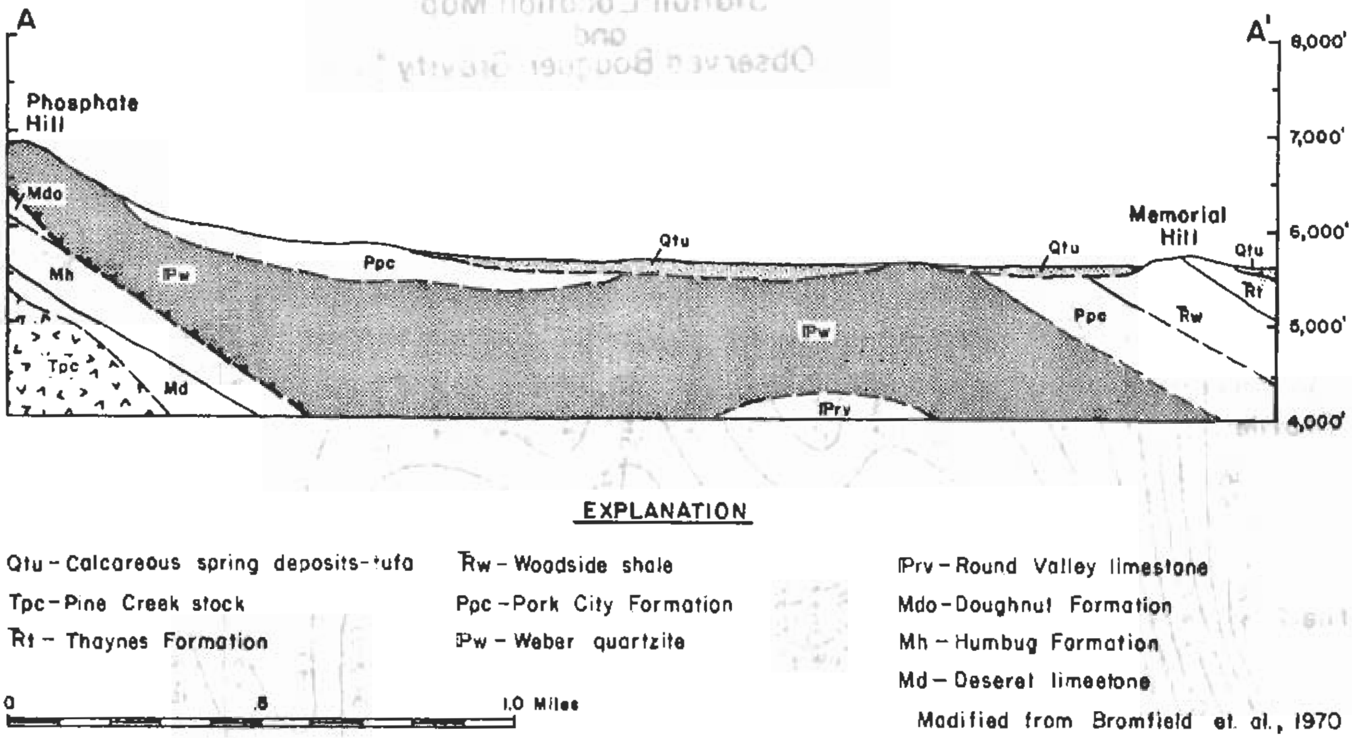
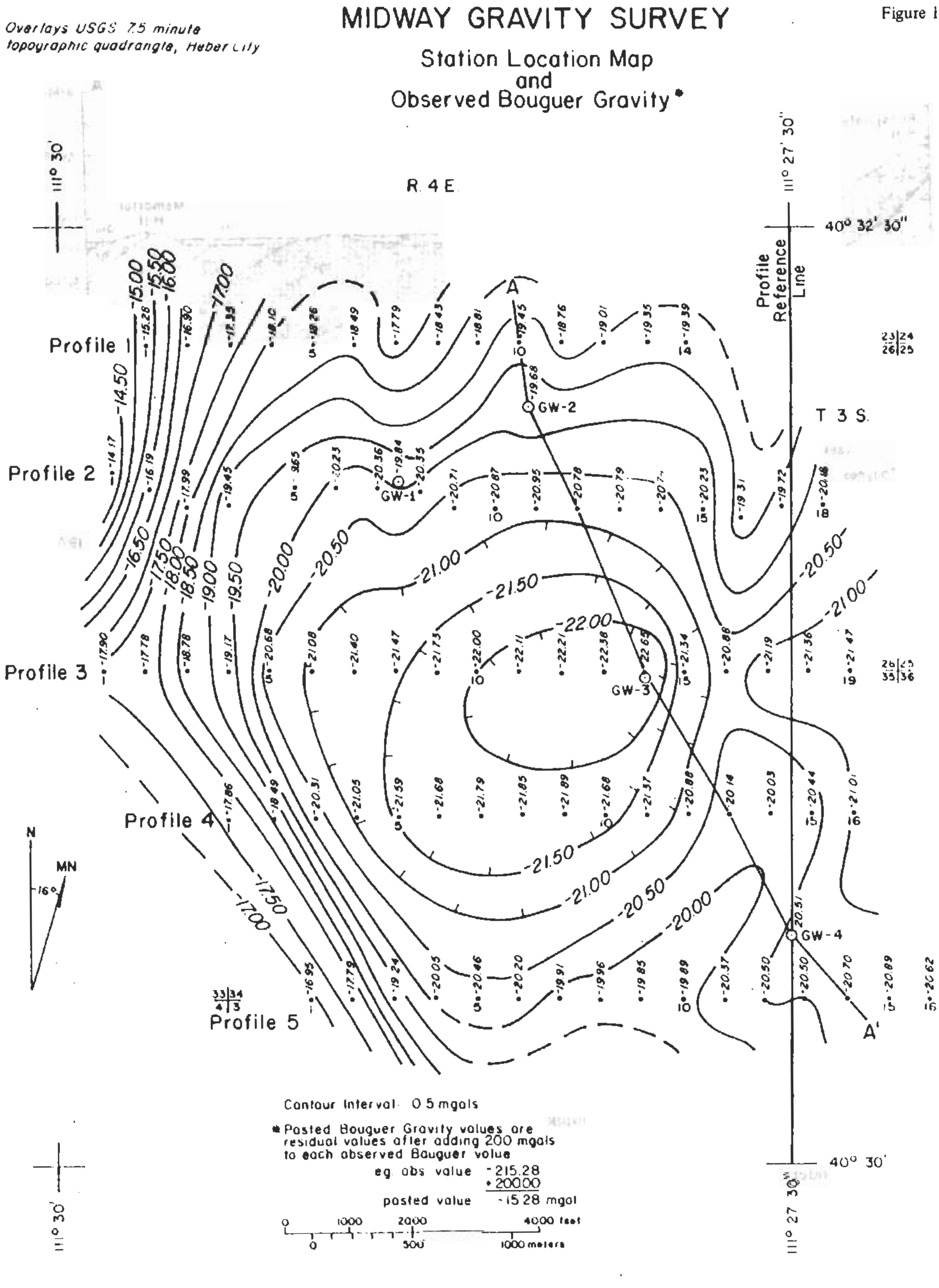


Figure 10. Geologic section across the Midway Hot Springs Area, Midway, Wasatch County, Utah, (from Bromfield, et. al., 1970).

In an attempt to better define the geologic structure in the vicinity of the Midway Hot Springs, a gravity survey was conducted in January and February of 1979 (Fox, 1979a). For this survey, gravity stations were established at intervals of 200 meters along 5 east-west profiles across the Midway area. The residual Bouguer anomaly gravity map showing the results of this survey is shown in figure 11. Of interest is the central gravity low centered between two of the major groups of hot springs. According to Fox (1979b), this anomaly cannot be attributed to a relatively thick deposit of unconsolidated sediments. Instead, this anomaly has been interpreted tentatively as due to a possible buried intrusive rock unit under the area (Fox 1979b). This interpretation should be used with caution because it is not strongly supported by the surrounding geological relationships. This negative anomaly could possibly be explained by extensive fracturing in the Weber Quartzite along the crest of the anticline thought to underlie the area.

Figure 11.


MIDWAY GRAVITY SURVEY
Station Location Map
and
Observed Bouguer Gravity*
Overlays USGS 7.5 minute topographic quadrangle, Heber City
R. 4 E.
T 3 S.
111° 30'
111° 27' 30"
40° 32' 30"
40° 30'
Profile Reference Line
Profile 1
Profile 2
Profile 3
Profile 4
Profile 5
A
A'
GW-1
GW-2
GW-3
GW-4
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-21.50
-22.00
Contour Interval 0.5 mgals
* Posted Bouguer Gravity values are residual values after adding 200 mgals to each observed Bouguer value
eg. obs. value -215.28
+200.00
posted value -15.28 mgal
0 1000 2000 4000 feet
0 500 1000 meters

DISCUSSION AND CONCLUSIONS

General Statement

The main purpose of this investigation is to evaluate the potential utilization of the geothermal energy of the Midway area. To do this, the geothermal system must be characterized as to areal extent, reservoir temperature, and heat source. The data gathered in the course of this investigation enable these parameters to be defined with varying degrees of success.

Areal Extent

Heat flow data, both qualitative and quantitative, provide the best indication of the areal extent of the Midway Hot Springs system. The areas of warm ground as indicated by differential melting of snow (figure 3) and the distribution of thermal springs (figure 6) indicate that the thermal system is confined to the area north of the town of Midway. The thermal area may extend farther to the north than is indicated by the thermal springs, but additional drilling would be needed to verify this.

Comparison of the areas of warm ground as indicated by the differential-snow-melt patterns (figure 3) with the geologic structure of the area (figure 10), suggests that these areas are contained in two northeast-southwest trending zones. The northern zone may be controlled by faulting, much of which is concealed by the tufa and alluvium. Although no faults of any significance have been mapped as coinciding with this zone, sufficient evidence such as slickensides and fault breccia is found in the Weber Quartzite at the south end of Phosphate Hill along the trend of this zone, to strongly suggest that faulting is present. The southern zone appears to coincide, at least in part, with the axis of an anticline projected under the area by Bromfield et al. (1970). These two zones probably represent the minimum extent of the thermal anomaly, and additional drilling will be necessary to better define the areal extent of the system.

Reservoir Temperature

Obviously, the maximum observed temperature of 46.3°C from the Coleman Hot Spring represents the minimum reservoir temperature. Temperatures of 65°C have been observed at the 3000 ft. level of the Mayflower mine which is located about 8 kilometers north of Midway (figure 2). If these systems are related and share a common heat source, then the reservoir temperature would be at least 65°C.

The data on water chemistry provide the best means for calculating the minimum temperature of the thermal system when utilized with chemical geothermometers. An upper limit to the reservoir temperature range is somewhat more difficult to predict. As was discussed earlier in the section on geothermometers, the temperature calculated using quartz solubility agrees very closely with the calculated Na-K-Ca temperature, whereas the observed temperatures in the hot springs are in agreement with the calculated silica temperature using the solubility of chalcedony. If the silica available to the system is a function of quartz solubility and if the assumptions made for the Na-K-Ca geothermometers are valid, then more optimistic projections of 76-80°C can be made for the reservoir temperature. A maximum reservoir temperature of 125°C is indicated by the mixing model. Therefore, the reservoir temperature for the Midway Hot Springs system lies between 46 and 125°C, and is probably between 70 and 125°C.

Source of Heat

Many geothermal systems in areas exhibiting a "normal" temperature gradient within the range of 8 to 50°C/km (White, 1973), are explained by deep circulation of meteoric water. In other systems, the waters are thought to circulate to a shallower depth. There, they are heated by a near-surface heat source such as a shallow magma chamber or areas heated by oxidation of sulfide minerals or by radioactive decay.

There is no evidence for the existence of either sufficient amounts of sulfide minerals undergoing oxidation or sufficient quantities of radioactive materials for them to be considered as a viable source of heat in the Midway area. Consequently, most models previously proposed for the Midway Hot Springs system suggest deep circulation of the meteoric waters along faults and fractures (Baker, 1968; Milligan et al., 1966). If the temperature gradient for G.W. 4 (30°C/km) represents the normal gradient for the area, then the meteoric waters would have to circulate to a depth of about 4 kilometers to be heated to the maximum reservoir temperature of 125°C. Available geologic information indicates that the area is not underlain by faulting sufficient to provide circulation to such depths. Therefore, a heat source located relatively close to the surface must be sought.

Two potential models for the system are proposed using the existing data. Both models suggest a relatively young intrusive body or related hydrothermal convection system as a heat source.

Although the temperature-gradient data suggest a heat source north of Midway, the Tertiary intrusive stocks that have been dated are generally considered to be too old (30-35 million years) to be a potential source of heat (Baker, 1968). However, a few kilometers to the north of Midway, near the workings of the Mayflower mine, a number of small intrusive bodies are present, some of which could be younger than the ones that have been dated. Because temperatures of up to 65°C have been observed in the Mayflower mine as its workings approached the intrusives, it is possible that the intrusives or a related hydrothermal convection system could provide heat for the system. With this model, meteoric water enters the system to the north and is heated as it circulates near the intrusives. This heated water then moves laterally along the Dutch hollow and Pine Creek faults and in fractures in the Weber Quartzite and underlying carbonate rocks. The water then moves to the surface in the Midway area along minor faults at the north edge of the area and through fractures along the crest of the anticline under Midway. This model is supported by the relatively high temperatures that have been encountered in the Mayflower mine, by the decrease in the temperature gradient between G.W.2 and G.W.4, and by the fact that G.W.3 encountered hot water under artesian pressure in the highly fractured Weber Quartzite.
pressure in the highly fractured Weber Quartzite.

The second model, proposed by Fox (1979b), is based on data from his gravity survey. He suggests that a relatively young intrustive body exists beneath the Midway area. Meteoric water circulates downward along faults and fractures, becomes heated by the intrusive, and rises to the surface through fractures

The first model appears more reasonable, but additional data must be gathered before either hypothesis can be positively accepted.

Potential Uses of the Thermal Water

The data gathered in the course of this investigation indicate that the northern part of the Midway area is underlain by a low-temperature geothermal system. The most promising areas for development as a direct- use heat source, at the present time, are two northeast- southwest trending zones that are relatively well-defined by differential-snow-melt patterns (figure 3). The geothermal area may extend farther north of these zones, but additional drilling is needed before the areal extent of the system can be defined.

The maximum observed temperature for the Midway system of 46°C (which could be considered as a minimum temperature for the reservoir) is within the range of temperature (38° to 80°C) generally considered as a minimum for space heating purposes (Lund et al., 1976). The estimated maximum temperature for the system (125°C) is not, however, high enough for most direct-use industrial processing purposes or for electrical generation, but would be hot enough for space heating.

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APPENDICES

Appendix I. Lithologic logs of G.W.1 – G.W.4

LITHOLOGIC LOG

Project Midway Geothermal **Ground Surface Elevation** ____

Well Number GW#1 **Depth to Water Table** Flowing 12 psi

Location 2100' FNL, 2700'FWL Sec. 27 T. 3 S., R. 4 E., SLM **Total Depth** 250' **Diameter** 6"

DEPTH ft.	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
5	tufa	lt. tan			H_2O at 4'
10	"				some pebbles near bottom
15	tufa and gravel		< 1/2"		poorly sorted
20	gravel		< 3/4"		poorly sorted limestone, quartzite, with some granite
25	tufa and gravel				
30	" " "				
35	gravel		1/4-3/4"		rounded, poorly sorted
40	sand				some small pebbles
45	gravel and sand		up to <1"		poorly sorted
50					
55					
60	coarse sand				mostly quartz, some small pebbles to 1/2"
65	sand & gravel				poorly sorted
70					
75					
80					
85	gravel				
90	sand		med-coarse		
95	sand & gravel		to 1/2"		poorly sorted
100					
105					
110					
115					
120					
125					
130	clay w/sand				
135	clay				
140					
145	clay w/gravel				
150					

LITHOLOGIC LOG

Project____________________ Ground Surface Elevation__________

Well Number GW#1 cont. Depth to Water Table__________

Location____________________ Total Depth________ Diameter______

DEPTH	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
155	Clay w/gravel				
160	sand and gravel				H_2O
165					mostly sand
170	limestone & quartzite	black ls. white qtz.			could be boulders H_2O stopped
175	sand & gravel				
180					clay at bottom
185	clay, sand, & gravel				very poorly sorted
190	sand and gravel		to 3/4"		angular to sub-angular
195					
200					
205					
210					
215	sand		med to coarse		abundant biotite
220	quartzite (boulder?)	white	fine		very hard slowed drilling
225					
230	sand & gravel				poorly sorted
235					
240	sand		fine-coarse		some minor gravel
245					
250					
					Drilling started 4/19/78
					Drilling completed 4/27/78
					Logged by: J. Kohler

LITHOLOGIC LOG

Project Midway Geothermal

Ground Surface Elevation ______

Well Number GW#2

Depth to Water Table ______

Location 350'FEL, 1000'FNL, Sec. 27 T.3 S., R.4 E., SLM

Total Depth 275' Diameter 6"

DEPTH	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
5	tufa	lt. tan			
10					
15					
20					
25					
30	silty clay w/minor tufa	lt.red-brwn.			
35					
40	quartzite or	lt.yellow tan			
45	sandy limestone				
50					some possible tufa frags.
55					
60					60-85 feet contains some silty clay
65					
70					
75					
80					
85					
90	quartzite	white-lt.gry.	fine		very clean, may be fractured in
95					part
100					
105					
110					
115					
120					
125					
130					
135					Fe staining in places
140					
145					lost hole circulation
150					

LITHOLOGIC LOG

Project ______________________ Ground Surface Elevation __________

Well Number GW#2 cont. Depth to Water Table __________

Location ______________________ Total Depth ________ Diameter ______

DEPTH	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
155	Quartzite	white to lt. gry.	vf-f		some Fe staining
160					
165					
170					
175		lt.gry-yellow gry			some yellowish cuttings w/black
180					grains (very friable)
185					
190					
195					
200					
205					
210					
215					
220					
225					driller reports slower drilling
230					rate
235					
240					
245					
250					
255					
260					
265					
270					
275					
					Drilling Started 5/12/79
					Drilling Completed 5/17/79
					Logged by: J. Kohler

LITHOLOGIC LOG

Project Midway Geothermal

Ground Surface Elevation ______

Well Number GW#3

Depth to Water Table flowing 25 psi

Location 25'FNL, 1350'FWL, sec. 35
T.3S., R.4 E., SLM

Total Depth 280'   Diameter 6"

DEPTH	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
5	tufa	white-lt.tan			very porous
10					some pieces have black coating
15					some clay
20					much clay
25					cavernous 23-26' contained hot <30°C water
30					some dark gry nodules contains sand and organic matter
35					abundant organic matter
40					some clay
45					some vf silt and dk.gry.nodules w/minor organic matter
50					
55					contains organic matter
60	clay w/sand				tr. of tufa
65					
70	clay	lt.grn-gry			
75					
80	vf silt w/ clay	yel brn-lt.gry			distinct color break from yellow vf silt to dk gry clay at 78'
85	sand w/gravel				poorly sorted
90					
95					
100					silty
105					
110	sand				minor gravel
115	clay	dk.gry			
120					
125	sand w/minor gravel				
130					minor clay
135	clay				some sand and gravel
140	sand and gravel				angular, poorly sorted
145	silt				minor snd,gravel,cly
150					

LITHOLOGIC LOG

Project ______

Ground Surface Elevation ______

Well Number GW#3 cont.

Depth to Water Table ______

Location ______

Total Depth ______ **Diameter** ______

DEPTH	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
155	gravel				minor silt angular, poorly sorted.
160	sand & gravel				mostly sand
165					minor silt and clay
170					dk. brn gry clay at bottom
175	sand w/small gravel				fairly clean, caving
180					
185					gravel becoming coarser -3/4"
190					
195	clay	lt.tan			
200	sand & gravel				may contain some tufa frags.
205					tr. clay
210					
215	clay at bottom				
220	quartzite	lt.tan			contact at 218' contains hot artesian water
225					
230					
235					
240					
245					minor limestone frags.
250					quartzite highly fractured
255					
260					
265					
270					
275					
280					flow >500 gpm 40°C
					Drilling Started 4/28/78
					Drilling Completed 5/2/78
					Logged by: J. Kohler

LITHOLOGIC LOG

Project Midway Geothermal

Ground Surface Elevation ____________

Well Number GW#4

Depth to Water Table 21'

Location 4300 FNL, 3700 FWL, sec.35, T.3 S., R.4E., SLM

Total Depth 190'

Diameter 6"

DEPTH	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
5	tufa	lt. tan			
10					
15					
20					
25					
30					some water
35					
40					
45					almost powdery
50					
55					
60					
65					
70					
75					
80					
85					
90					
100					
105	sand & gravel		to 3/4"		angular to sub-angular, poorly sorted, contains
110					H_2O
115					
120					
125					
130					
135					
140					some tufa in gravel
145					mostly sand
150					

LITHOLOGIC LOG

Project ____________________

Ground Surface Elevation ____________

Well Number GW#4 cont.

Depth to Water Table ____________

Location ____________________

Total Depth ________ Diameter ______

DEPTH	ROCK TYPE	COLOR	GRAIN SIZE		COMMENTS
155	Tufa (?)				thin bed
160	Conglomerate?				contains abundant chert,
165					quartzite, and limestone frags. gravel could be contamination
170					from above Driller reports formation is
175					very hard
180					
185					
190					
					Drilling Started 5/5/78
					Drilling Completed 5/10/78
					Logged by: J. Kohler

Appendix II. Temperature measurements and profiles G.W.1 – G.W.4

APPENDIX II.

Temperature Measurements from gradient wells GW No 1 - GW No. 4, Midway, Wasatch County, Utah

Gradient Well No 1. — Date of Measurement 5/ 6/78

No 1.	Depth (meters)	Temp. °C
1.	2.5	20.698
2.	5.0	21.978
3.	7.5	22.334
4.	10.0	23.232
5.	12.5	24.898
6.	15.0	25.178
7.	17.5	25.238
8.	20.0	25.152
9.	22.5	25.131
10.	25.0	25.191
11.	27.5	25.114
12.	30.0	25.114
13.	32.5	25.088
14.	35.0	25.067
15.	37.5	25.084
16.	40.0	24.995
17.	42.5	25.003
18.	45.0	25.046
19.	47.5	25.033
20.	50.0	25.152
21.	52.5	25.067
22.	55.0	25.152
23.	57.5	25.492
24.	60.0	25.276
25.	62.5	25.276
26.	65.0	25.294

Gradient Well No. 1 — Date of Measurement 5/ 9/78

No. 1	Depth (meters)	Temp. C
1	2.5	20.301
2	5.0	21.136
3	7.5	21.459
4	10.0	22.161
5	12.5	23.691
6	15.0	24.158
7	17.5	24.26
8	20.0	24.213
9	25.0	24.23
10	50.0	24.166
11	62.5	24.307

Gradient Well No. 1 — Date of Measurement 5/29/78

No. 1	Depth (meters)	Temp. °C
1	2.5	21.709
2	5.0	22.416
3	7.5	22.569
4	10.0	22.778
5	12.5	23.484
6	15.0	24.026
7	17.5	24.23
8	20.0	24.273
9	22.5	24.226
10	25.0	24.149
11	27.5	24.111
12	30.0	24.09
13	32.5	24.06
14	35.0	24.039
15	37.5	23.997
16	40.0	23.967
17	42.5	23.942
18	45.0	23.934
19	47.5	23.934
20	50.0	23.929
21	52.5	23.963
22	55.0	24.073
23	57.5	24.115
24	60.0	24.128
25	62.5	24.12

Gradient Well No. 2 — Date of Measurement 5/29/78

No. 2	Depth (meters)	Temp. °C
1	2.5	22.019
2	25.0	33.428
3	50.0	35.182
4	65.0	36.683
5	70.0	37.08
6	75.0	37.394
7	77.5	37.557
8	80.0	37.713
9	82.5	37.863
10	84.0	37.929

Gradient Well No. 2 — Date of Measurement 6/ 7/78

No. 2	Depth (meters)	Temp. °C
1	0.0	14.995
2	2.5	23.629
3	5.0	25.496
4	7.5	28.068
5	10.0	29.651
6	12.5	31.711
7	15.0	32.766
8	17.5	33.321
9	20.0	33.624
10	22.5	33.665
11	25.0	33.692
12	27.5	33.815
13	30.0	33.918
14	32.5	33.994
15	35.0	34.161
16	37.5	34.357
17	40.0	34.512
18	42.5	34.661
19	45.0	34.848
20	47.5	35.072
21	50.0	35.314
22	52.5	35.558
23	55.0	35.896
24	57.5	36.171
25	60.0	36.379
26	62.5	36.511
27	65.0	36.691
28	67.5	36.88
29	70.0	37.088
30	72.5	37.257
31	75.0	37.394
32	77.5	37.533
33	80.0	37.705
34	82.5	37.854
35	84.0	37.291

Gradient Well No. 2 — Date of Measurement 10/27/78

No. 2	Depth (meters)	Temp. °C
1	0.	13.129
2	2.5	22.729
3	5.0	23.604
4	7.5	25.174
5	10.0	27.908
6	12.5	30.829
7	15.0	32.571
8	17.5	33.379
9	20.0	33.574
10	22.5	33.594
11	25.0	33.635
12	27.5	33.723
13	30.0	33.873
14	32.5	33.914
15	35.0	33.969
16	37.5	34.163
17	40.0	34.296
18	42.5	34.457
19	45.0	34.627
20	47.5	34.791
21	50.0	35.021
22	52.5	35.276
23	55.0	35.631
24	57.5	35.878
25	60.0	36.03

26	62.5	36.151
27	65.0	36.336
28	67.5	36.513
29	70.0	36.669
30	72.5	36.826
31	75	36.953
32	77.5	37.08
33	80.0	37.224
34	82.5	37.353

Gradient Well — Date of Measurement 5/9/78

No. 3	Depth (meters)	Temp. °C
1	2.5	30.483
2	5	40.63
3	7.5	43.03
4	10	43.457
5	12.5	43.447
6	15	43.457
7	17.5	43.457
8	25	43.478
9	50	43.56
10	75	43.735
11	82.5	43.652

Gradient Well — Date of Measurement 6/7/78

No. 3	Depth (meters)	Temp. °C
1	0	26.153
2	2.5	39.404
3	5	41.521
4	7.5	42.191
5	10	42.282
6	12.5	42.282
7	15	42.282
8	25	42.282
9	50	42.252
10	75	42.344
11	82.5	42.395

Gradient Well — Date of Measurement 10/27/78

No. 3	Depth (meters)	Temp. °C
1	2.5	27.226
2	5	39.581
3	7.5	41.325
4	10	41.756
5	12.5	41.795
6	75	41.835
7	85	41.835

Gradient Well — Date of Measurement 5/11/78

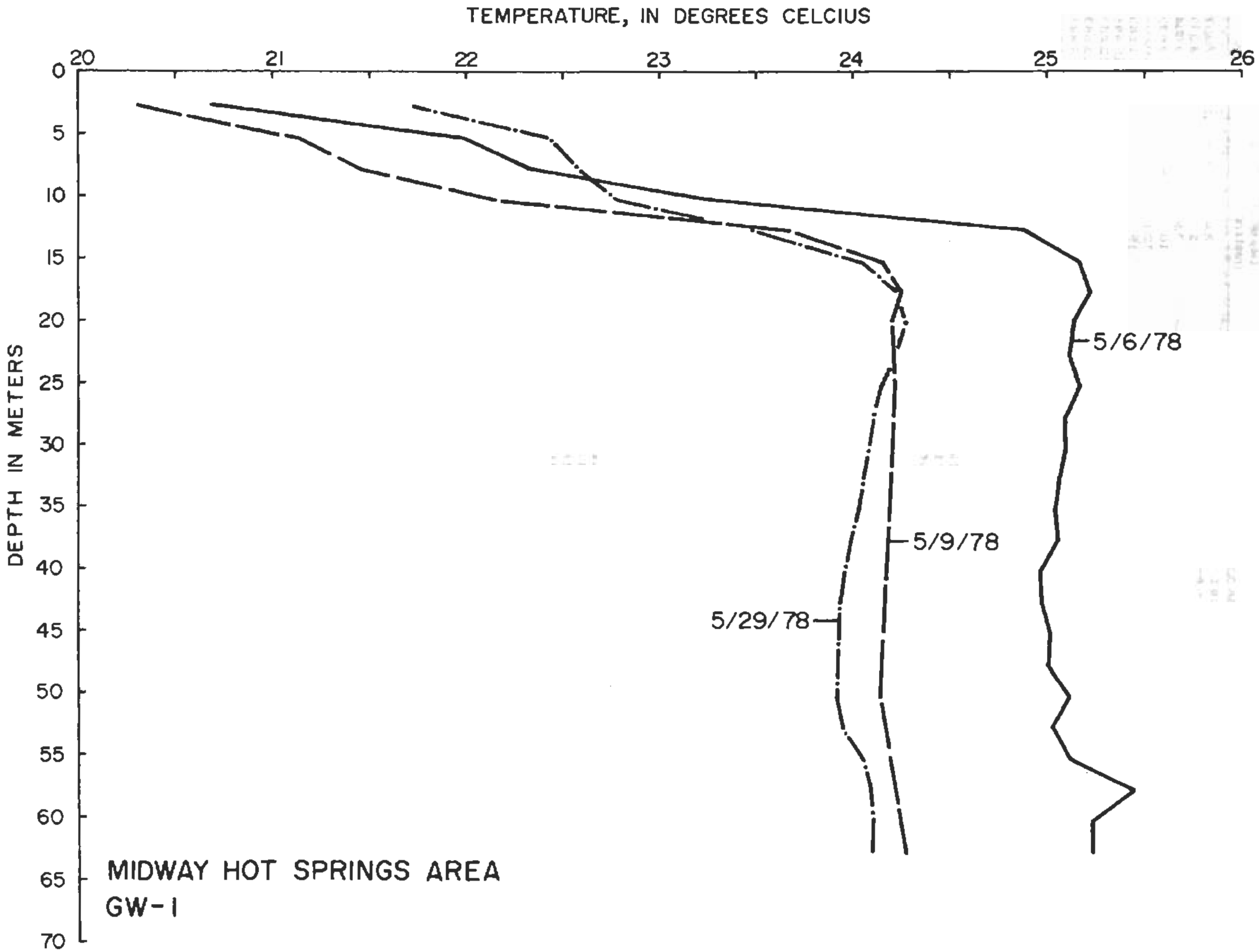
No. 4	Depth (meters)	Temp. °C
1	2.5	12.352
2	5	12.935
3	7.5	12.158
4	10	12.322
5	12.5	12.822
6	15	13.049
7	17.5	13.818
8	20	14.67
9	22.5	14.87
10	25	14.921
11	27.5	14.996
12	30	15.098
13	32.5	15.098
14	35	15.162
15	37.5	15.251
16	40	15.251
17	42.5	15.303
18	45	15.458
19	47.5	15.51
20	50	15.614

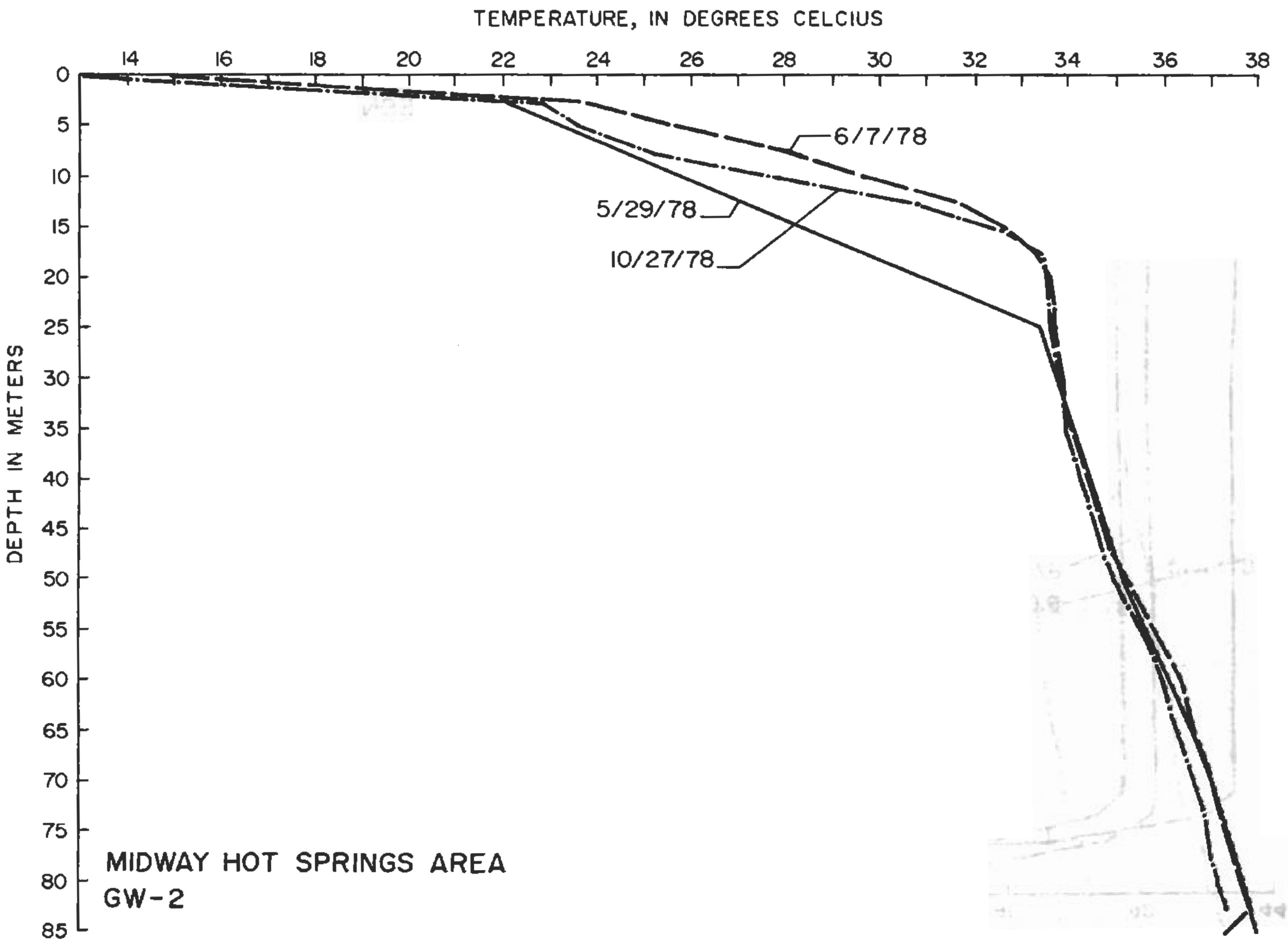
Gradient Well — Date of Measurement 6/7/78

No. 4	Depth (meters)	Temp °C
1	2.5	7.367
2	5	8.339
3	7.5	9.804
4	10	10.439
5	12.5	10.966
6	15	11.565
7	17.5	12.496
8	20	13.463
9	22.5	13.643
10	25	13.887
11	27.5	14.047
12	30	14.173
13	32.5	14.216
14	35	14.246
15	37.5	14.294
16	40	14.373
17	42.5	14.409
18	45	14.552
19	47.5	14.586
20	50	14.666

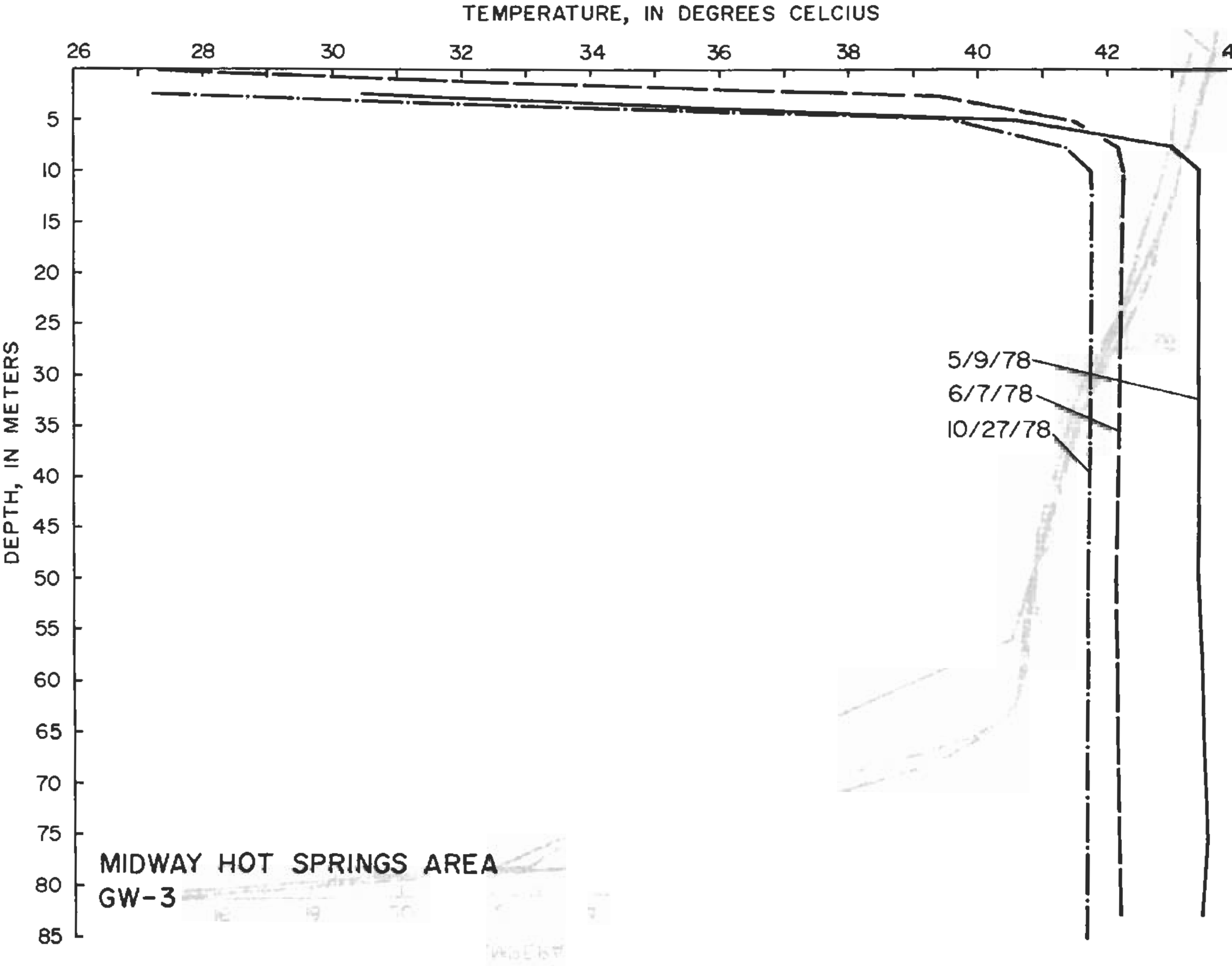
Gradient Well — Date of Measurement 10/27/78

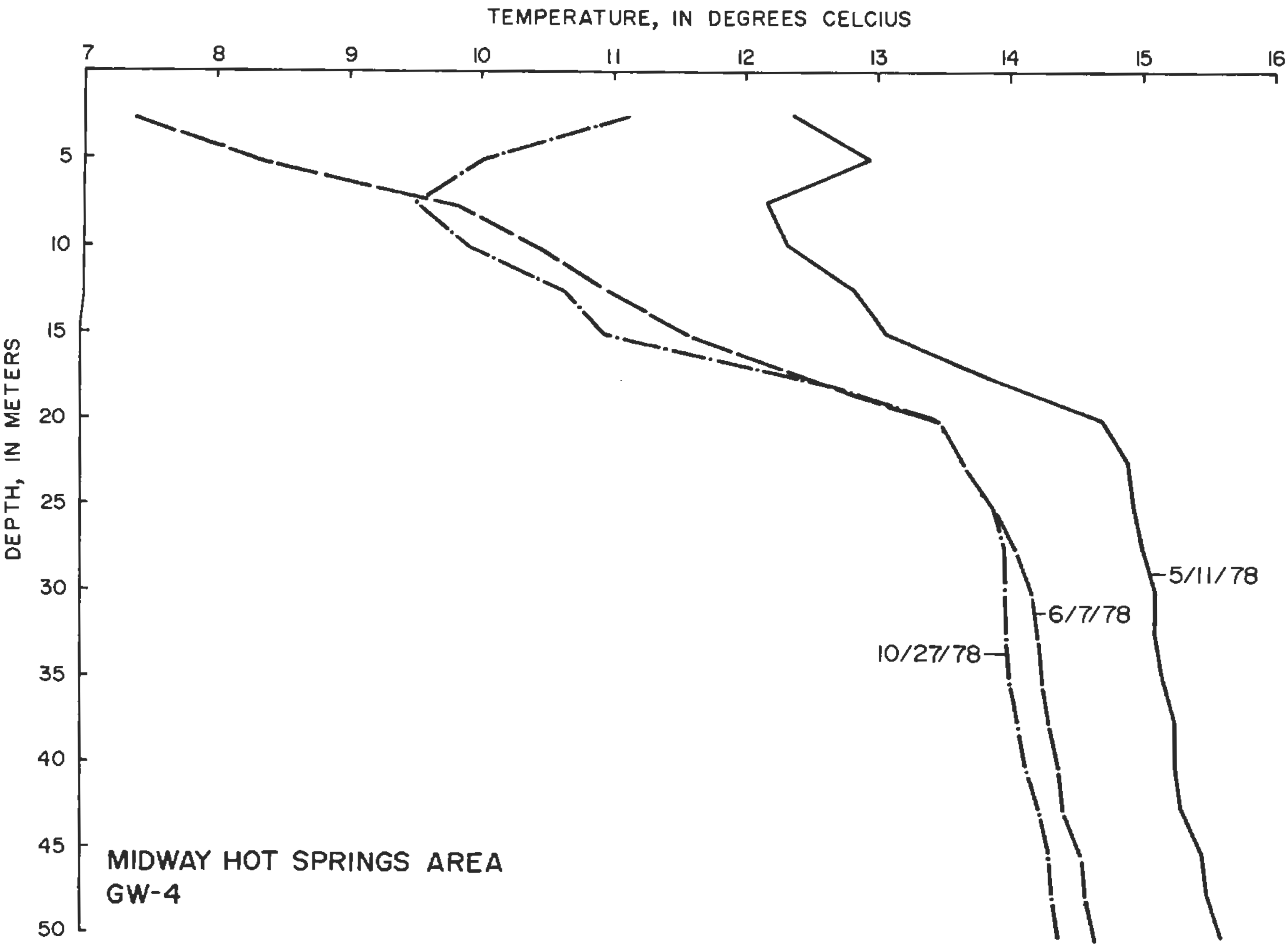
No. 4	Depth (meters)	Temp. °C
1	2.5	11.11
2	5	10.011
3	7.5	9.494
4	10	9.912
5	12.5	10.624
6	15	10.925
7	17.5	12.346
8	20	13.437
9	22.5	13.641
10	25	13.858
11	27.5	13.958
12	30.	13.968
13	32.5	13.971
14	35	13.996
15	37.5	14.059
16	40	14.12
17	42.5	14.222
18	45	14.301
19	47.5	14.324
20	50	14.378


TEMPERATURE, IN DEGREES CELCIUS
20
21
22
23
24
25
26
DEPTH IN METERS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
5/6/78
5/9/78
5/29/78
MIDWAY HOT SPRINGS AREA
GW-1



TEMPERATURE, IN DEGREES CELCIUS
14
16
18
20
22
24
26
28
30
32
34
36
38
DEPTH IN METERS
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
6/7/78
5/29/78
10/27/78
MIDWAY HOT SPRINGS AREA
GW-2


TEMPERATURE, IN DEGREES CELCIUS
26
28
30
32
34
36
38
40
42
44
DEPTH, IN METERS
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
5/9/78
6/7/78
10/27/78
MIDWAY HOT SPRINGS AREA
GW-3


TEMPERATURE, IN DEGREES CELCIUS
7
8
9
10
11
12
13
14
15
16
DEPTH, IN METERS
5
10
15
20
25
30
35
40
45
50
5/11/78
6/7/78
10/27/78
MIDWAY HOT SPRINGS AREA
GW-4