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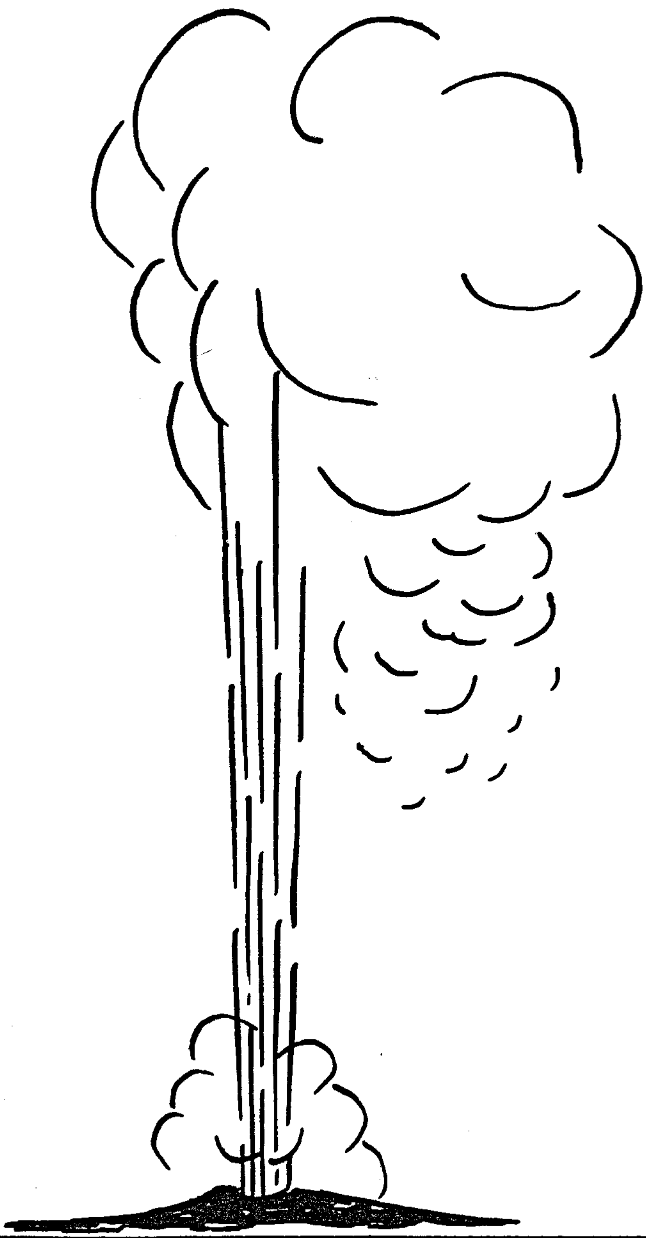

LOW- TO MODERATE-TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT FOR NEVADA: AREA SPECIFIC STUDIES, PUMPERNICKEL VALLEY, CARLIN AND MOANA

Final Report, June 1, 1981—July 31, 1982

By
Dennis T. Trexler
Brian A. Koenig
George Ghusn, Jr.
Thomas Flynn
Elaine J. Bell

Work Performed Under Contract No. AC08-81NV10220

University of Nevada
Reno, Nevada

U. S. DEPARTMENT OF ENERGY

Geothermal Energy

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LOW- TO MODERATE- TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT FOR NEVADA: AREA SPECIFIC STUDIES, PUMPERNICKEL VALLEY, CARLIN AND MOANA

Final Report
June 1, 1981 - July 31, 1982

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U.S. Department of Energy
Division of Geothermal Energy
Under Contract No. DE-AC08-81NV10220

Abstract

Geological, geophysical and geochemical surveys were used in conjunction with temperature gradient hole drilling to assess the geothermal resources in Pumpernickel Valley and Carlin, Nevada. This program was funded by the U.S. Department of Energy, Division of Geothermal Energy (contract number DE-AC08-81NV10220) and is based on a statewide assessment of geothermal resources that was completed in 1979. The exploration techniques are based on previous federally-funded assessment programs that were completed in six other areas in Nevada and include:

1. Literature search and compilation of existing data.
2. Geologic reconnaissance
3. Chemical sampling of thermal and non-thermal fluids
4. Interpretation of satellite imagery
5. Interpretation of low-sun angle aerial photographs
6. Two-meter depth temperature probe survey
7. Gravity survey
8. Seismic survey
9. Soil-mercury survey
10. Temperature gradient drilling

The work in Pumpernickel Valley demonstrated that the widespread geothermal fluids are likely channelled to the surface by range bounding faults. Temperatures of geothermal fluids have been estimated to be 170°C, based on chemical geothermometers. A previously unrecognized geothermal prospect was discovered on the west side of Pumpernickel Valley where there are no surface manifestations of thermal fluids. The prospect was first identified on the basis of a two-meter depth temperature probe survey. A maximum temperature of 70°C was subsequently measured at a depth of 76 m in a temperature gradient hole. Thermal fluid flow for this prospect is fault controlled and surface discharge is

precluded by a thick impermeable clay layer above the geothermal fluids. This area is also coincident with a steep gradient in gravity contours and high soil-mercury values.

In Carlin, two existing hot springs separated by 11 km (7 mi.) were found to represent two distinct hydrothermal circulation systems. Thermal fluid flow is controlled by two unrelated geologic structures; there are also no chemical or isotopic similarities in the fluids. A maximum temperature of 90°C was calculated for thermal fluids in Carlin based on chemical geothermometers.

In addition to the assessment program, baseline data were collected from geothermal wells in Moana, a small residential area in Reno, Nevada. The data include well locations, water temperatures, chemical analyses, and some temperature-depth profiles. Chemical and isotopic analyses of fluids from selected wells suggest that significant contamination of the geothermal reservoir occurs during the winter months and is likely the result of misuse of the reservoir.

Data necessary for the preparation of a new geothermal resource map for Nevada were compiled and provided to the National Oceanographic and Atmospheric Administration. Nine hundred-sixteen wells and springs with temperatures greater than 20°C are shown on the map. Areas having potential for discovery of geothermal resources in the near surface are delineated.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the land owners, ranchers and others for their cooperation, assistance and support during the course of this project. Mr. Tony Tipton and Mr. and Mrs. "Buck" Tipton provided valuable information in Pumpernickel Valley. In Carlin, we would like to thank Mrs. Cherie Aiazzi, City Clerk, and Mr. Delbert Reese of the Maggie Creek Ranch. Mr. Ron Parratt and Ms. Anne Zelinsky of the Southern Pacific Land Company provided needed assistance in the area of land permits. Jim Cress of the Nevada Highway Department helped us find a secure place to store some of our supplies and equipment. We would also like to thank Sharon Miles, Dr. Robert Barnett, and Bill and Carolyn Gadda for their cooperation in Moana. And we would especially like to thank Margie Johnson, Heather Dolan, and Cameron Covington for all their help in the preparation of this report.

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Introduction

In May, 1981, the Division of Earth Sciences began an assessment of low and moderate temperature resources (less than 150°C) in Carlin and Pumpernickel Valley, Nevada. This work was funded by the U.S. Department of Energy, Division of Geothermal Energy (DOE/DGE). The program consisted of analysis and interpretation of existing data as well as additional data obtained in field studies. The exploration methods used in the field studies were specifically developed for definition and characterization of shallow-depth geothermal resources that can be economically developed for direct-use applications.

Assessment of geothermal resources for specific areas is based on the results of a statewide geothermal resource assessment program that was completed in 1979 and involved analysis of regional-scale data. The study culminated in the publication of a 1:500,000-scale map entitled "Geothermal Resources of Nevada and Their Potential for Direct Utilization" (Trexler and others, 1979). The map provides technical resource information for more than 300 thermal springs and wells throughout the state. In addition, approximately 40 large areas were judged to have potential for development of geothermal resources. Pumpernickel Valley and Carlin were selected as two areas having a potential for geothermal resource development. An assessment of those resources is presented in this report.

In addition to Carlin and Pumpernickel Valley (fig. 1), this report also presents information on the Moana geothermal resource, which is located south of Reno, Nevada, and is currently being used for residential and commercial space heating.

The exploration techniques employed in this assessment are based on previous DOE/DGE funded assessment programs that were completed in Carson-Eagle Valley, Big Smoky Valley, Caliente, Hawthorne, and Paradise Valley. These

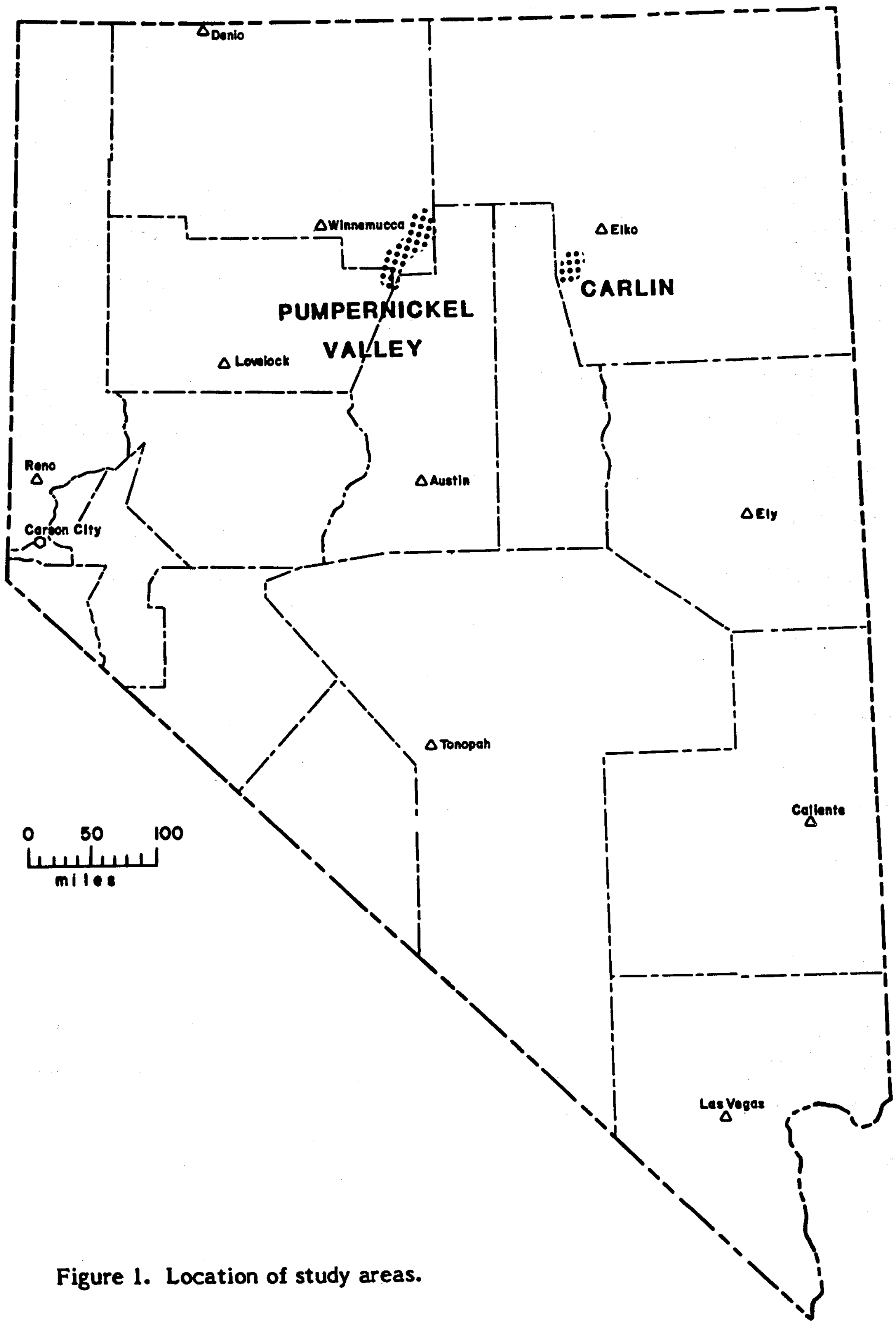


Figure 1. Location of study areas.

assessment programs were established to expand the geothermal resource data base by characterizing known geothermal areas, evaluating new exploration techniques, and possibly identifying new resources. The following list describes the techniques that were used in the program and is presented here to minimize duplication of text in the technical discussion.

Methods Employed in Carlin and Pumpernickel Valley

1. Search for and Examination of Existing Information

This task includes the scrutiny of a number of possible data sources. Topographic maps served as the bases for documenting spatial variations of gathered data. A search of appropriate literature revealed the nature and extent of existing geological, geophysical, and geochemical data. Well logs from the Office of the State Engineer and water analysis records of the Nevada Consumer Health Protection Service were reviewed for their relevant geologic and chemical data.

2. Area Geologic Reconnaissance

Field excursions to both areas were completed early in the program. Stratigraphy, lithology, and structural features were examined to gain personal familiarity with rock characteristics. This phase was also used to determine accessibility within the study areas and define possible impediments to later efforts.

3. Fluid Chemical Sampling and Analysis

Samples of both thermal and non-thermal fluids were collected and analyzed. Collected samples included both surface waters and groundwaters. Analyses consisted of major, minor, and trace dissolved constituents and hydrogen and oxygen stable light isotopic ratios. The sampling was accomplished early in the study to permit examination of the results and additional sampling if required. These data were used to determine the nature of recharge in the systems, in distinguishing thermal and non-thermal fluids, and assessing the degree of mixing of hot and cold waters.

4. Study of High Altitude Aerial Imagery

Imagery types included black and white photographs at various scales available from the EROS Data Center and various black and white and color imagery produced from LANDSAT and Skylab missions. This imagery provided information on large scale lineations, regional structural trends, area lithologic changes, and alteration zones.

5. Low Sun-Angle Photography (LSAP) to Delineate Surface Structural Features and Trends

LSAP photos at a scale of 1:30,000 were obtained for both study areas. This scale and the low sun-angle illumination permit detection of subtle surface features not apparent on imagery flown at greater altitudes or illuminated by vertical sun. Prior experience has demonstrated that features interpreted from LSAP can be correlated with subsurface structures which likely influence the localization of geothermal fluids.

6. Two-Meter Depth Temperature Probe Survey

A two-meter depth temperature probe survey was conducted in the Pumpernickel Valley and Carlin study areas in October and early November, 1981. Thermistors encased in 2 cm (.75 in.) diameter PVC pipe served as the sensing devices. An 8 cm (3 in.) diameter auger was used to drill over 150 holes in both study areas. The holes were backfilled following probe emplacement, and readings were taken after a minimum of 24 hours equilibration time. Previous studies (Flynn in Trexler and others, 1981) demonstrate that this period is sufficient to reach or very closely approach thermal equilibrium.

Testing of individual probes in a relatively uniform temperature medium (ice water) provides a means of determining the variations among the individual units. This test was deemed necessary because the sensor manufacturer lists an accuracy of ±0.5°C for the thermistor, and two conductor and three conductor sensors were utilized. Test results, listed in Table 1, indicate that the average readings of the two types of thermistors are not significantly different if the ±0.5°C accuracy limitations are considered. Additionally, accuracy limitations are noted by the 1.0°C and 0.3°C ranges in measured temperatures. Some of the observed variation is probably due to a lack of true temperature uniformity in the ice water bath. However, the magnitude of the variations does imply that two probes must differ by at least 1.0°C to qualify as measuring two different temperatures.

Difficulties other than those resulting from probe variations can also adversely affect the reliability of a shallow-depth temperature probe survey. Temperature changes resulting from progression along the annual wave are a prime

TABLE I

TEMPERATURE PROBE CALIBRATION

PROBE NUMBER	OLD/NEW	ICE WATER TEST	PROBE NUMBER	OLD/NEW	ICE WATER TEST
1	OLD	2.3	24	NEW	1.7
2	OLD	2.2	25	NEW	1.7
3	OLD	2.1	26	NEW	1.7
4	OLD	2.0	27	NEW	1.9
5	OLD	1.5	28	NEW	1.4
6	OLD	1.9	29	NEW	1.4
7	OLD	1.7	30	NEW	1.9
8	OLD	1.7	31	NEW	1.9
9	OLD	1.6	32	OLD	1.5
10	OLD	1.7	33	OLD	1.4
11	OLD	1.7	34	OLD	1.8
12	OLD	1.4	35	OLD	1.8
13	OLD	1.7	36	OLD	1.4
14	OLD	1.9	37	OLD	1.4
15	OLD	2.2	38	OLD	2.3
16	OLD	1.6	39	OLD	2.4
17	OLD	2.1	40	OLD	2.1
18	OLD	1.7	41	OLD	1.5
19	OLD	2.3	42	OLD	1.9
20	OLD	2.1	43	NEW	1.2
21	OLD	2.0	44	NEW	1.4
22	SCRATCHED		45	NEW	1.7
23	NEW	1.1			

TYPE	NUMBER	X	σ	RANGE
Two Conductor	(12)	1.58	0.28	1.4 - 2.4
Three Conductor	(32)	1.84	0.31	2.2 - 1.9

example. This problem is discussed in detail by Olmsted (1977). Annual wave temperature corrections were calculated from temperature measurements on control probes that remained in place throughout the survey. Temperature data for control probes PVT-1 and PVT-12 are plotted versus time in Figure 2. From these data, an average correction is computed for each measurement day. The correction is added to raw data, permitting all temperature measurements to be compared as if they were collected in a single day. Local nonlinearities in the curves of Figure 2 probably represent the effects of weather systems on two separate sites with slightly different thermal conductivity and/or albedo.

Differences in probe site elevations represent another potential source of error. Temperature in a static air mass decreases at the rate of 1.9°C (3.5°F) per 304.8 m (1000 ft) increase in elevation. Appropriate corrections are computed by determining the elevation of the lowest probe in the study area for use as a base. Elevations of other probes are also determined and the magnitudes of the differences from the base are computed. The formula for the correction is: $Tc = Ti + ((Ei - El) L_n)$.

Where Tc = Temperature corrected for elevation difference

Ei = Elevation of probe requiring correction

El = Elevation of lowest probe in study area

L_n = Normal lapse rate (in °C/m or °F/ft)

Ti = Uncorrected temperature reading

7. Gravity Survey

Gravity data have been used extensively throughout the Basin and Range Province to identify large and small-scale subsurface geologic structures (Thompson and Sandberg, 1958; Thompson, 1959; Stewart, 1971; and Goldstein and Paulsson, 1979). Gravity data have been used in geothermal exploration to identify

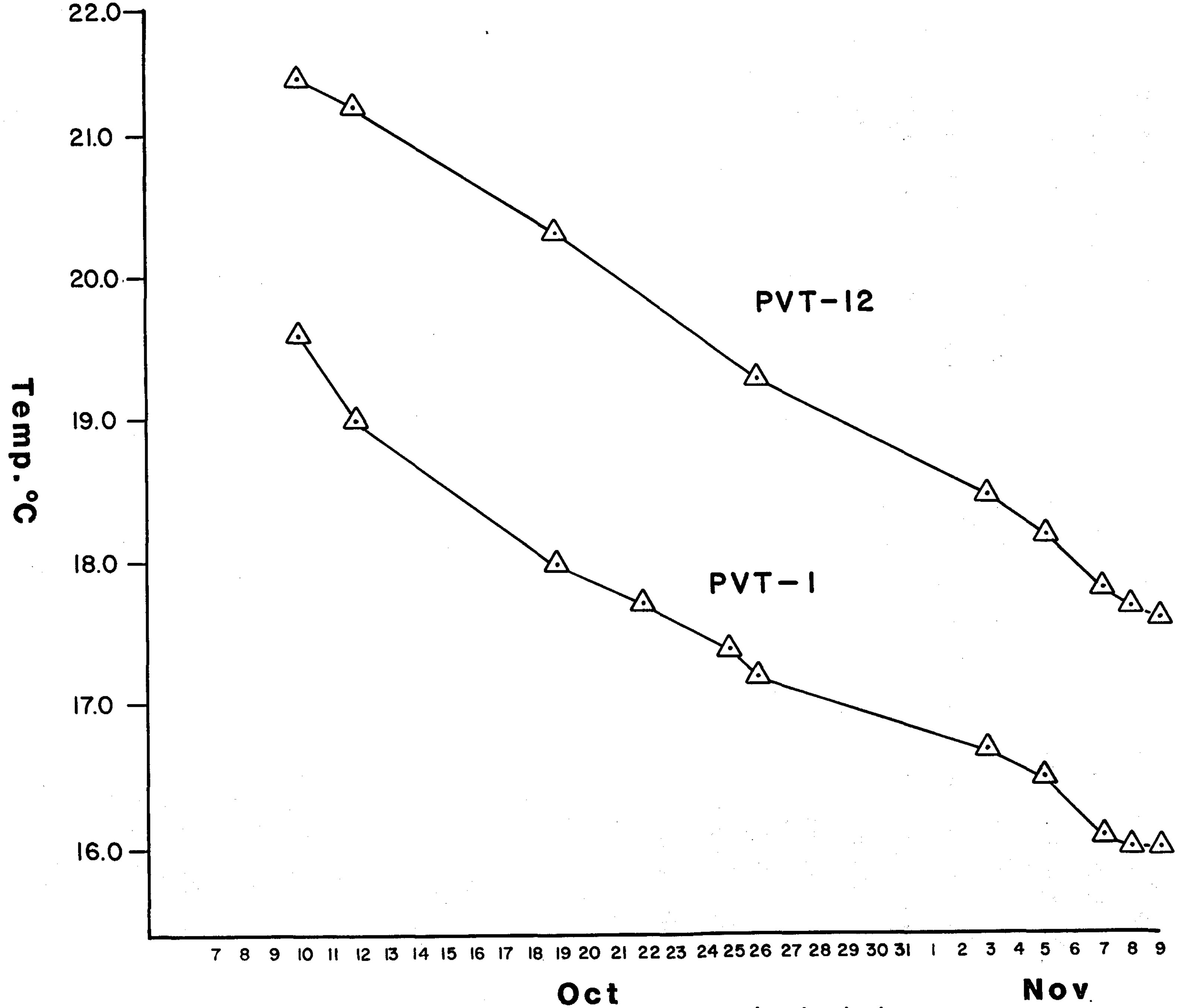


Figure 2. Temperature-time variations recorded by control probes in the Pumpernickel Valley study area.

subsurface faults that may control the flow of rising thermal fluids (Koenig and others, 1980; Flynn and others, 1980). Carrier and Chapman (1980) used gravity data to delineate the subsurface configuration of a silicic volcanic dome in the Black Rock Desert, Utah.

In this study, gravity surveys were used principally to identify faults in the subsurface that act as controls on the movement of geothermal fluids. The gravity data were also used in Pumpernickel Valley to develop a model that roughly approximates the basement configuration.

8. Seismic Survey

Seismic data were purchased for the Carlin study area. These data consist of approximately three line miles of a speculative survey that was conducted in Susie Creek. Although the data were obtained in an area considerably north of the hot springs, some of the structures associated with the springs also transect the seismic survey line. An interpretation of the data is presented in the technical discussion.

9. Soil Mercury Survey

Because of the low cost and ease of sample collection, soil mercury surveys have been used extensively in geothermal exploration programs. Previous work in other regions in Nevada indicate that this technique may be area-dependent. Matlick and Buseck (1975) have shown that soil-mercury surveys are a reliable exploration technique for some geothermal resources.

Approximately 170 soil samples were collected at 1.6 km (1 mi.) intervals throughout both study areas. Samples were collected at a depth of 25-30 cm (10-12 in.) and were air dried prior to analysis. Soil analyses were performed on a Jerome Gold-Film Mercury Analyzer. It was necessary to use a .25 mg scoop of -80 mesh seived sample because of the overall low levels of mercury. Mercury vapor was used as a standard during the analyses. Combined instrument-operator error is estimated to be 15 percent.

10. Temperature Gradient Drilling

a) 35-meter Depth Temperature Gradient Holes

Shallow-depth temperature gradient holes were drilled throughout both study areas. The purpose of this drilling program was to further examine thermal anomalies discovered during the 2-m depth temperature probe survey and to obtain accurate subsurface data in areas where similar data were not available. Drill site selection was also based on analyses of geologic structures from air photos and gravity data, as well as the results of the soil-mercury survey. Table 2 summarizes the drill-site selection criteria for all the holes drilled in both areas. Five drill sites were selected in Pumpernickel Valley and three in Carlin.

In November, 1981, a standard on-foot archaeological reconnaissance of aboriginal and historical cultural resources was completed. This clearance work was performed for drill sites on both federal and privately owned land. In conjunction with this work, appropriate personnel in the Elko and Winnemucca, Nevada, BLM District Offices were contacted as well as the Federal Register, National Register of Historic Places, and Annual Listing of Historic Properties. Drill sites were all located adjacent to existing roads and measured 75 m^2 (250 $ft.^2$). The results of the on-foot reconnaissance were negative and no other records of historical or aboriginal sites were found.

Hole No.	2-m Probe	Limited or No Data	Geologic Structures	Hg-Soil
Pumpernickel Valley				
PVHT-1		X	X	
PVHT-2	X		X	
PVHT-3	X		X	X
PVHT-4	X			X
PVHT-5	X		X	
Carlin				
CHT-1	X			
CHT-2	X		X	
CHT-3	X		X	

Table 2. Drill-site selection criteria for 35 m (120 ft.) temperature gradient holes.

Drilling began in December, 1981, and was completed in January, 1982. Unusually cold weather hampered the drilling considerably. A Mobil B-80 rotary-mud drill rig was used for all the holes. Both drag and tri-cone mill tooth drill bits were used in the operation. Temperature of return mud was monitored continuously and drill chip samples were collect at 3 m (10 ft.) intervals.

The drilled-holes were cased with 5 cm (2 in.) diameter PVC pipe that was plugged at the bottom. The top of the annulus was cemented and the casing was filled with water. Temperature measurements were made with an Enviro-Labs, Inc. cable reel digital thermometer. Prior to measuring the wells, the thermometer was calibrated in both ice water and boiling water to an accuracy of 1°C.

b) 65-148 Meter Depth Temperature Gradient Holes

Five holes ranging in depth from 65 to 148 m (210 to 485 ft.) were drilled in the area surrounding the Kemp benchmark on the westside of Pumpernickel Valley. The purpose of this drilling program was to further investigate resource characteristics, such as temperature and depth, to identify structural and stratigraphic controls, and to ascertain the areal extent of the resource. A complete description of the drilling program is presented in the text with figures in the technical discussion.

Methods Used in the Moana Geothermal Resource Area

Information from a resource that is currently being used was acquired by taking fluid samples from selected wells on a quarterly basis. Temperature profiles were performed on the same wells to determine the physical effects of exploitation. Baseline data were collected during the non-usage summer months for comparison with information collected later in the study. Additional commitments under this task included maintaining up-to-date locations of newly drilled wells, performing additional temperature profiles where permitted, and assembling the acquired data in a usable format.

State Map

Preparation of an updated geothermal map for Nevada was deemed appropriate since appreciable data have been generated by numerous U.S. Department of Energy sponsored programs and extensive industry exploration since publication of the first map defining the "Geothermal Resources of Nevada and Their Potential for Direct Utilization" (Trexler and others, 1979).

All new data concerning the location, temperature and chemistry of the geothermal springs and wells were verified as to completeness and accuracy. These data were added to the existing GEOTHERM file so they could be extracted in an abbreviated format for incorporation in the map explanation.

Areas where surface water temperatures are greater than 40°C or where temperatures of 40°C may be encountered at depths of less than 500 m (1500 ft) were delineated. In addition, areas favorable for the discovery of thermal waters at shallow depths (less than 1000 m) of sufficient temperature for direct application were identified. The map will be published by NOAA and should be available in Fall of 1982.

PUMPERNICKEL VALLEY

Geographic Setting

The Pumpernickel study area encompasses both Pumpernickel Valley and the region surrounding the Blossom Hot Pot thermal springs, a total of approximately 520 square kilometers (200 sq. mi.) in the southeast corner of Humboldt County and the northeast corner of Pershing County, north-central Nevada (fig. 1).

The southern portion of Pumpernickel Valley trends northward, bounded by the Sonoma Range to the west and the Tobin Range to the east, while the northern portion of the valley trends northeastward, flanked by Edna Mountain and Buffalo Mountain (fig. A1). Elevations range from an average elevation of about 1400 m (4600 ft.) on the valley floor to greater than 2440 m (8000 ft.) on the surrounding mountain peaks. Blossom Hot Pot occurs within a broad, northwest-trending topographic depression. This unnamed depression is delineated by parts of several physiographic highs, including Battle Mountain, the Sheep Creek Range, Edna Mountain and the Osgood Mountains.

Drainage flows northeastward via Ragan Creek to the Humboldt River. Average annual rainfall ranges between 12.7 and 25.4 cm (5 and 10 in.), occurring mostly during the winter. Maximum temperatures of 40° C have been recorded in summer and minimum temperatures of -30° C were recorded in winter.

The Western Pacific and Southern Pacific railroads transect the northeast part of the study area. Vehicle traffic is via U.S. Highway 40 and the improved and unimproved roads transecting the valley, connecting the ranches.

Geologic Setting

Sedimentary and igneous rocks of the area range in age from Cambrian through Tertiary, with unconsolidated deposits of Pleistocene and Recent age. Precambrian rocks have not been recognized in this area. Silurian and Devonian

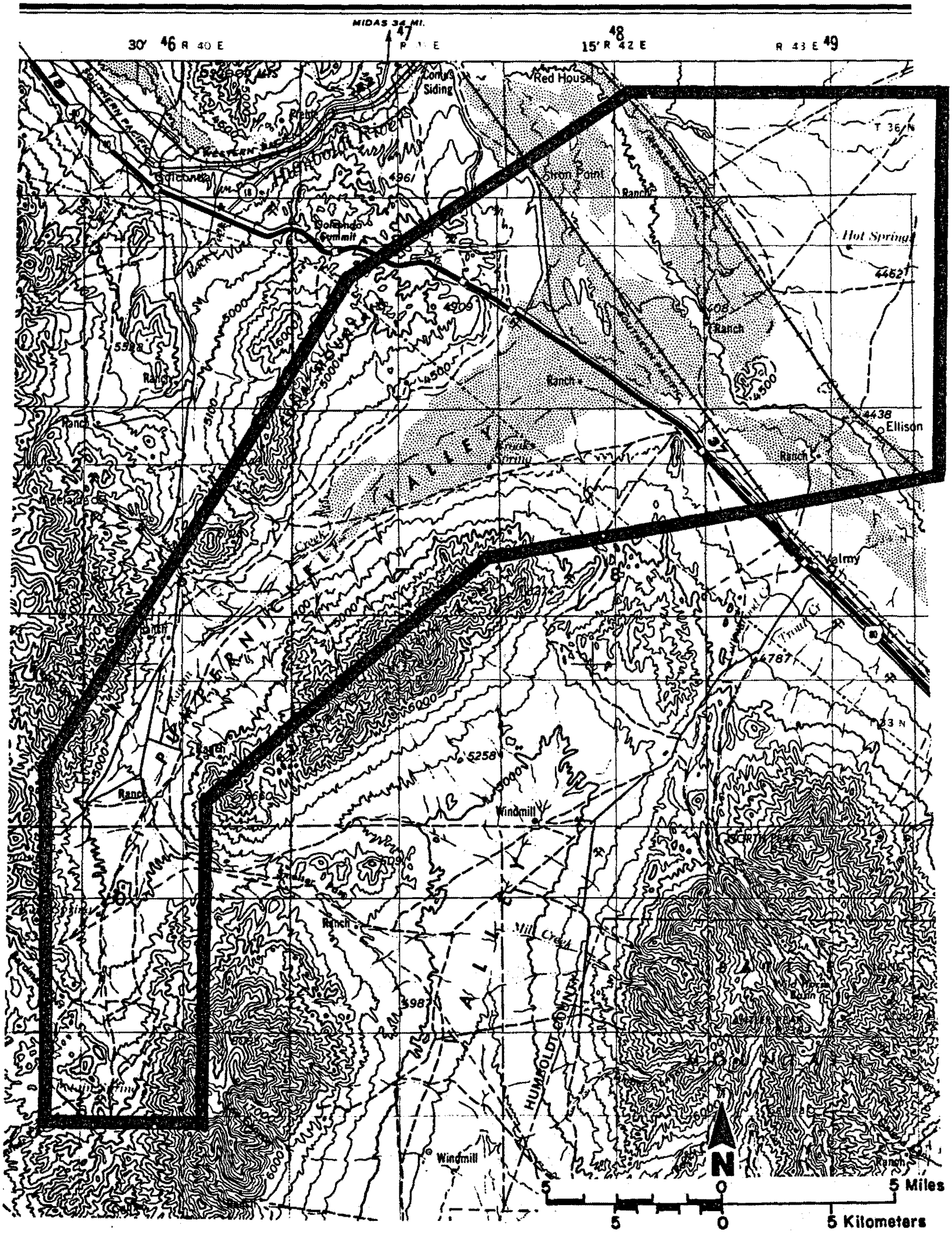


Figure A1. Pumpernickel Valley study area.

rocks outcrop in an area about 32 km (20 mi.) to the southeast, but have not been recognized in this study area. The generalized geology shown on Figure A2 is modified from Ferguson and others (1951) and Ferguson and others (1952). Table A1 lists the major lithologies common to the area as depicted on the map.

The following narrative summarizes relevant geologic events for the Pumpernickel Valley study area.

Paleozoic Era

Three major depositional provinces existed in central Nevada from early Cambrian through middle Devonian time. The most comprehensive analysis of the geology of this area is presented by Stewart (1980). Using data from Erickson and Marsh (1974), Ferguson and others (1951), Ferguson and others (1952), Silberling (1975), and Willden (1964), Stewart presents a series of palinspastic maps that show the areal extent of these depositional provinces and how they evolve through time. The easternmost province, the Eastern Assemblage, is interpreted as a north-trending miogeosyncline characterized by extensive accumulations of shallow-water marine carbonates. This province extended from central Nevada to eastern Utah and parts of western Colorado. A second depositional province, the Western Assemblage, was located in what is now western Nevada and eastern California in a configuration that was roughly parallel to the miogeosyncline. This area is interpreted as a eugeosyncline and is characterized by massive accumulations of siliceous shale, chert, greenstone, and volcanic rocks. A third smaller depositional province, the Transitional Assemblage, located between the eastern and western depositional provinces consists of interbedded shale and limestone.

This pattern of deposition remained virtually unchanged until the onset of the Antler Orogeny in the late Devonian period. During this orogeny which ended in

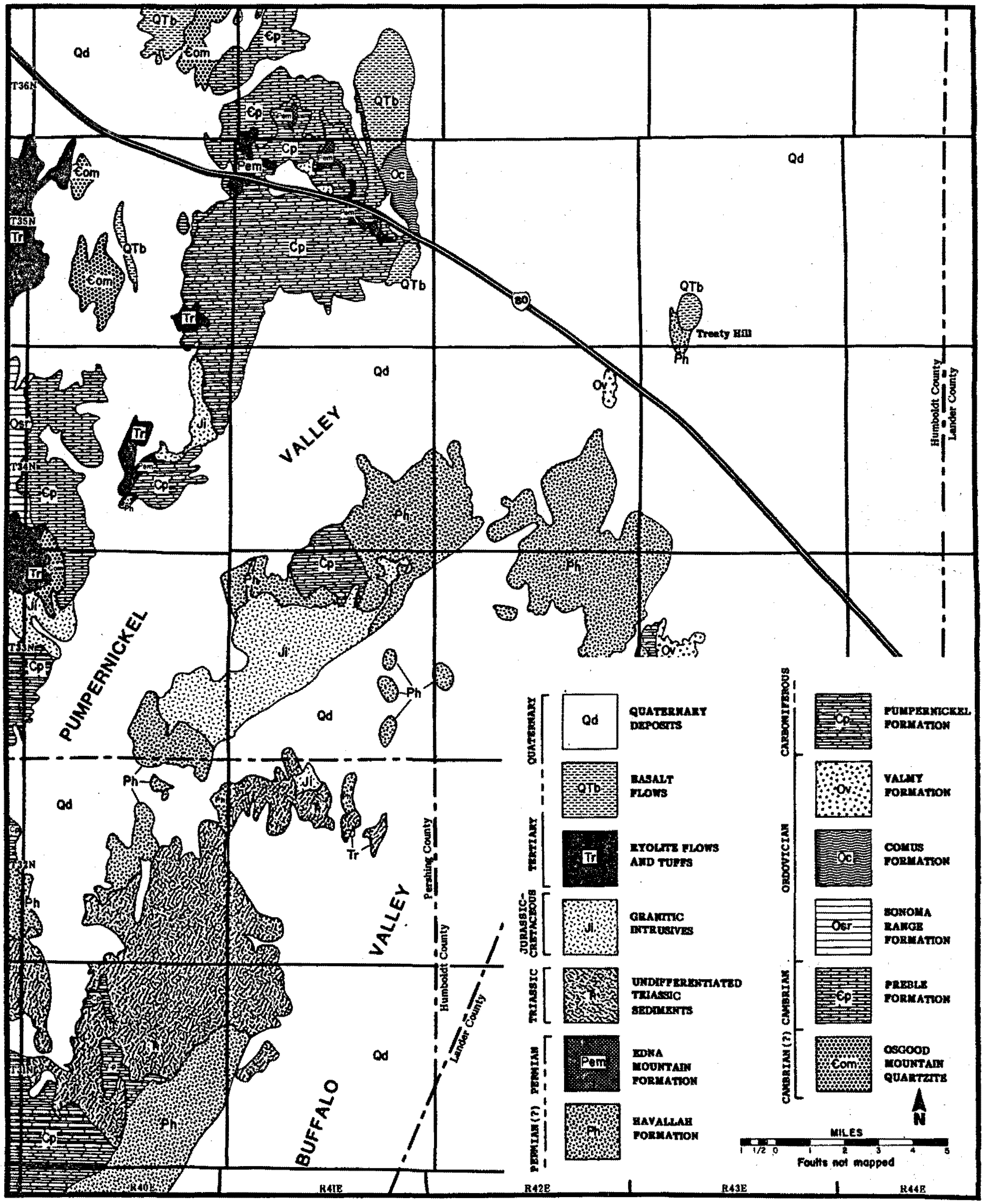


Figure A2. Generalized geologic map of Pumpernickel Valley.

TABLE AI

Lithologic descriptions and ages of selected geologic units in the Pumpernickel Valley study area.

AGE	MAP SYMBOL	LITHOLOGY
Quaternary	Qd	Quaternary deposits: includes younger eolian, lacustrine and fluvial sediments; Pleistocene Lake Lahontan deposits; and older Pleistocene gravels generally along mountain fronts.
	QTb	Basalt flows: Plio-Pleistocene age.
Tertiary	Tr	Rhyolite flows and tuffs: Miocene and older (?) age.
Jurassic-Cretaceous (?)	Ji	Granitic intrusives: all quartz-bearing igneous rocks that pre-date Tertiary intrusive rocks; principally granodiorite with local compositional variations to quartz diorite and quartz monzomite, with mafic border facies.
Triassic	T_R	Undifferentiated Triassic sediments: includes lower Triassic China Mountain Formation, middle Triassic Favret, Panther Canyon, and Augusta Formations, and upper Triassic Cane Spring Formation. Sequences of conglomerate, sandstone, shale, limestone and dolomite.
Permian	Pem	Edna Mountain Formation: sandstone and quartzite with slate, limestone and calcareous sandstone. Mapped areas may include Antler Peak Limestone of Pennsylvanian (?) age.
Permian (?)	Ph	Havallah Formation: chert, slate and quartzite with limestone and conglomerate.

Table Al (Con't)

Carboniferous	Cp	Pumpernickel Formation: chert and siliceous argillite with greenstone, limestone and clastic sediments. Pennsylvanian (?) in age.
Ordovician	Ov	Valmy Formation: quartzite and chert, with siliceous slate, argillite and greenstone. Middle (?) Ordovician in age.
	Oc	Comus Formation: slate, grading to chert with limestone and quartzite. Lower (?) Ordovician in age.
	Osr	Sonoma Range Formation: chert, siliceous argillite and slate with andesite, limestone, quartzite, and pillow basalt. Lower (?) Ordovician in age.
Cambrian	Єp	Preble Formation: schist, slate, and hornfels with limestone. Middle or Upper Cambrian in age.
	Єom	Osgood Mountain Quartzite: quartzite, with quartz mica schist. Lower Cambrian in age.

early Mississippian, Western Assemblage siliceous rocks were thrust eastward along the Roberts Mountain Thrust by as much as 145 km (90 mi) over coeval carbonates of the Eastern Assemblage.

Several tectonic models have been suggested to explain this orogenic episode including gravity sliding of "allochthonous" (not-in-place) units from the newly formed Antler Highland (Ketner, 1977) and island arc-continental collisions (Burchfield and Davis, 1972; Silberling, 1975; Poole, 1974). Evidence for the existence of the Antler Highland is derived largely from the absence of late Devonian age rocks west of the Robert's Mountain Allochthon (thrust sheet), and also from syn- and post-tectonic clastic deposits (conglomerate and arkosic sandstone) on both the east and west sides of the thrust sheet. Proponents of plate tectonic models cite the presence of volcanogenic rocks in the Western Assemblage as evidence for an island arc which may have persisted offshore from the North American continent throughout much of the Paleozoic era (Stewart, 1980).

Post-Antler Orogeny depositional patterns are similar to those developed in early Paleozoic time. The Eastern Assemblage, although less extensive, continued to accumulate shallow water carbonates in a bank extending from eastern Nevada to Colorado. In central Nevada, however, the Antler Highland contributed coarse clastics to a deep water zone just west of the carbonate province, while siliceous and volcanic rock types accumulated just west of the Antler Highland (Stewart, 1980).

This pattern of deposition persisted until the Sonoma Orogeny of late Permian to early Triassic age. The Sonoma Orogeny is similar in character to the Antler Orogeny and resulted in the eastward lateral movement (thrusting) of deep water siliceous and coarse clastic rocks over coeval shallow water carbonates.

Several models have been suggested to explain the juxtaposition of siliceous rocks over the carbonates. The most recent models outlined by Stewart (1980) propose that an east-dipping plate located under the offshore island arc (Antler Highland) began to accelerate toward the continent. This resulted in the landward migration of the island arc and the obduction or over-thrusting of siliceous sediments over the carbonate deposits on the continental margin. Alternatively, Speed (1977) proposed the emplacement of the siliceous sediments over the continental carbonate rocks along the top of a west-dipping plate which was subducted under the island arc just west of the continental margin. Although the exact mechanism is still uncertain, the orogeny is recognized by superposition of Pennsylvanian and Permian age deep water siliceous sediments (Havallah and Pumpernickel Formations) over shallow water carbonate rocks of the same age (Antler Peak and Edna Mountain Limestones).

Mesozoic Era

Triassic sediments in western Nevada occur in two depositional provinces. The Winnemucca Formation has been interpreted as a shallow shelf deposit consisting of shale with subordinate amounts of limestone, dolostone and sandstone. Also outcropping in the East Range (west of the study area), the Raspberry Formation has been assigned to a deep-water basinal province consisting of pelite and sandstone with limestone conglomerate. These sediments are thought to post-date the Sonoma Orogeny. Within the study area, Triassic sedimentary rocks occur in the north end of the Tobin Range. These sediments consist of limestone and dolomite with shale, sandstone and conglomerate which have all been affected by both regional and contact metamorphism associated with igneous activity during the Cretaceous period. These metamorphosed sedimentary rocks apparently represent a continuation of depositional patterns that began in mid-Triassic time.

Plutonic rocks of Jurassic-Cretaceous age (Willden, 1964) are widespread throughout Nevada and are well exposed in the Sonoma Range, Edna Mountain and

Buffalo Mountain. Compositionally, these rocks are primarily granodiorite; locally, they may consist of quartz diorite and quartz monzonite with border facies of diorite and gabbro. All of the granodiorites in the study area are considered to be a continuation of the Sierra Nevada Batholith. Emplacement of these plutonic rocks was accompanied by regional metamorphism, folding and faulting, as well as contact metamorphism of Triassic sedimentary rocks.

Cenozoic Era

Two important events occurred in central Nevada approximately 17 m.y. BP which helped shape present topographic features: tectonic forces changed from compression to extension, and volcanic rock compositions shifted from rhyolitic and calc-alkaline to basalt and basaltic andesite.

The onset of extensional tectonics produced widespread block faulting throughout the Basin and Range. Vertical displacement along high-angle (60°) normal faults varies from area to area, but most estimates range from 1800 to 4600 meters (6000 to 15,000 ft.) (Stewart, 1980). The exact nature of the faulting is still uncertain although several models have been proposed (Stewart, 1980; p. 110). A shift from acidic to basic type volcanic rocks accompanied Basin and Range faulting. Within the study area, both Miocene age rhyolite flows and tuffs and Pliocene (Plio-Pleistocene) age basalt flows are present.

Quaternary age deposits constitute the most extensive rock type in the area. Older alluvial deposits are located adjacent to the mountain ranges and consist of coarse alluvial fan deposits and debris slides. Younger alluvial deposits include lacustrine sediments from Lake Lahontan, stream gravels, playa deposits, and sand dunes. Most evidence of earlier Basin and Range faulting as been obscured by these younger Quaternary deposits.

Buffalo Mountain

The northern and southernmost portions of Buffalo Mountain are underlain by Havallah and Pumpernickel Formations (fig. A2). These are intruded by coarsely crystalline granodiorite of Jurassic-Cretaceous (?) age. The Pumpernickel Formation is exposed in the center of an overturned northwest-trending anticline. Plio-Pleistocene gravels overlie and are in fault contact with Havallah Formation at the southern end of the mountain. Buffalo Mountain is bounded by normal range front faults.

Edna Mountain

Phyllitic shale and quartzite of the Cambrian Preble Formation and overlying Ordovician through Pennsylvanian rocks crop out in an arc around the north end of the range (fig. A2). Preble Formation is in fault contact with Ordovician slates of the Comus Formation in the eastern part of the range north of U.S. Highway 40. Ordovician chert and quartzite of the Valmy Formation outcrop at Lone Tree Hill to the northeast of Buffalo Mountain. The Preble Formation is unconformably overlain by Pennsylvanian conglomerate, sandstone, shale and limestone of the Battle Formation, or by the Pennsylvanian Highway Limestone, an offshore equivalent of the upper part of the Battle Formation (Ferguson and others, 1952), or along the west front of the range, by the Pennsylvanian-Permian (?) age Antler Peak Limestone. The Permian sandstone and quartzite of the Edna Mountain Formation unconformably overlie the Cambrian and Pennsylvanian age rock units.

Most of the range is underlain by Carboniferous chert and argillite of the Pumpernickel Formation which was emplaced by the Golconda thrust (Ferguson and others, 1952). Locally, Permian chert, slate and quartzite of the Havallah Formation are present, but are not depicted in detail on the map (fig. 2).

The upper plate rocks have been intruded at several places by small bodies of coarsely crystalline granodiorite of Jurassic-Cretaceous (?) age. At the south end of the range granodiorite intrudes both upper and lower plate rocks, thus limiting the age of faulting. Tertiary Miocene rhyolitic flows and tuffs overlie older rocks along the western side of the range. Plio-Pleistocene olivine basalt flows, shown on the map (fig. 2) as QTb, overlie older rocks in the northeastern part of the range and at Treaty Hill to the east near the Humboldt River.

The range is bounded by high angle normal faults that locally displace Quaternary alluvium.

Sonoma Range

The Sonoma Range is principally underlain by rocks of Paleozoic age in both stratigraphic and structural contact (fig. A2). Cambrian (?) age Osgood Mountain Quartizte and slate and schist of the middle to upper Cambrian age Preble Formation are exposed along the east front of the range. These Cambrian rocks are in thrust fault contact with the sequence of Ordovician chert, argillite and slate of the Sonoma Range Formation. Tertiary rhyolite flows and tuffs unconformably overlie these rocks in the northern and east-central portions of the range.

The southern portion of the Range, bounding the west side of Pumpernickel Valley, is primarily underlain by slate, argillite and limestone sequences of the Pumpernickel Formation and the intertonguing chert and quartzite of the Permian age Havallah Formation. Triassic age sedimentary shale, sandstone, limestone and conglomerate are exposed in the southernmost part of the Sonoma Range. These sequences represent the China Mountain, Panther Canyon and Augusta Formations.

The dominant structural features of the Sonoma Range are the thrust faults, including the Golconda thrust (Golconda-Tobin thrust), the Clear Creek thrust, the

Sonoma thrust and the Thomas thrust. Generally, these thrust faults have emplaced older Paleozoic units over rocks as young as Permian age (Willden, 1964). The high-angle normal faults are less extensive and are generally present as range-bounding structures or affect formations in the southern end of the range.

Tobin Range

The north end of the Tobin Range, bounding southern Pumpernickel Valley on the east, is underlain principally by the Pumpernickel Formation and Permian age Havallah Formation (fig. A2). These rock sequences are generally in thrust or normal fault contact with younger Triassic sedimentary sequences that include the China Mountain, Favret, Panther Canyon, Augusta and Cave Spring Formations. These rocks are all part of the upper plate of the Golconda thrust. Locally, Tertiary rhyolite flows and tuffs are present. This northern portion of the Tobin Range is dominated structurally by high-angle normal faults within the mountain block between Pumpernickel and Buffalo Valleys.

Lineament Analysis

Photogeologic interpretation was conducted of Pumpernickel Valley and vicinity to identify and delineate lineaments and faults. NASA mission 74-160 photography (1:30,000 and 1:120,000 scale), Landsat color composite imagery (scene 44-32, 1:250,000 scale, 9 Oct., 1976), and AMS mission 109 photography (1:60,000 scale) were evaluated. Lineaments identified on the imagery were compiled on a 1:250,000 scale map and then delineated on Figure A3. The continuity of the lines indicates the integrity of the feature.

Synoptic coverage was provided by the small-scale imagery, with genetic origin of the lineaments determined from evaluation of the larger scale

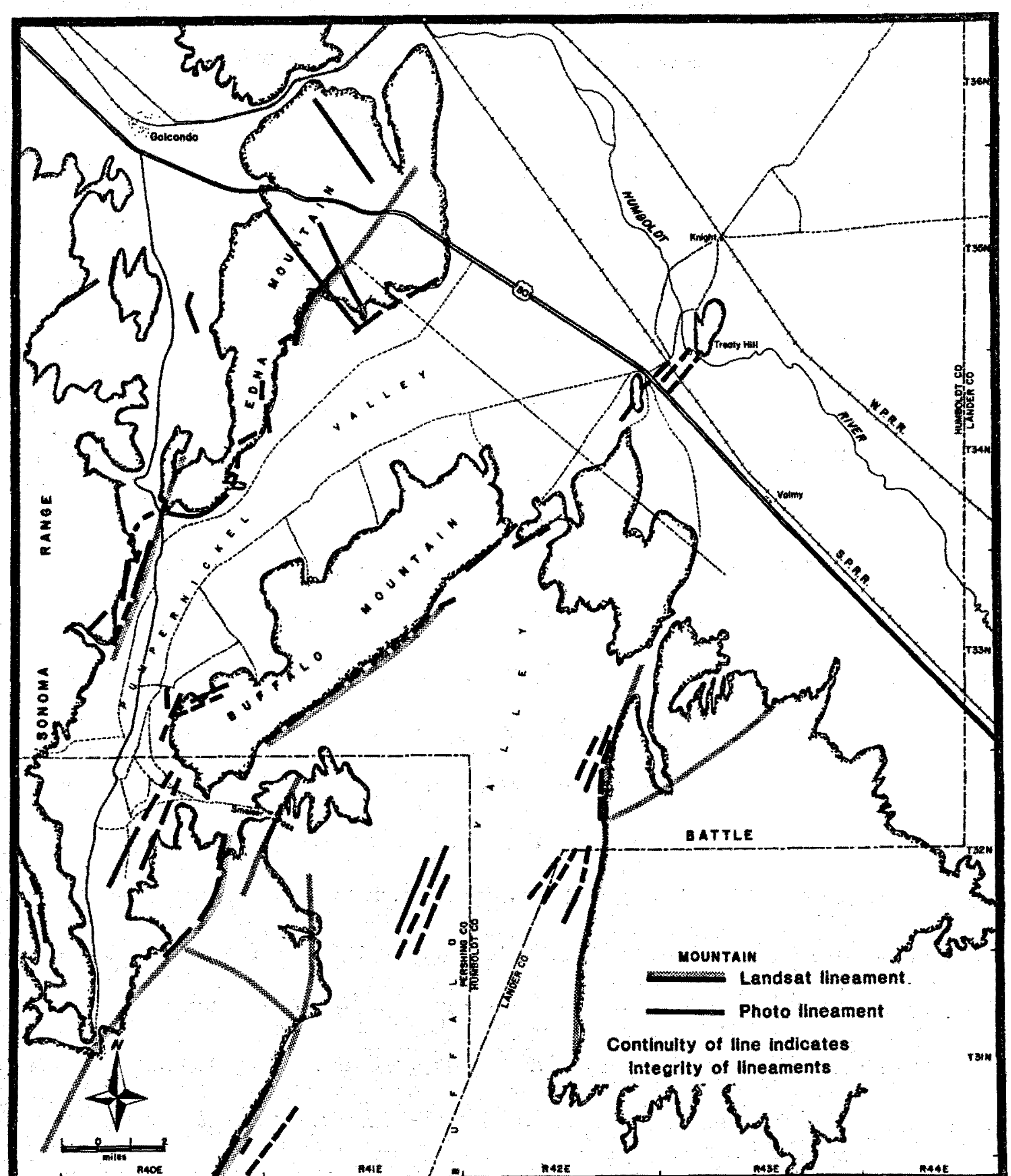


Figure A3. Lineament map of Pumpernickel Valley.

photography. In general, the lineaments represent fault scarps that bound the mountain blocks or transect the alluvial valley areas. Those lineaments within the mountain ranges are recognized as fault contacts between varying bedrock lithologies. Features depicted on Figure A3 correlate with north to northeast-trending range bounding faults indicated in the literature (Ferguson and others, 1951; Ferguson and others, 1952; Johnson, 1977; Willden, 1964). The faults transecting alluvium in the central portion of Buffalo Valley and, in particular, the frontal fault zones bounding Pumpernickel Valley were recognized in this photogeologic analysis and are not indicated in the literature. These features define the local structural setting for the Pumpernickel Valley geothermal resource.

The dominant northeast-trending lineaments represent the major lineament trend in north-central Nevada (fig. A4). This trend was first identified as the Midas Trench (Rowan and Wetlaufer, 1973; Rowan, 1975) and was defined in the vicinity of Pumpernickel Valley on the basis of 1) the abrupt truncation of the Humboldt, East and Sonoma Ranges, 2) the transection of these ranges by deep northeast-oriented canyons and 3) the marked linearity of Buffalo Mountain. Mabey and others (1978) included the Midas Trench in an northeast-trending zone, the Humboldt zone, of faulting that extends across nothern Nevada. Rowan and Wetlaufer (1981) have redefined this zone and renamed it the Humboldt structural zone to indicate its tectonic significance. They delineated the Humboldt structural zone (fig. A4) on the basis of northeast-trending faults; the distribution and alignment of Cenozoic (Miocene) volcanic rocks, Cenozoic granitic plutons, and aeromagnetic anomalies; northeast-trending gravity gradients; variation in seismic crustal velocities; rate of vertical crustal uplift and the presence of high heat flow and hot spring activity.

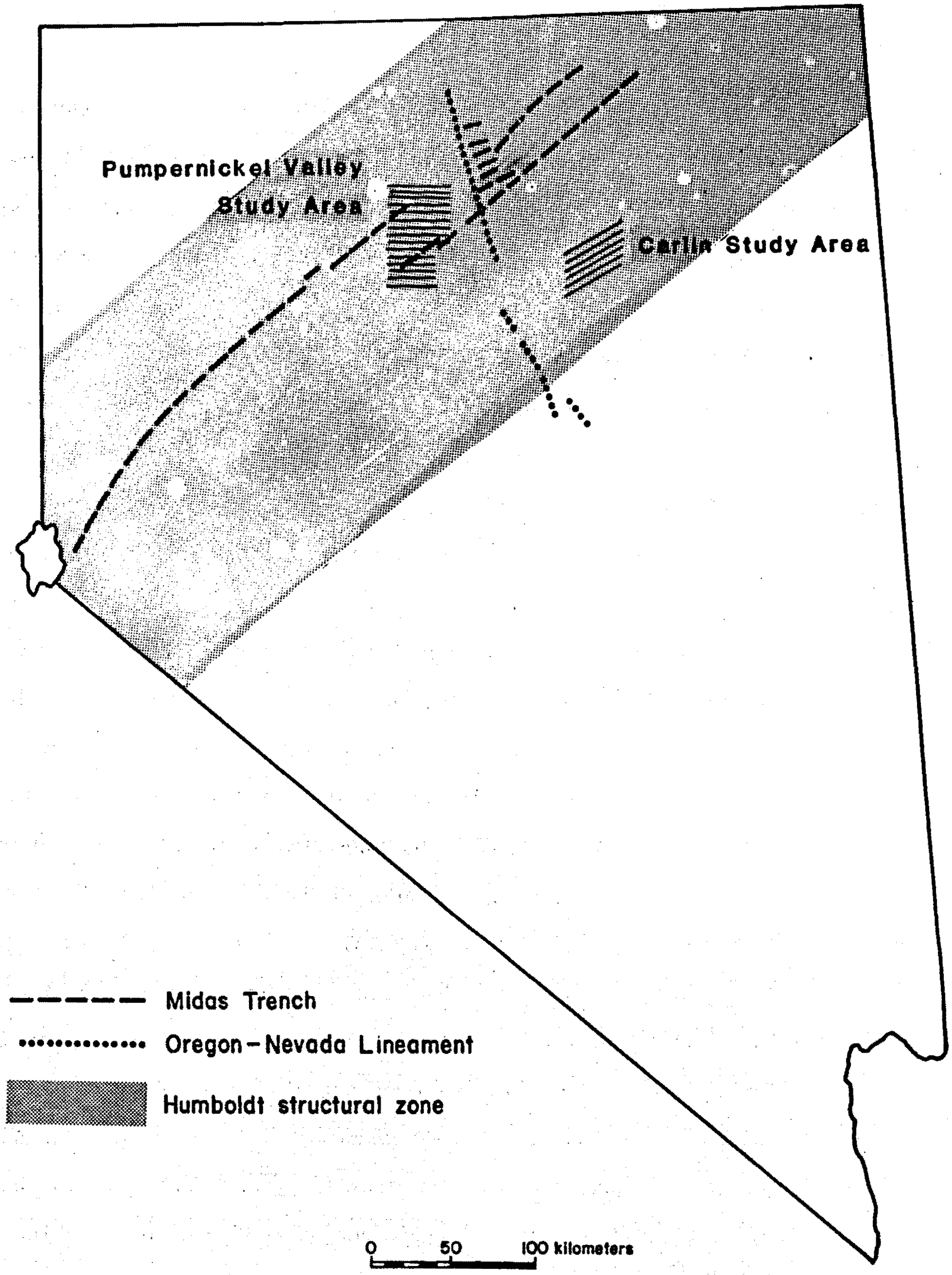


Figure A4. Location and trend of regional structural elements (modified after Rowan and Wetlaufer, 1975, 1981).

Figure A5 indicates the fault scarps along the southern end of Edna Mountain. Of particular interest is the re-entrant along the range front defined by the northeast-trending range front faults and the northwest-trending fault cutting bedrock. The apparent truncation of shorelines by the northeast-trending fault just east of the road suggests the fault is tectonically active with late Pleistocene to Holocene fault displacement. No hot springs have been located along this feature; however, an inactive hot spring mound was located near this structure (fig. A5).

Temperature Profiling of Existing Wells

Recent mineral exploration drilling has produced seven, six-inch diameter open and uncased wells north of the Tipton Ranch and east of Pumpernickel Valley (fig. A6). A thermistor probe and digital thermometer were used to gather temperature versus depth data from these holes. These data are listed in Table A2.

Gravity Survey

The entire study area is included in a regional gravity map of the 1:250,000-scale Winnemucca, Nevada, 1° by 2° quadrangle (Erwin, 1974). This map was useful for examining regional geologic structures, but small-scale (less than 1 km) structures could not be recognized. The regional gravity map was also used in the preparation of a residual gravity map.

In addition to the regional gravity map, data were also purchased for the south half of Pumpernickel Valley. Data for 380 gravity stations were acquired and the approximate location of this data set is shown in Figure A7. The data set consists of the complete Bouguer gravity anomaly and elevation for stations spaced at 1-2 km intervals (0.6-1.2 mi.).

In addition to the purchased data, a gravity survey at the north half of the study area was completed. The area covered by the gravity survey is also shown in

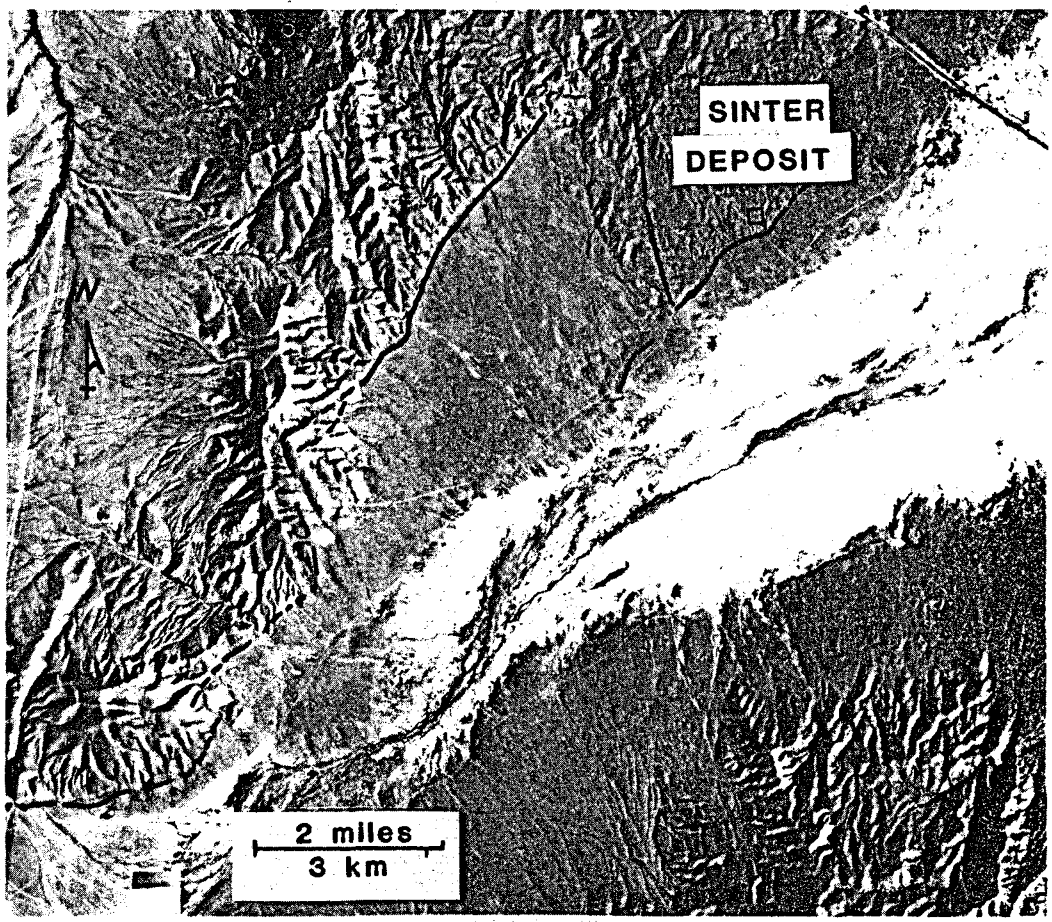


Figure A5. Aerial photograph of southwest side of Edna Mountain showing faults and location of sinter deposit.

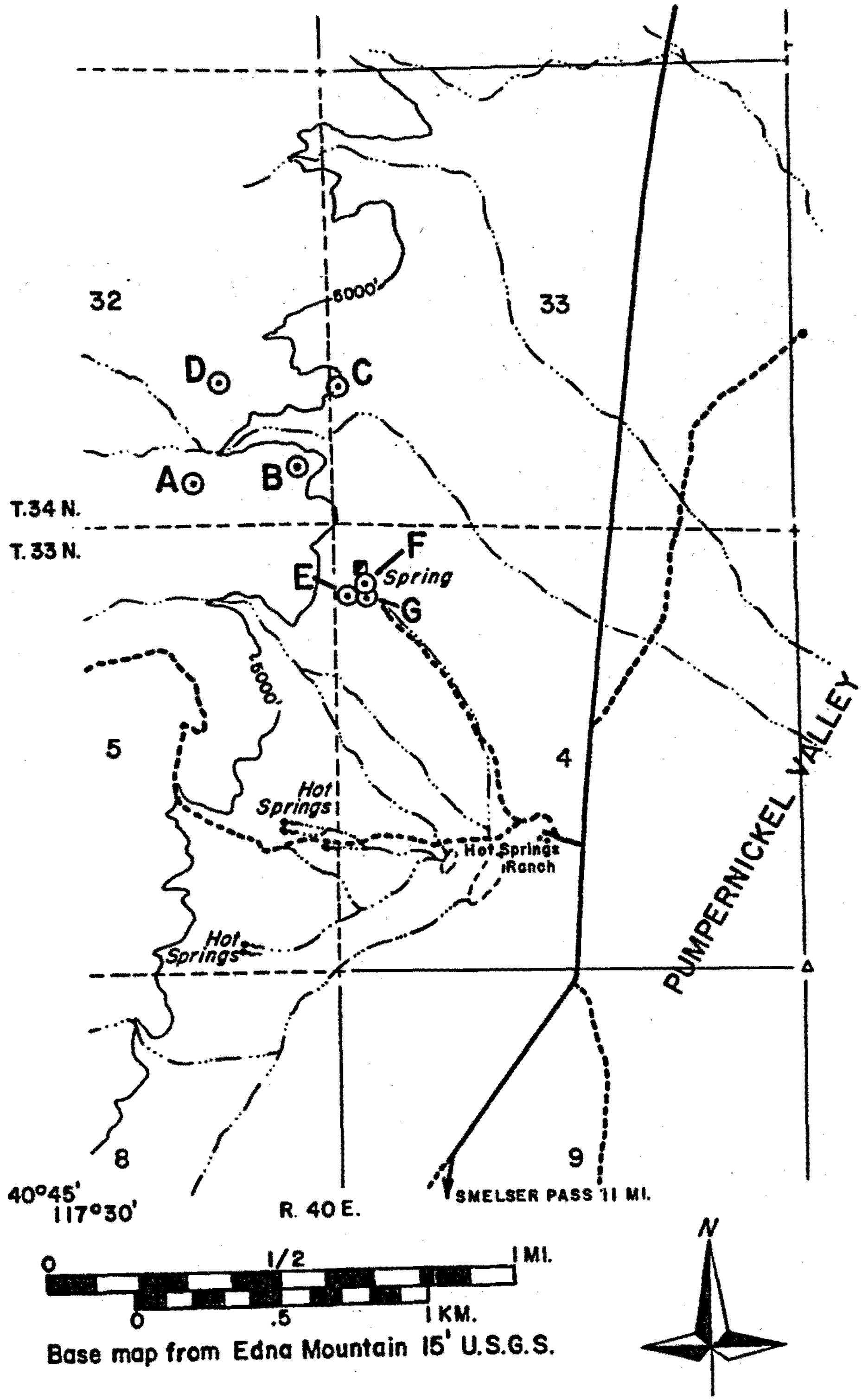


Figure A6. Location of mineral exploration wells in Pumpernickel Valley.

Table A2.

Temperature-Depth Profile Data for
Mineral Exploration Wells East of Pumpernickel Valley
(Locations shown on Fig. A7)

Well A

DEPTH	TEMP°C
100'	12.8
150'	13.0
200'	13.4
250'	16.5
275'	18.2
298'	18.2

Well B

DEPTH	TEMP°C
100'	13.6
150'	19.0
175'	20.2
187'	20.2

Well C

DEPTH	TEMP°C
100'	15.5
125'	15.9
150'	16.2
175'	16.2
195'	17.4

Well D

DEPTH	TEMP°C
25'	14.4
50'	15.3
75'	15.8
100'	17.3
125'	18.2
135'	18.3

Well E

DEPTH	TEMP°C
10'	17.5
10'	18.2
30'	18.7
40'	19.8
50'	27.2
60'	28.8
70'	30.0
80'	31.0
90'	31.9
100'	32.7
110'	33.1
120'	33.5
130'	34.1

Well F

DEPTH	TEMP°C
1'	21.9
20'	43.0

Well G

DEPTH	TEMP°C
10'	31.0
15'	44.6

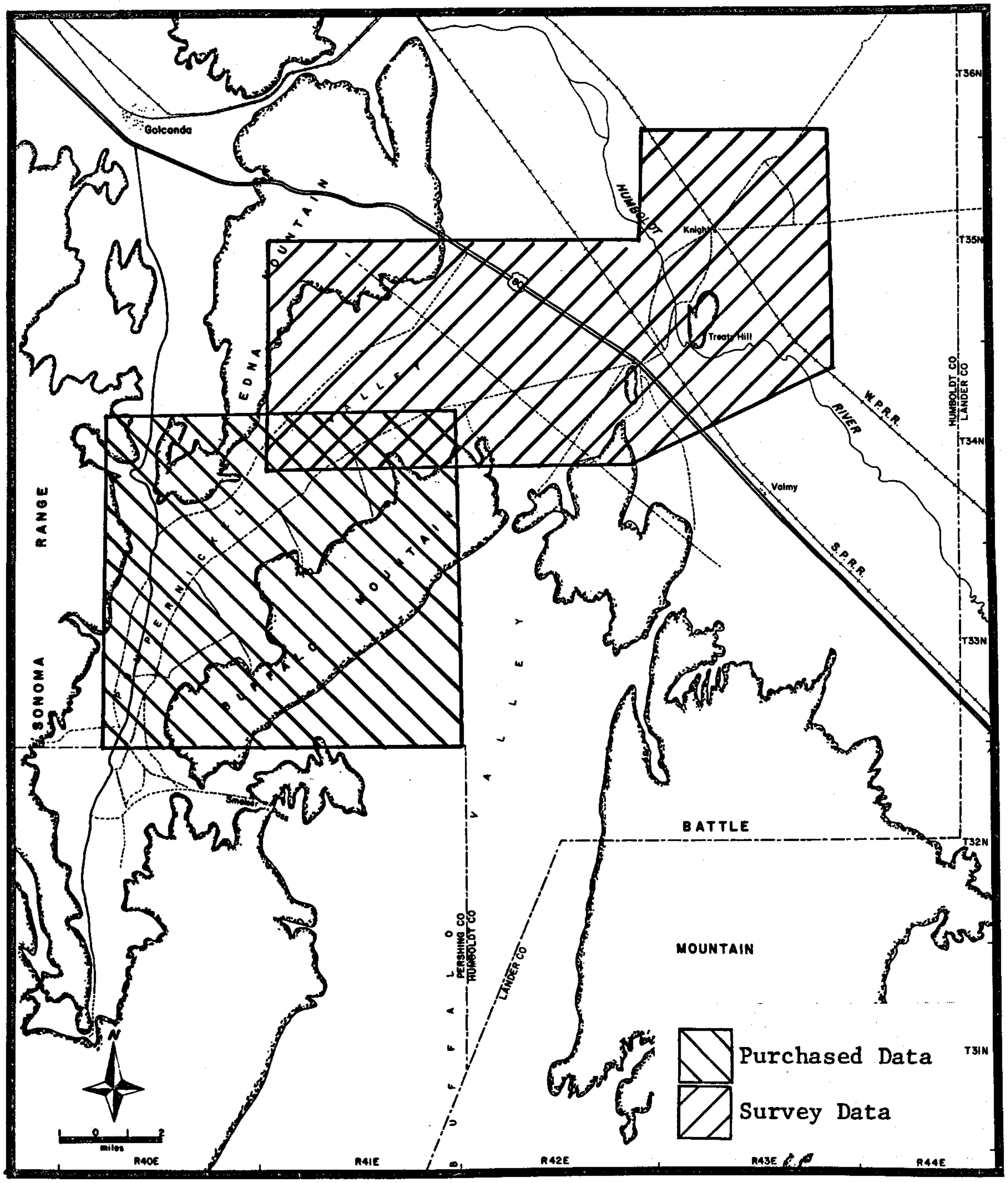


Figure A7. Approximate extent of gravity data sets, Pumpernickel Valley.

Figure A7. Approximately 150 stations, spaced at intervals of 1-2 km were occupied during this survey. The survey was completed in November, 1981; data were obtained with a LaCoste and Romberg gravimeter. The final data set consisted of station elevations, latitude, longitude, and all appropriate gravity observations including terrain corrected complete Bouguer values.

The purchased gravity data were combined with the gravity survey data to construct a complete Bouguer anomaly map of the entire study area. This map was used in the preparation of a residual gravity anomaly map.

The complete Bouguer gravity anomaly map was superimposed with a 40 x 50 matrix and the gravity data were digitized. Another 40 x 50 matrix of the regional gravity data (Irwin, 1974) was prepared for the same area and also digitized. The residual gravity anomaly was obtained by subtracting the regional matrix from the complete Bouguer anomaly matrix. This matrix was then multiplied by -1 to obtain a three-dimensional model that roughly corresponds to the configuration of the surface of basement rocks in Pumpernickel Valley. This is a simple computational filtration technique that is used to resolve some of the small-scale basement structures that would otherwise be obsured by the effects of the regional gravity field.

The residual gravity anomaly map of Pumpernickel Valley is illustrated by computer-generated, three-dimension graphics in Figures A8, A9, A10, and A11. In these diagrams, a sketch map is provided as a reference for the location of the geothermal areas. The reference corner (A) is rotated 90° counter-clockwise for the computer generated figures only. These rotations are necessary to overcome some of the masking effects provided by the topography of the illustrations.

In Figure A8, reference corner (A) is on the left and the viewing angle is to the northwest. The viewing elevation angle is 20° above the grid plane which

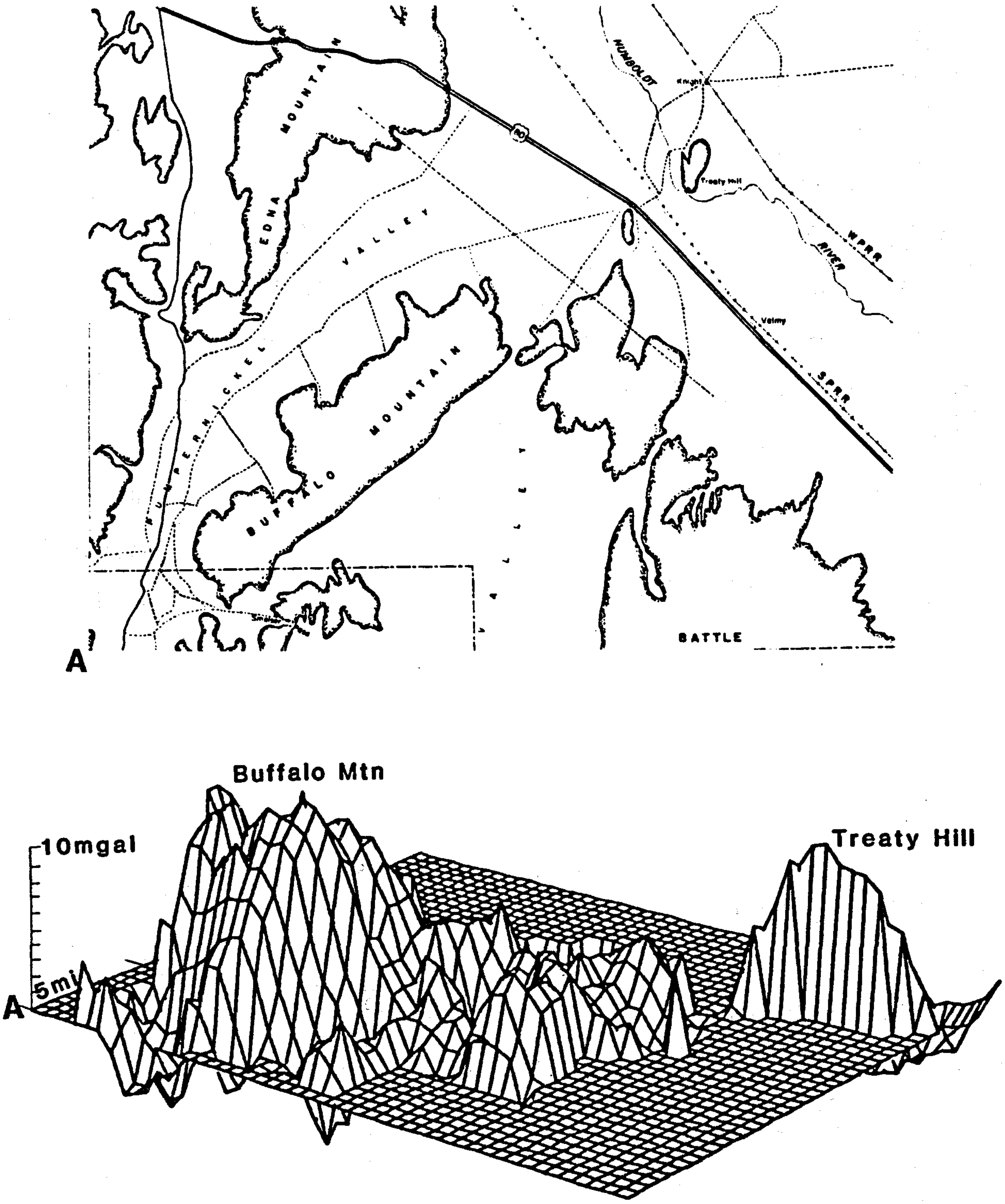


Figure A8. 3-dimension computer generated residual gravity map of Pumpernickel Valley, looking northwest (NCAR plot).

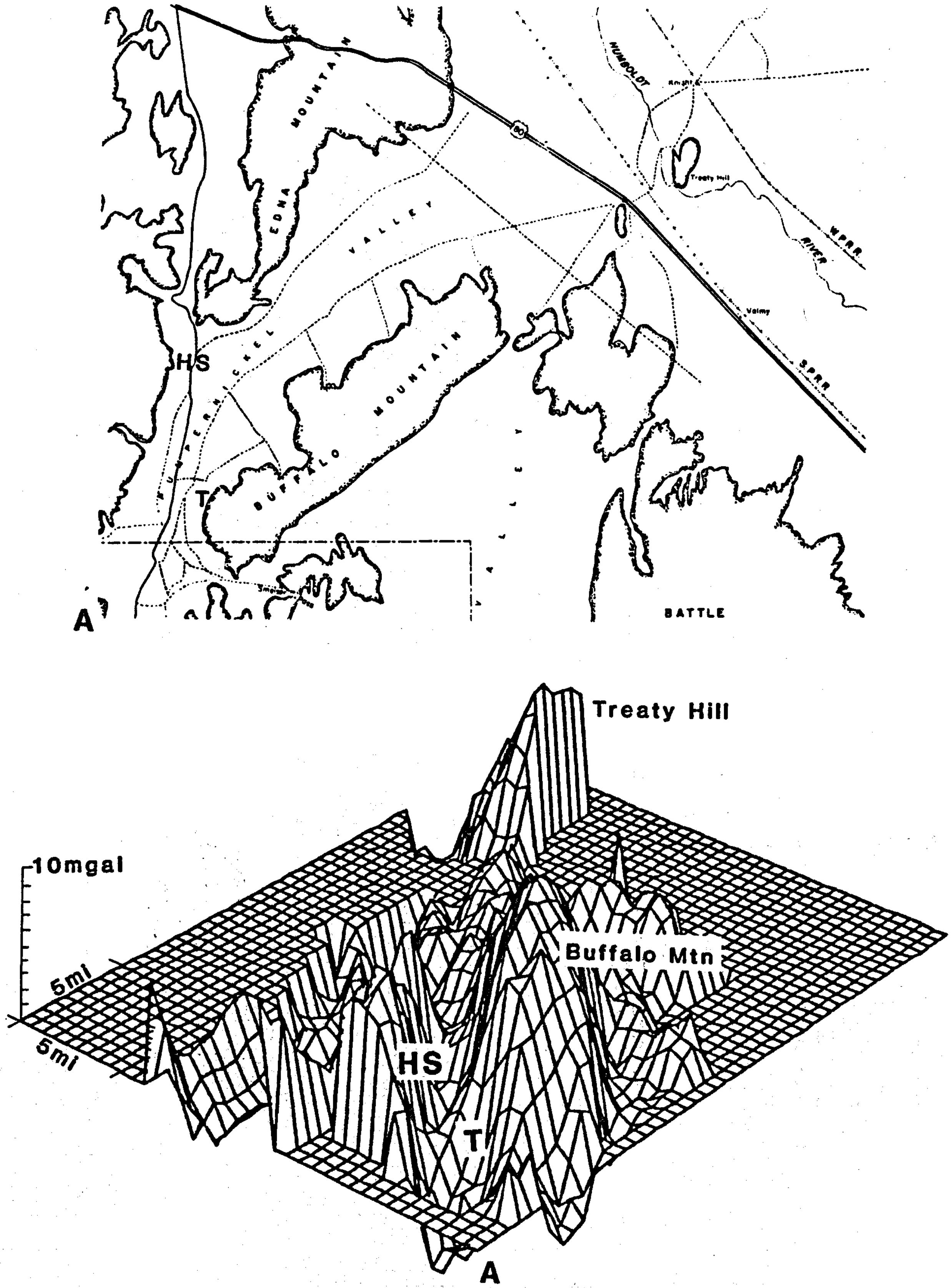


Figure A9. 3-dimension computer generated residual gravity map of Pumpernickel Valley, looking northeast: HS, Hot Springs Ranch; T, Tipton II ranch (NCAR plot).

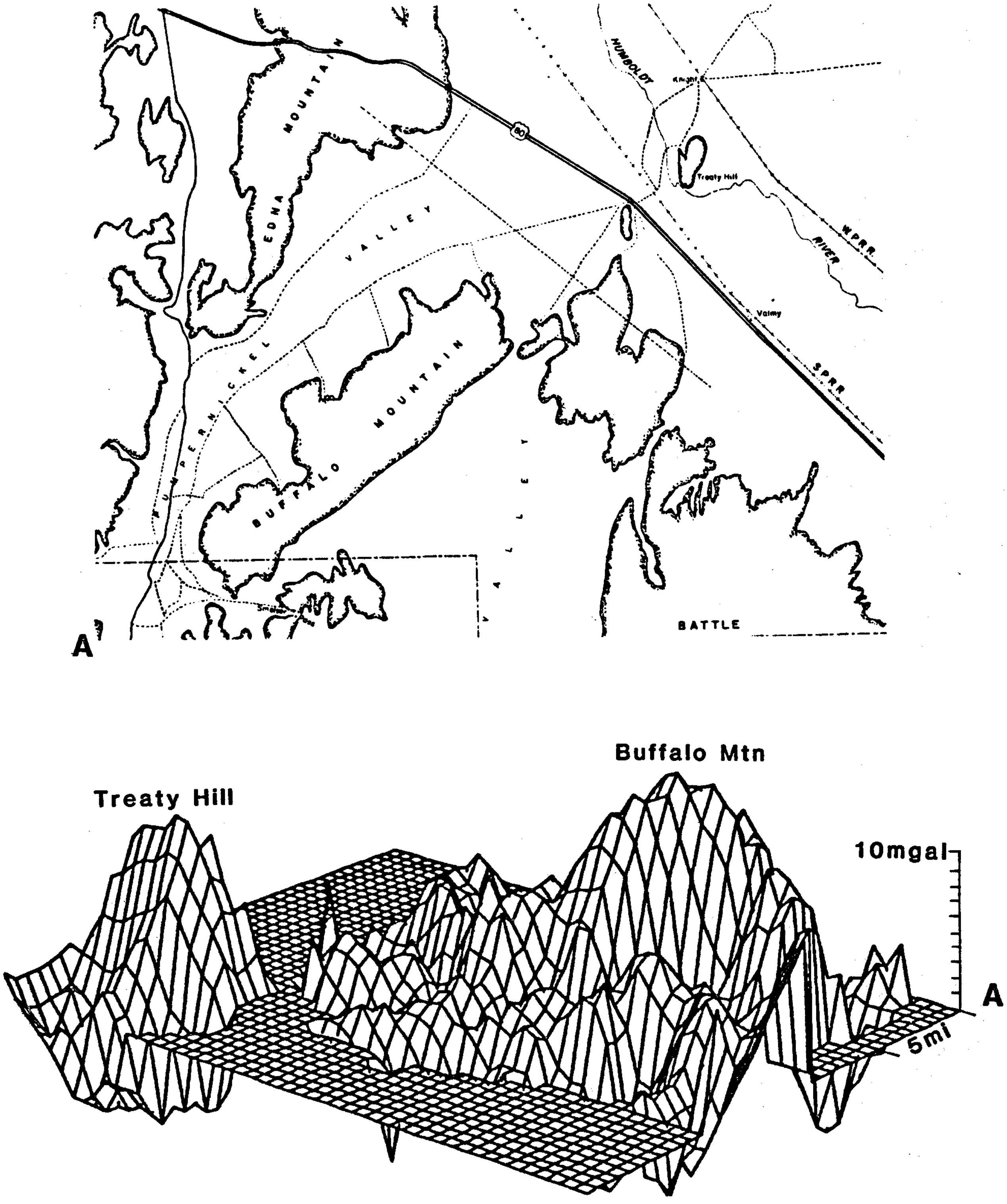


Figure A10. 3-dimension computer generated residual gravity map of Pumpernickel Valley, looking southeast (NCAR plot).

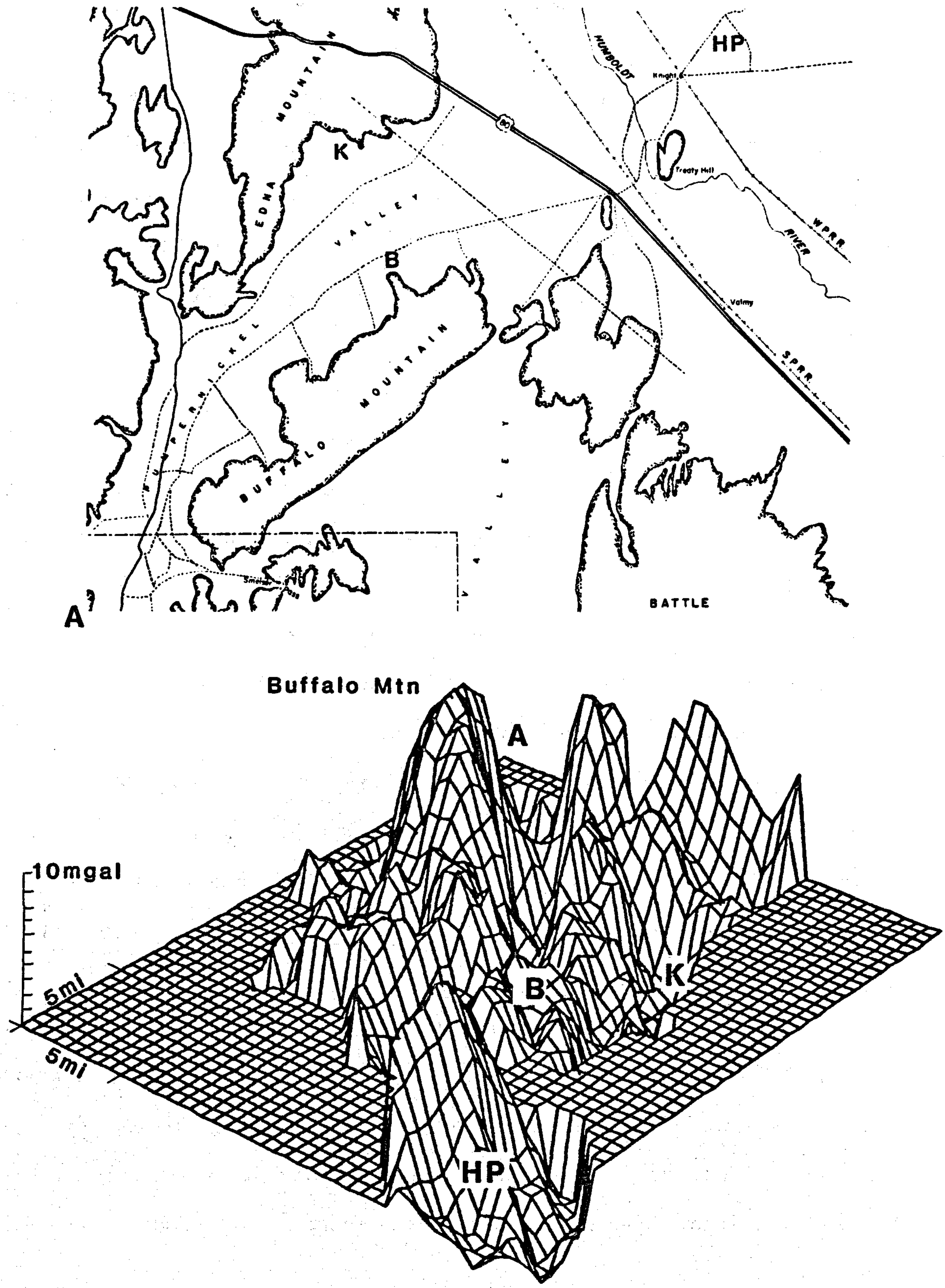


Figure A11. 3-dimension computer generated residual gravity map of Pumpernickel Valley, looking southwest: B, Brooks Spring; HP, Blossom Hot Pot; K, Kemp thermal anomaly (NCAR plot).

represents an area of no data. The two large features are the potential fields associated with Buffalo Mountain, a prominent range with as much as 600 m (2000 ft.) of relief, and Treaty Hill, a small inselberg that rises only 60 m (200 ft.) above the Humboldt River flood plain. The steep gravity gradients located on the east side of Buffalo Mountain correlate with the northeast-trending range-bounding fault.

In Figure A9, the reference corner (A) has been rotated 90° counter-clockwise. The viewing angle is to the northeast and the viewing elevation is 30° above the grid-plane. From this angle, the steep gravity gradients on both sides of Buffalo Mountain are much easier to recognize. The geothermal springs at the Hot Springs Ranch (HS) are also located along steep gravity gradients. These gradients correlate well with fault scarps located along the east side of the Sonoma Range. The warm spring at the Tipton II ranch (T) is also coincident with steep gravity gradients on the south side of Buffalo Mountain.

In Figure A10, the reference corner has been rotated another 90° counter-clockwise. The viewing angle is to the southeast and the viewing elevation is 20° above the grid plane. This view is similar to that in Figure A8 and shows the relative sizes of the potential fields associated with Buffalo Mountain and Treaty Hill.

In Figure A11, the reference corner (A) has again been rotated 90° counter-clockwise. The viewing angle is to the southwest and the viewing elevation is 30° above the horizon. This figure shows that both Kemp (K) and Blossom Hot Pot (HP) are associated with steep gradients in the gravity contours. Brooks Spring (B) is located in a slight depression, and is also associated with moderately steep gradients.

In general, the gravity data show that Pumpernickel Valley is a northeast trending depression that is fault-bounded on the east by the uplifted Buffalo

Mountain and on the west by Edna Mountain and the Sonoma Range (fig. A3). In Figure A11, the slight gravity high located between B and K, appears to be a buried fault-bounded graben. The faults on either side of this graben may be conduits for the thermal fluids at Brooks Spring and Kemp.

The gravity survey data were used to estimate a maximum depth-to-basement of approximately 400 m (1300 ft.), located in the southern end of Pumpernickel Valley, 8 km (5 mi.) east of the Hot Springs Ranch. The calculation is based on a formula developed by Thompson and Sandberg (1958) for determination of thickness of alluvial material. The formula is:

T = A/0.013S where:

T = thickness (in feet)

A = difference (in mgals) between the regional and local gravity anomaly

S = difference in specific gravity between the bedrock and alluvial material (a value of .5 was used)

.013 = constant

Soil Mercury Survey

Approximately 130 soil samples were collected at 1.6 km (1 mi.) intervals throughout the Pumpernickel Valley study area. Sample sites and associated values for Pumpernickel Valley are shown in Figure A12. Mercury values ranged from 0 to 76 ppb (parts per billion), with an estimated background value of 20 ppb.

Figure A12 indicates that above-background soil-mercury values are closely associated with the Tipton Ranch (1) and the Blossum Hot Pot (5) geothermal areas. Although no soil sample was collected at Kemp (4), the diagram shows a small area with abovebackground values is located approximately 2 km (1.2 mi.) to the northwest. Anomalous mercury values were also obtained from soil samples

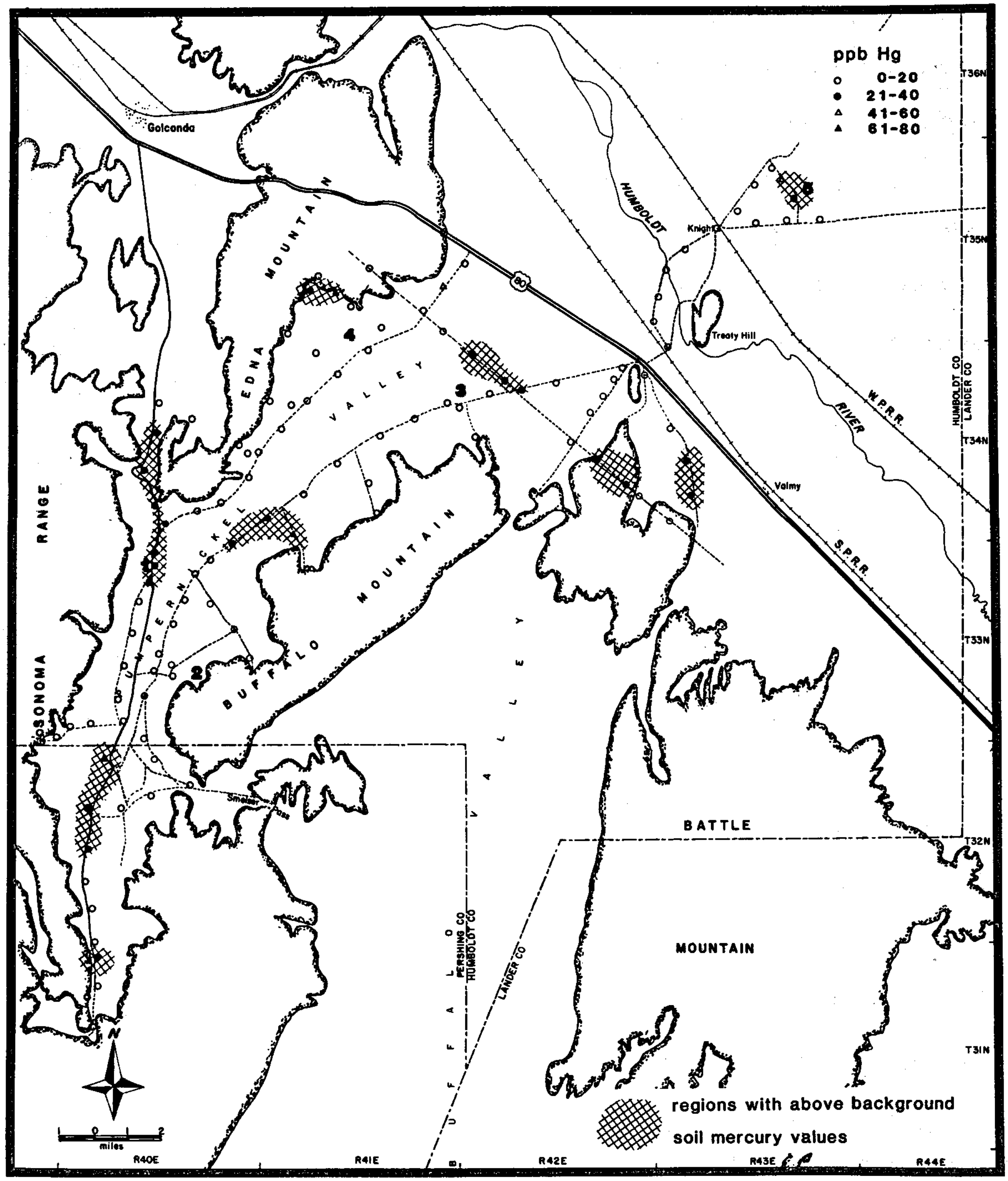


Figure A12. Soil mercury sample locations and values, Pumpernickel Valley. Known geothermal areas: 1 - Hot Springs Range; 2 - Tipton II warm spring; 3 - Brooks Spring; 4 - Kemp; and 5 - Blossom Hot Pot.

obtained 2 km to the northeast and 3 km to the southeast of Brooks Spring (3). Soil sampled in the immediate vicinity of this site had only background values. There were no anomalous soil-mercury values associated with the Tipton II warm spring (2).

The data also indicate many regions with above background soil-mercury values that are not associated with any known surface or subsurface geothermal activity. These areas are not correlated with mercury mining areas. The regions may represent depositional areas for detrital mercury derived from zones of hydrothermal alteration in the Sonoma Range as well as Buffalo Mountain.

Two-Meter Depth Temperature Probe Survey

Approximately 110 temperature probe stations were established along existing roads throughout the study area during October and November, 1981. The drilled holes were backfilled around the PVC encased probes and allowed to equilibrate for a minimum of 24 hours. Drilled material ranged from dry pebbly silt in the alluvial fans to water saturated clays on the playas. Temperature measurements on control probes in conjunction with measurements on station probes allowed accurate annual wave temperature corrections.

Figure A13 shows probe locations, by number, and also delineates those areas where relatively higher temperatures were recorded. Data for the Pumpernickel Valley survey, listed in Table A3, include probe number, elevation, and appropriate corrections. Thermal anomalies can be depicted only after a reasonable estimate of background temperatures have been established. Previous studies (Flynn, in Trexler and other, 1981) have shown that even small amounts of interstitial water can significantly affect the results of the survey. In Pumpernickel Valley, probe sites located on the relatively dry alluvial fans generally

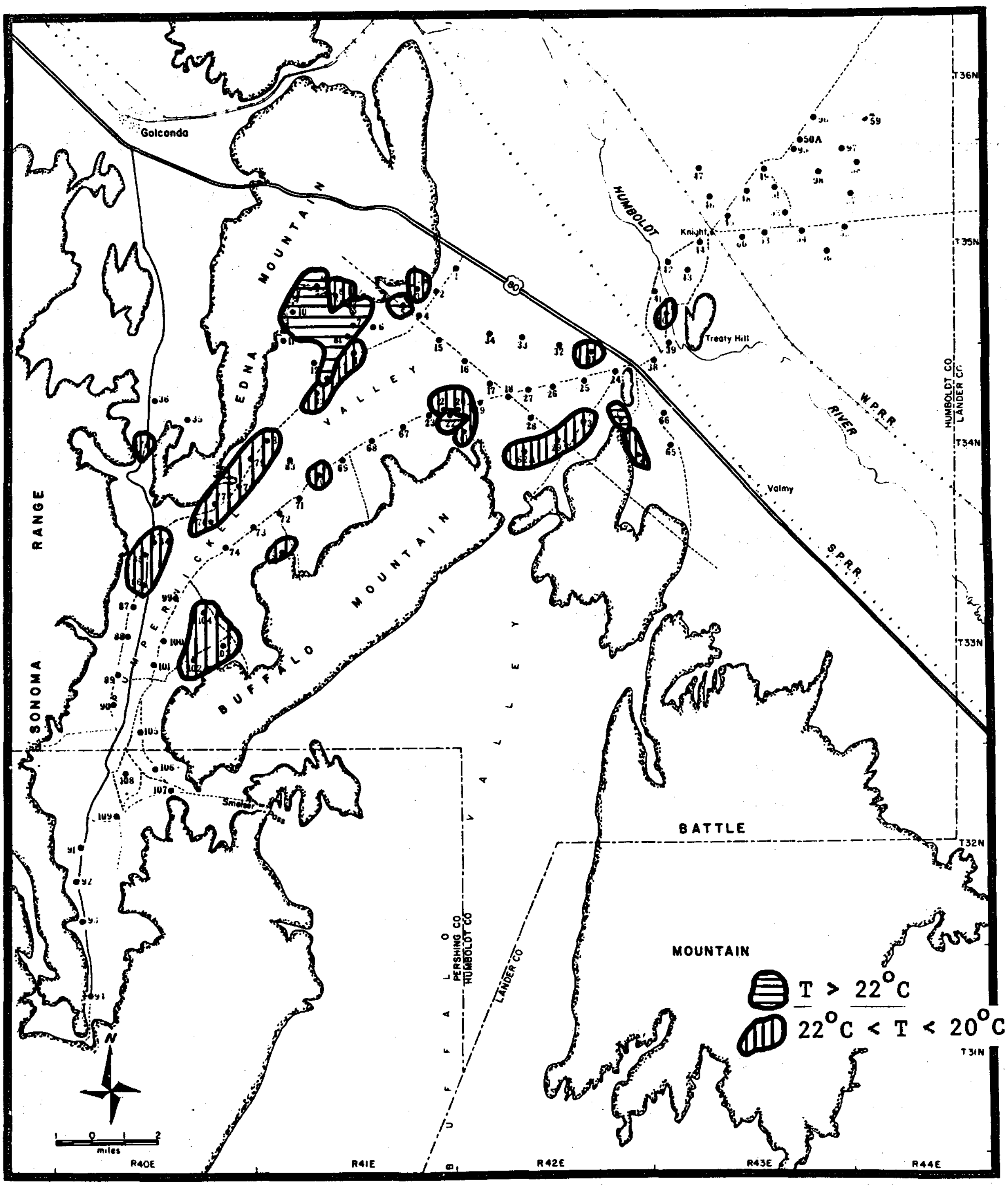


Figure A13. Locations of two-meter temperature probes in Pumpernickel Valley, showing areas of relatively higher temperatures.

PVT-1 4405

PVT-12 4620

TABLE A3

TWO-METER TEMPERATURE PROBE

PUMPERNICKEL VALLEY

Probe	Final Reading	Date	Annual Wave Correction	Temp.Corrected for effects of Annual Wave	Elevation/ Elevation Temperature Correction	Corrected Temperature
PVT-2	19.0	10 Oct	±0.0	19.0	4407/	-
PVT-3	21.0	10 Oct	±0.0	21.0	4520/+02	21.2
PVT-4	19.9	10 Oct	±0.0	19.9	4440/	-
PVT-5	22.0	10 Oct	±0.0	22.0	4520/+0.2	22.2
PVT-6	19.6	10 Oct	±0.0	19.6	4440/	-
PVT-7	23.4	10 Oct	±0.0	23.4	4620/+0.4	23.8
PVT-8	19.3	10 Oct	±0.0	19.3	4800/+0.7	20.0
PVT-9	21.8	10 Oct	±0.0	21.8	5000/+1.1	22.9
PVT-10	21.3	10 OCT	±0.0	21.3	5040/+1.2	22.5
PVT-11	23.0	10 Oct	±0.0	23.0	4920/+1.0	24.0
PVT-13	22.3	12 Oct	+0.4	22.7	4490/+0.2	22.9
PVT-14	20.8	12 Oct	+0.4	21.2	4480/+0.1	21.3
PVT-15	15.3	19 Oct	+1.4	16.7	4418/	-
PVT-16	15.3	19 Oct	+1.4	16.7	4414/	-
PVT-17	16.0	19 Oct	+1.4	17.4	4418/	-
PVT-18	17.1	19 Oct	+1.4	18.5	4442/	-
PVT-19	17.2	19 Oct	+1.4	18.6	4444/	-
PVT-20	20.0	19 Oct	+1.4	21.4	4444/	-
PVT-21	18.7	19 Oct	+1.4	20.1	4443/	-
PVT-22	23.8	22 Oct	+1.8	25.6	4460/+0.1	25.7
PVT-23	18.3	19 Oct	+1.4	19.7	4440/	-
PVT-24	17.3	19 Oct	+1.4	18.7	4450/	-
PVT-25	18.4	19 Oct	+1.4	19.8	4455/+0.1	19.9
PVT-26	17.5	19 Oct	+1.4	18.9	4460/+0.1	19.0
PVT-27	17.8	19 Oct	+1.4	19.2	4465/+0.1	19.3
PVT-28	17.6	19 Oct	+1.4	19.0	4550/	-
PVT-29	19.0	19 Oct	+1.4	20.4	4620/+0.4	20.8
PVT-30	18.8	19 Oct	+1.4	20.2	4574/+0.3	20.5
PVT-31	20.5	22 Oct	+1.8	22.3	4416/	-
PVT-32	15.3	22 Oct	+1.8	17.1	4406/	-

TABLE A3, cont.
TWO-METER TEMPERATURE PROBE
PUMPERNICKEL VALLEY

Probe	Final Reading	Date	Annual Wave Correction	Temp.Corrected for effects of Annual Wave	Elevation/ Elevation Temperature Correction	Corrected Temperature
PVT-33	14.9	22 Oct	+1.8	16.7	4408/	-
PVT-34	14.4	22 Oct	+1.8	16.2	4413/	-
PVT-35	15.4	25 Oct	+2.1	17.5	4995/+1.1	18.6
PVT-36	15.9	25 Oct	+2.1	18.0	5080/+1.3	19.3
PVT-37	17.7	25 Oct	+2.1	19.8	5118/+1.3	21.1
PVT-38	14.8	22 Oct	+1.8	16.6	4425/	-
PVT-39	14.2	22 Oct	+1.8	16.0	4418/	-
PVT-40	18.7	22 Oct	+1.8	20.5	4415/	-
PVT-41	14.6	22 Oct	+1.8	16.4	4408/	-
PVT-42	16.2	22 Oct	+1.8	18.0	4415/	-
PVT-43	16.9	22 Oct	+1.8	18.7	4411/	-
PVT-44	15.3	22 Oct	+1.8	17.1	4405/	-
PVT-45	17.6	22 Oct	+1.8	19.4	4432/	-
PVT-46	15.7	22 Oct	+1.8	17.5	4425/	-
PVT-47	15.2	22 Oct	+1.8	17.0	4419/	-
PVT-48	16.3	23 Oct	+2.0	18.3	4432/	-
PVT-49	16.3	7 Nov	+3.5	19.8	4410/	-
PVT-50A	14.5	8 Nov	+3.6	18.1	4452/	-
PVT-51	28.9	23 Oct	+2.0	30.9	4415/*	-
PVT-52	16.5	23 Oct	+2.0	18.5	4425/	-
PVT-53	15.5	23 Oct	+2.0	17.5	4452	-
PVT-54	16.0	23 Oct	+2.0	18.0	4435/	-
PVT-55	15.5	23 Oct	+2.0	17.5	4462/+0.1	17.6
PVT-56	17.0	23 Oct	+2.0	19.0	4438	-
PVT-57	15.0	23 Oct	+2.0	17.0	4452/	-
PVT-58	16.0	23 Oct	+2.0	18.0	4465/+0.1	18.1

*This may be erroneous - in group of 3

TABLE A3, cont.

TWO-METER TEMPERATURE PROBE

PUMPERNICKEL VALLEY

Probe	Final Reading	Date	Annual Wave Correction	Temp.Corrected for effects of Annual Wave	Elevation/ Elevation Temperature Correction	Corrected Temperature
PVT-59	16.0	23 Oct	+2.0	18.0	4482/+0.1	18.1
PVT-60	16.6	25 Oct	+2.1	18.7	4425/	-
PVT-61	19.1	25 Oct	+2.1	21.2	4615 +0.4	21.6
PVT-62A	17.2	9 Nov	+3.5	20.7	4660/+0.5	21.2
PVT-63	19.7	23 Oct	+2.0	21.7	4540/+0.3	22.0
PVT-64	19.5	23 Oct	+2.0	21.5	4508/+0.2	21.7
PVT-65	15.8	23 Oct	+2.0	17.8	4480/+0.1	17.9
PVT-66	16.1	23 Oct	+2.0	18.1	4450/	-
PVT-67	17.0	25 Oct	+2.1	19.1	4475/+0.1	19.2
PVT-68	17.0	25 Oct	+2.1	19.1	4480/+0.1	19.2
PVT-69	16.0	25 Oct	+2.1	18.1	4529/+0.2	18.3
PVT-70	18.0	25 Oct	+2.1	20.1	4545/+0.3	20.4
PVT-71	17.0	25 Oct	+2.1	19.1	4535/+0.2	19.3
PVT-72	17.5	25 Oct	+2.1	19.6	4565/+0.3	19.9
PVT-73	17.5	25 Oct	+2.1	19.6	4574/+0.3	19.9
PVT-74	16.0	25 Oct	+2.1	18.1	4575/+0.3	18.4
PVT-75	17.8	25 Oct	+2.1	19.9	4840/+0.8	20.7
PVT-76	15.8	26 Oct	+2.2	18.0	4570/+0.3	18.3
PVT-77	17.8	26 Oct	+2.2	20.0	4570/+0.3	20.3
PVT-78	17.4	26 Oct	+2.2	19.6	4550/+0.3	19.9
PVT-79	19.2	26 Oct	+2.2	21.4	4620/+0.4	21.8
PVT-80	17.6	26 Oct	+2.2	19.8	4550/+0.3	20.1
PVT-81	22.4	5 Nov	+3.2	25.6	4592/+0.4	26.0
PVT-82	18.5	5 Nov	+3.2	21.7	4480/+0.1	21.8
PVT83	14.7	5 Nov	+3.2	17.9	4510/+0.2	18.1
PVT-84	16.9	5 Nov	+3.2	20.1	4680/+0.5	20.6
PVT-85	17.1	5 Nov	+3.2	20.3	4675/+0.5	20.8
PVT-86	16.8	5 Nov	+3.2	20.0	4650/+0.5	20.5
PVT-87	15.8	5 Nov	+3.2	19.0	4685/+0.5	19.5
PVT-88	15.6	5 Nov	+3.2	18.8	4705/+0.6	19.4

TABLE A3, cont.

TWO-METER TEMPERATURE PROBE

PUMPERNICKEL VALLEY

Probe	Final Reading	Date	Annual Wave Correction	Temp.Corrected for effects of Annual Wave	Elevation/ Elevation Temperature Correction	Corrected Temperature
PVT-89	15.4	5 Nov	+3.2	18.6	4726/+0.6	19.2
PVT-90	15.2	5 Nov	+3.2	18.4	4775/+0.7	19.1
PVT-91	14.2	7 Nov	+3.5	17.7	5065/+1.3	19.0
PVT-92	13.1	7 Nov	+3.5	16.6	5160/+1.4	18.0
PVT-93	12.8	7 Nov	+3.5	16.3	5290/+1.7	18.0
PVT-94	12.8	7 Nov	+3.5	16.3	5850/+2.7	19.0
PVT-95	15.5	8 Nov	+3.6	19.1	4455/+0.1	19.2
PVT-96	13.8	8 Nov	+3.6	17.4	4453/+0.1	17.5
PVT-97	14.5	8 Nov	+3.6	18.1	4460/+0.1	18.2
PVT-98	13.9	8 Nov	+3.6	17.5	4465/+0.1	17.6
PVT-99	15.6	9 Nov	+3.5	19.1	4635/+0.4	19.5
PVT-100	14.7	9 Nov	+3.5	18.2	4660/+0.5	18.7
PVT-101	15.4	9 Nov	+3.5	18.9	4684/+0.5	19.4
PVT-102	15.5	9 Nov	+3.5	19.0	4920/+1.0	20.0
PVT-103	15.9	9 Nov	+3.5	19.4	4960/+1.0	20.4
PVT-104	16.6	9 Nov	+3.5	20.1	4720/+0.6	20.7
PVT-105	14.9	9 Nov	+3.5	18.4	4820/+0.8	19.2
PVT-106	13.9	9 Nov	+3.5	17.4	4945/+1.0	18.4
PVT-107	14.4	9 Nov	+3.5	17.9	5050/+1.2	19.1
PVT-108	13.9	9 Nov	+3.5	17.4	4890/+0.9	18.3
PVT-109	14.2	9 Nov	+3.5	17.7	4960/+1.0	18.7

had higher recorded temperatures than probes located in the wetter valley and playa areas.

Thermal anomalies were mapped adjacent to the Tipton Ranch Hot Springs (#3, fig. A13) and Brooks Hot Springs (#1, fig. A13). These anomalies are probably the result of lateral flow of thermal fluids through the porous alluvial gravels. No anomaly was recorded at Blossom Hot Pot (#4, fig. A13), probably due to the large volumes of water in and on the playa sediments. Heat loss through evaporation at the surface can conceal subtle temperature differences that arise from subsurface heat sources. The large thermal anomaly located east of Edna Mountain is not associated with any known thermal fluids. Corrected temperatures as high as 26°C were measured in this area.

Fluid Chemistry

Bulk Fluid Composition

Fourteen fluid samples collected in the study area include non-thermal surface waters and groundwaters, and thermal groundwaters. Seasonal variations in chemical composition are not considered because all the samples were collected in a period of less than twenty days. Table A4 is a compilation of bulk chemical, physical, and sample location data for the fluids. Analytical laboratory pH values are given. Silica concentrations were derived from undiluted but acidified samples.

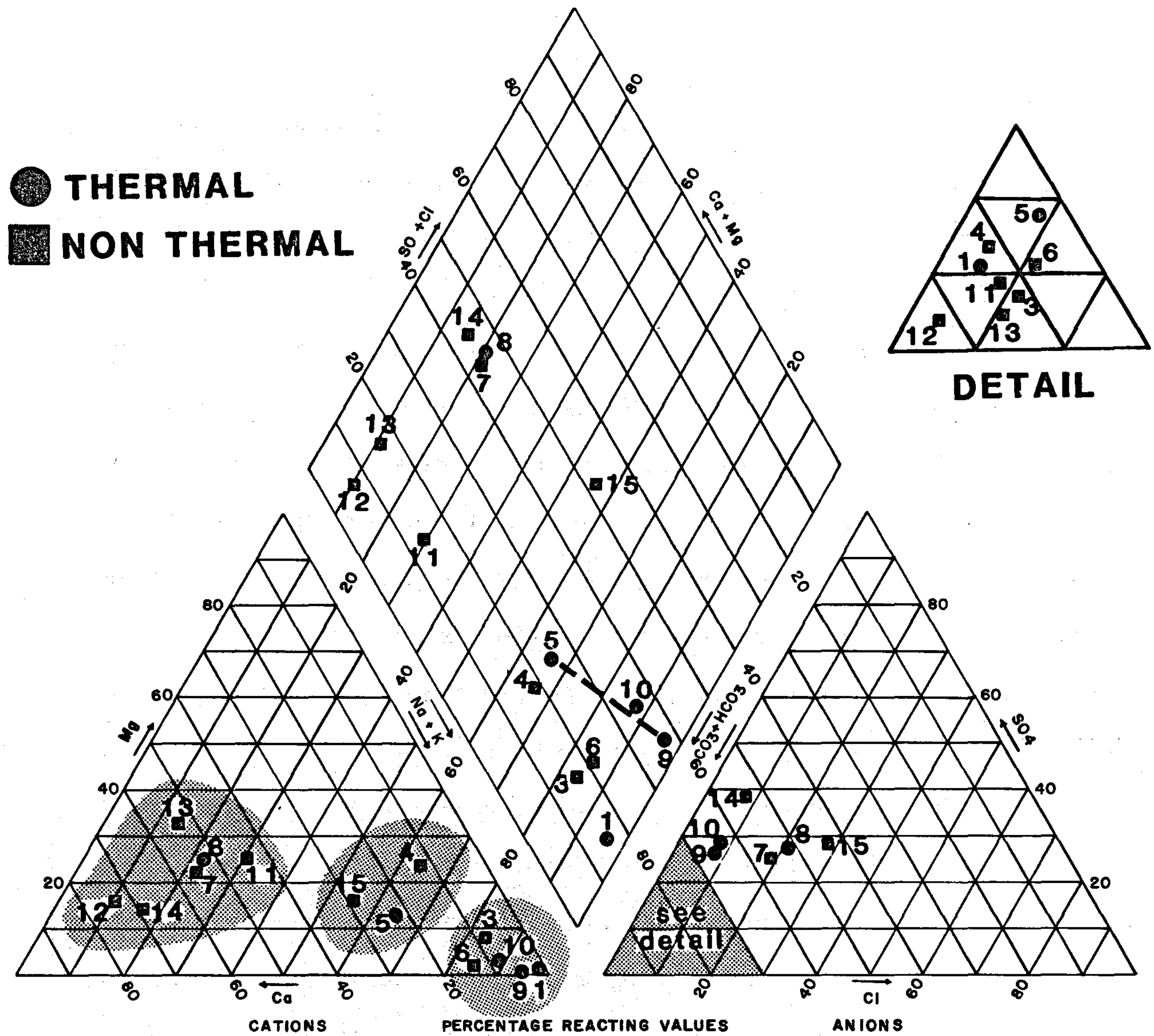
A comparison of bulk chemical character of the fluids is made by converting concentrations to relative percents of equivalents and plotting the values on a tri-linear variation diagram (Piper, 1944). Figure A14 depicts the results of applying this process to Pumpernickel Valley waters. Cation compositions fall into three distinct groups: a high sodium - low calcium and magnesium cluster, a second set relatively enriched in both calcium and magnesium, and a third set intermediate

PUMPERNICKEL VALLEY

Sample Designation	Site Name	Location	TEMP °C	pH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Al^{+++}	Fe	Li^{+}	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	F^{-}	$NO_3^{=}$	B	SiO_2	Comments
PVFC-1	Blossom Hot Pot	SW/4 NW/4 SW/4 Sec 11 T35N R43E	58.0	7.5	4.0	5.3	660.0	31.0	<0.1	0.14	0.80	0.	1510.7	162.	63.7	9.40	8.0	1.80	41.	Taken from hottest orafice, flow of a few l/s
PVFC-3	Humboldt River at Ellison Ranch	SW/4 SW/4 SW/4 Sec 19 T35N R43E	13.3	8.2	22.0	12.4	270.0	15.4	<0.1	0.25	0.29	27.3	628.0	74.	37.9	3.80	7.1	0.90	31.	River level low and flowing slowly
PVFC-4	Stonehouse Spring	SW/4 SE/4 SW/4 Sec 1 T34N R41E	17.2	7.2	33.0	11.0	104.0	14.9	<0.1	0.06	0.31	0.	358.6	44.	15.9	2.60	4.4	0.50	31.	Flow of a few l/s, very clean
PVFC-5	Brooks Spring	NE/4 NW/4 NE/4 Sec 13 T34N R41E	35.3	7.2	48.0	16.2	160.0	17.0	<0.1	0.07	0.35	0.	498.9	86.	32.9	1.70	12.4	0.93	40.	Issues from a section of tufa covered by alluvium, flow ≅ 3 l/s
PVFC-6	Sulfur Spring	SE/4 SE/4 NW/4 Sec 34 T 35N R41E	18.3	7.7	22.5	3.3	180.0	15.0	<0.1	0.12	0.55	0.	462.6	52.	37.9	3.80	4.4	0.93	63.	Flow is from pipe in ground into a stock tank w/algae growths, flow ≈ 0.3 l/s
PVFC-7	Buffalo Mountain Cold Spring	NW/4 NE/4 NW/4 Sec 27 T33N R40E	15.0	7.7	30.0	13.2	22.0	2.4	<0.1	0.11	<0.01	0.	155.1	56.	31.9	0.33	1.8	0.12	34.	Small but steady flow
PVFC-8	Buffalo Mountain Warm Spring	SE/4 SE/4 SW/4 Sec 22 T33N R40E	26.9	7.7	47.0	13.0	20.0	1.9	<0.1	0.12	<0.01	0.	138.6	54.	31.2	0.26	0.9	0.06	35.	Large flow ≈ 130 GPM
PVFC-9	Hot Springs West of Tipton Hot Well	SE/4 NE/4 SE/4 Sec 5 T33N R40E	80.3	8.0	11.5	0.9	230.0	25.0	<0.1	0.17	1.30	0.	434.0	144.	36.1	9.80	2.7	1.70	140.	Moderate flow, thermophyllic algae samples collected 3 m downstream from orafice
PVFC-10	Hot Springs ¼ Mile South of PVFC-9	SW/4 SW/4 SE/4 Sec 5 T33N R40E	49.2	6.7	20.0	2.8	210.0	24.0	<0.1	0.24	1.20	0.	421.0	144.	35.1	10.00	8.0	1.40	98.	Moderate flow, periodic gas bubbling, orafice in altered alluvium
PVFC-11	Spanish Basin Cold Spring	SE/4 SE/4 SW/4 Sec 22 T33N R39E	2.2	7.6	32.5	11.2	23.0	4.0	<0.1	0.08	<0.01	0.	166.3	14.	10.6	0.40	19.5	0.08	23.	Small but steady flow, issues from regolith on fractured granite
PVFC-12	Stream, North End of Tobin Range	NW/4,NW/4,NE/4 Sec 32 T32N R40E	10.0	8.0	56.0	7.9	9.2	0.8	<0.1	0.18	0.01	0.	202.7	8.	6.0	0.41	8.0	0.04	11.	Rapid large volume flow, > 2 l/s
PVFC-13	Summit Spring	NW/4 SW/4 NE/4 Sec 18 T32N R41E	13.9	7.8	39.5	15.4	13.6	0.9	<0.1	0.14	<0.01	0.	185.4	12.	13.1	0.13	8.0	0.06	10.	Near pond which it feeds
PVFC-14	Kent Spring	SW/4 SW/4 NE/4 Sec 18 T32N R40E	≈10	7.7	108.0	15.2	26.0	2.7	<0.1	0.11	<0.01	0.	247.7	136.	24.1	0.19	16.0	0.04	21.	Issues from gravels in a deeply incised drainage, small flow
PVFC-15	Irrigation Well Sec 20 T33N R40E	SE/4 NW/4 SW/4	23.5	7.7	45.5	16.0	100.0	7.1	<0.1	0.85	0.16	0.	223.5	99.	80.4	2.20	5.3	0.20	33.	Collected from non-operational irrigation well

TABLE A4.

Bulk chemical, physical and sampling location data, Pumpernickel Valley.



- 1. BLOSSOM HOT POT
- 3. HUMBOLDT RIVER AT ELLISON
- 4. STONEHOUSE SPRING
- 5. BROOKS HOT SPRING
- 6. SULFUR SPRING
- 7. TIPTON 2 COLD SPRING
- 8. TIPTON 2 WARM SPRING
- 9. HOT SPRING WEST OF TIPTON I
- 10. HOT SPRING SOUTHWEST OF TIPTON I
- 11. SPANISH BASIN COLD SPRING
- 12. STREAM NORTH END OF TOBIN RANGE
- 13. SUMMIT SPRING
- 14. KENT SPRING
- 15. TIPTON WARM WELL

Figure A14. Trilinear diagram for fluid samples from Pumpernickel Valley.

between the other types. Two general anion assemblages include a relatively compact group near the carbonate + bicarbonate apex, and a second more sulfate rich group with variable amounts of chloride. These distinctions may be related in part to the sample locations.

Variations in bulk fluid composition with areal distribution are readily observed through the use of modified stiff diagrams plotted on a regional base map (fig. A15). Sodium enriched waters are restricted to areas within the valley while, with one exception, high calcium fluids are from the surrounding mountains. In general, it appears that fluids representing deeper circulation are of the sodium bicarbonate type. Those circulated through surface or near-surface environments are relatively more calcium and magnesium rich, with varying anionic compositions that probably represent near-surface water-rock interaction.

Water collected from the Humboldt River bears a strong similarity in bulk chemistry to the sodium-bicarbonate types discussed above. This situation raises a question as to the origin of this fluid. Either a near-surface phenomenon dictates fluid composition within the valley itself, or fluids of deeper origin are infiltrating the river and controlling its composition. The former hypothesis is supported by observations made during other phases of the study. White puffy ground consisting largely of bicarbonate salts has been observed at several localities. In addition, acid reactive solids were observed to depths as great as 18 m (60 ft.) in 35 m (120 ft.) temperature gradient holes. This suggests that fluids sampled within the valley may bear a chemical signature related to reactions with sodium carbonate or sodium bicarbonate present in the alluvium. Arguments supporting a deeper origin for this fluid composition include: the dominance of this ionic pair in hot fluids from adjacent areas such as Leach Hot Springs and Buffalo Valley Hot Springs, a similar composition for fluids collected from a hot well (3071 ft. deep) adjacent to

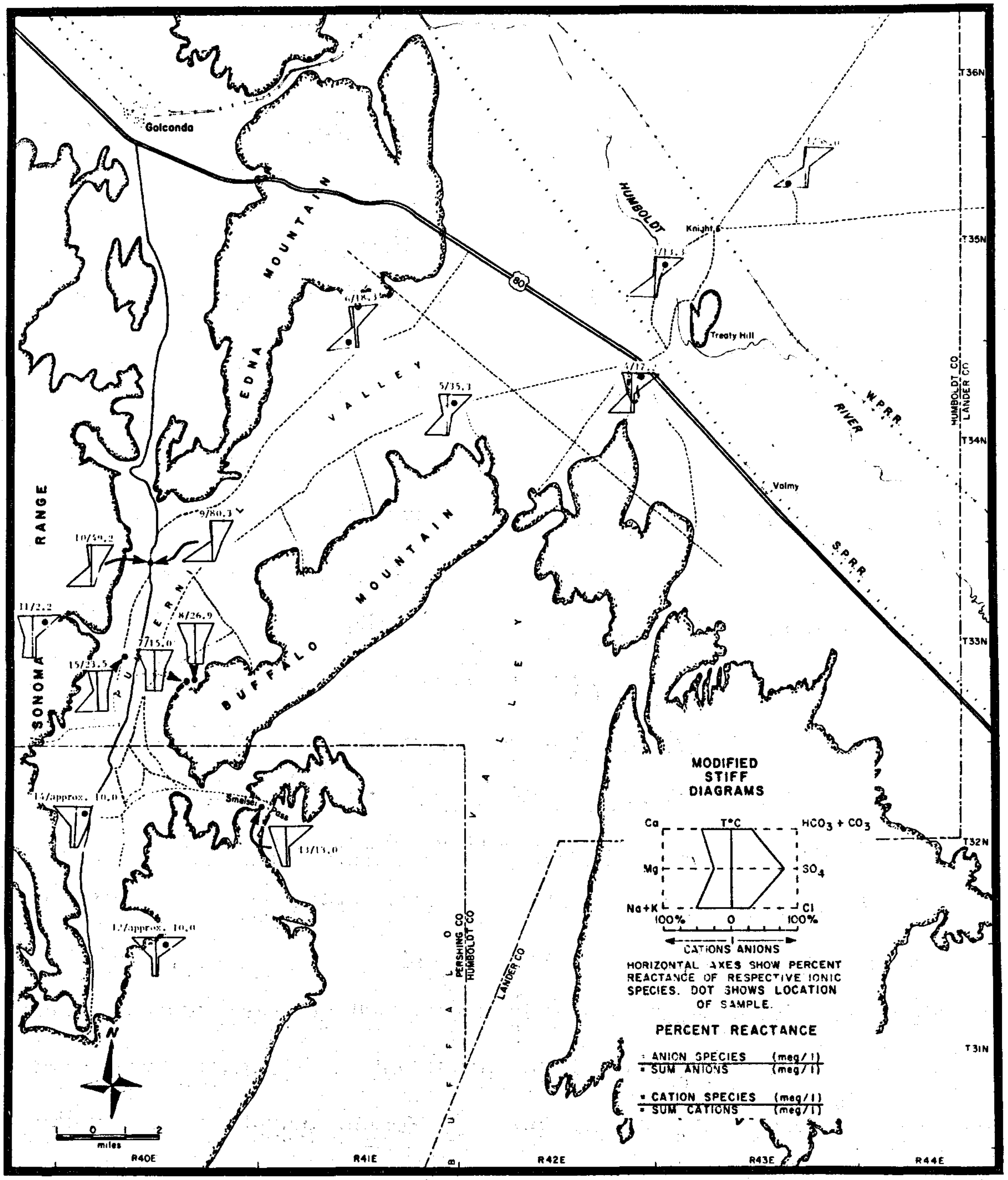


Figure A15. Modified Stiff diagram - Pumpernickel Valley study area.

sample PVFC-9, and stable light isotope composition of fluids such as PVFC-9 and PVFC-3 (see isotope discussion).

The colinear arrangement of points 5, 9, and 10 within all three parts of Figure A14 indicates that one of the fluids may be the result of mixing of the remaining two. Calculations outlined in Piper (1944) supports this hypothesis. A mixture consisting of approximately 70% sample 9 and 30% sample 5 would produce a composition of sample 10.

Stable Light Isotopes

Stable light isotopic compositions provide an additional means of studying the possible relationships among fluids. Isotopic data for Pumpernickel Valley waters are listed in Table A5 and plotted in Figure A16. The line labeled "$\delta D = 8\delta^{18}O + 10$ 0/00" is the worldwide meteoric water line of Craig (1963). Repeat analyses of several samples indicate that the analytical error limits are liberal and that actual precision is generally better than the bars (fig. A16) suggest.

Isotopically the waters fall into two general groups: those which lie within ± 1 0/00 $\delta^{18}O$ of the meteoric water line, and a second set which exhibit oxygen "shifts" greater than 2.5 0/00. Water samples 8, 11, 12, and 13, belonging to the first group, fall essentially along the meteoric line. Each of these fluids contains relatively low concentrations of dissolved constituents and appears to represent shallow near-surface flow, including sample 12, a stream. Sample 14 has a similar deuterium content to samples 8 and 13 but exhibits a notably lighter oxygen value. Its flow path has carried it through alluvium within the valley. The high calcium and sulfate contents and small oxygen shift are probably a result of water-rock interactions following infiltration.

Fluid samples 6 and 7 appear to be very similar in isotopic composition, and possess intermediate deuterium levels, even though the sampling points are

Sample Number	δD 0/00	$\delta^{18}O$/0/00
PVFC 1	-128	-16.3
PVFC 3	-128	-14.5
PVFC 4	-129	-16.5
PVFC 5	-127	-16.5
PVFC 6	-124	-16.0
PVFC 7	-125	-16.1
PVFC 8	-120	-16.0
PVFC 9	-131	-14.8
PVFC 10	-128	-16.3
PVFC 11	-114	-15.6
PVFC 12	-114	-15.3
PVFC 13	-121	-16.0
PVFC 14	-121	-15.5
PVFC 15	-134	-15.5

Table A5. Hydrogen and Oxygen Stable Isotope Analyses for Samples from Pumpernickel Valley.

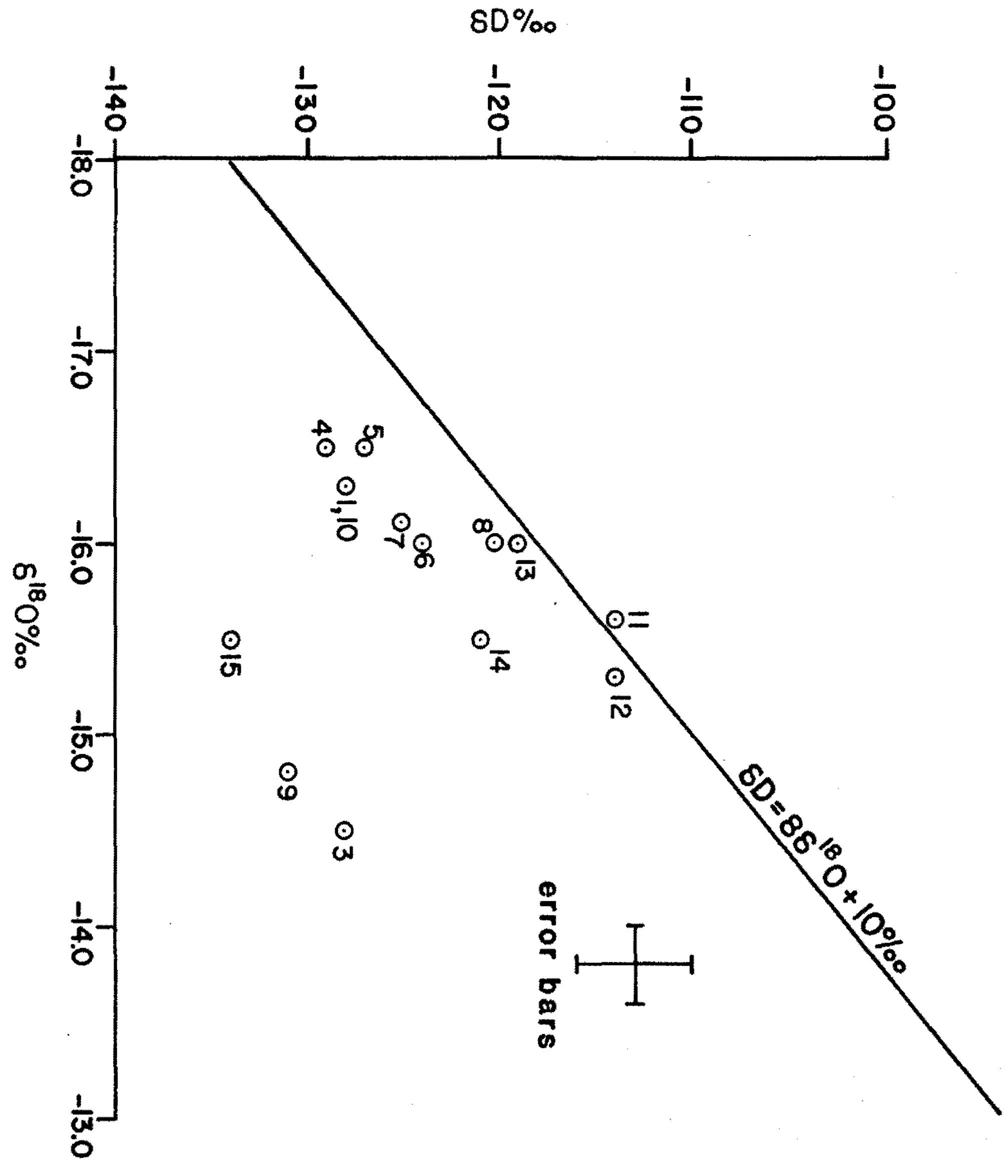


Figure A16. Hydrogen and oxygen stable isotope compositions of water samples from Pumpernickel Valley. Worldwide meteoric water line after Craig (1963).

separated by a distance of 19 km (12 mi.) and are located on opposite sides of the valley (fig. A15). The bulk chemistry of sample 6 resembles that of fluids from deeper circulation while that of sample 7 is virtually identical to fluid 8. Physical proximity of sample sites 7 and 8 also suggests these waters may have a common source. The isotopic similarities of samples 6 and 7 may be due to analytical errors in the deuterium analyses.

More than one-third of the waters sampled have deuterium values in a relatively narrow range between -127 0/00 and -131 0/00. All of these fluids possess bulk chemical compositions characteristic of deep circulation. Two-thirds of this group (samples 1, 4, 5, 10) cluster near the meteoric water line and are, within analytical limits, indistinguishable. Samples 3 and 9 probably share a common recharge area with this group but they exhibit a notable oxygen "shift". Sample 9 is the hottest fluid sampled and its relatively enriched ^{18}O level is probably related to water-rock exchange at depth. Fluid sample 3, however, is taken from the Humboldt River. The large oxygen "shift" of river water suggests that fluid composition at the sampling point is strongly influenced by infiltration of fluid isotopically similar to the hot springs west of the Tipton Ranch.

Sample 15 possesses an isotopic signature that is not readily explained in terms of other waters collected. It exhibits not only a significant oxygen "shift", but is also lighter with respect to deuterium. These characteristics imply that it has been involved in rock-water exchange and recharges from a different region than the other fluids sampled in Pumpernickel Valley.

Chemical Geothermometers

Silica and cation chemical geothermometers have been calculated for selected fluids from the Pumpernickel Valley (table A6). Only waters with

PUMPERNICKEL VALLEY
CHEMICAL GEOTHERMOMETERS

SAMPLE DESIGNATION	MEASURED TEMP. °C	QUARTZ NO STEAM LOSS	QUARTZ MAXIMUM STEAM LOSS	CHALCEDONY	AMORPHOUS SILICA	Na-K-Ca	Na-K-Ca WITH Mg CORRECTION
PVFC-1	58.0	92.9	94.7	62.2	-21.7	178.7	53.2
PVFC-5	35.3	91.7	93.8	61.1	-22.6	174.9	48.9
PVFC-6	18.3	112.9	112.1	83.9	-4.5	170.9	106.6
PVFC-8	26.9	85.9	88.7	54.9	-27.5	20.0	20.0
PVFC-9	80.3	156.9	149.2	132.5	34.8	196.1	171.1
PVFC-10	49.2	136.1	131.8	109.2	15.9	191.9	158.1
PVFC-15	23.5	83.4	86.5	52.2	-29.6	69.7	69.7

TABLE A6.
Chemical geothermometers calculated for selected fluid samples, Pumpernickel Valley.

measured temperatures greater than 20°C, with the exception of sample 6, are listed. The majority of the tabulated values indicate subsurface temperatures less than 100°C. There are many significant differences between estimates calculated from silica polymorphs and those computed using Na, K, and Ca concentrations. Usually, the cation value is notably higher. Applying the magnesium correction of Fournier and Potter (1979) results in a closer agreement between temperature estimates.

Calculated subsurface temperatures exceed 100°C for PVFC-6, PVFC-9, and PVFC-10. Samples 9 and 10 were collected from a system of springs in alluvial materials near the range bounding fault west and southwest of a 936 m (3071 ft.) deep geothermal well on the Tipton Ranch. Calculated subsurface temperatures for PVFC-9 range from 35°C to 60°C greater than temperatures measured at depth in the well. This suggests that a hotter, but as yet unlocated reservoir, may feed the fault controlled system.

Temperatures calculated for PVFC-6 using both silica and magnesium corrected cation equations show good agreement (table A6). The measured temperature is only 18°C and the collection site does not have any indications of geothermal activity. Despite these conditions, the chemical indications of geothermal temperatures are not unrealistic. The sample is collected from a location approximately one kilometer from the Kemp area where drilling conducted during this study has detected a previously unknown resource. Temperatures of 70°C were recorded in the Kemp drill hole. Fluids at Sulfur Spring issue along a possible fault scarp that appears to be part of the same structural trend that controls the thermal fluids in the Kemp area.

Discussion

Examination of the bulk chemical and isotopic data raises several questions that cannot be answered with available data. For example, fluid samples 7 and 8 issue from a thin cover of alluvial materials on opposite sides of a small topographic high. Sample 8 flows at approximately 130 GPM and has a measured temperature of 26.9°C while sample 7 flows only a very small fraction of that volume and with a temperature of 15°C. The bulk chemical composition of the two fluids are virtually identical and it seems reasonable to assume that sample 7 may result from conductive cooling of sample 8. Isotopic data, however, suggest that these two waters have different origins. Additional chemical sampling and more precise stable light isotope analyses, may resolve this dilemma.

The compositional variations of fluid chemistry for Pumpernickel Valley may be the result of near-surface mixing of many different cold water types with a single thermal fluid of uniform composition. An accurate analysis of this primary thermal fluid might be obtained by sampling fluids at the bottom of the deep geothermal well at the Tipton Ranch.

Isotope analyses show some similarities among thermal fluids. Non-thermal fluids are generally isotopically heavier than thermal fluids and plot near the worldwide meteoric line (Craig, 1963). The Humboldt River waters exhibit the greatest ^{18}O shift and these data are difficult to justify in terms of known isotopic processes.

Temperature Gradient Drilling

35 Meter Depth Temperature Gradient Holes

The locations of the five shallow-depth temperature gradient holes in Pumpernickel Valley are shown in Figure A17. These holes were allowed to

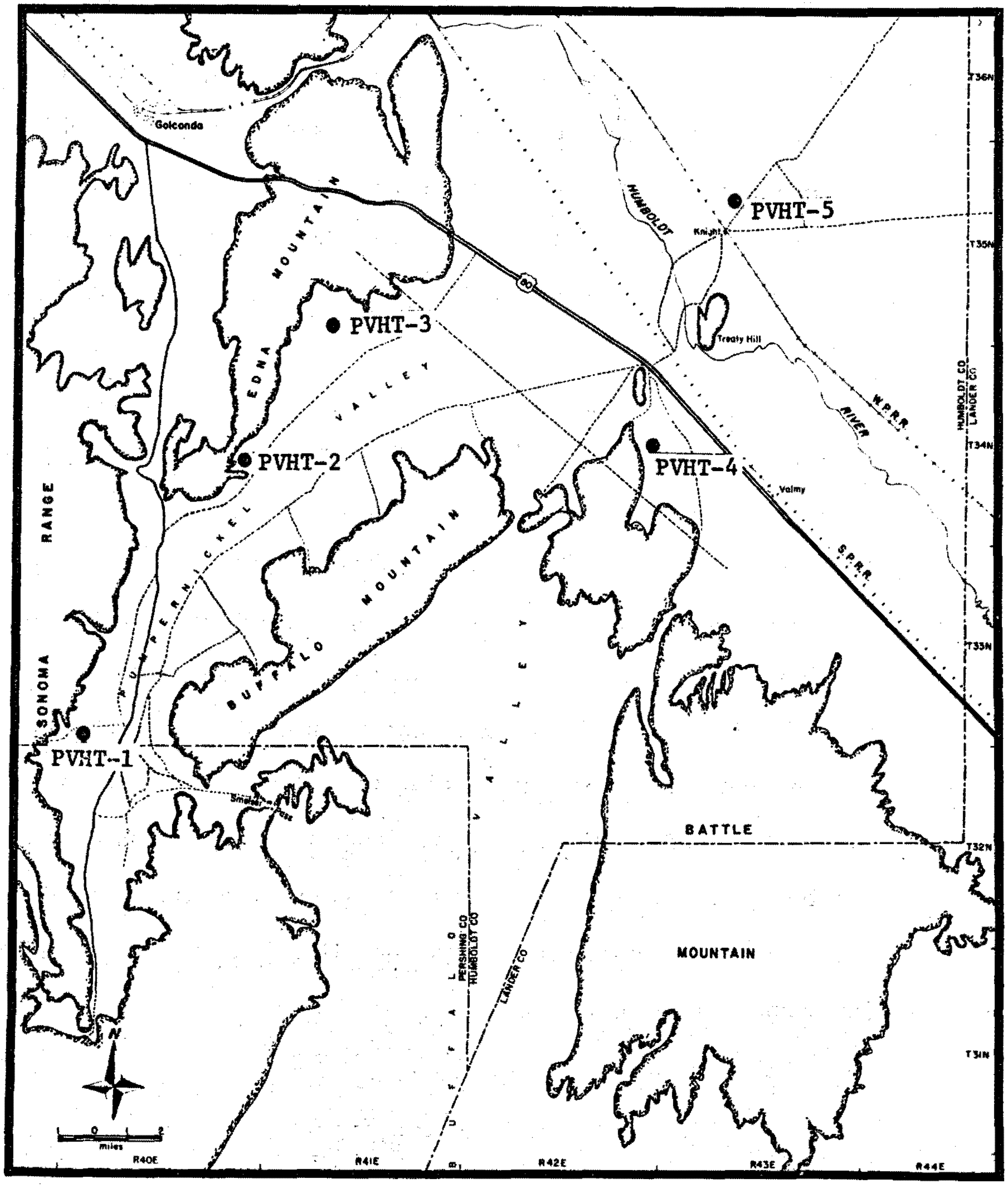


Figure A17. Location of temperature gradient holes in Pumpernickel Valley.

equilibrate for three to four weeks before the temperature gradient was measured. During this time, lithologic logs of all the drill holes were completed and are illustrated in Figures A18 through A22. Most of the drill chips in the Pumpernickel Valley holes are alluvial gravels, silts, sand, and clay. A thick sequence of lacustrine clay was penetrated in holes PVHT 4 and 5, and the basaltic bedrock was encountered in PVHT 5.

Temperature-depth profiles are illustrated in Figures A23 and A24. Temperature gradients were calculated for the bottom 10 m (30 ft.) of each hole and are listed in Table A7.

Temperature gradients in Pumpernickel Valley range from 25°C/km to 600°C/km. Temperature-depth profiles for PVHT-1, 2, and 4 do not indicate the presence of a near-surface heat source. The unusually large temperature gradient (600°C/km) at PVHT-3 (fig. A21) is significant because there are no surface expressions of thermal fluids at or near the drill site. A temperature of 26°C was measured at this site which is located at the Kemp benchmark, during the 2-m depth temperature probe survey. The temperature gradient measured at drill site PVHT-5 may reflect the influence of Blossom Hot Pot, which is located approximately 3 km (2 mi.) to the east.

PVHT-1

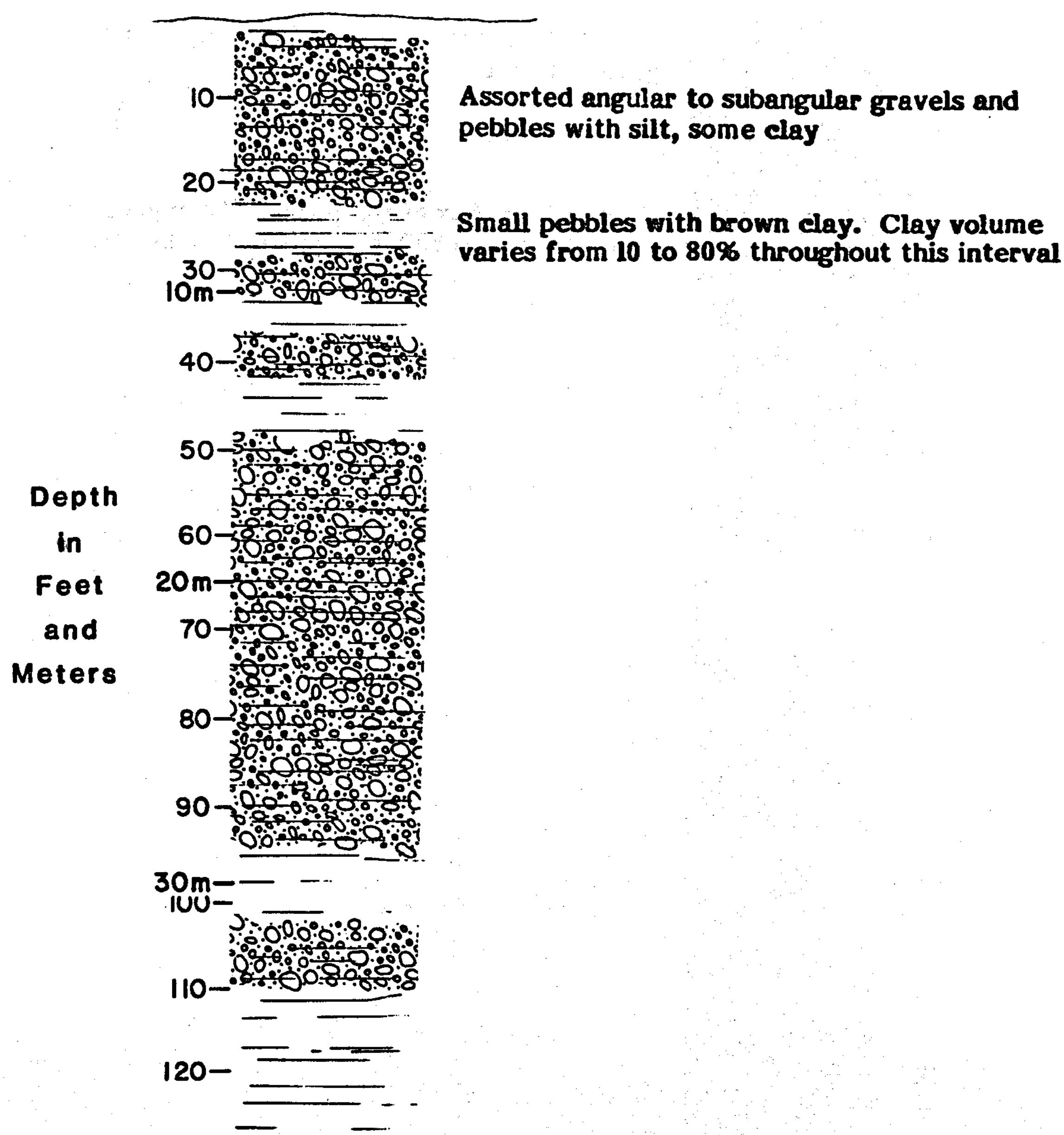


Figure A18. Lithologic log of PVHT-1 in Pumpernickel Valley.

PVHT-2

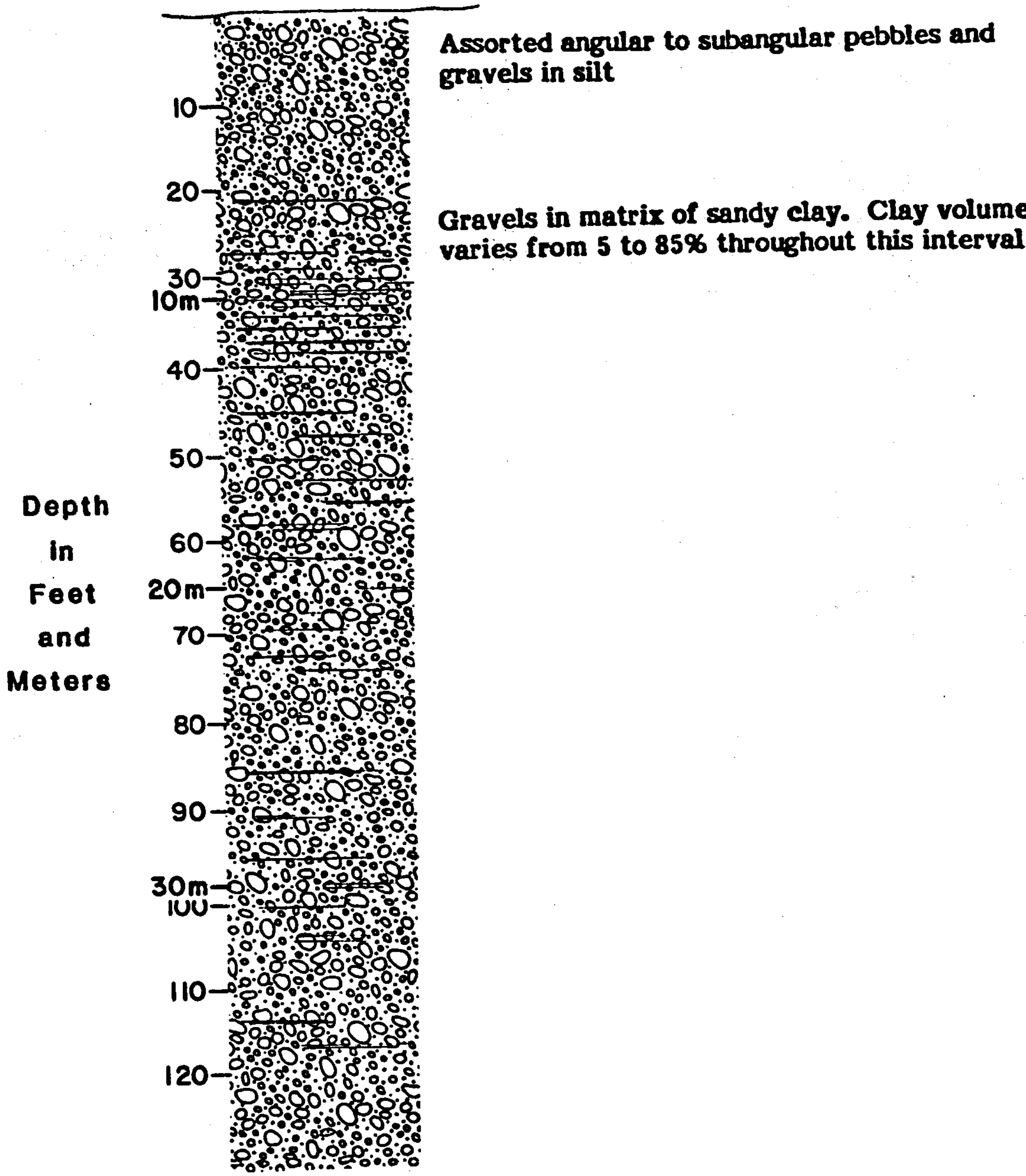


Figure A19. Lithologic log of PVHT-2 in Pumpernickel Valley.

PVHT-3

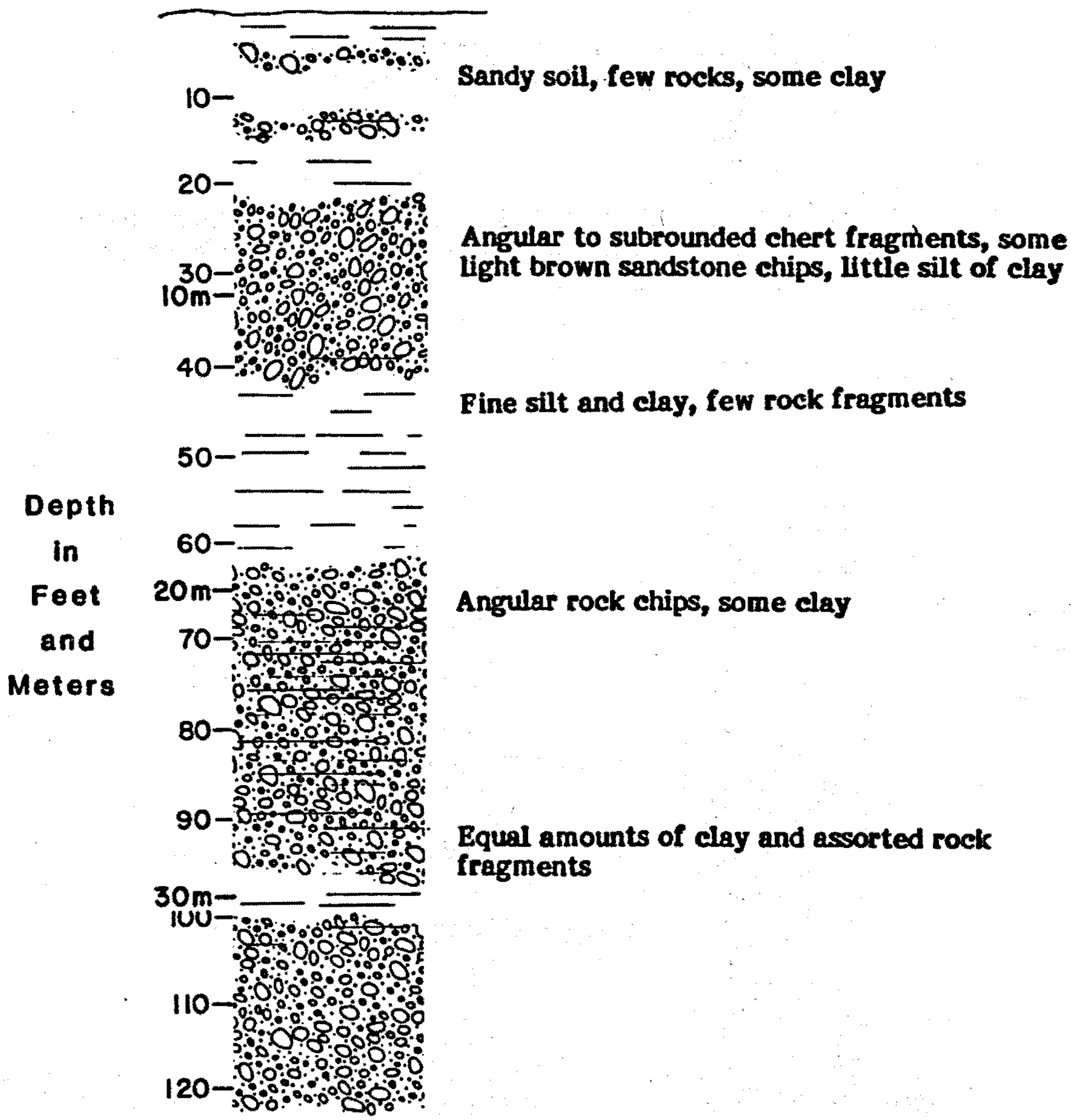


Figure A20. Litologic log of PVHT-3 in Pumpernickel Valley.

PVHT-4

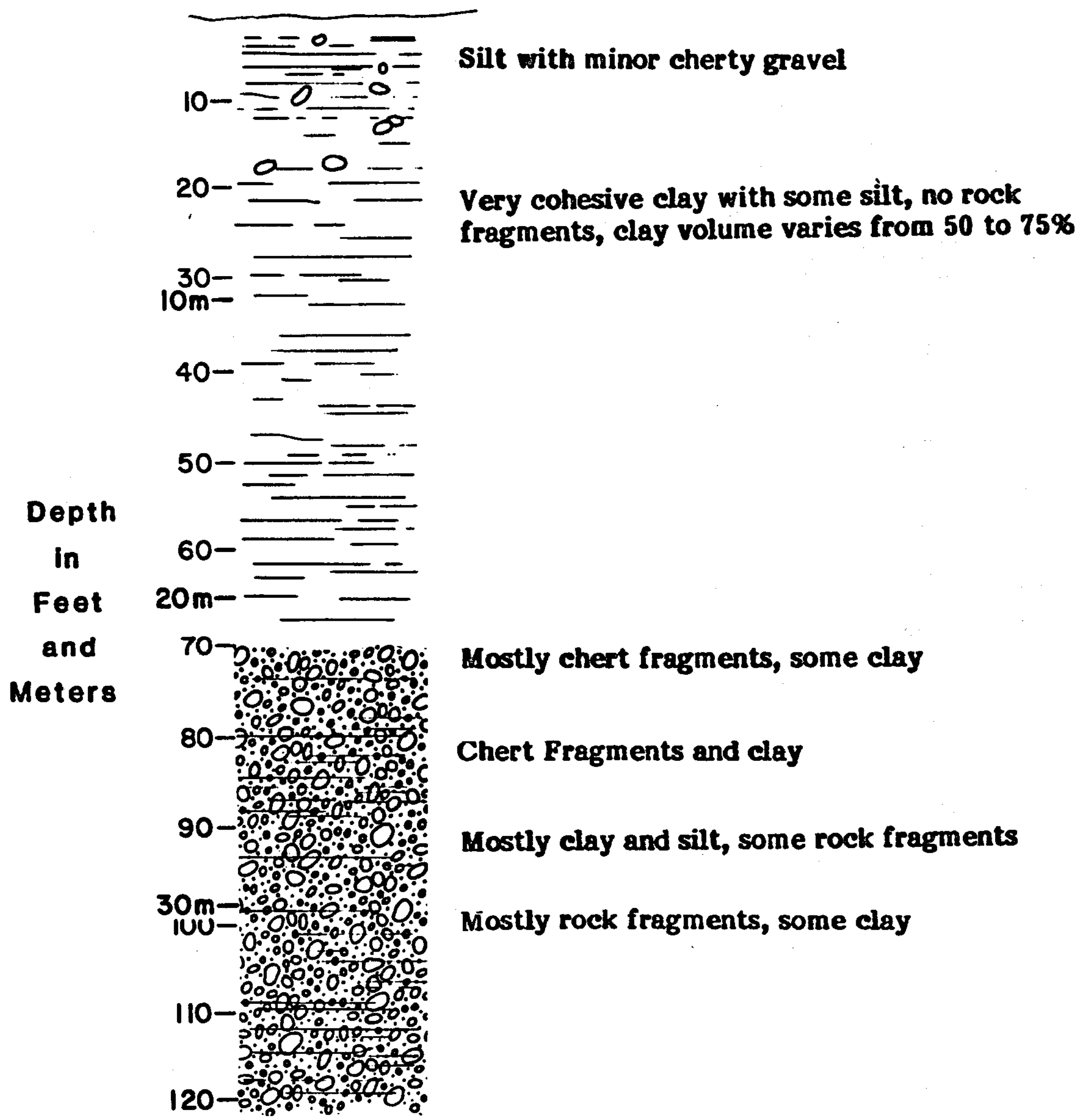


Figure A21. Lithologic log of PVHT-4 in Pumpernickel Valley.

PVHT-5

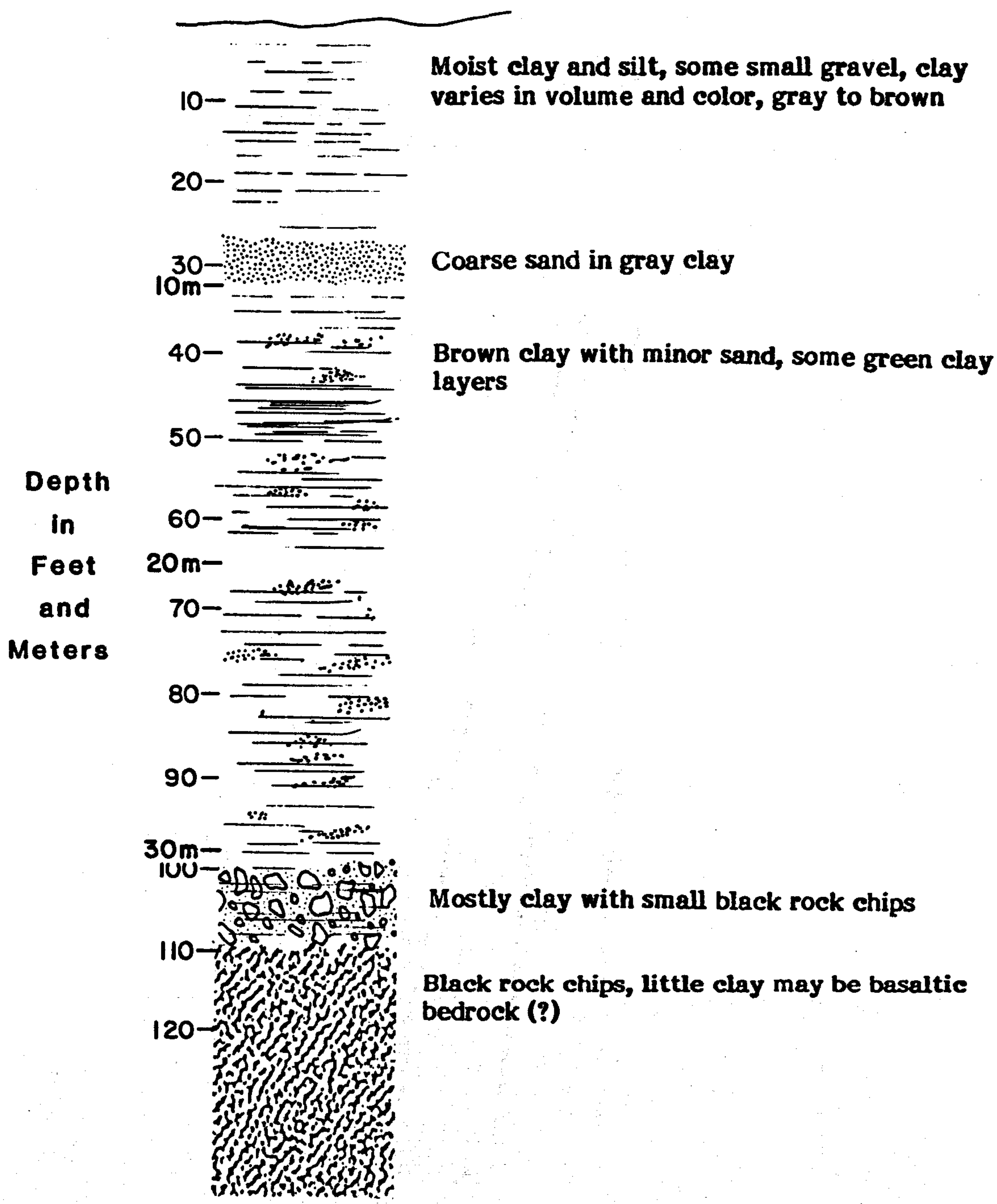


Figure A22. Lithologic log of PVHT-5 in Pumpernickel Valley.

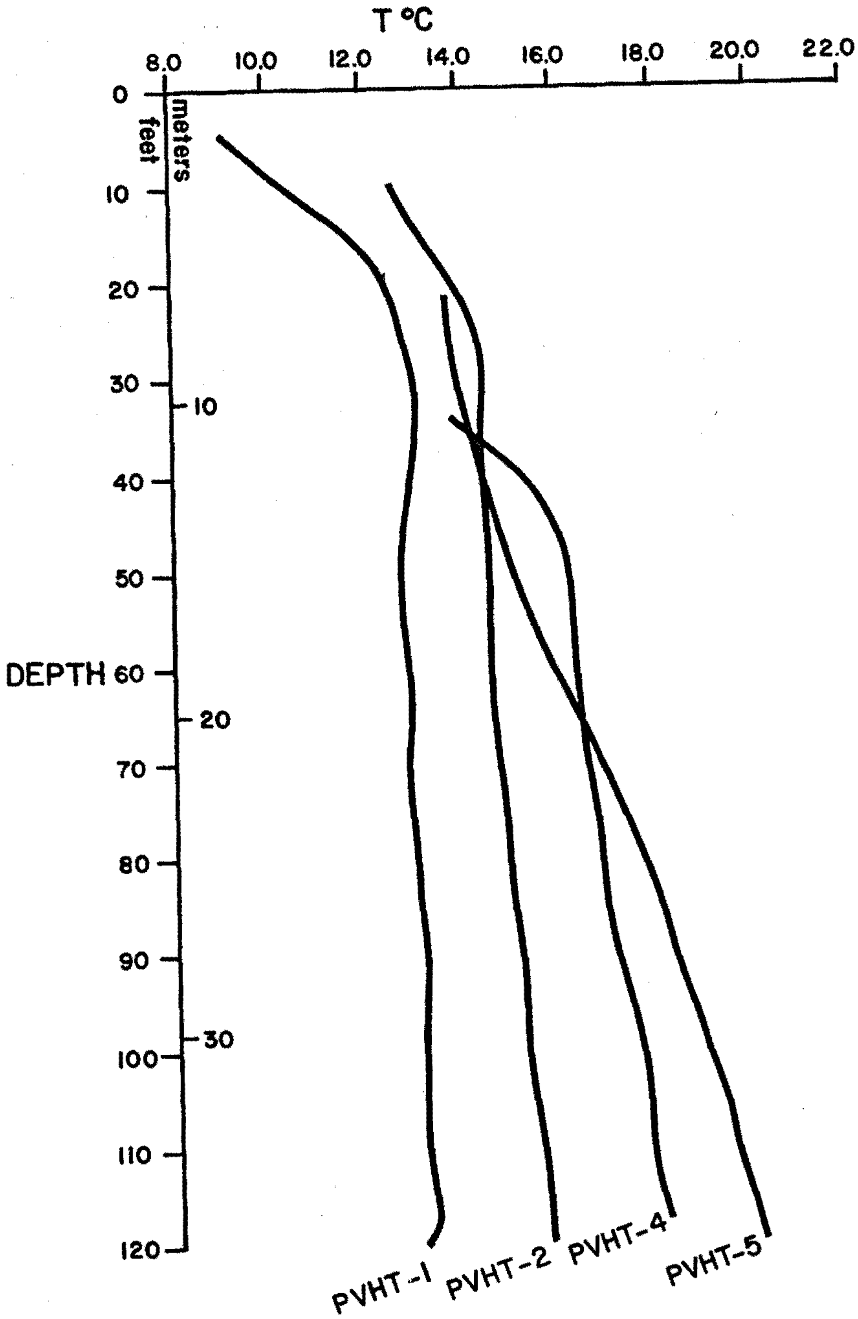


Figure A23. Temperature-depth profiles for PVHT-1, 2, 4, and 5 in Pumpernickel Valley; profiles measured 6 February, 1982.

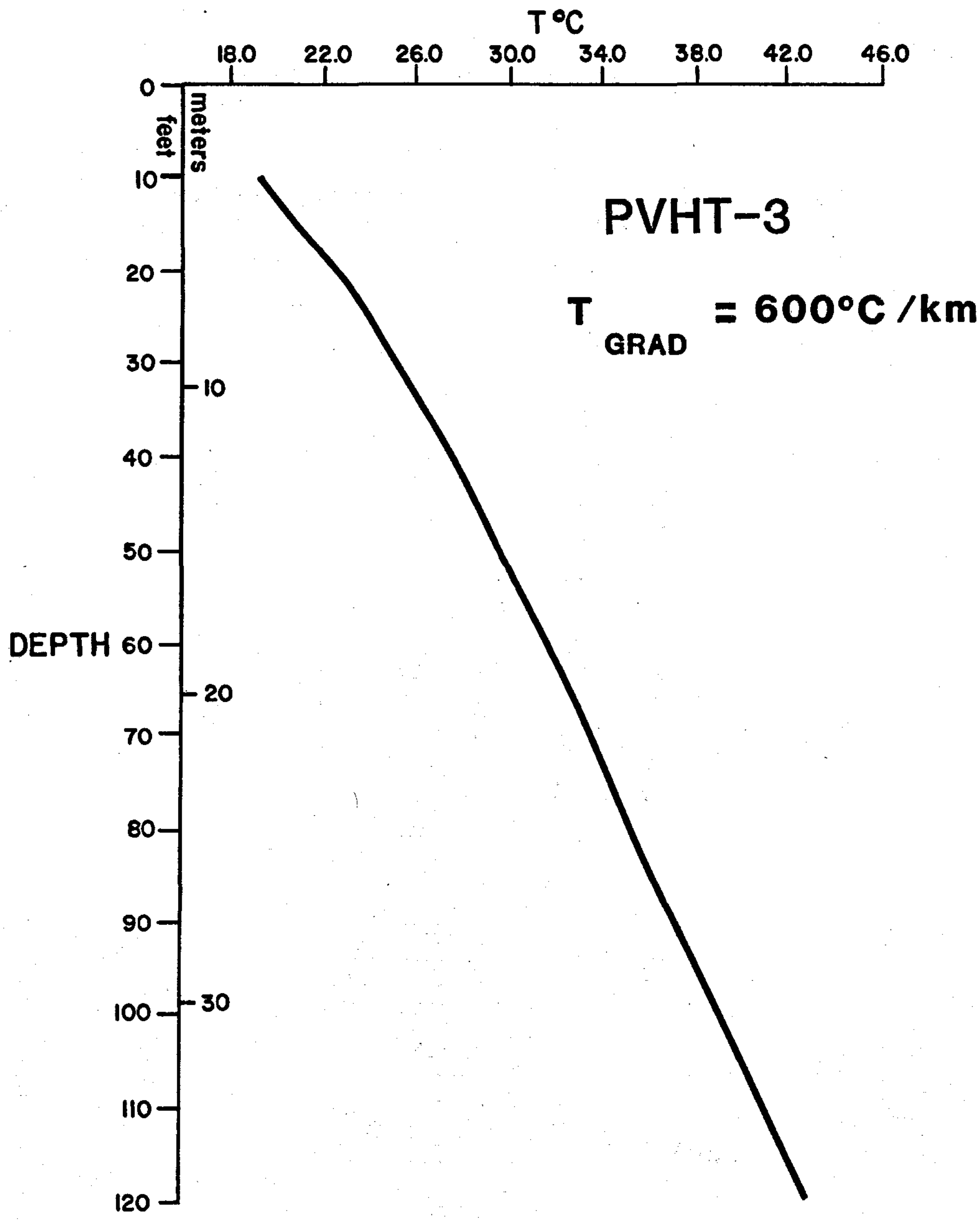


Figure A24. Temperature-depth profile for PVHT-3 in Pumpernickel Valley; profile measured 6 February, 1982.

Table A7

Pumpernickel Valley Temperature Gradients

HOLE	GRADIENT $^{o}C/Km$
PVHT-1	25
PVHT-2	60
PVHT-3	600
PVHT-4	100
PVHT-5	220

65 to 145 Meter Depth Temperature Gradient Holes

Five intermediate-depth temperature gradient holes were drilled in Pumpernickel Valley to determine the areal extent of the thermal anomaly near the Kemp Benchmark. The five sites were selected on the basis of interpretation of nearby geologic structures that may control the flow path of thermal fluids. Thermal fluids are often coincident with faults and fault intersections (Trexler and others, 1979). Three fault zones have been identified in the Kemp area (fig. A5). The drill sites (fig. A25) were located adjacent to the mapped fault zones to identify the primary structural controls of the Kemp thermal anomaly.

Prior to drilling, an archaeological clearance was completed for all the drill sites. The same procedure was used at these sites as in the previous drilling program. No archaeological or historical artifacts were discovered at any site.

Drilling began in April, 1982, and was completed in May, 1982. A Gardner Denver 15W rotary rig, with both air and mud drilling capability, was used throughout this drilling program. Most of the drilling was completed with mud and mud additives. Air drilling was used to penetrate bedrock.

Return mud temperatures were monitored continuously and drill chip samples were collected at 6 m (20 ft) intervals. A cursory examination of the drill cuttings was made.

After drilling was completed, the holes were cased with threaded and coupled steel pipe which was plugged at the bottom. The pipe was then filled with water, the annulus was backfilled with cuttings, and the top of the annulus was cemented. The holes were then allowed to equilibrate for three to four weeks.

Lithologic logs were prepared from analysis of the cuttings. The lithologic logs, shown in Figures A26 through A30, show that alluvium is the principal material encountered. Absolute lithologic correlations cannot be made between

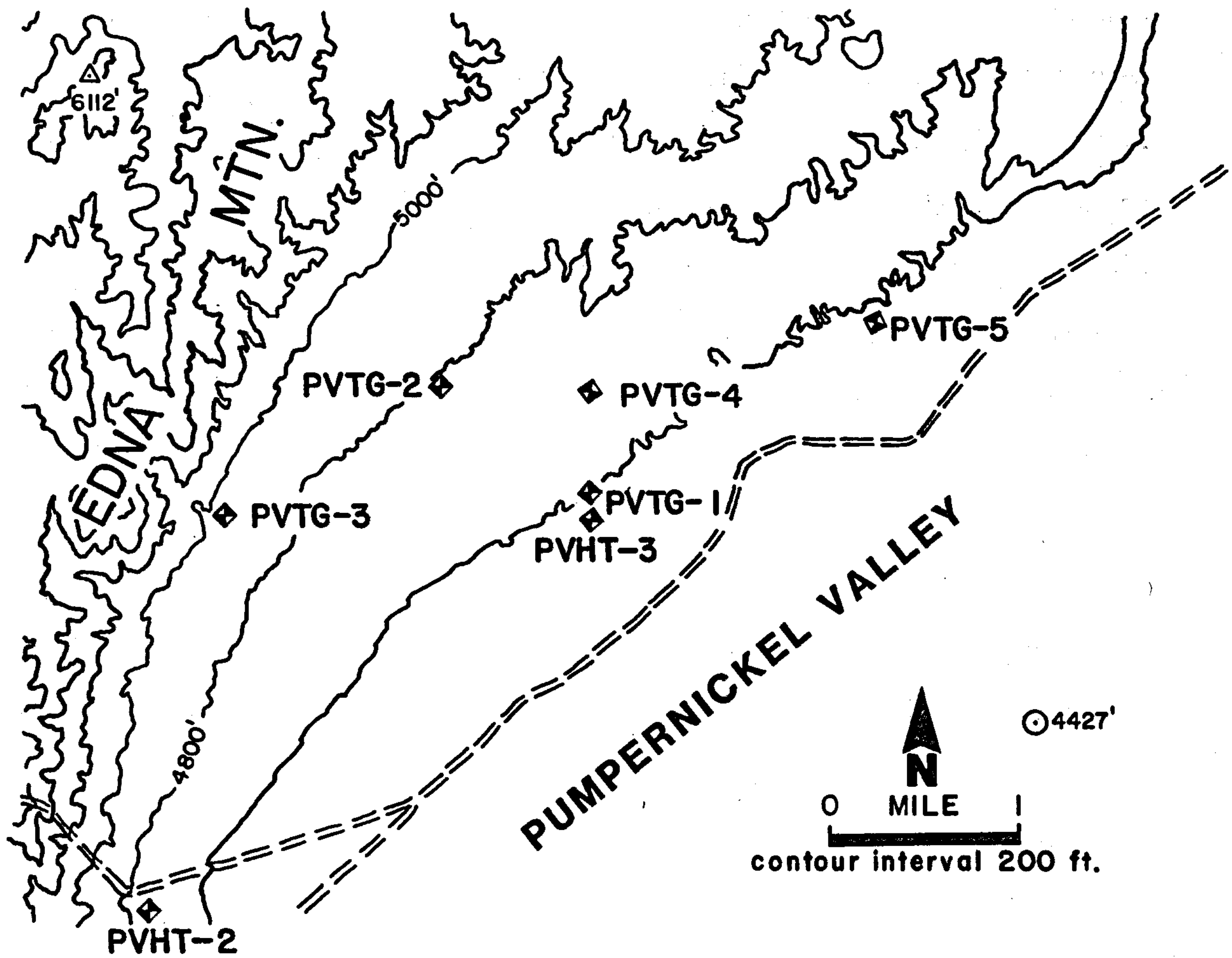


Figure A25. Location of temperature gradient holes near Kemp, Pumpernickel Valley.

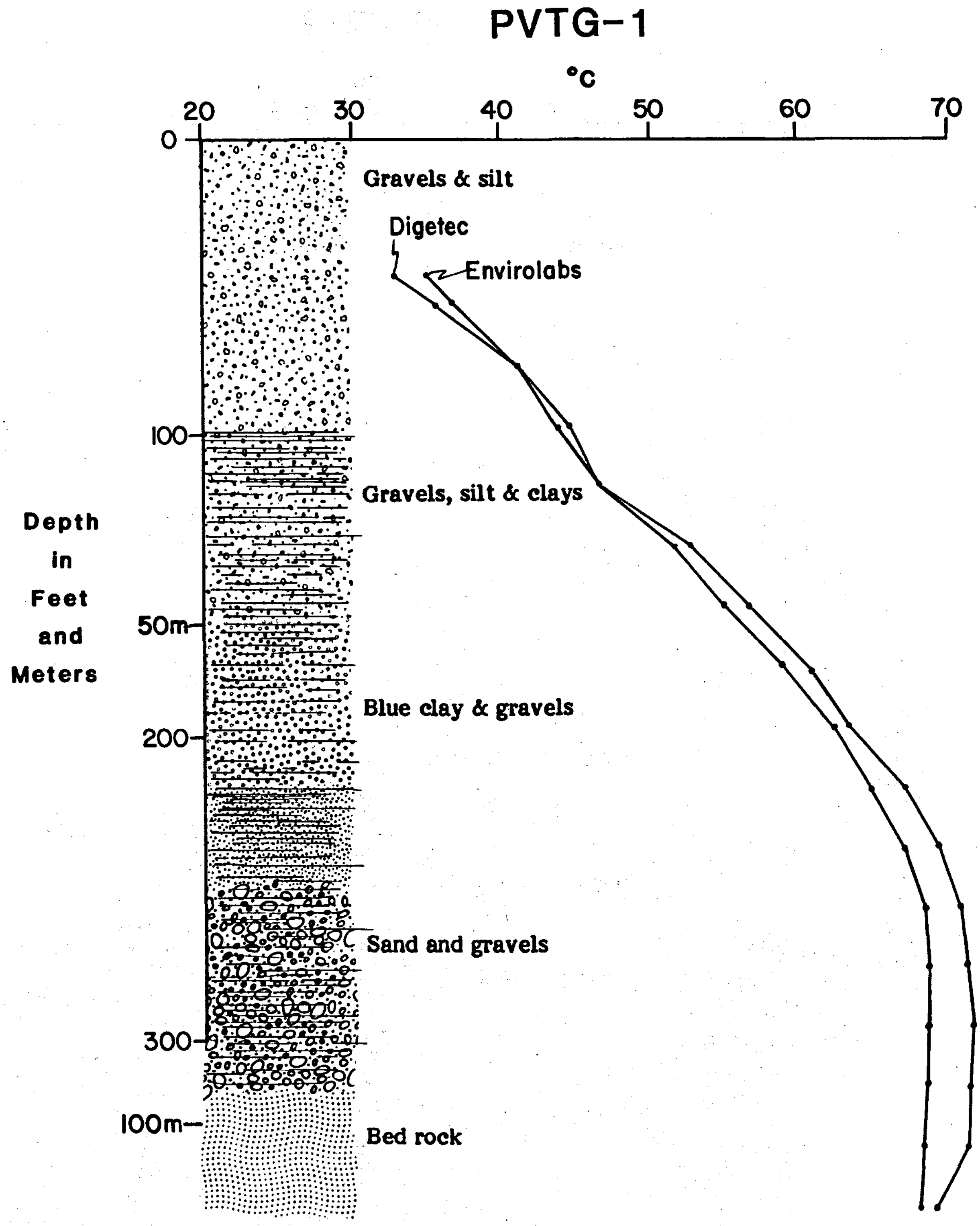


Figure A26. Lithologic log and temperature-depth profile of PVTG-1 in Pumpernickel Valley.

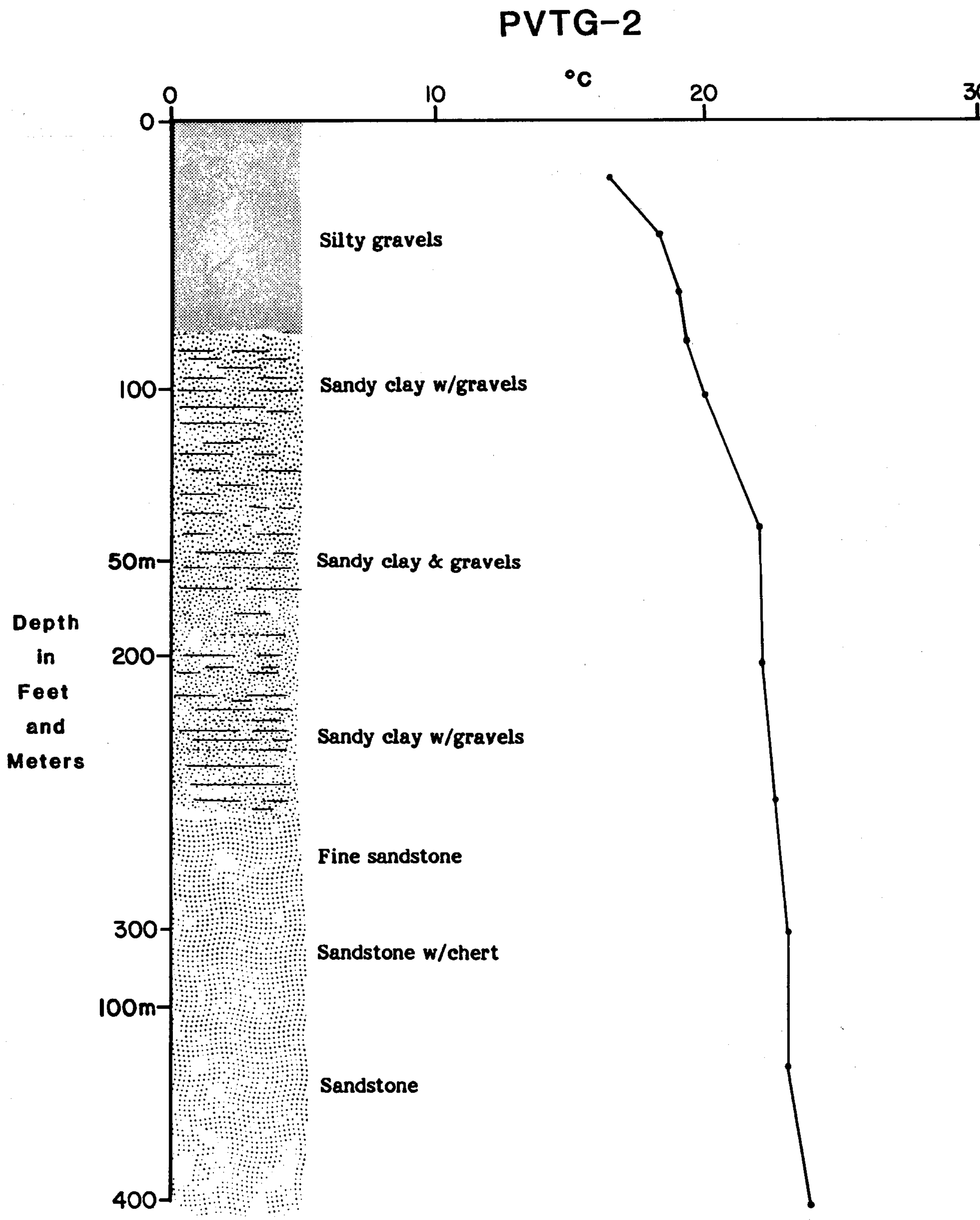


Figure A27. Lithologic log and temperature-depth profile of PVTG-2 in Pumpernickel Valley.

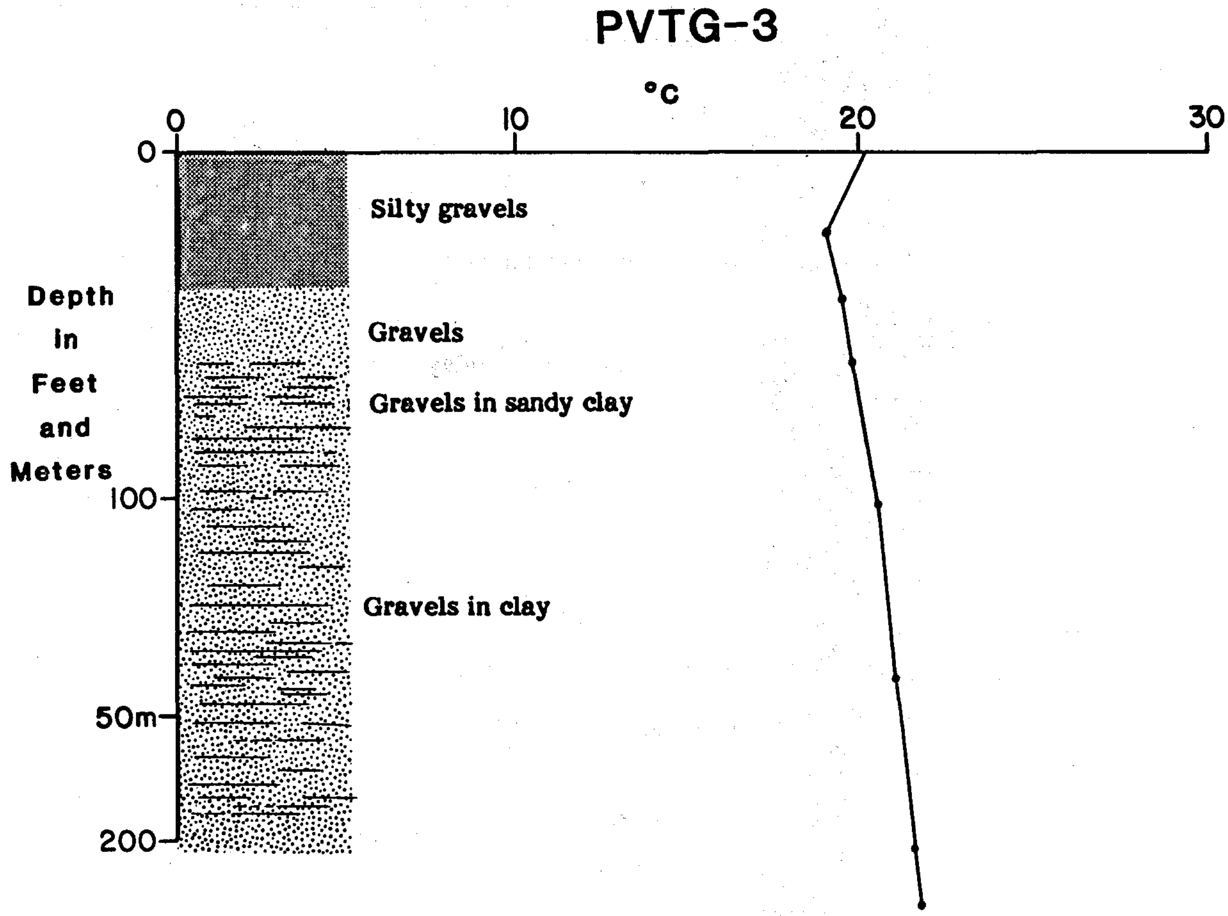


Figure A28. Lithologic log and temperature-depth profile of PVTG-3 in Pumpernickel Valley.

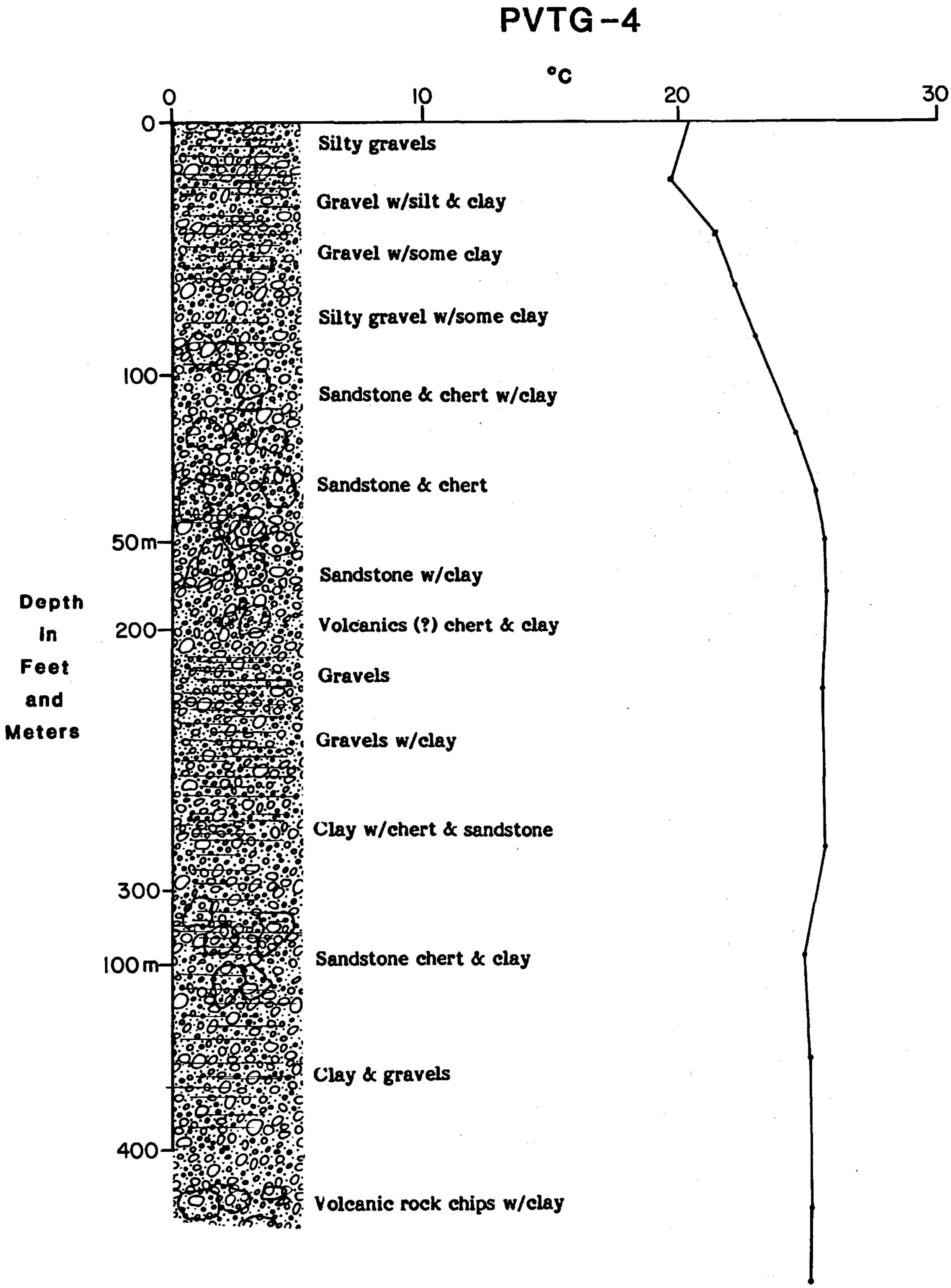


Figure A29. Lithologic log and temperature-depth profile of PVTG-4 in Pumpernickel Valley.

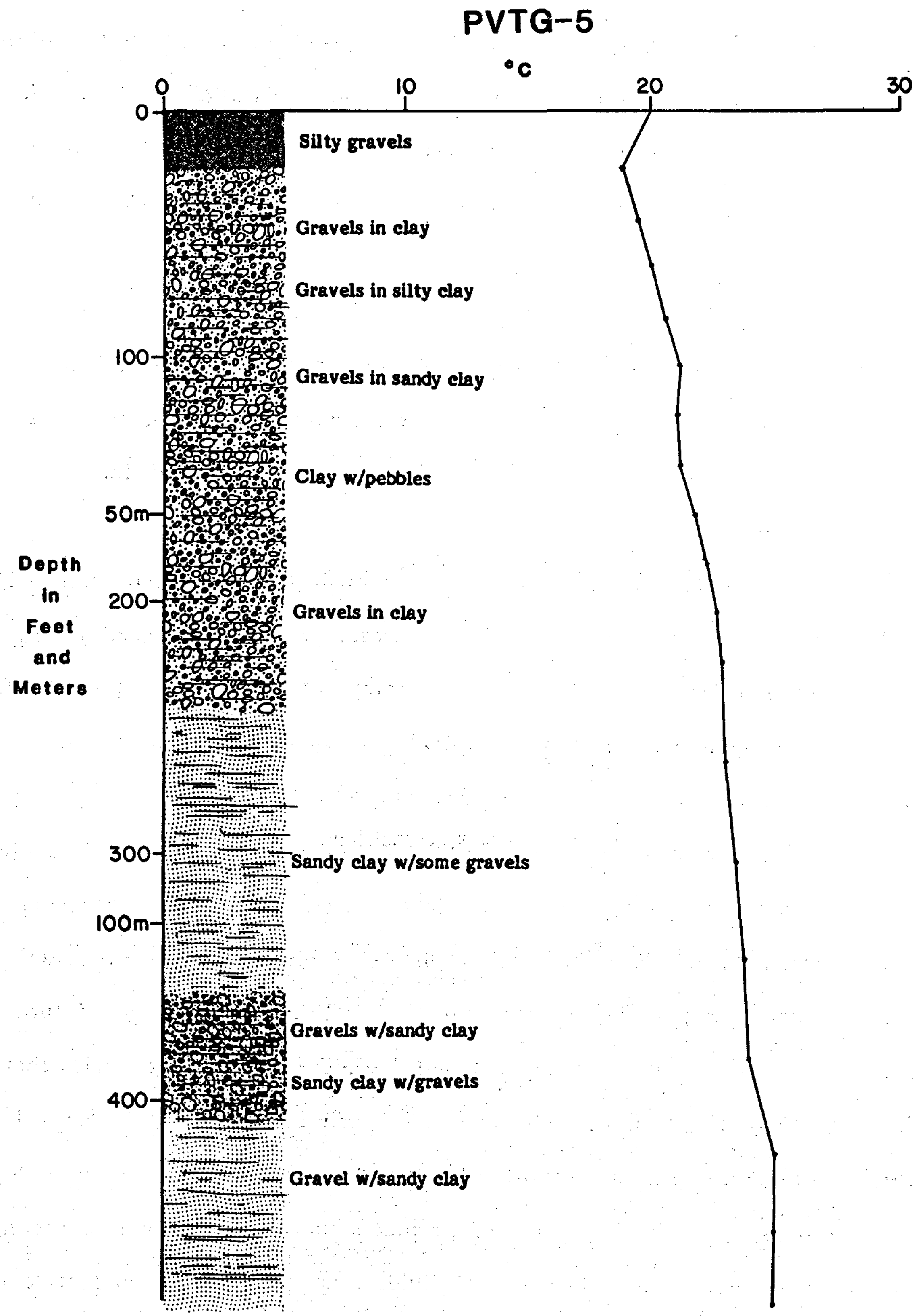


Figure A30. Lithologic log and temperature-depth profile of PVTG-5 in Pumpernickel Valley.

holes because of the large vertical and lateral facies changes that occur in alluvial fans. Bedrock was encountered in holes PVTG-1 and PVTG-2. The bedrock was identified as cherty sandstone and greywacke of the Pennsylvanian age Pumpernickel Formation, which can be seen in small outcrops on the east side of Edna Mountain.

Temperature-depth profiles were completed for all wells and are also shown in Figure A26 through A30. Temperatures were measured with digital-readout cable reel thermistor probes. Measurements were made during descent at 3 to 6 m (10 to 20 Ft.) intervals. Two to three minutes were allowed for probe re-equilibration between readings.

Temperature gradients in holes PVTG-2 through PVTG-5 ranged from 3°C/km to 30°C/km. Significant volumes of cold water were encountered during air drilling in holes PVTG-2 and PVTG-4. The temperature depth profiles for these holes represent typical northern Basin and Range Province gradients and do not suggest the presence of a near-surface heat source.

The temperature-depth profile for PVTG-1 shows a constant gradient (600°C/km) to a depth of approximately 75 m (250 ft.). The well is isothermal to a depth of approximately 100 m (325 ft.) and shows a slight temperature reversal near the bottom of the hole. The combined data from lithologic and temperature logs suggest that the sand and gravel layer above the bedrock is saturated with thermal fluids that range in temperature from 68°C to 70°C. Stratigraphic controls for these fluids include the bedrock and the thick zone of blue clay and gravel. Flow is restricted to a 20 m (100 ft.) zone of permeable sands and gravels. The large temperature gradient above the thermal fluids is largely due to conductive heat transfer. The isothermal zone represents thermal equilibrium within the geothermal reservoir.

A generalized lithologic correlation between wells PVTG-1 and PVTG-2 was combined with data derived from interpretation of the gravity data. Figure A31 shows a possible stratigraphic and structural cross-section through the thermal anomaly at PVTG-1. This model is consistent with all the available data and indicates that the areal extent of the geothermal reservoir is 1.6 km (1 mi.) or less. The fault that supplies thermal fluids is believe to be located less than 0.5 km (0.8 mi.) west of PVTG-1. Fluids probably flow into the valley, but there are no thermal fluids discharging at the surface in this area.

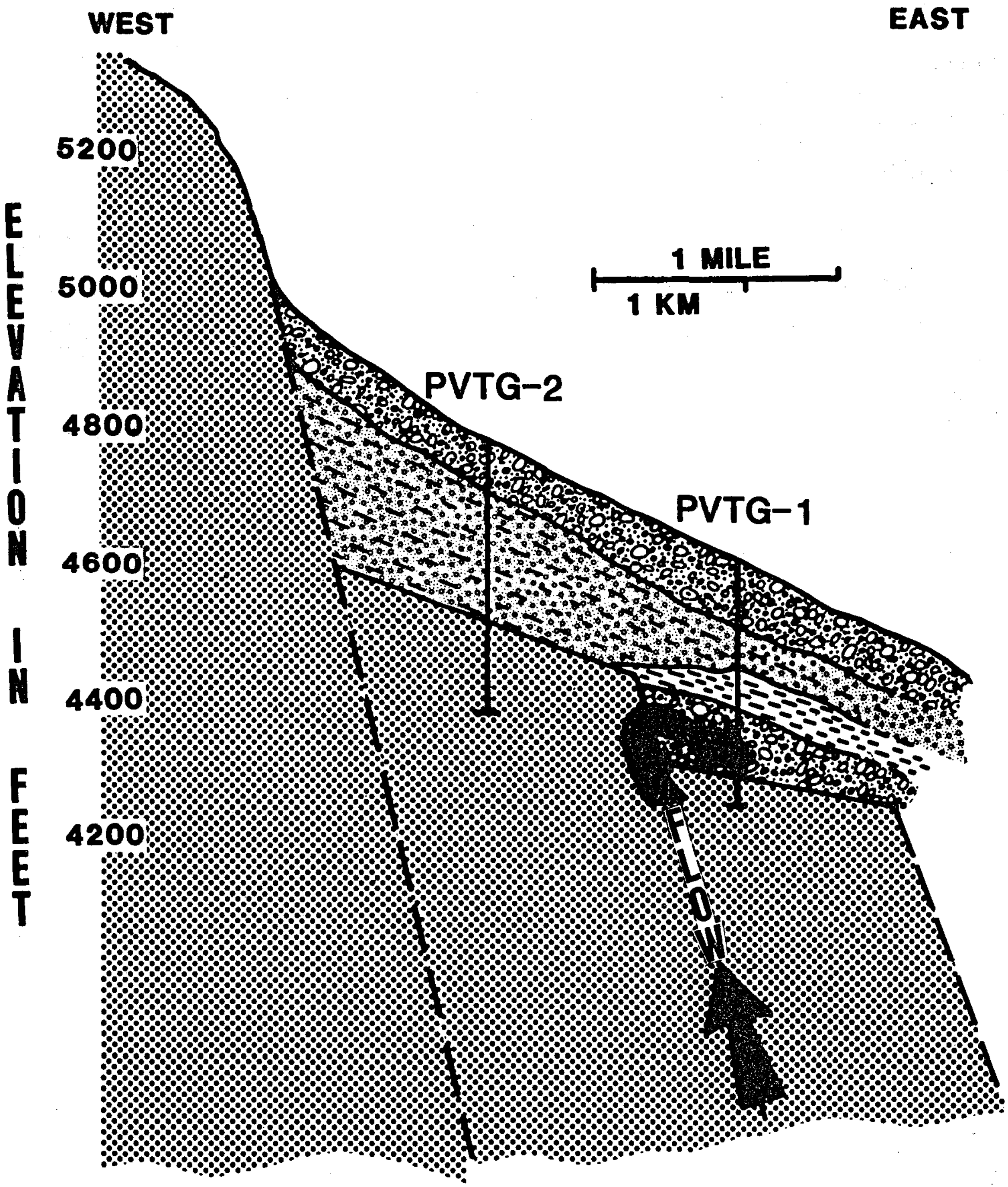


Figure A31. A stratigraphic and structural model through the Kemp geothermal anomaly.

CARLIN

Geographic Setting

The Carlin study area encompasses approximately 104 square kilometers (40 sq. mi.) along the Elko-Eureka County line in northeastern Nevada (fig. 1). The town of Carlin (pop. 1500) lies 47 km (18 mi.) west of Elko in the Humboldt River Valley. The study area is transected by the Southern Pacific Railroad, Interstate Highway 80 and secondary roads (fig. B1).

District space heating is a viable application of the geothermal resources in the area and the town is interested in using the resource (Fiore, 1980).

Geologic Setting

The Carlin region is underlain by Cambrian through Mississippian age Eastern Assemblage rocks (fig. B2). This shallow-water, miogeosynclinal sequence is predominantly limestone and dolomite with minor amounts of shale and quartzite. Remnants of Western Assemblage siliceous and volcanic rocks are present as part of the Roberts Mountain thrust (Antler Orogeny). These Ordovician through Devonian age rocks of the Vinini and Valmy Formations consist of shale, chert, quartzite and siltstone with minor limestone and greenstone.

Tertiary units include the silicic volcanics of the upper Miocene age Palisade Canyon rhyolite and the lacustrine deposits of the Carlin Formation. The Carlin Formation consists of tuffaceous sandstone, siltstone and conglomerate with tuff and ash, diatomite, limestone and shale as mapped by Regnier (1960). Roberts and others (1967) indicate the Carlin Formation is Pliocene in age and consider it correlative with the middle member of the Humboldt Formation of Sharp (1939). Smith and Ketner (1978) refer to this sequence as the Humboldt Formation and indicate an upper Miocene age.

Quaternary deposits include alluvium of silt, sand and gravel along streams and as slope wash and gravels that are non-tuffaceous deposits on benches and

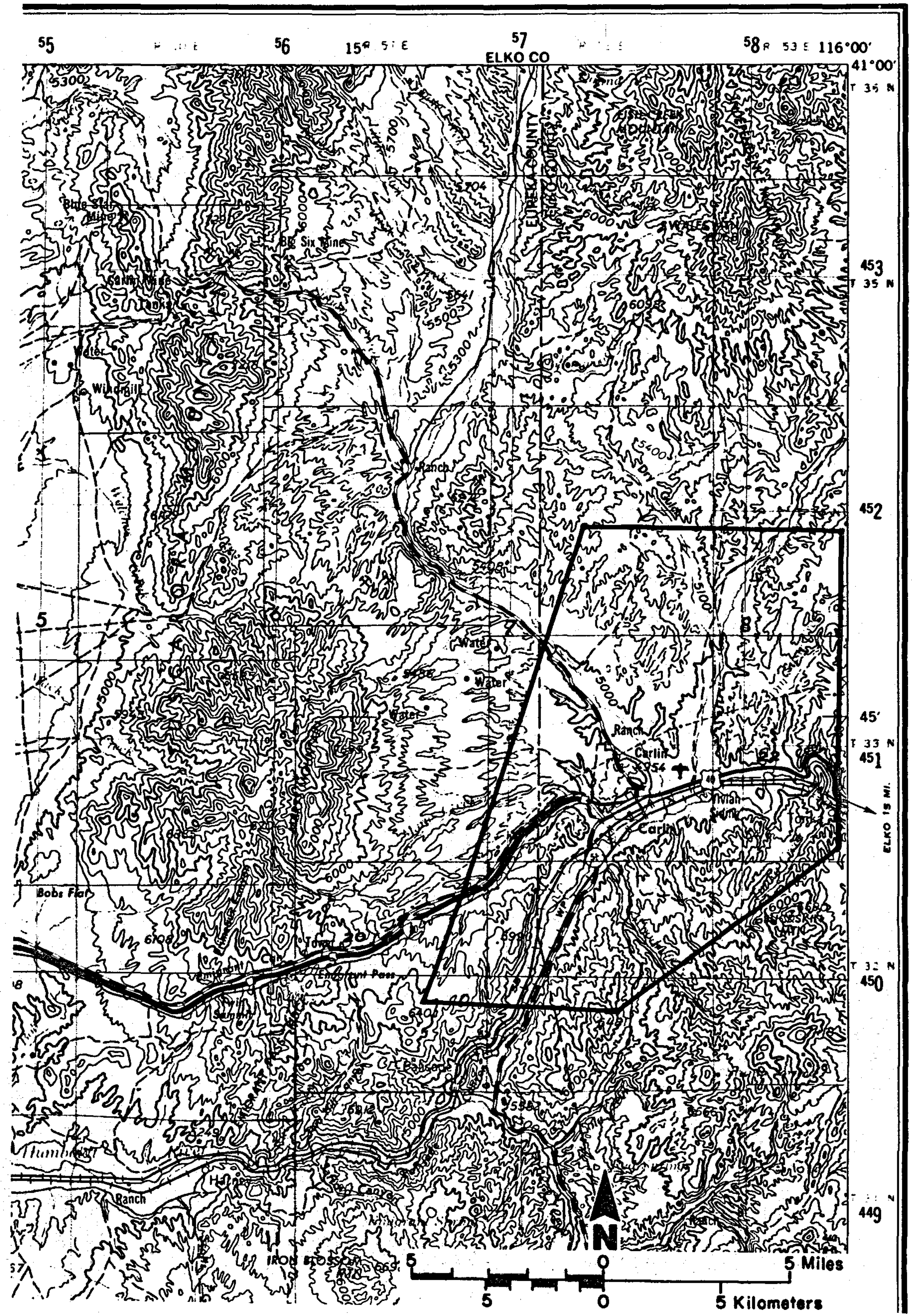


Figure B1. Carlin study area.

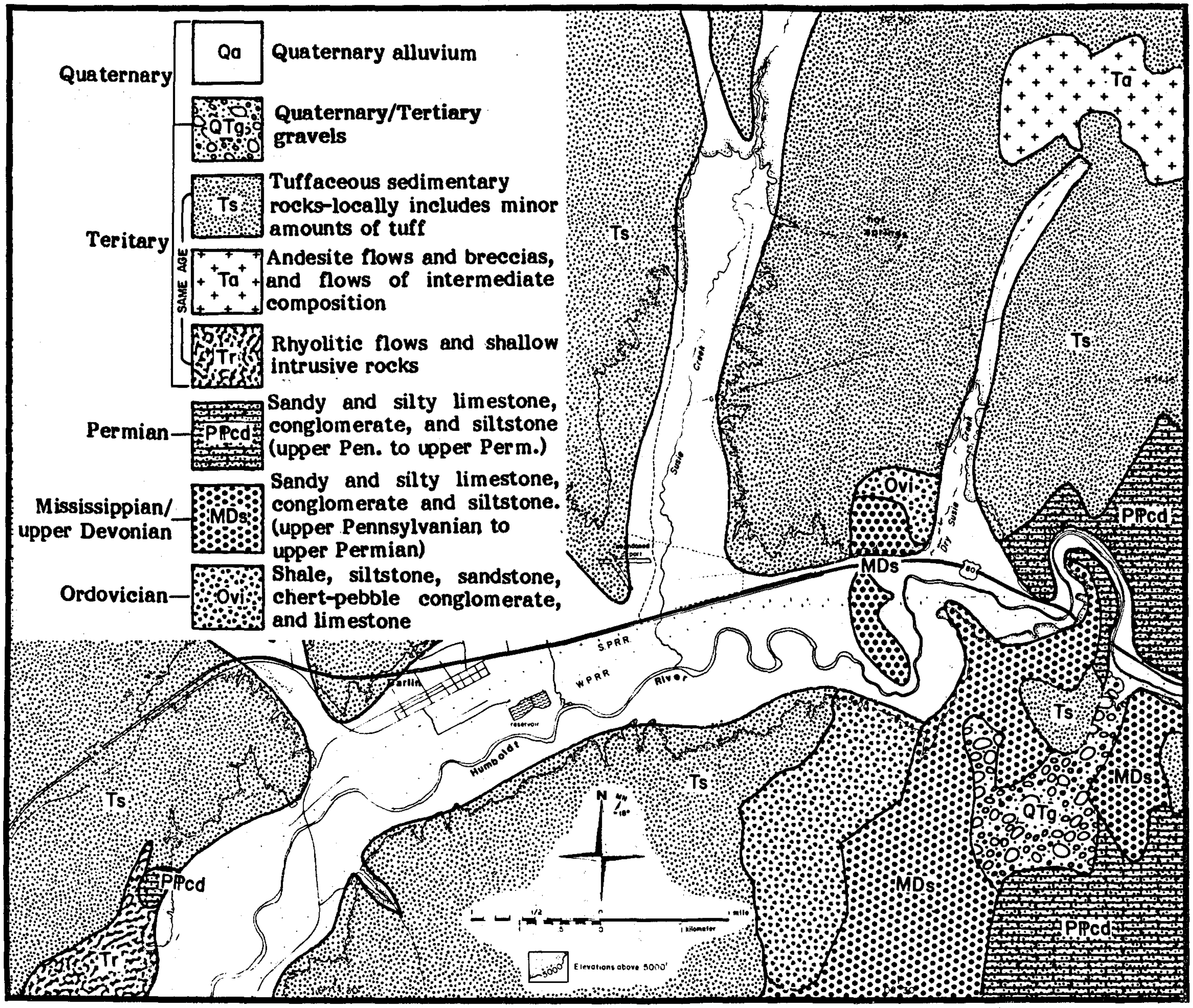


Figure B2. Generalized geologic map of the Carlin area.

terraces (fig. B2). Locally, sinter deposits are associated with hot spring activity.

Structurally, the Carlin study area does not fall into the typical Basin and Range setting. Rather, it is a broad area of low relief in which Tertiary silicic volcanic flows, tuffs and tuffaceous sediments have been deposited in a relatively shallow basin on Paleozoic sedimentary units. Intense deformation is recorded in the Paleozoic rocks and includes folding and high-angle thrust faulting. Some high-angle faulting in the Tertiary units near Susie Creek is inferred by Smith and Ketner (1978). Field examination of Tertiary units during the reconnaissance phase of this study revealed the presence of a narrow zone of high angle faults. These faults are visible in a road cut located approximately one mile west of Carlin on old U.S. Highway 40.

Several occurrences of thermal fluids are noted in the area. A warm spring issues from the Palisade Canyon rhyolite in Sec. 5, T33N, R 52E. Temperatures measured in the spring range from 24° to 35°C. To the northeast, a group of springs flow from river deposits within and adjacent to the Humboldt River. Flow rates are low, but temperatures as high as 79°C are documented. Hot water was encountered in two wells drilled within one-third mile of The Hot Springs. A second group of hot springs is present in Sec. 8, T33N, R53E near Dry Susie Wash. Fluids discharge at a moderate rate with temperatures as high as 64°C.

Lineament Analysis

Photogeologic interpretation was conducted of Carlin and vicinity to identify and delineate lineaments. NASA mission 74-160 photography (1:30,000 and 1:120,000 scale), Landsat color composite imagery (scene 44-32, 1:250,000 scale, 9 Oct., 1976), and AMS mission 109 photography (1:60,000 scale) were evaluated. Lineaments identified on the imagery were compiled on a 1:250,000 scale map and then delineated on Figure B3. The continuity of the lines indicates the integrity of the feature.

Synoptic coverage was provided by the small-scale imagery, with genetic origin of the lineaments determined from evaluation of the larger scale photography. Two sets of lineaments are generally defined by topographic discontinuities, lithologic contrasts, and by linear drainages that may reflect underlying structural control. The northeast-trending features are probably representative of the Humboldt structural zone and north- to northwest-trending features are probably related to the Oregon-Nevada lineament (fig. A4).

Most of the lineaments depicted on Figure B3 correlate with faults identified on detailed imagery. In general, the lineaments and faults identified by this study are not indicated in the literature (Roberts and others, 1967; Stewart and Carlson, 1976; Smith and Ketner, 1978). Faults transect Tertiary age Palisade Canyon rhyolite and Carlin Formation, define lithologic boundaries, and may be the controlling structures for springs and hot springs.

Gravity

The entire area is included in a regional gravity map (Erwin, 1974). The data indicate that a large circular basin, roughly 11 km (7 mi.) in diameter, is located 10 km (6 mi.) north of the city of Carlin. This feature probably represents the structural basin that existed in this area throughout much of the Cenozoic Era. As much as 600 m (2000 ft.) of the Humboldt Formation (Smith and Ketner, 1978) now occupy this basin. These rocks are Miocene-age lake sediments and are widespread throughout the area.

A limited amount of gravity data from the Carlin area was purchased. Generalized interpretations of the data were made and are illustrated in Figure B4.

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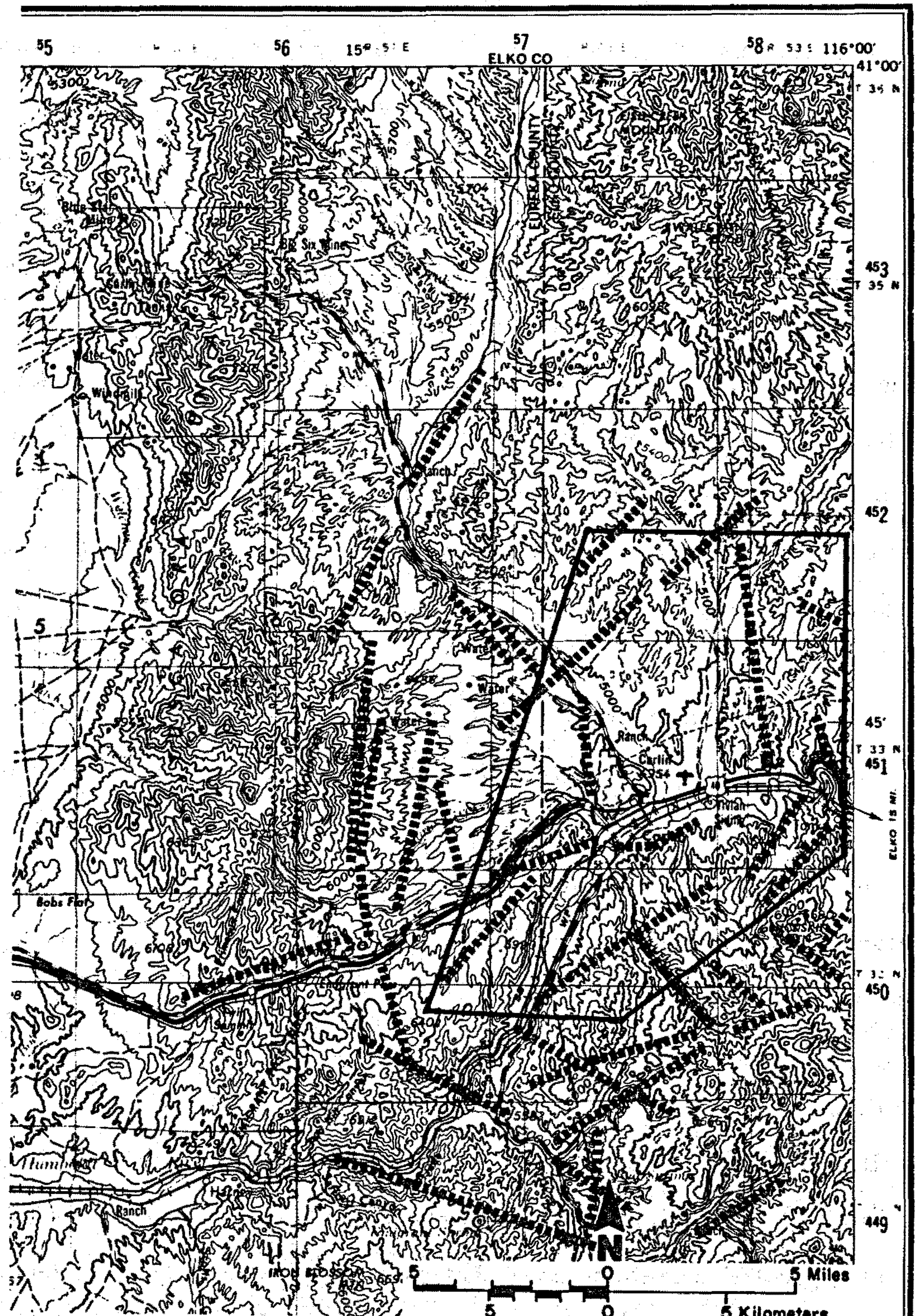


Figure B3. Lineament map of Carlin area.

The interpretations are based on data from approximately 100 gravity stations, at 1.6 km (1 mi.) intervals. The survey was not tied to any known gravity base station and therefore no residual gravity anomaly map could be produced.

Figure B4 shows the only two features that have any bearing on the geothermal occurrences at Carlin. Both features are coincident with the location of the Carlin Hot Springs (1) and the unnamed warm spring (2). The gravity survey did not extend to the area near the unnamed hot spring (3).

The northeast trend in the gravity contours may represent a fault zone. A similar trending fault was identified in a road cut through the Humboldt Formation 1 km (.6 mi.) west of Carlin. To the south, the Humboldt River has cut a northeast-trending channel into the Palisade Canyon Rhyolite. This northeast trend can also be recognized in gravity contours in Cresent Valley (Erwin, 1974), 40 km (25 mi.) to the southwest.

The small circular feature adjacent to the trend in the gravity contours is also coincident with the location of Carlin Hot Springs. The springs are located in the river bed and its banks and discharge 80°C thermal fluids. This feature is believed to represent densification of the river deposits as a result of mineral precipation by the thermal fluids. Some calcareous sinter has been observed surrounding the springs.

Seismic Data

Reflection seismic data were purchased for an area in Susie Creek, approximately 11 km (7 mi.) northeast of Carlin. These data represent only 4.8 km (3 mi.) of a speculative seismic survey that covered approximately 74 km (40 mi.) and was completed in 1980. The location of the seismic line survey, as well as the 4.8 km section for which data were purchased, is shown in Figure B5.

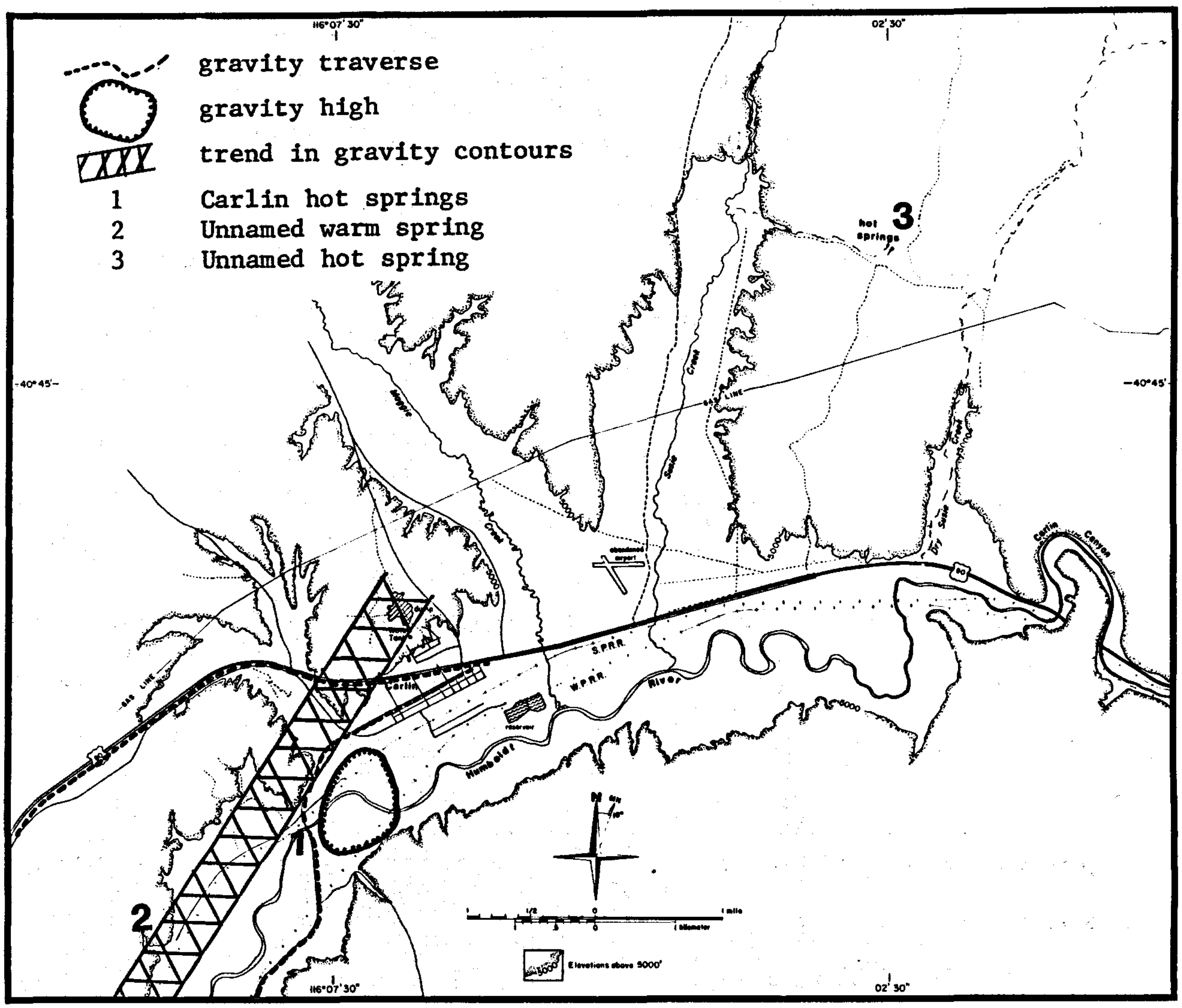


Figure B4. Generalized interpretation of gravity data for Carlin.

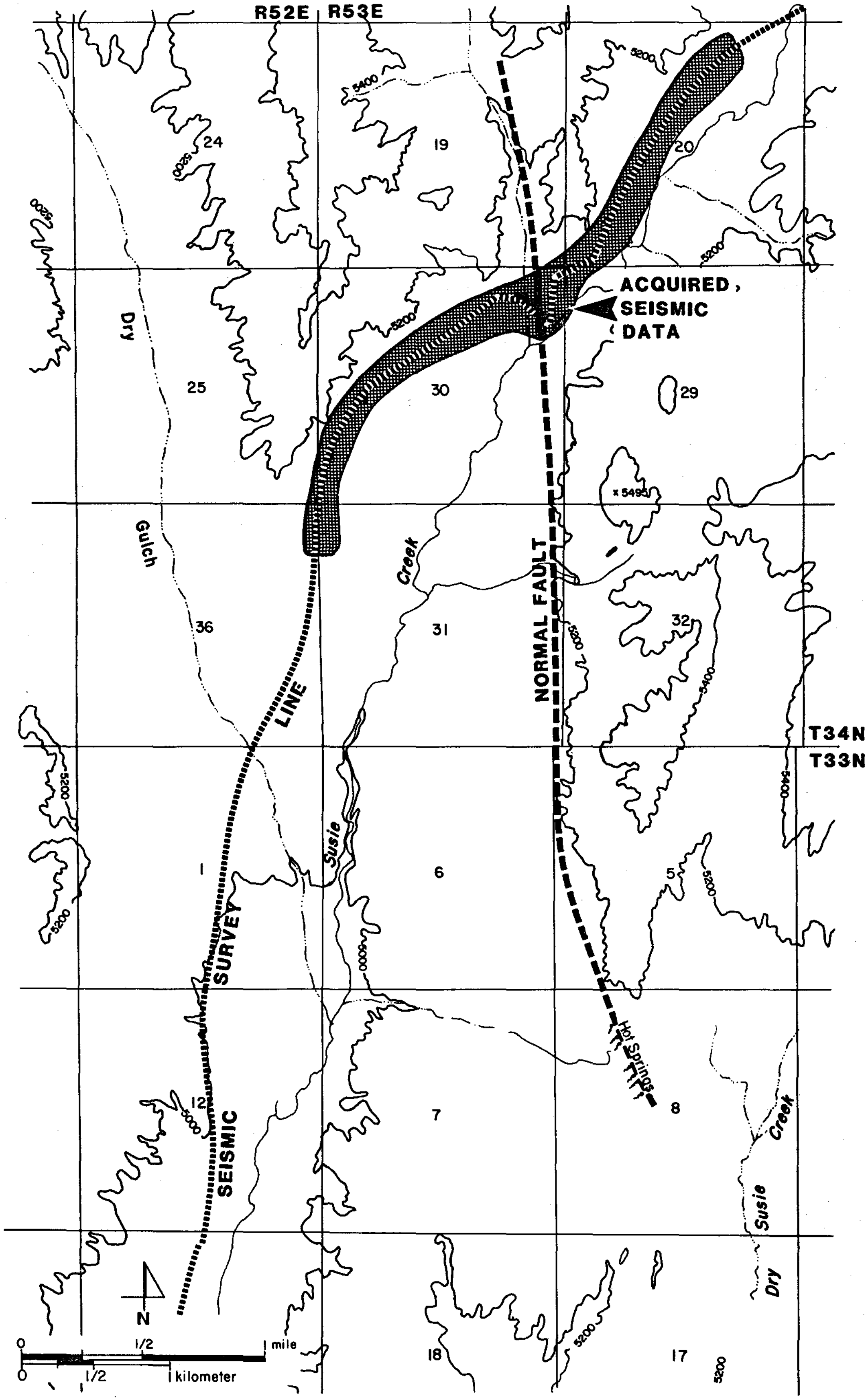


Figure B5. Location of seismic data near Carlin.

Approximately three linear miles of seismic data were obtained in the area shown to examine some of the subsurface structures associated with a north-trending linear feature identified on air photos and satellite imagery (fig. B3). This lineament is thought to be a fault, based on the steep break in topography, alignment of drainages and range tops, and the alignment of both thermal and non-thermal springs along this zone.

Because the seismic survey was speculative, the data quality is highly variable. Several good reflecting surfaces can be recognized within 2 km (1.2 mi.) of the surface. The quality of the data decreases below 2 km.

The seismic data show steeply dipping (45°) reflectors extending from the surface down to the southwest to a depth of approximately 2100 m (7000 ft.). The intersection of these reflectors with the surface is coincident with a steep break in the topography. This break in the topography has already been described as a fault zone and extends south through the hot springs.

Root mean square seismic velocities for various time intervals were provided for several shot point locations along the survey line. These data were converted to approximate depths to reflecting surfaces and a simple geologic cross-section along the seismic line was constructed (fig. B6). This figure shows a normal fault offsetting rocks that range in age from Miocene to Paleozoic. The fault strikes north (fig. B6) and dips to the west. The exact dip angle is not known but probably is 45° to 60°. The intersection of the fault zone with the surface is coincident with a steep break in topography (fig. B6).

Further examination of the geologic map (Smith and Ketner, 1978) shows a northwest trending fault in the Carlin Canyon area. This fault appears to be a southern extension of the fault shown in Figure B5. Examination of relative displacements along these faults, as well as their similar trend, suggest that they

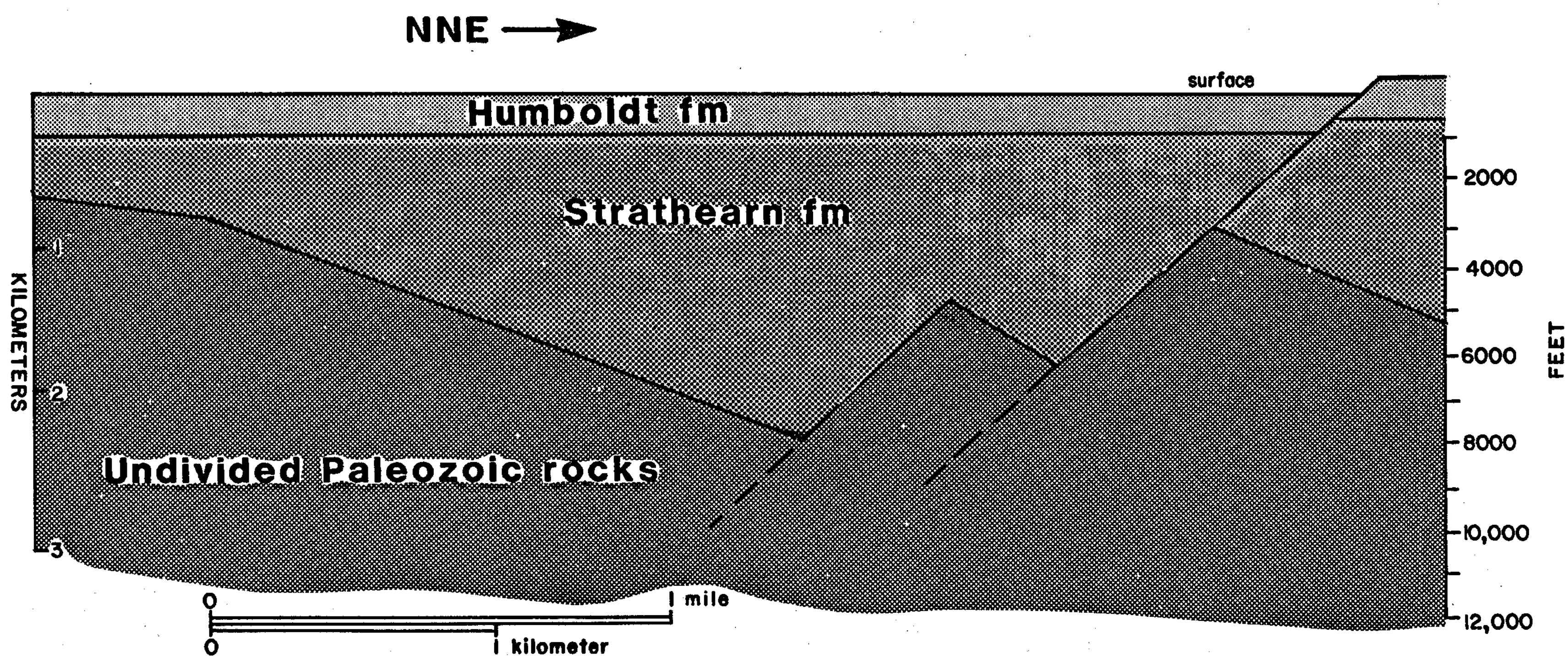


Figure B6. Generalized geologic section along seismic line near Carlin.

comprise a hinge fault that extends from north of Susie Creek to an area south of Carlin Canyon. The exact location of the hinge line is not known, but it appears to be closely associated with the location of the thermal springs. Pathways for the flow of these thermal fluids are provided by permeable zones associated with both the fault and hinge zones.

Soil Mercury Survey

Approximately 40 soil samples were collected at 1.6 km (1 mi.) intervals throughout the Carlin study areas. Sample sites and associated values for Carlin are shown in Figure B7. Mercury values ranged from 0 to 38 ppb. A background value of 20 ppb was estimated for the Carlin area.

Figure B7 shows that the above background soil-mercury values form a narrow zone that trends northeast. Both Carlin Hot Springs (1) and the unnamed warm spring (2) are closely associated with this zone. This zone is also subparallel to a series of normal faults that were identified in a road cut through lake sediments (Carlin Formation) approximately one km west of Carlin. Although there are no mercury mines near Carlin, hydrothermal alteration in the Palisades Canyon Rhyolite is widespread in this area.

Soil samples collected in the area surrounding the unnamed hot spring (3) showed only background soil-mercury values. No other samples from the Carlin study area indicated above background soil-mercury values.

Two-Meter Depth Temperature Probe Survey

Forty-four temperature probe stations were established in Carlin during a three day period in November, 1981 (fig. B8). The holes were drilled along existing roads, backfilled, and allowed to equilibrate for 24 hours. Nearly all of the drilled

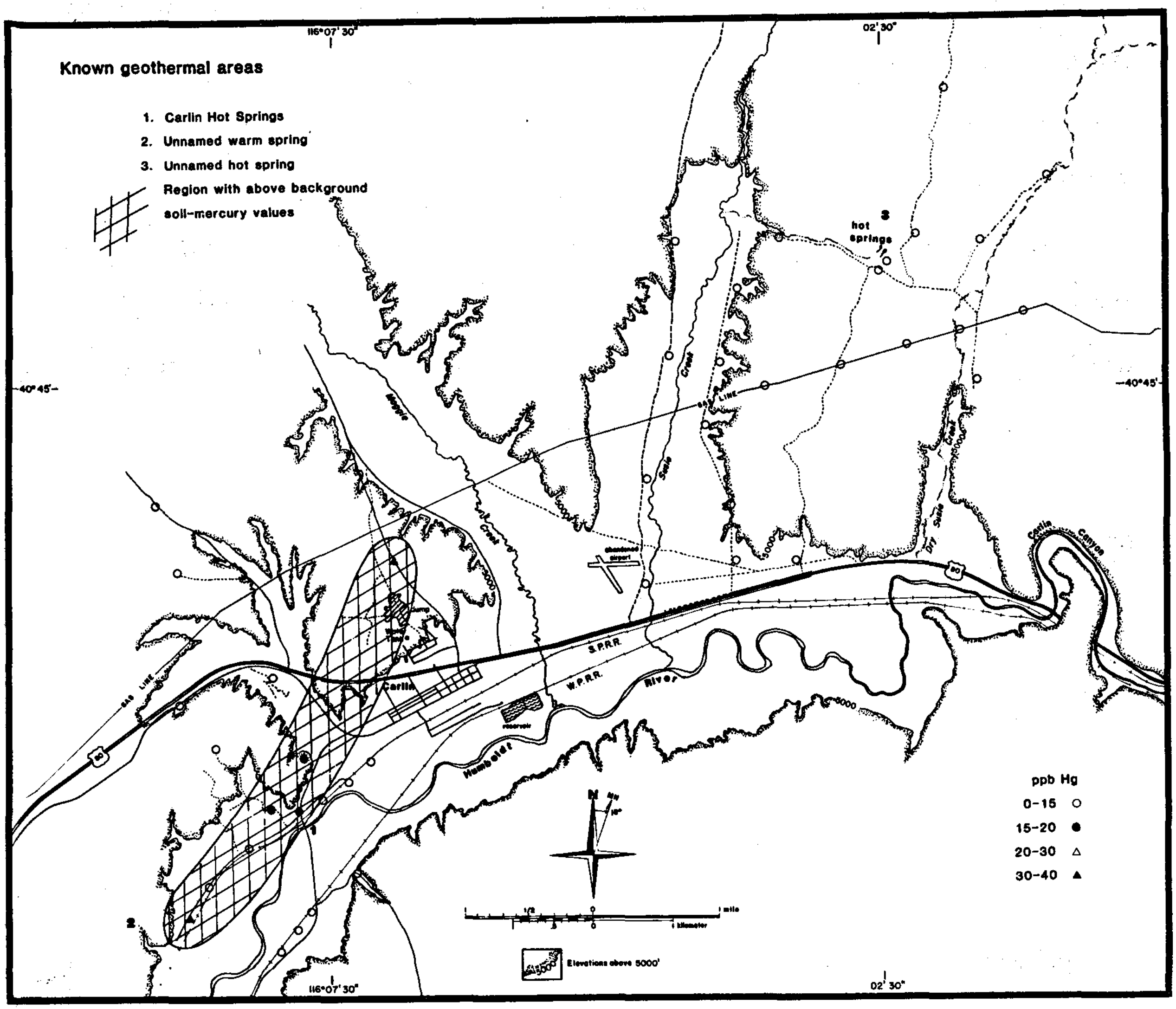


Figure B7. Location of soil-mercury sampling sites in the Carlin area, showing relative values.

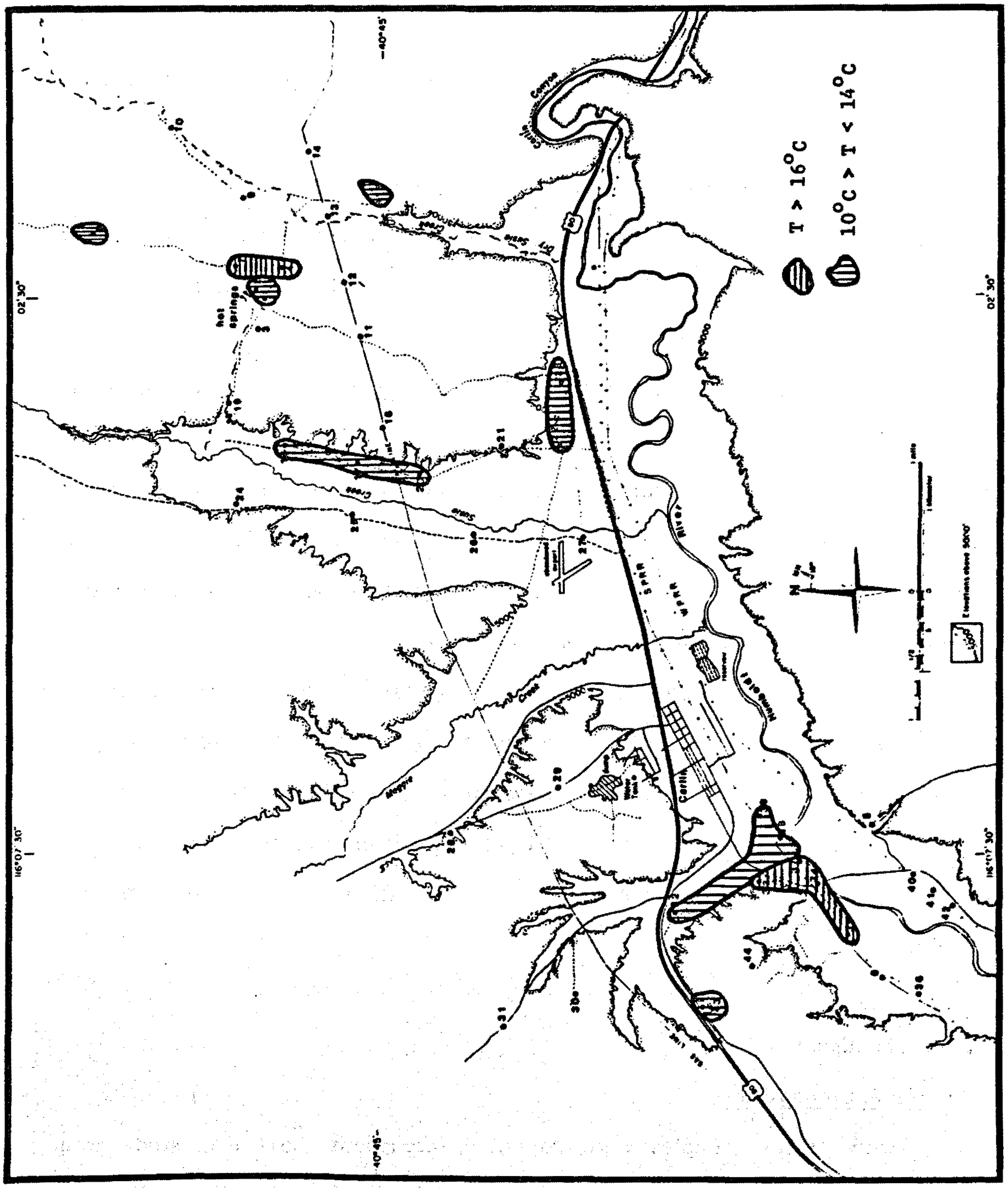


Figure B8. Location of two-meter temperature probe sites in Carlin, showing areas of relatively higher temperatures.

material consisted of moist or dry silty gravels. Water saturated clays were encountered near Carlin Hot Springs.

Elevation differences between control probes and other stations were insignificant and this correction was not considered necessary. Annual wave corrections were also small but were used in calculating the final temperature. Temperature probe data are listed in Table B1.

Probe locations and areas having relatively high temperatures are shown in Figure B8.

Thermal anomalies occur at both Carlin Hot Springs and the unnamed hot spring northeast of Carlin. The survey data near Carlin Hot Springs indicate that the influence of the thermal fluids is not restricted to the hot springs discharge area alone. Relatively high temperatures were recorded 1.5 km north of the springs. A much smaller area of anomalous temperatures surrounds the hot springs to the north. Several other isolated areas with above background temperatures can also be seen in Figure 8. These areas are not associated with any known thermal fluids. These areas do not coincide with any significant structural trend and may only represent areas where heat loss due to evaporation of interstitial water was slight.

Fluid Chemistry

Bulk Fluid Composition

Twelve water samples were collected throughout the Carlin study area. Sample sites included both thermal and non-thermal fluids. All samples were collected within a four day period and variations in chemical composition as a result of seasonal changes were not considered. Table B2 lists the bulk chemical compositions of the samples.

TABLE B1

Corrections for
Two-Meter Temperature Probe Study
Carlin

PROBE	DATE	TEMP	CORRECTION	CORRECTED READING
CT-1	11 Nov 81	14.7	-0.2	14.5
CT-2	11 Nov 81	15.2	-0.2	15.0
CT-3	11 Nov 81	13.8	-0.2	13.6
CT-4	11 Nov 81	16.5	-0.2	16.3
CT-5	11 Nov 81	13.8	-0.2	13.6
CT-6	11 Nov 81	12.8	-0.2	12.6
CT-7	12 Nov 81	17.0	+0.1	17.1
CT-8	12 Nov 81	15.6	+0.1	15.7
CT-9	12 Nov 81	13.8	+0.1	13.9
CT-10	12 Nov 81	12.7	+0.1	12.8
CT-11	12 Nov 81	13.7	+0.1	13.8
CT-12	12 Nov 81	13.1	+0.1	13.2
CT-13	12 Nov 81	11.5	+0.1	11.6
CT-14	12 Nov 81	13.8	+0.1	13.9
CT-15	12 Nov 81	14.3	+0.1	14.4
CT-16	12 Nov 81	12.6	+0.1	12.7
CT-17	12 Nov 81	15.4	+0.1	15.5
CT-18	12 Nov 81	14.9	+0.1	15.0
CT-19	12 Nov 81	12.4	+0.1	12.5
CT-20	12 Nov 81	14.3	+0.1	14.4
CT-21	12 Nov 81	13.8	+0.1	13.9
CT-22	12 Nov 81	15.0	+0.1	15.1
CT-23	12 Nov 81	15.1	+0.1	15.2
CT-24	12 Nov 81	13.3	+0.1	13.4
CT-25	12 Nov 81	13.1	+0.1	13.2
CT-26	12 Nov 81	12.7	+0.1	12.8
CT-27	12 Nov 81	13.1	+0.1	13.2
CT-28	12 Nov 81	13.6	+0.1	13.7
CT-29	12 Nov 81	13.6	+0.1	13.7
CT-30	12 Nov 81	13.2	+0.1	13.3

TABLE B1, cont.

Corrections for
Two-Meter Temperature Probe Study
Carlin

PROBE	DATE	TEMP	CORRECTION	CORRECTED READING
CT-31	12 Nov 81	13.4	+0.1	13.5
CT-32	13 Nov 81	14.3	+0.2	14.5
CT-33	13 Nov 81	15.7	+0.2	15.9
CT-34	13 Nov 81	46.1	+0.2	46.3
CT-35	13 Nov 81	17.7	+0.2	17.9
CT-36	13 Nov 81	12.8	+0.2	13.0
CT-37	13 Nov 81	16.3	+0.2	16.5
CT-38	13 Nov 81	13.9	+0.2	14.1
CT-39	13 Nov 81	14.9	+0.2	15.1
CT-40	13 Nov 81	13.1	+0.2	13.3
CT-41	13 Nov 81	11.2	+0.2	11.4
CT-42	13 Nov 81	11.8	+0.2	12.0
CT-43	13 Nov 81	14.8	+0.2	15.0
CT-44	13 Nov 81	13.3	+0.2	13.5

	CT-1	CT-2	CT-3	T
11 Nov 81	14.5	13.6	12.6	+0.0
12 Nov 81	14.4	13.5	12.5	+0.1
13 Nov 81	14.4	13.4	12.4	+0.2

CARLIN

Sample Designation	Site Name	Location	TEMP °C	pH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Al^{+++}	Fe	Li^{+}	$CO_3^{=}$	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	F^{-}	$NO_3^{=}$	B	SiO_2	Comments
CFC-1	Long John Warm Spring	SW/4 Sec 5 T32N R52E	22.5	7.7	42.0	9.6	28.	10.0	< 0.1	0.39	< 0.01	0	178.4	40.	17.0	0.54	8.9	0.06	68	Issues from culvert in rhyolite, flow est. ≈300 GPM
CFC-2	S.P. Spring	SW/4 Sec 28 T33N R52E	≈10.0	7.5	48.0	12.1	28.	9.7	< 0.1	0.14	< 0.01	0	196.6	46.	15.9	0.42	21.3	0.08	55.	In Situ Temp. not possible Near City Well
CFC-3	Rye Patch Spring	NE/4 NW4 Sec 12 T32N R52E	13.0	7.6	81.0	40.0	37.	5.5	< 0.1	0.01	< 0.01	0	321.4	146.	22.7	0.55	9.8	0.12	19.	Sampled from pipe, flow est. ≈2 GPM
CFC-4	Barrow's Well	SW/4 Sec 33 T33N R52E	79.0	6.9	57.0	12.8	55.	18.0	< 0.1	0.21	0.32	0	311.8	58.	11.7	1.2	< 0.4	0.25	69.	Pumped at 40 GPM
CFC-5	Dry Susie Hot Springs	NW/4 Sec 8 T33N R53E	65.0	7.6	13.0	5.6	240.	30.0	< 0.1	0.07	0.32	0	680.8	28.	9.2	2.8	< 0.4	0.27	52.	Sample taken from top of ridge, pool surrounded by wooden enclosure
CFC-6	Lower Dry Susie Spring	NW/4 SE/4 Sec 14 T33N R53E	15.0	7.7	42.0	6.2	17.	5.5	< 0.1	0.05	< 0.01	0	149.9	12.	10.3	0.40	33.2	0.04	53.	Collected near outflow point
CFC-7	Humboldt River	SW/4 Sec 33 T33N R52E	18.5	7.9	52.5	14.8	50.	11.5	< 0.1	0.11	< 0.01	0	295.4	46.	19.1	0.70	4.4	0.10	35.	Collected ≈100 m downstream from last hot spring in River Channel
CFC-8	Carlin Hot Springs	SE/4 Sec 33 T33N R53E	82.0	7.3	57.0	13.4	56.	18.0	< 0.1	0.12	0.34	0	335.2	56.	10.6	1.5	< 0.4	0.36	68.	Hottest springs in River Channel
CFC-9	Carlin Hot Springs	SE/4 Sec 33 T33N R53E	49.0	6.9	67.0	14.8	56.	18.8	< 0.1	0.12	0.37	0	335.2	66.	12.0	1.5	15.1	0.31	64.	Approx. 40 m south of River, much gas evolving
CFC-10	Humboldt River	SE/4 Sec 33 T33N R53E	12.0	8.2	49.0	15.6	51.	10.8	< 0.1	0.12	< 0.01	20.5	221.8	48.	20.9	0.67	26.6	0.16	29.	Collected 300 m upstream from hot spring area
CFC-11	Cherry Spring	SE/4 Sec 21 T33N R51E	-	7.3	83.0	30.0	9.	2.9	< 0.1	0.14	< 0.01	0	356.9	48.	5.3	0.50	< 0.4	<0.01	14.	
CFC-12	Maggie Creek	SW/4 Sec 15	-	7.6	41.5	14.8	30.0	10.7	< 0.1	0.05	0.05	0	207.9	44.	15.9	0.68	1.8	<0.01	51.	

Table B2. Bulk fluid composition for Carlin.

Sample site locations are shown in Figure B9, with equivalent weight percents for major anion and cation constituents shown graphically (modified after Stiff, 1953). These symbols permit comparative analyses of bulk chemical constituents of the fluid samples on a regional basis. The data show the areal extent of both thermal and non-thermal fluids that are compositionally similar to Carlin Hot Springs (samples 8 and 9). Dry Susie Creek Hot Spring, Cherry Spring, and Rye Patch Spring (samples 5, 11, and 3, respectively) are chemically different from the Carlin-type waters and are quickly distinguished on the basis of the shape of their respective symbols.

An alternative to the use of modified Stiff diagrams is the use of Piper diagrams (Piper, 1944) (fig. B10). Equivalent weight percent data are used in these trilinear diagrams to examine variations in fluid chemical composition and to possibly determine the extent of mixing. Fluid sample 10 was taken from the Humboldt River upstream from Carlin Hot Spring (sample 9). Sample 7 was taken from the Humboldt River downstream of Carlin Hot Springs and is compositionally intermediate between samples 9 and 10. These data clearly illustrate that Humboldt River waters are mixing with discharge from Carlin Hot Springs, resulting in a significant change in chemical composition of the river waters. In addition to chemical changes, the temperature of the river water increased 6.5°C (11.7°F), indicating that a significant amount of heat has been added to the river. The zone of influence of these fluids extends 5.5 km (3.5 mi.) to the north where compositionally similar fluids were taken from a domestic water well (sample 12). Mixing throughout the Carlin area appears to be variable and widespread.

Fluid sample 5 was taken from Dry Susie Creek Hot Spring, 11 km (7 mi.) northeast of Carlin. This spring is chemically dissimilar to any other fluid and probably represents thermal waters from a distinct hydrothermal circulation

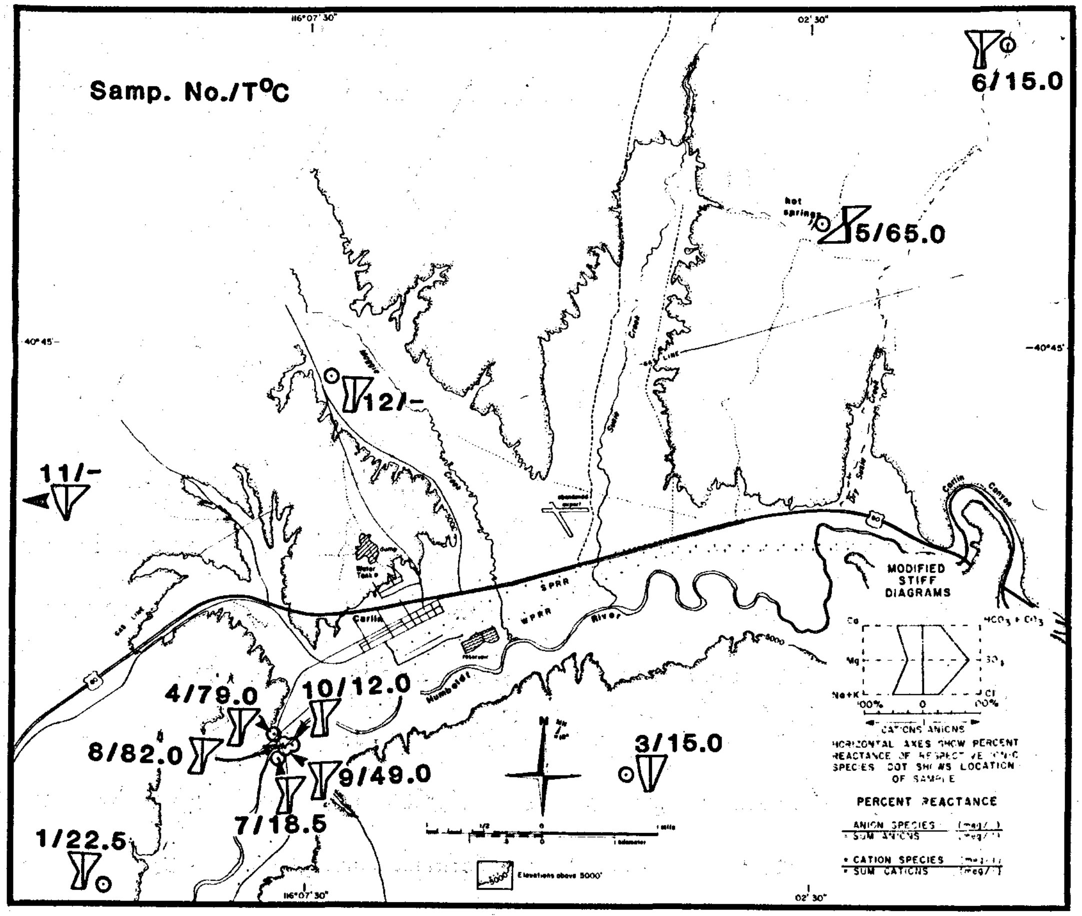
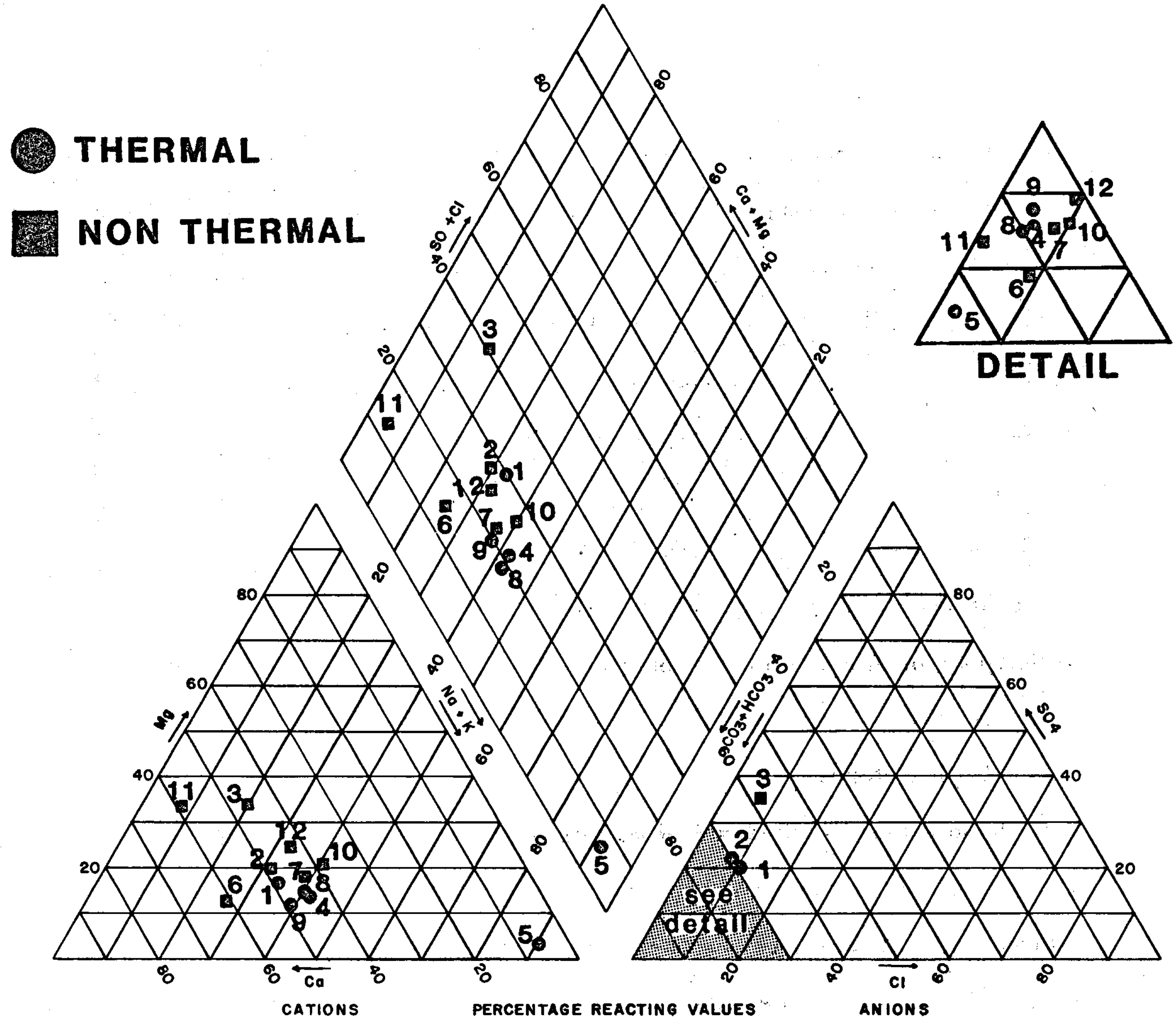


Figure B9. Modified Stiff diagrams for Carlin study area.



● 1. LONG JOHN WARM SPRING

■ 2. S.P. SPRING

■ 3. RYE PATCH SPRING

● 4. BARROWS WELL

● 5. DRY SUSIE HOT SPRINGS

■ 6. LOWER DRY SUSIE SPRING

■ 7. HUMBOLDT R. DOWNSTREAM

● 8. CARLIN HOT SPRINGS 82°C

● 9. CARLIN HOT SPRINGS 49°C

■ 10. HUMBOLDT R. UPSTREAM

■ 11. CHERRY SPRING

■ 12. MAGGIE CREEK RANCH WELL

Figure B10. Trilinear plot of fluid samples from Carlin.

system. The absence of nearby compositionally similar fluids suggests that there is very little mixing of surface waters associated with this spring.

Non-thermal fluid samples 3 and 11 are beyond the zone of influence of Carlin Hot Springs as illustrated in Figures B9 and B10. These samples represent waters enriched in calcium, magnesium and bicarbonate and were probably considerably influenced by Paleozoic carbonate rocks.

Estimates of total dissolved solids (TDS) illustrate the differences between Carlin thermal fluids and those from Dry Susie Creek Hot Springs. The TDS for Carlin fluids range from 400 to 600 ppm. For Dry Susie Creek Hot Spring the TDS is 1100 ppm; bicarbonate ions account for nearly 65% of the TDS.

Stable Light Isotopes

In addition to bulk chemical analyses, samples were collected for analyses of deuterium and ^{18}O. These data are used in conjunction with bulk chemical data to further examine similarities among thermal fluids and to ascertain the degree of mixing of thermal and non-thermal fluids. Table B3 lists the values of stable light isotopes collected in Carlin.

These isotope values are graphically illustrated in Figure B11. This figure is based on work by Craig (1963) and is a convenient way to depict the isotopic composition of fluid samples relative to a worldwide sampling of meteoric waters (represented by the straight, sloping line). The values in this diagram represent per mil differences between fluid samples and a standard water (SMOW - standard mean ocean water).

Fluid samples from Carlin are displaced below the Craig (1963) worldwide meteoric water line by approximately 10 per mil (10 0/00). This indicates that the Carlin waters are isotopically lighter than the average meteoric water. Two

Sample Number	δD 0/00	$\delta^{18}O$/0/00
CFC 1	-135	-15.9
CFC 2	-130	-15.4
CFC 3	-129	-15.4
CFC 4	-131	-15.9
CFC 5	-137	-17.2
CFC 6	-128	-15.5
CFC 7	-120	-14.7
CFC 8	-132	-15.9
CFC 9	-125	-15.6
CFC 10	-117	-14.3
CFC 11	-126	-16.0
CFC 12	-129	-15.6

Table B3. Hydrogen and Oxygen Stable Isotope Analyses for Samples from Carlin

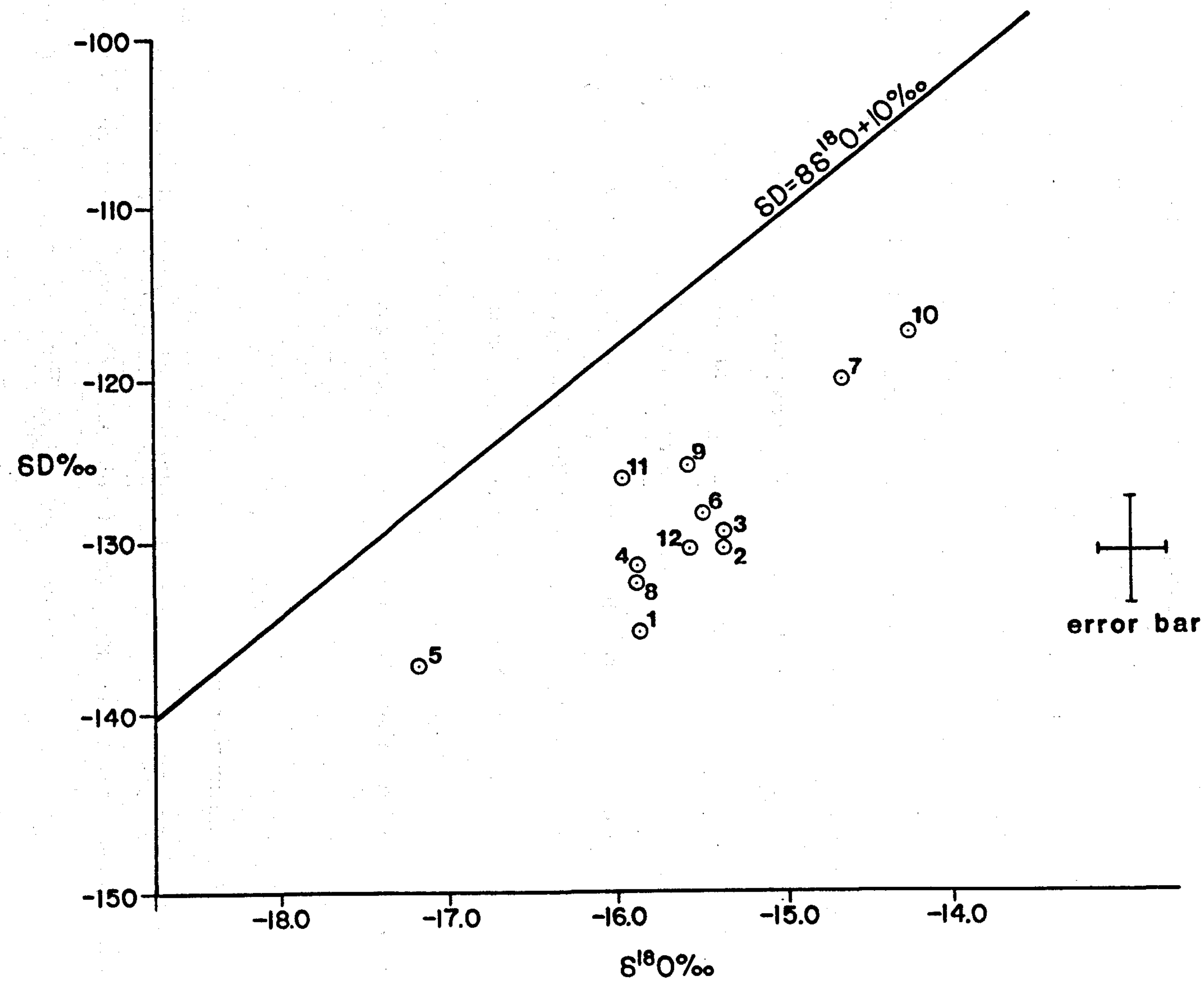


Figure B11. Stable light isotope composition of Carlin waters. Worldwide meteoric water line after Craig (1963).

factors that increase the proportion of lighter isotopes are precipitation at relatively high elevations, and precipitation inland from a coastal area. Both of these factors are operative in Carlin and probably account for this shift.

The isotopically heaviest waters in Carlin are samples CFC 7 and 10; both were obtained from the Humboldt River. Both samples represent isotopic fractionation by evaporation. In this process, surface waters that are subjected to continued evaporation are rendered "heavy" by the evaporative removal of a greater proportion of lighter isotopes. Sample CFC 7, which is isotopically lighter than CFC 10, represents mixing with Carlin thermal fluids. This mixing was also illustrated by the bulk fluid chemistry.

All of the other Carlin fluids, with the exception of sample CFC 5, form a tight group and, if analytical errors are considered, are nearly indistinguishable from one another. Thermal fluids appear to be generally lighter than non-thermal fluids, possibly indicating a recharge from a somewhat higher elevation. Previous studies (Koenig in Trexler and others, 1981) have shown that meteoric waters undergo rapid changes in isotopic composition with moderate changes in elevation. Sample CFC 5 shows no isotopic similarity to any other fluid. The fact that it is considerably lighter than the other samples suggests recharge at much higher elevations.

Chemical Geothermometers

Both silica and cation chemical geothermometers were calculated for five thermal fluids in the Carlin study area (table B4). The six temperature estimates are presented for comparative purposes only. More extensive thermodynamic calculations should be completed to establish dissolved species stabilities for these fluids.

Table B4.

CARLIN

CHEMICAL GEOTHERMOMETERS

SAMPLE DESIGNATION	MEASURED TEMP. °C	QUARTZ NO STEAM LOSS	QUARTZ MAXIMUM STEAM LOSS	CHALCEDONY	AMORPHOUS SILICA	Na-K-Ca	Na-K-Ca WITH Mg CORRECTION
CFC-1	22.5	116.7	115.4	88.0	-1.1	68.8	68.8
CFC-4	79.0	117.5	116.0	88.8	-0.5	88.7	86.7
CFC-5	65.0	103.6	104.1	73.9	-12.5	204.0	72.0
CFC-8	82.0	116.7	115.4	88.0	-1.1	88.9	83.9
CFC-9	49.0	113.7	112.8	84.7	-3.8	86.7	78.7

Quartz geothermometers are commonly used to determine subsurface temperatures at high-temperature (7200°C) geothermal systems. For fluids with temperatures less than 80°C, the quartz geothermometer temperature estimates are generally higher than actual measured temperatures. This appears to be the case for Carlin fluids and probably indicates that the fluids are not in equilibrium with respect to quartz. The values for amorphous silica are also inconsistent with measured temperature values and are not considered in this discussion.

The chalcedony and magnesium-corrected cation geothermometers agree very well with measured temperatures and probably accurately represent the highest expected temperatures in this area. The calculated data show that the Carlin thermal fluids are the hottest in the area and temperatures as high as 90°C may be encountered in the near subsurface.

Shallow-Depth Temperature Gradients

The locations of the three shallow-depth temperature gradient holes in Carlin are shown in Figure B12. These holes were allowed to equilibrate for three to four weeks before the temperature gradients were measured. Lithologic logs of these holes were completed during this time and are illustrated in Figures B13 through B15. The lithologies encountered in these three holes were all very similar and probably represent various depositional facies of the Humboldt Formation.

The temperature-depth profiles (fig. B16) for the Carlin drill holes are similar to PVHT 1, 2, and 4 in Pumpernickel Valley. With the exception of the very small increase in temperature in CHT-3, there is no indication of a significant source of near-surface heat at these sites. Temperature gradients calculated for the bottom 10 m (30 ft.) of each hole are listed in Table B5.

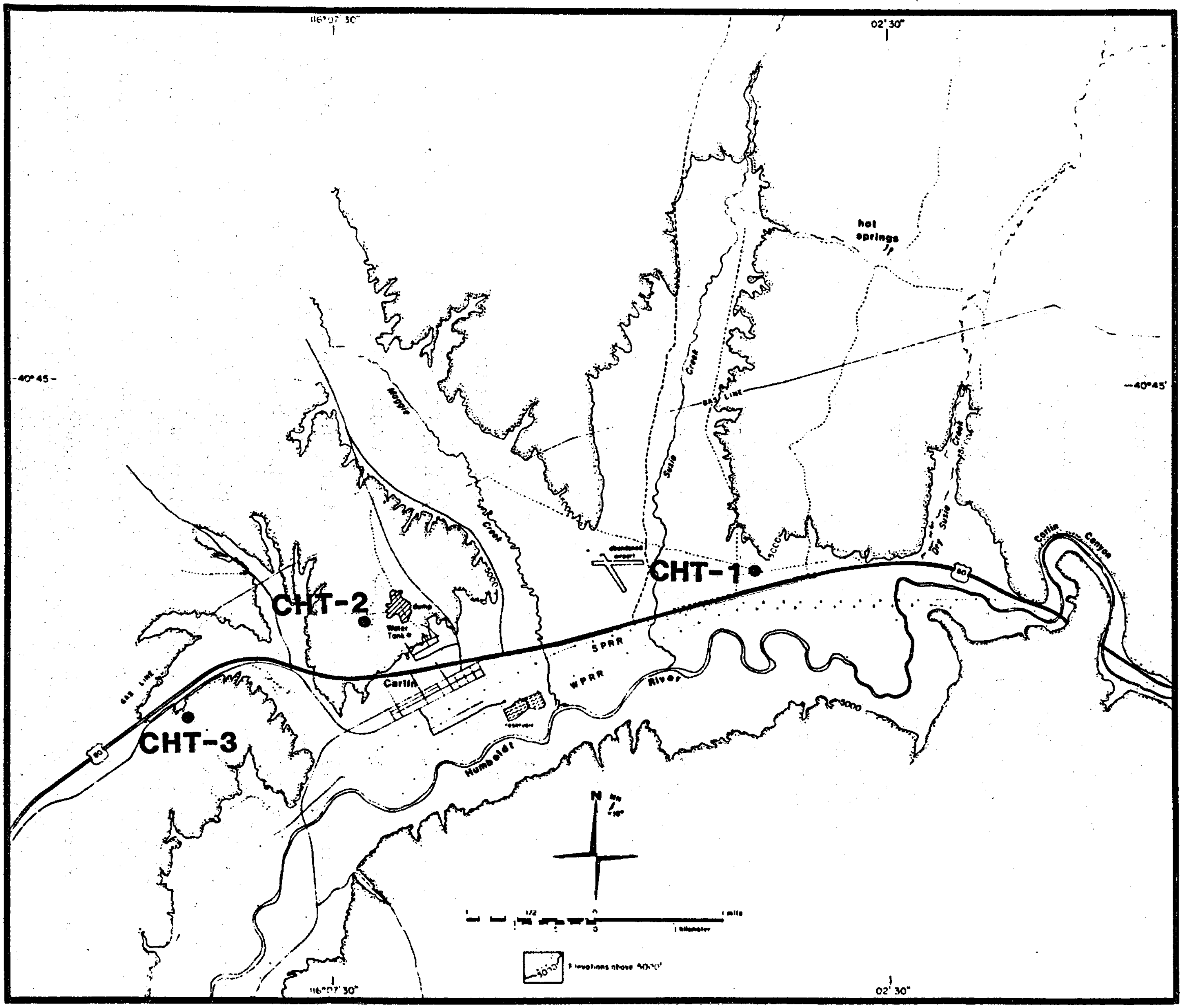


Figure B12. Location of shallow-depth temperatures gradient holes at Carlin.

CHT-1

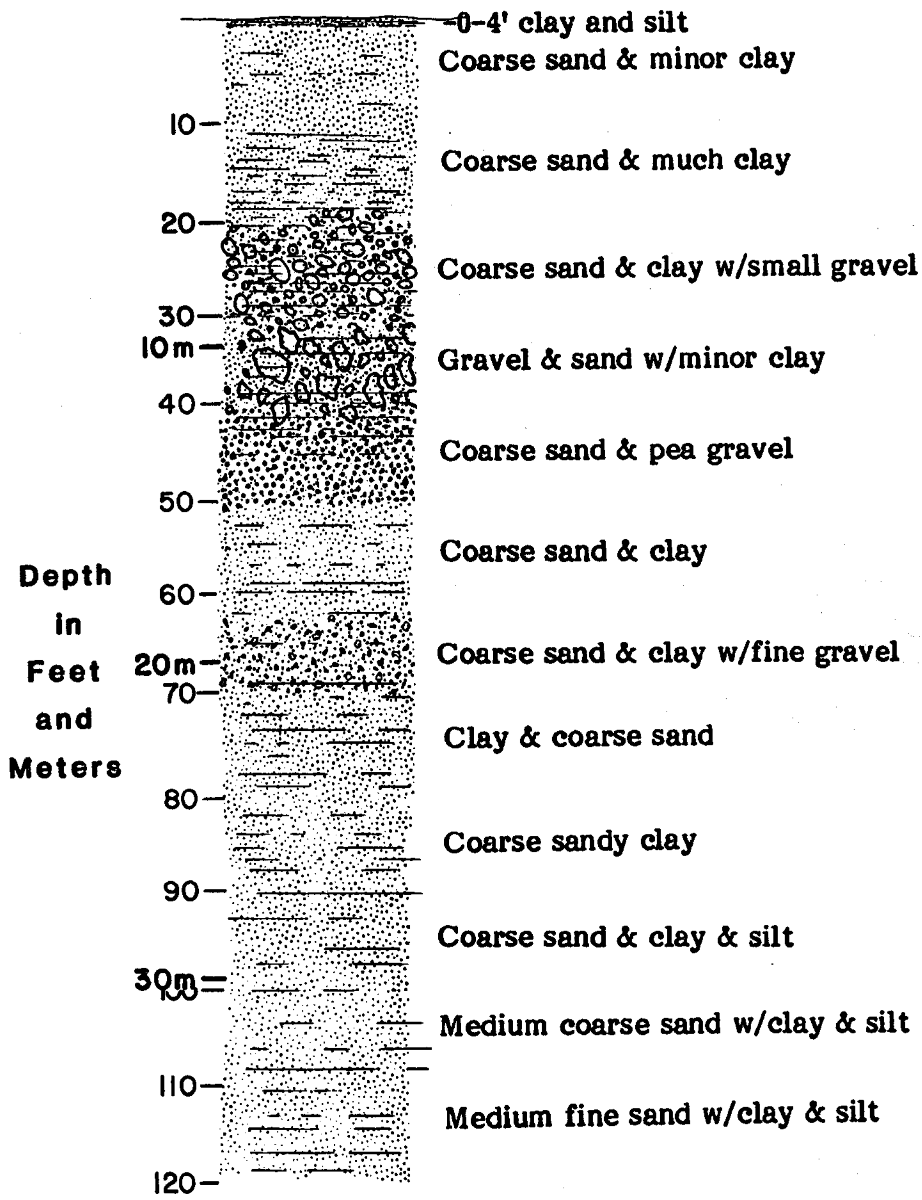


Figure B13. Lithologic log of CHT-1 at Carlin.

CHT-2

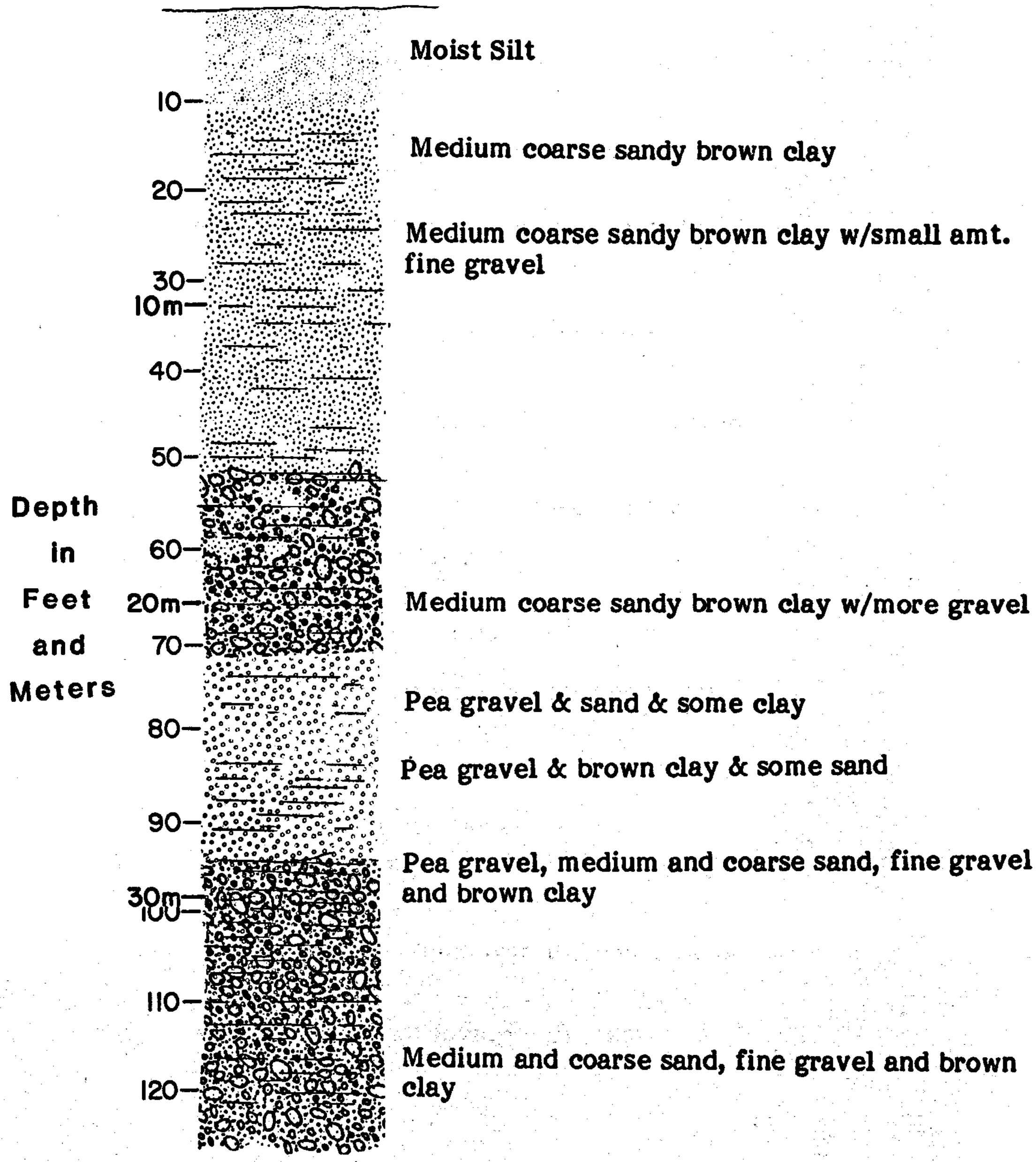


Figure B14. Lithologic log of CHT-2 at Carlin.

CHT-3

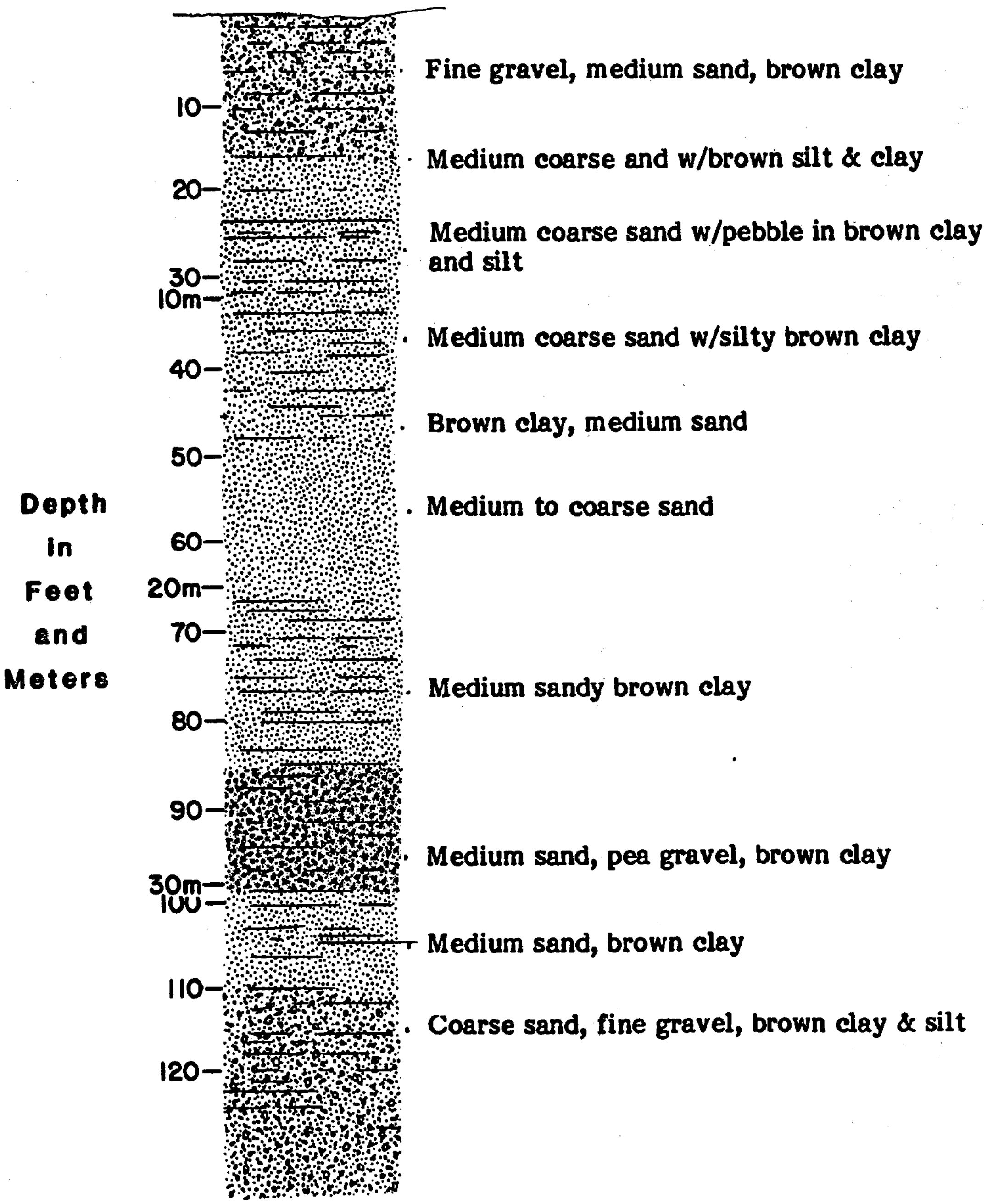


Figure B15. Lithologic log of CHT-3 at Carlin.

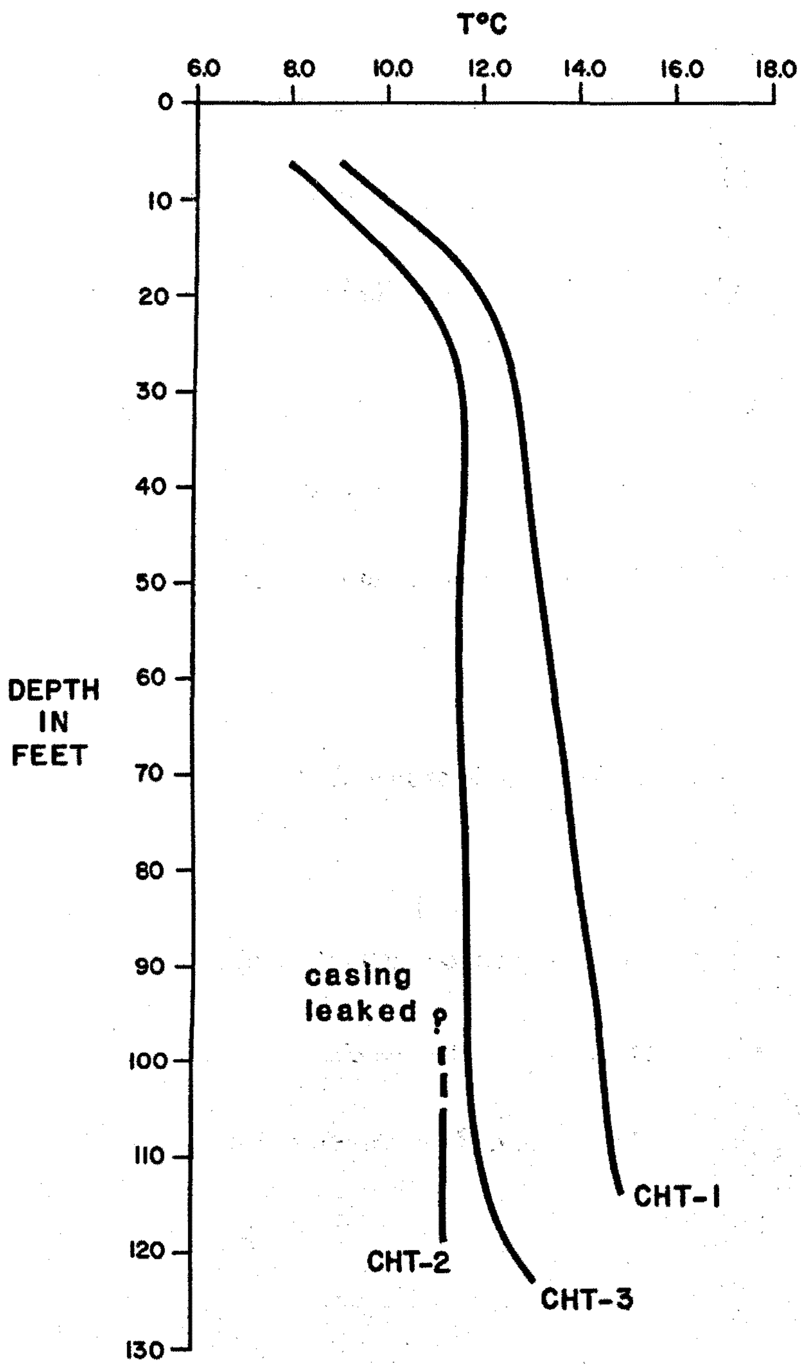


Figure B16. Temperature-depth profiles of CHT-1, 2 and 3 at Carlin; profiles measured on 7 February, 1982.

Table B5

Carlin Temperature Gradients

HOLE	GRADIENT °C/Km
CHT-1	100
CHT-2	insufficient data
CHT-3	110

MOANA GEOTHERMAL AREA

Introduction

The Moana area, located in southwest Reno, is one of four geothermal resources in the Truckee Meadows. The Truckee Meadows is a structural basin bounded on the east by the Virginia Range and on the west by the Carson Range, a spur of the Sierra Nevada Mountains, Figure C1. The other three areas are: Steamboat Hot Springs, a highly studied resource located at the south end of the basin, with reported temperatures in excess of 200°C (400°F) at a depth of 900 m (3000 ft.); Lawton Hot Spring, located at the northwestern edge of the meadows with temperatures of 60°C (140°F) at depths of 30 meters (100 ft.); and the Wedekind Mining District, located along the north edge of the basin, where hot water was reported in mine shafts a a depth of 65 m (2.5 ft.).

The Moana geothermal area covers approximately 10 square kilometers (4 sq. mi.) in Sections 22 through 27, T19N, R19E. Moana Hot Springs, the only known surface expression of thermal fluids, ceased to flow several years ago. This was reportedly due to a practice known as "pump and dump" in which thermal fluids are pumped out of a well, circulated through a heating system, and dumped into a sewage line. This practice remains in widespread use.

As part of the U.S. Department of Energy state-coupled geothermal resource assessment program, the Division of Earth Sciences was funded to gather information on this extensively used resource. The data set for Moana includes the number and location of wells in the resource area, depth to resource, and temperatures of fluids. In addition, four wells were selected to monitor variations in water chemistry and temperature over a period of one year.

Previous studies of the Moana geothermal area include Bateman and Scheibach (1975) and Garside and Schilling (1979). Both studies presented water

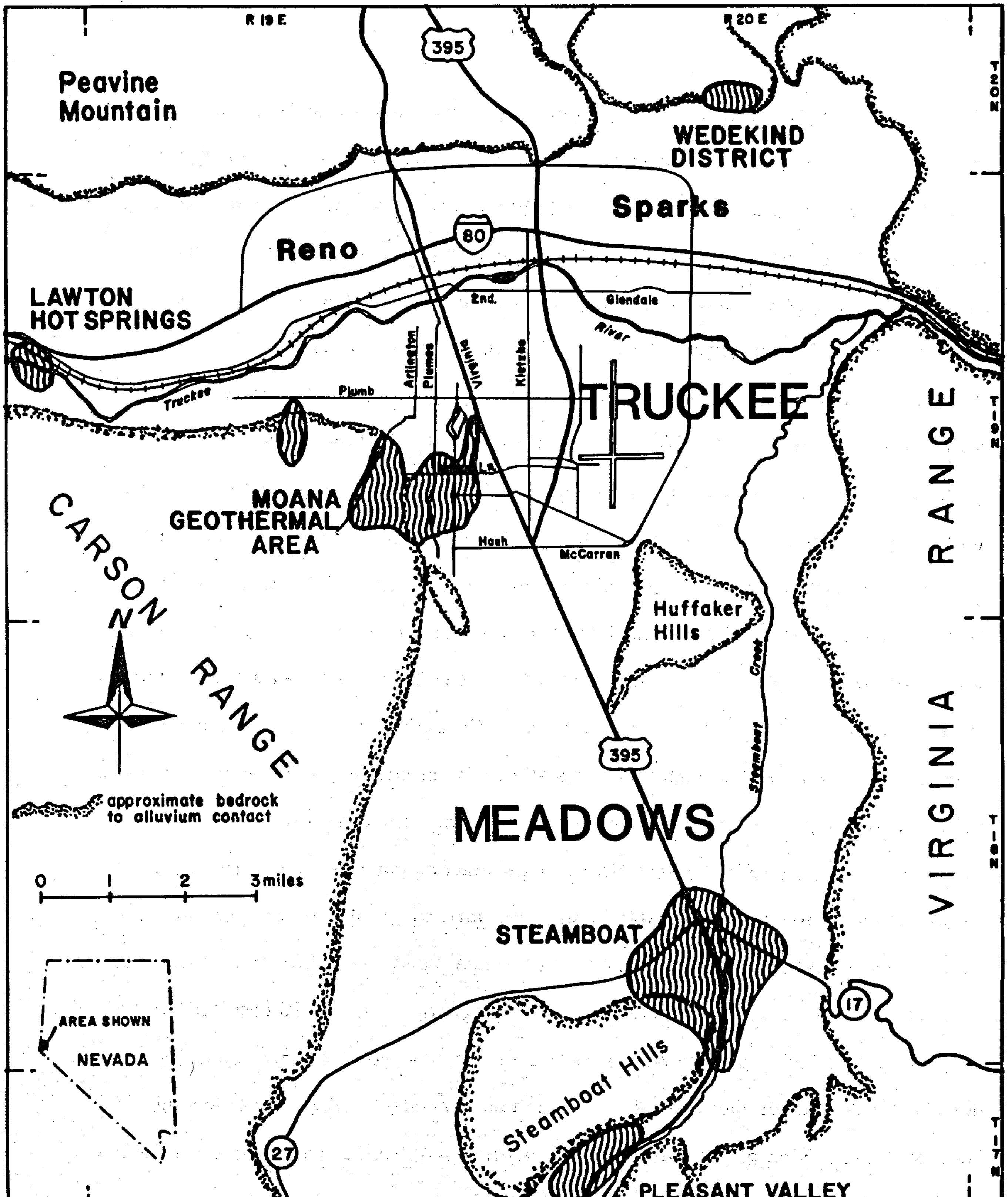


Figure C1. Location of the Moana geothermal area and other geothermal resources in the Truckee Meadows basin (modified from Bateman and Scheiback, 1975).

temperature and chemical data, as well as a brief discussion of geology and present uses of the resource. Additional temperature, water chemistry, and lithologic data were obtained from the Office of the State Engineer. Data gathered from contact with area homeowners and some water well drillers are also included in this file. This study contains temperature, location, and well depth data for more than 100 wells, including 17 temperature-depth profiles (fig. C2 through C6).

Resource utilization in Moana is limited to commercial and residential space heating. A typical design includes a copper-tube heat exchanger which is installed in the well bore. Cold water is pumped down one leg of the tube, is heated by the geothermal fluids in the well bore, and is circulated in radiators or forced-air heaters located within the buildings. In some wells, typically those with temperatures greater than 65°C (150°F) heat transfer within the well bore is sufficient to meet the heating load demands of the homes in Moana. Wells with temperatures less than 65°C require a draw-off pump to stimulate circulation within the well bore. Pumps are generally thermostatically controlled and are designed to pump some of the heat-depleted fluids from the well. The draw-off fluids are pumped into either existing sewage lines or leach pits, and are replaced by hotter formation fluids. Pumping continues until the well base temperature has been raised enough to meet the demands of the heat-load.

During this study, sustained pumping of geothermal fluids resulted in an apparent reduction in the artesian pressure of the reservoir. Several homeowners noted a substantial temperature decrease and one artesian well stopped flowing. It is clear that widespread pumping of geothermal fluids has already had a detrimental effect on the resource.

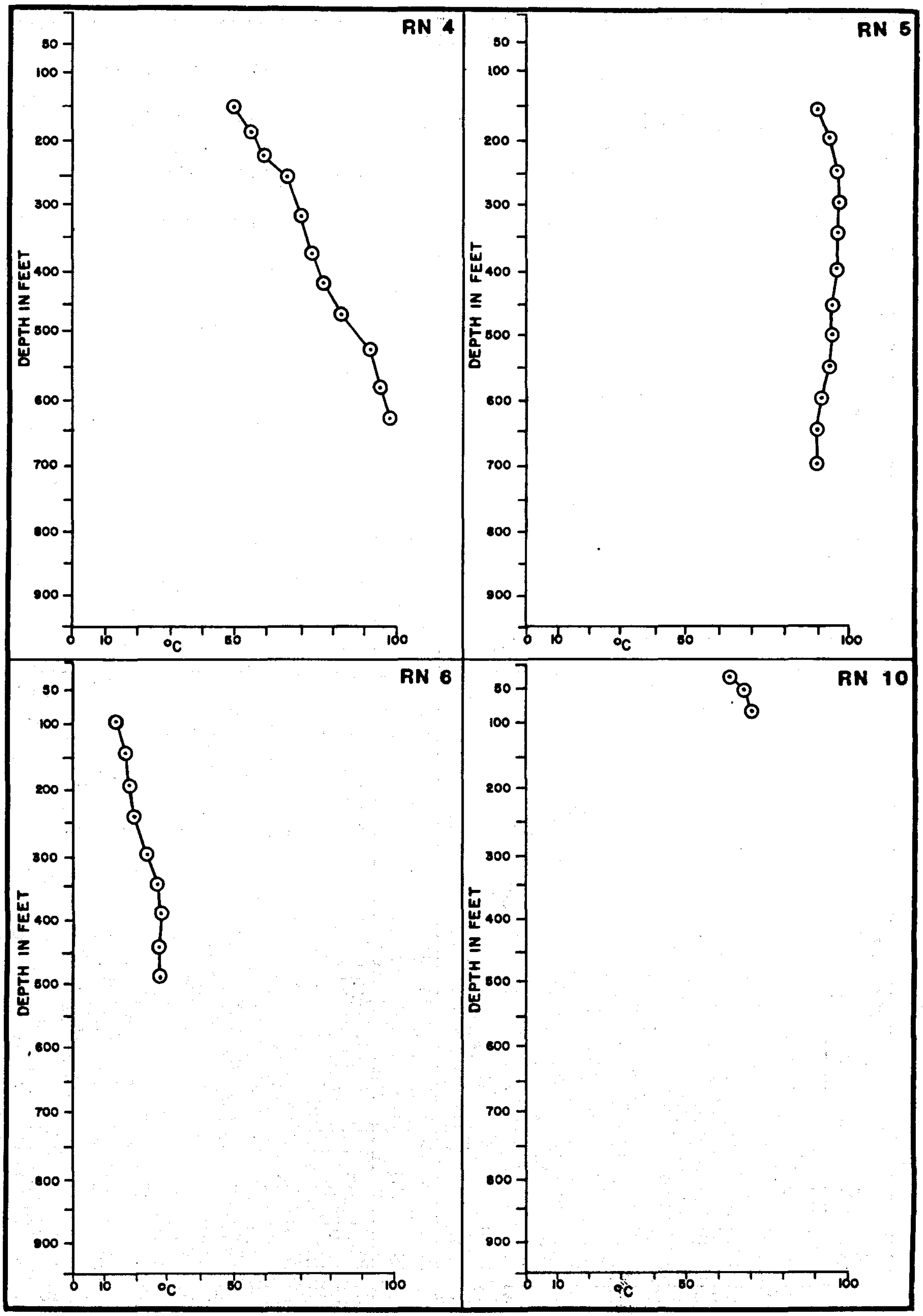


Figure C2. Temperature-depth profiles of wells RN 4, 5, 6, and 10 in Moana geothermal area.

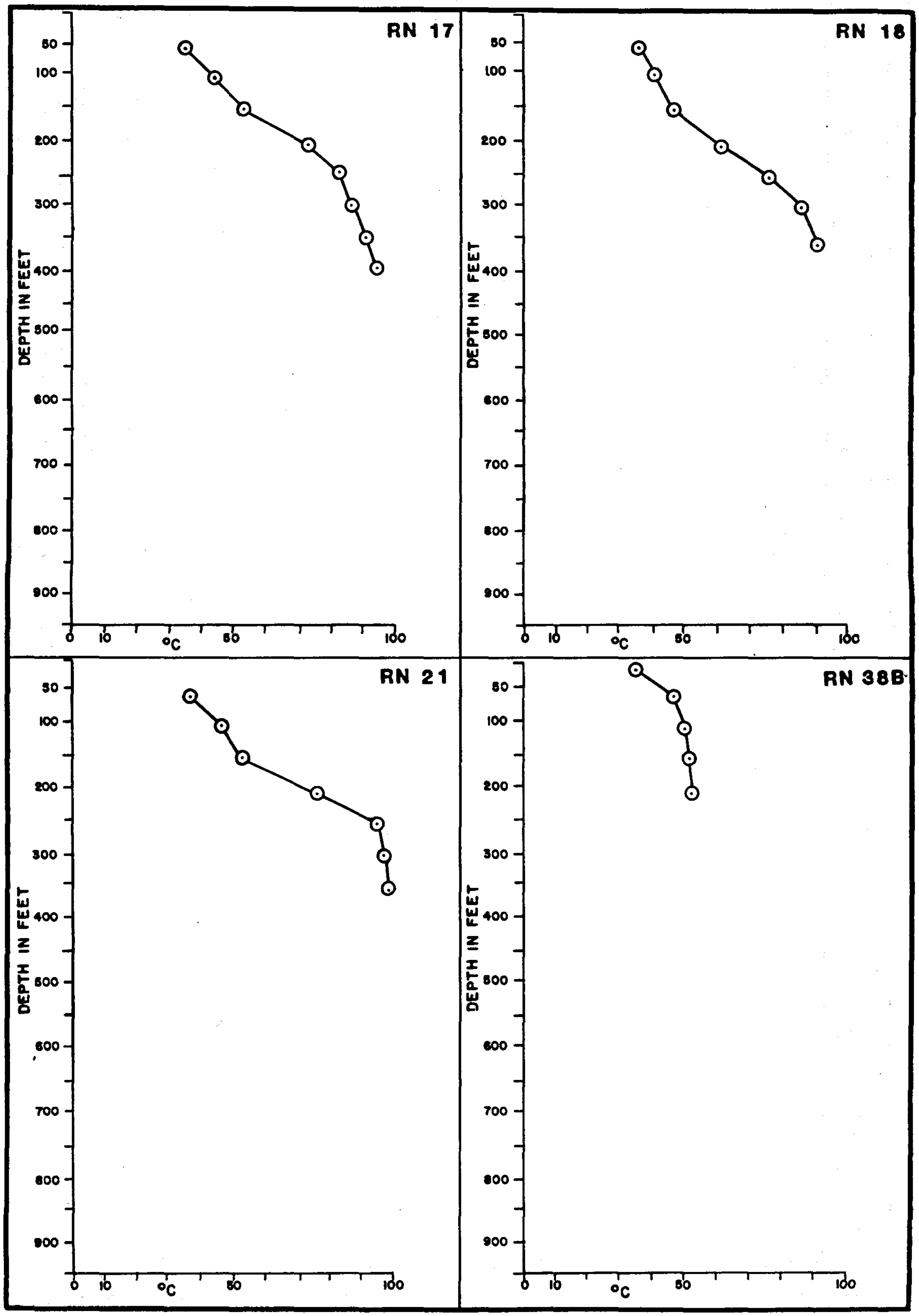


Figure C3. Temperature-depth profiles of wells RN 17, 18, 21, and 38B in Moana geothermal area.

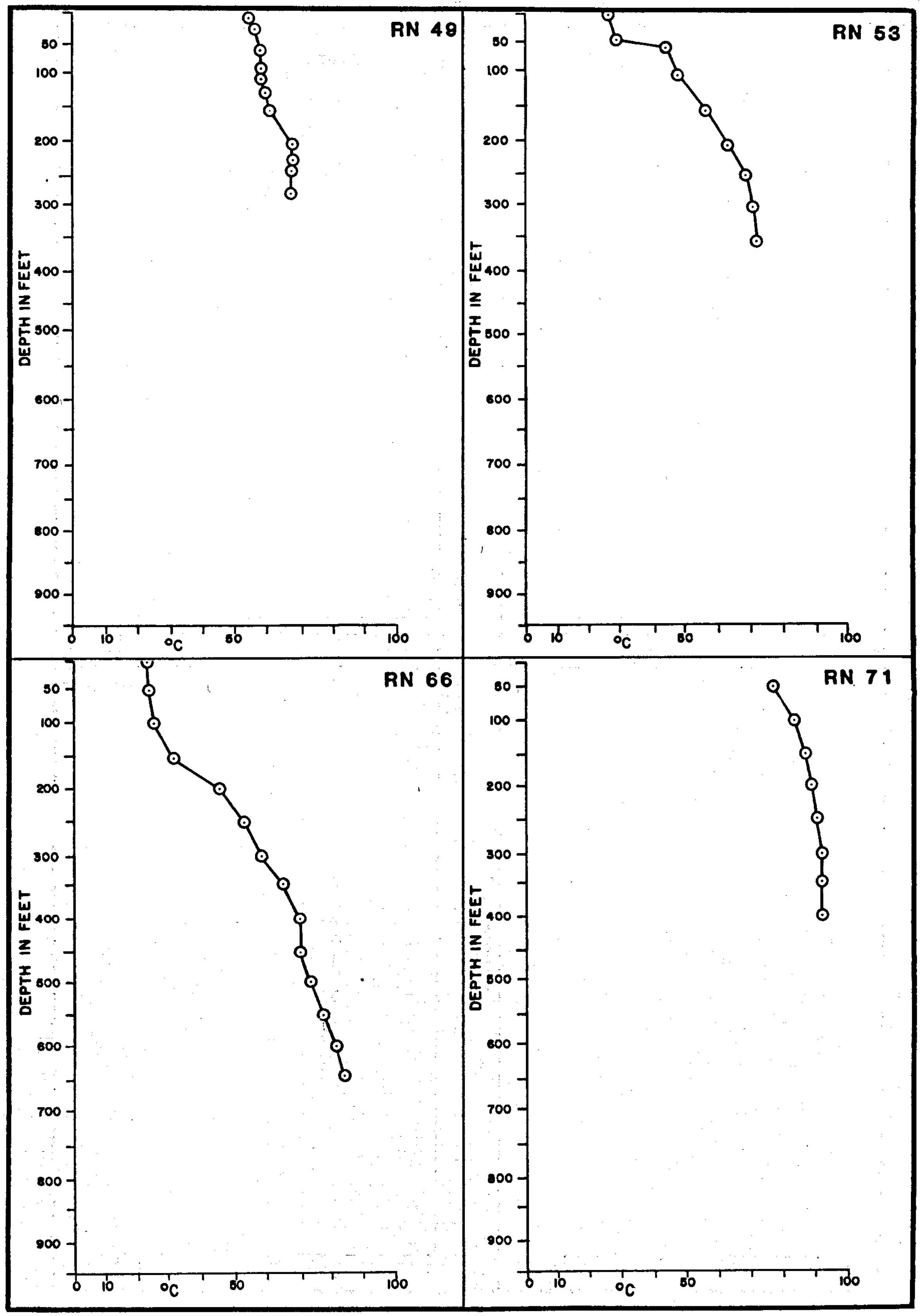


Figure C4. Temperature-depth profiles of wells RN 49, 53, 66, and 71 in Moana geothermal area.

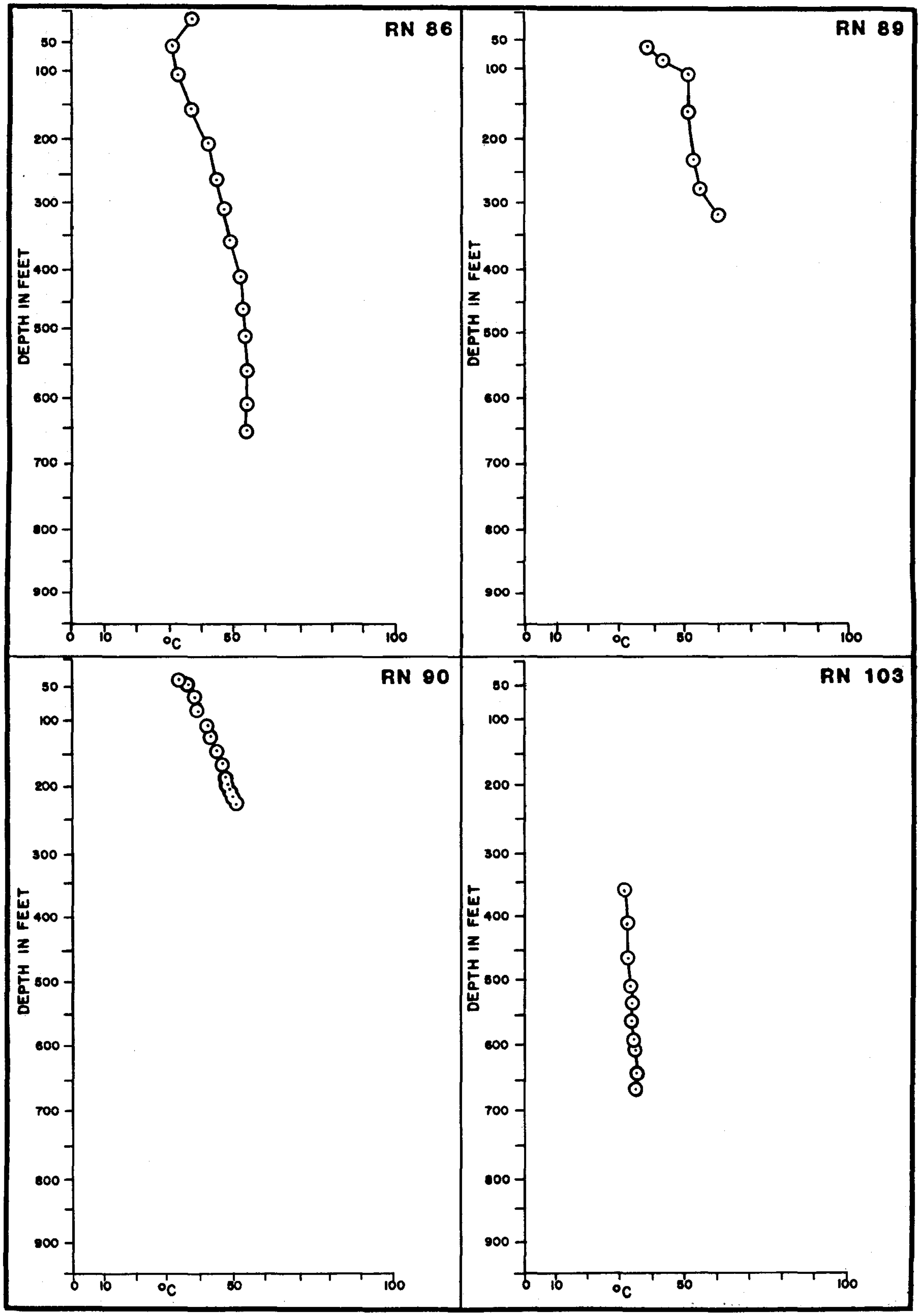


Figure C5. Temperature-depth profiles of wells RN 86, 89, 90, and 103 in Moana geothermal area.

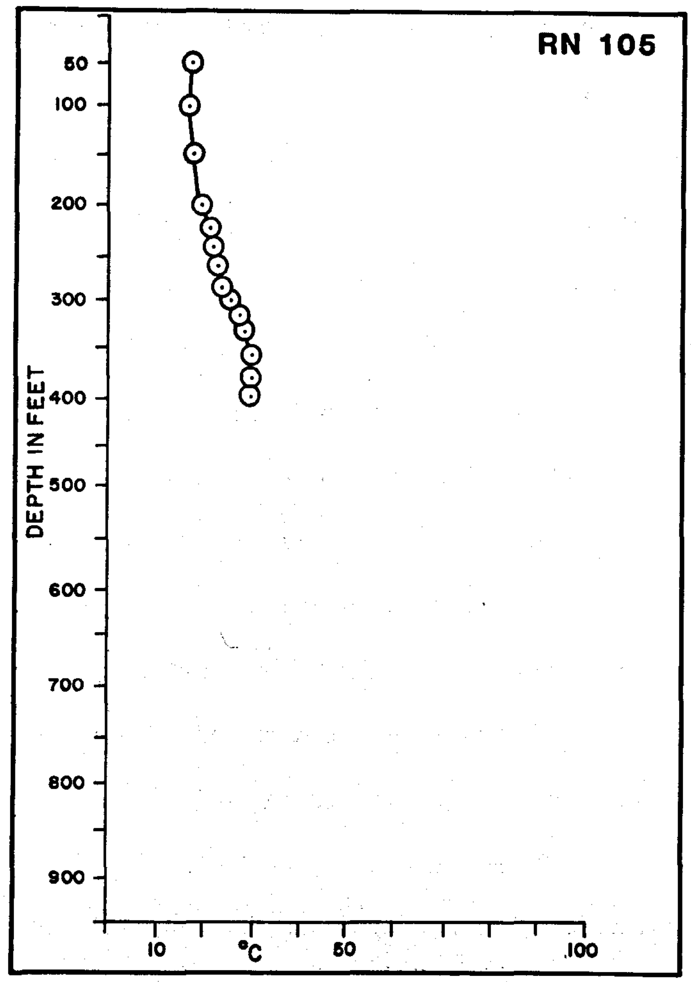


Figure C6. Temperature-depth profile of well RN 105 in Moana geothermal area.

Geology

The Moana area is located along the western edge of the Truckee Meadows, a structurally controlled basin, and is characterized by Tertiary volcanic and sedimentary rocks overlain by Quaternary glacial outwash and alluvium. Numerous normal faults, some with antithetic movement, offset Tertiary units and a few cut Quaternary outwash deposits.

The oldest rocks in the area are andesite flows and flow beccias of the Kate Peak Formation. Sedimentary rocks of Tertiary age unconformably overlie the volcanic rocks and consist of three mapable units comprising the Sandstone of Hunter Creek (Bingler, 1975). The basal unit is a poorly bedded coarse sand and angular pebble gravel composed of detritus from the underlying Kate Peak Formation. The middle and thickest member is a gray-white diatomaceous siltstone which when wet appears bluish in color and is noted as "blue clay" in drillers logs. The diatomaceous siltstone grades upward to a well-sorted, well-rounded, locally crossbedded sand and gravel. The Sandstone of Hunter Creek is exposed along the Carson Range and dips to the east under the Moana area.

Quaternary units include glacial outwash of Illinoian and Wisconsinan age, Pleistocene alluvium and pediment gravels and Holocene fluvial and alluvial deposits (Bingler, 1975; Trexler, 1976). These units are thin and overlie the Tertiary volcanic and sedimentary rocks.

Normal faulting, associated with the uplift of the Carson Range to the west, has complicated the relationships between the Tertiary and Quaternary units. Splays of the major frontal fault offset all units except Holocene deposits. Some faults indicate an antithetic sense of movement relative to the major range bounding fault. This type of movement has produced a series of horsts and grabens throughout the Moana area.

Figure C7 illustrates the two major structural trends in the Moana area: a series of north-south trending subparallel faults and another set of northeast trending faults. In the northeastern portion of the area these faults form a graben now occupied by Virginia Lake. Along the eastern boundary of the area the sense of movement is antithetic and juxtaposes older Donner Lake outwash with younger alluvium.

Interpretation of black and white aerial photography dating from 1931 indicates the presence of tonal lineaments which trend east-west and northwest. These lineaments have not been confirmed as faults by geologic mapping; however, in many instances they are coincident with lithologic contacts.

A group of north- to northeast-trending faults extends south of Virginia Lake towards Manzanita Lane, an area with many high temperature shallow-depth wells. The concentration of wells with high temperatures in this area indicates that geothermal fluids may be fault-controlled.

Geothermal Resources

Approximately 150 residences and businesses use geothermal fluids in the Moana area for space heating and domestic hot water heating. Most of the thermal waters do not meet Public Health Service water quality standards and therefore cannot be used directly for domestic purposes. Some warm water in the northern part of the area does comply with these standards and is used directly for domestic hot water.

Data on the location, temperature, depth, and static water level have been collected for 114 wells. Figure C8 shows the location of the wells, with well numbers referring to information contained in the Appendix. Temperatures range from 26° to 97°C (79° to 205°F) with the major concentration of wells occurring in

QUATERNARY — HOLO — Alluvium (QA)

QUATERNARY — PLEISTOCENE — Tahoe Outwash (QTO): Glacial outwash of boulders to gravels and sands.

QUATERNARY — PLEISTOCENE — Donner Lake Outwash (QDO): Older glacial outwash debris with weathered horizons.

QUATERNARY — PLEISTOCENE — Pediment gravels and stream gravels (QP).

Alluvial fan deposits of Peavine Mountain (QPF).

TERTIARY — Sandstone of Hunter Creek (TH): Upper member. Interbedded gray brown to greenish gray siltstones, silty sandstones and sandy conglomerates. Middle member. Interbedded white to gray diatomaceous siltstones and sandy diatomaceous siltstones.

TERTIARY — Kate Peak Formation (TK): Gray to red-brown porphyritic andesitic flows, breccias and mudflows, undifferentiated.

Fault, ball on downthrown side. Dotted where inferred.

Lineaments and probable faults identified from [illegible] aerial photographs. Dotted were vague or inferred.

Figure C7. Generalized geologic map of the Moana area.

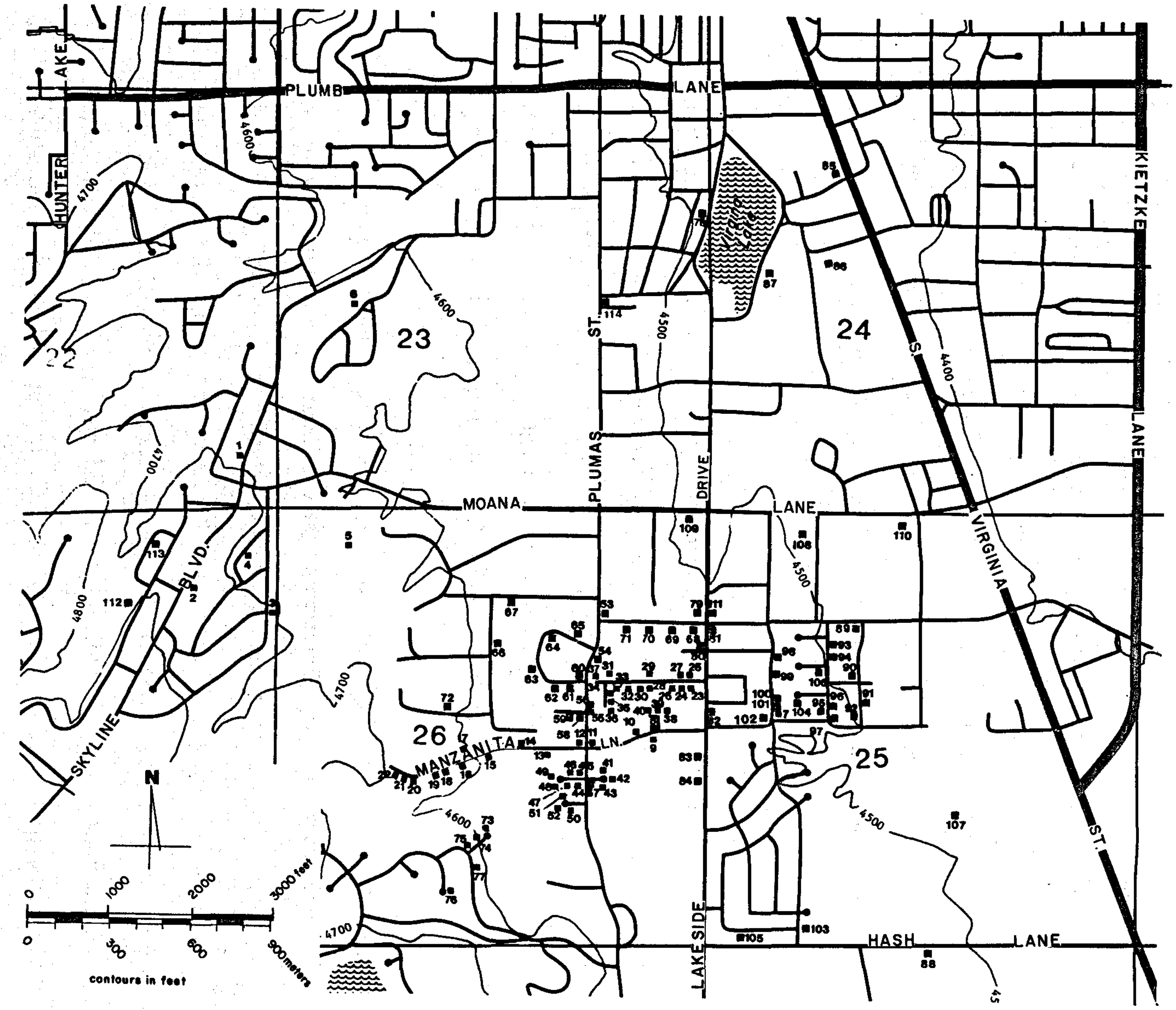


Figure C8. Location of thermal wells in the Moana area.

the Manzanita Lane, Sweetwater Drive and Plumas Street area. Thermal fluids occur near the surface at this location and some wells have artesian flow. Wells drilled outside of the area must be drilled to greater depths to reach high temperature fluids. Water temperatures in wells east of the central area are generally cooler, and may represent mixing of geothermal fluids with cold groundwater. Recent drilling west of Skyline Boulevard indicates that temperatures of 82°C (180°F) are present at depths of 260 m (850 ft.). The hot water aquifer is under artesian pressure and permeability is good.

Moana Area Water Chemistry

A water sampling program was developed for the Moana area as part of the long-term baseline data collection. Chemical analyses were performed on samples from four wells over a nine month period. The samples were taken in September, 1981, before the heating season, in January, 1982, during the time of peak load on the geothermal resource, and in May, 1982, after the major part of the heating season was over.

Chemical analyses were performed to determine if chemical variations occur in the geothermal reservoir as a function of stress (heat utilization). Sampling sites (wells) were selected at various locations within the known geothermal reservoir. Two wells (record Nos. 6 and 86) are not currently extracting geothermal heat and represent a static condition similar to conditions within the undisturbed geothermal reservoir. Well number 6 is located on the northwest edge of the Moana geothermal resource. It is 155 m (510 ft.) deep and has a temperature of 26°C (79°F). Well number 86 is located along the eastern margin of the resource and is 228 m (750 ft.) deep with a maximum temperature of 53°C (128°F).

The other two wells used in the sampling program are located near the center of the resource where high temperatures occur near the surface. Well number 57 was not sampled in September, but in November, 1981. At that time the 30 m (100 ft.) deep well produced water at approximately 5 GPM under artesian conditions. By the time the next sample was taken the well ceased to flow naturally and was being pumped to bring hot water into the well bore. The maximum measured temperature in this well was 92°C (197°F). The second well in the central portion of the Moana geothermal area was well number 10. It is also 30 m (100 ft.) deep and has a temperature of 65.8°C (140°F). The well is pumped periodically when water in the well bore cools down due to the extraction of heat.

The relative composition of the major ionic species in samples collected during the nine-month study period did not change. Figures C9, C10 and C11 and Tables C1, C2, C3, and C4 show the constituent composition of the individual analyses in parts per million. There was, however, and increase in the carbonate ion concentration in wells 6, 10, and 57, with a corresponding decrease in the bicarbonate ion concentration in wells 10 and 57. The carbonate ion concentration in well 6 increased and the bicarbonate ion concentration remained the same. This can be attributed to the increase in pH from 7.4 to 8.5 between January and May, 1982.

The major cation and anion concentrations in well 6 were 40 percent lower during the January sampling that the samples taken in Septemper, 1981, and May, 1982. This decrease in total ionic concentrations is probably the result of dilution by rain water during the winter months. The casing for the well is below grade and is located in a paved driveway at the residence. Precipitation would tend to drain to the casing and infiltrate along the outside of the casing and mix with the natural groundwaters. Water level measurements were not taken during sampling to substantiate the influx of rain water into the well bore. However, the relative ionic composition of the waters did not change suggesting some type of dilution.

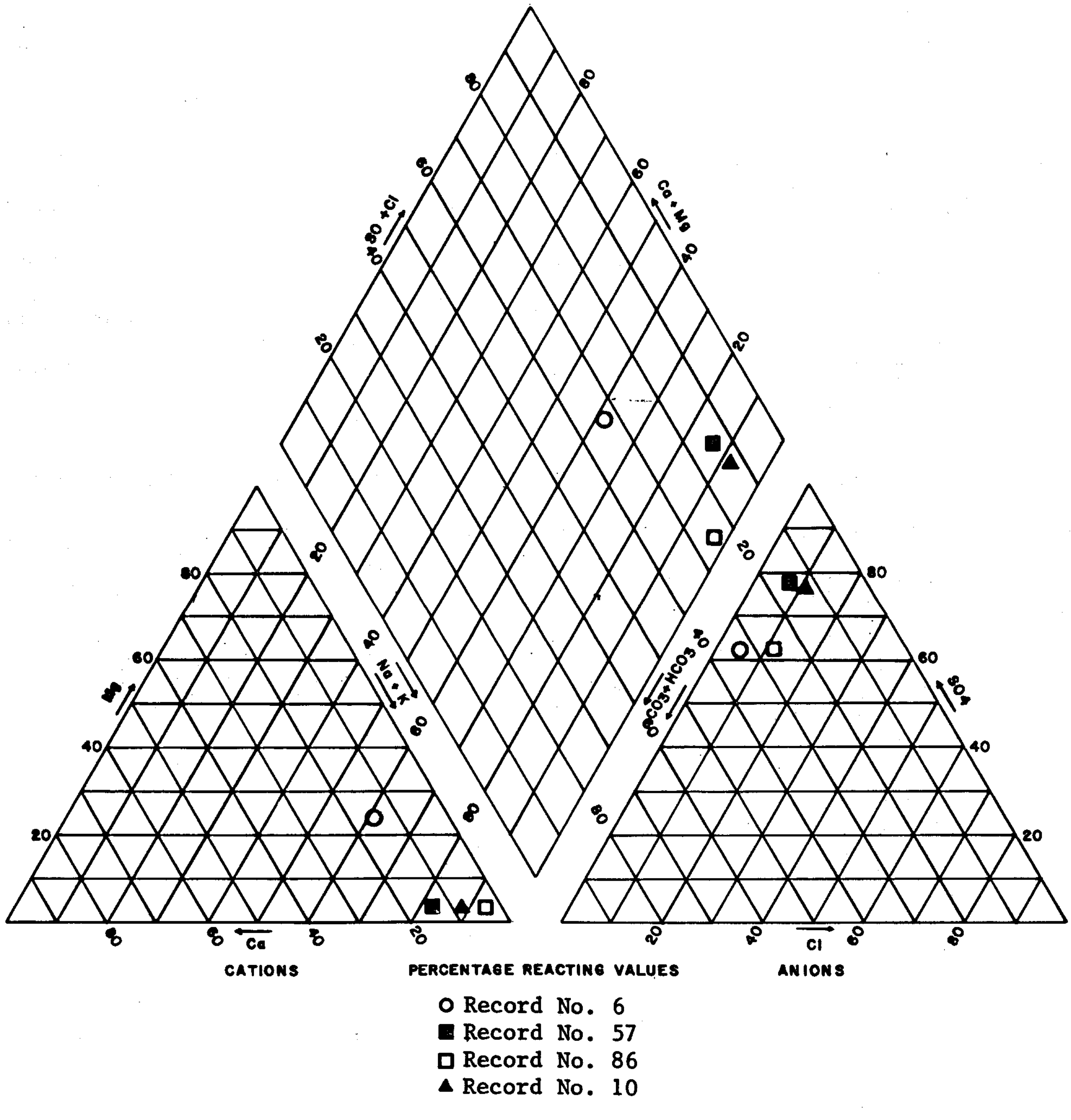


Figure C9. Trilinear plot of major ionic species in wells 6, 57, 86, and 10 for samples collected in Moana area in September, 1981.

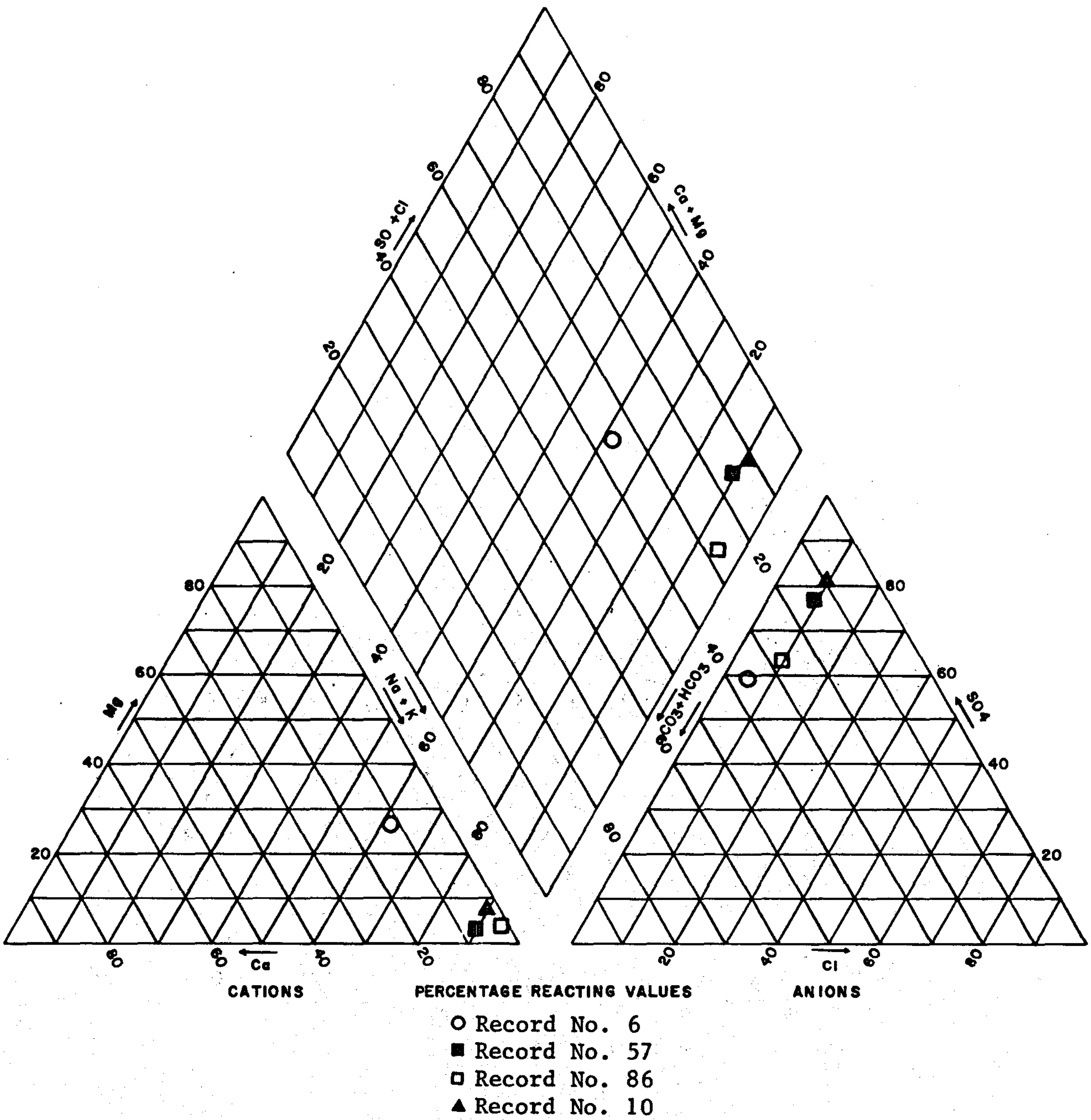


Figure C10. Trilinear plot of major ionic species in wells 6, 57, 86, and 10 for samples collected in Moana area in January, 1982.

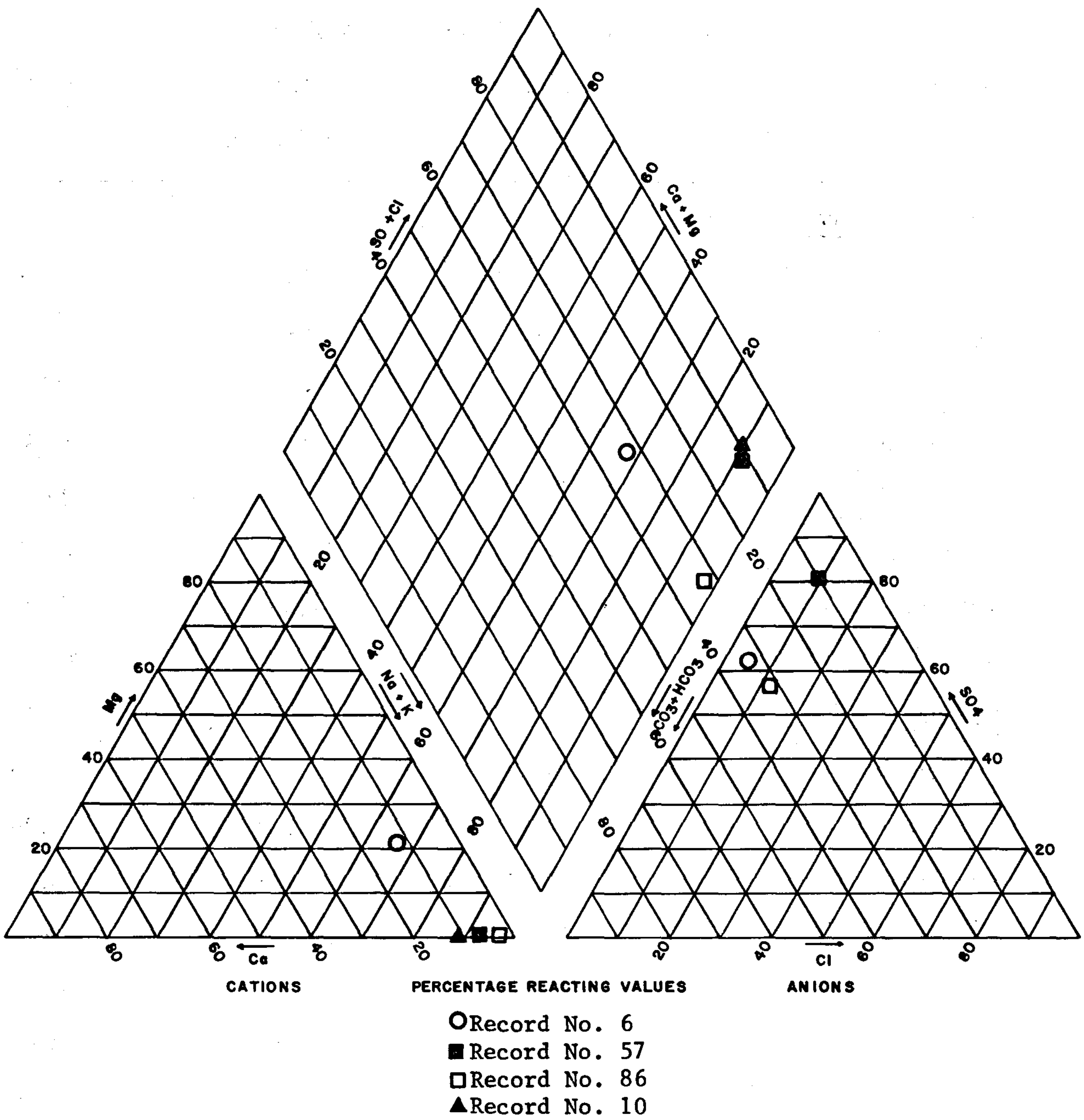


Figure C11. Trilinear plot of major ionic species in wells 6, 57, 86, and 10 for samples collected in Moana area in May, 1982.

TABLE C1

Chemical Analysis of Water from Well No. 6

DATE	9/81	1/82	5/82
		Parts/Million	
CONSTITUENTS			
Calcium	46.	28.	41.5
Magnesium	48.	36.	44.
Sodium	235.	146.	227.
Potassium	22.	16.6	19.4
Carbonate	0.	0.	34.1
Bicarbonate	330.0	252.1	265.9
Chloride	38.2	24.4	35.4
Sulfate	520.	325.	470.
Nitrate	2.2	4.4	2.2
Fluoride	0.07	0.11	0.13
Dissolved Iron	19.60	15.70	0.20
Lithium	0.02	0.02	0.02
Dissolved Aluminum	0.1	(-) 0.1	(-) 0.1
Silica	66.	37.	42.
Boron	0.66	0.61	0.60
p^H	7.2	7.4	8.5

(-) refers to "less than".

* refers to insufficient sample

TABLE C2

Chemical Analysis of Water from Well No. 57

DATE	11/81	1/82	5/82
		Parts/Million	
CONSTITUENTS			
Calcium	31.	26.	27.
Magnesium	0.09	0.05	0.06
Sodium	265.	265.	270.
Potassium	8.6	9.4	10.
Carbonate	0.	0.	6.8
Bicarbonate	98.8	84.9	64.1
Chloride	47.1	47.1	47.4
Sulfate	500.	490.	500.
Nitrate	4.9	(-) 0.4	0.4
Fluoride	5.4	4.3	4.4
Dissolved Iron	0.12	*	(-) 0.05
Lithium	0.23	0.24	0.23
Dissolved Aluminum	(-) 0.1	*	(-) 0.1
Silica	113.	110.	106.
Boron	1.4	1.6	1.5
p^H	8.0	7.9	8.1

(-) refers to "less than".

* refers to insufficient sample

TABLE C3

Chemical Analysis of Water from Well No. 86

DATE	9/81	1/82	5/82
		Parts/Million	
CONSTITUENTS			
Calcium	5.0	5.	2.5
Magnesium	0.1	0.05	0.03
Sodium	180.	165.	168.
Potassium	7.7	8.5	8.6
Carbonate	34.1	34.1	6.8
Bicarbonate	71.0	69.3	133.4
Chloride	28.0	30.4	30.4
Sulfate	250.	225.	210.
Nitrate	(-) 0.4	(-) 0.4	0.4
Fluoride	2.6	2.4	2.7
Dissolved Iron	1.60	0.27	0.16
Lithium	0.12	0.12	0.12
Dissolved Aluminum	(-) 0.1	(-) 0.1	(-) 0.1
Silica	4.	2.	4.
Boron	0.84	1.1	0.92
pH	9.4	9.5	8.5

(-) refers to "less than".

TABLE C4

Chemical Analysis of Water from Well No. 10

DATE	9/81	1/82	5/82
		Parts/Million	
CONSTITUENTS			
Calcium	25.5	25.5	26.5
Magnesium	0.08	0.05	0.06
Sodium	270.	270.	255.
Potassium	8.5	9.3	9.4
Carbonate	0.	0.	6.8
Bicarbonate	94.4	92.7	59.8
Chloride	47.8	47.4	49.6
Sulfate	480.	500.	480.
Nitrate	1.3	(-) 0.4	0.4
Fluoride	4.8	4.4	5.0
Dissolved Iron	(-) 0.10	*	(-) 0.05
Lithium	0.22	0.24	0.23
Dissolved Aluminum	0.1	*	(-) 0.1
Silica	117.	116.	113.
Boron	1.2	1.6	1.4
pH	7.9	7.8	8.1

(-) refers to "less than".

* refers to insufficient sample

The results of the limited chemical sampling program indicate that in the short term (9 months) chemical variation of the major ionic constituents is not apparent in the four wells sampled. Longer term, several years, sampling and chemical analysis may be necessary to detect changes in the chemistry of the geothermal fluids as a result of mixing. In addition the chemistry of the non-thermal and thermal fluids should be known so that mixing models could be generated. Without this information only subjective interpretations can be made as to the deterioration of the resource by contamination from overlying cool ground waters.

Stable Light Isotopes

In addition to the bulk chemical analyses, geothermal fluids for selected wells were sampled and analyzed for deuterium and ^{18}O. The data are listed in Table C5.

Isotopic data for the Gadda and Barnett wells, plotted in Figure C12, show that a significant increase in the isotopic compositions of these fluids occurred between the September, 1981, collection and January, 1982, collection. These are the only two wells for which reliable data were collected on those two dates. The data for the Peppermill well, September collection is suspect, and the Miles well was only sampled in January, 1982. The Gadda and Barnett data support the hypothesis that geothermal fluids in Moana are mixing with isotopically heavier, and colder, meteoric waters. Other supporting data for this hypothesis include the decrease in temperature, decrease in hydrostatic pressure, and decrease in the total dissolved solid content of the geothermal fluids, which were discussed in the previous section.

Sample	δ D 0/00	δ ^{18}O 0/00
	Collected Sep.-Nov. 1981	
Gadda	-122	-15.0
Barnett	-111	-13.1
Peppermill	* -84/-85	-13.3
	Collected Jan. 1982	
Gadda	-114	-15.1
Barnett	-107	-13.3/-13/1
Peppermill	-110/-111	-14.8
Miles	-114	-15.6

* indicates suspect data.

Table C5. Stable light isotopic composition of selected geothermal well waters in Moana.

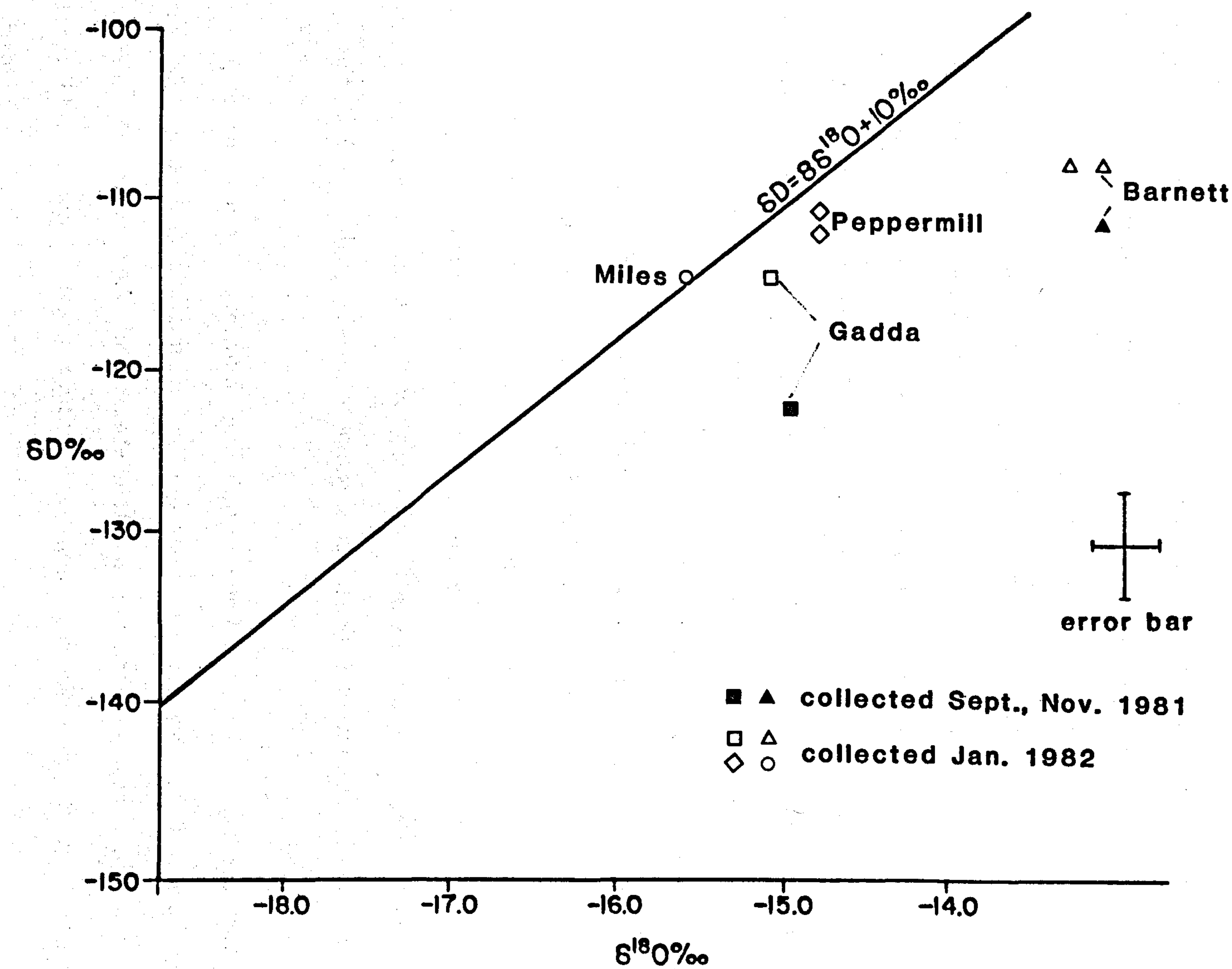


Figure C12. Hydrogen and oxygen stable isotope composition of waters from three Moana wells.

Summary and Conclusions

Pumpernickel Valley

Geothermal fluids are widely distributed throughout Pumpernickel Valley and measured temperatures range from 27°C to 104°C. Most of these fluids discharge at or near prominent range-bounding faults, which are the principal structural controls. Many of these faults are easily recognized on 1:30,000-scale low-sun angle aerial photographs; some can be seen on 1:120,000-scale high altitude photographs, as well as on 1:250,000-scale satellite imagery. Gravity data throughout the study area indicate that range-bounding faults are coincident with steep gradients in gravity contours. These steep gradients represent considerable downward displacement along the fault and the maximum depth to bedrock is approximately 400 m (1300 ft.).

Chemical analyses of thermal and non-thermal fluid samples collected throughout the valley show a wide range of chemical compositions. The highest temperature fluids is sodium-bicarbonate type. Interpretation of isotopic data for these fluids are largely inconclusive but suggest that the chemical composition of the Humboldt River is significantly affected by the local geothermal fluids. Geochemical thermometers indicate that temperatures as high as 170°C can be expected in this area.

Surface exploration techniques, including 2-m depth temperature probe surveys and soil mercury surveys, were used to delineate a previously unknown geothermal prospect. A maximum termperature of 70°C was subsequently measured in a 110 m (360 ft.) deep temperature gradient hole. Additional temperature gradient hole drilling in this area, near the Kemp benchmark, indicated that this prospect is limited in areal extent to 1 km^2 or less.

Carlin

Geothermal fluids occur in two areas near Carlin and appear to represent two discreet hydrothermal circulation systems. The fluids are separated by 11 km (7 mi.) and show no chemical or isotopic similarities. Carlin Hot Springs discharge 0.5 km west of the City of Carlin in and along the Humboldt River. These springs are closely related to a steep gradient in gravity contours. The gravity data suggest that a northeast-trending normal fault is the principal structural control. The same area is the site of anomalous soil mercury values. Portions of the zone registered high temperatures in a 2-m depth probe survey.

Northeast of Carlin, Dry Susie Creek Hot Spring discharges from a fault scarp that can be identified on 1:120,000-scale high altitude photographs. This fault strikes north-northwest; seismic data and geologic mapping suggest that it is a hinge fault and that the hinge line is roughly coincident with the hot springs location. The two spring systems are limited in areal extent and no other thermal areas were identified in subsequent 35 m (120 ft.) depth temperature gradient holes. Chemical geothermometers suggest that Carlin Hot Springs fluids may reach temperatures of at least 90°C.

Moana

Data for over 100 geothermal wells were collected in the Moana area. This data compilation represents the most significant contribution to resource assessment ever made in Moana. Most of the geothermal wells on record are used for commercial and residential space heating and plans for expanding use of the resource have already been formulated.

Bulk chemical analyses, as well as stable light isotopic analyses of selected wells, strongly suggest that the geothermal fluids are mixing with meteoric and ground waters during the winter months. In addition, local residents report significant temperature and hydrostatic pressure decreases in geothermal wells throughout the Moana area. Geothermal reservoir contamination by cold ground waters may occur naturally, but in Moana this effect may be accelerated by poorly completed geothermal wells. Casings in many of the older wells were not properly cemented and cold water flow around the annulus probably accounts for many of these problems. More detailed, goal-oriented research in this area is needed to formulate recommendations for extensive resource development and preservation.

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APPENDIX

Data on Geothermal Wells in Moana

Explanation

RECORD NUMBER:	refers to number on Figure C8.
ADDRESS:	is the street address where well is located.
AREA COORDS:	is a meter coordinate system based on meters west and south of the intersection of Plumb Lane and Virgina Street. Intersection coordinates are 10,000W and 10,000S. Example 12570 11900 indicates that this well is located 2570 meters west and 1900 meters south of the intersection of Plumb Lane and Virginia Street.
LEGAL DESCRIPTION:	provides the location based on township, range and section; parts of sections are provided by NE, NW, indicating northeast-quarter of the northwest quarter of the identified section.
DRILLER:	identifies the drilling contractor listed at the beginning of the table.
DEPTH:	is the depth of the well in meters. To convert to feet multiply meters by 3.28. Example: 290 m x 3.28 = 951 feet.
TEMP:	indicates the maximum temperature measured in the well in degrees Centigrade. To convert degrees Centigrade (°C) to degrees Fahrenheit (°F) multiply by 1.8 and add 32. Example; 83° C X 1.8 = 147.6. 147.6 + 32 = 179.6° F or 180° F. Temperatures are time dependent and may vary from values listed.
TEMP. PROFILE:	a "yes" indicates that a temperature profile of the well is available and included in this report, refer to Figures C2 through C6.
COMMENTS:	this line is for additional information such as depth to water.

Drilling Contractors

A & B Contractors
Lovelock, Nevada 89419

ACE
551 Hwy 50 E
Carson City, Nevada 89701

American Drilling
83 Frontage Road
Dayton, Nevada 89403

Aqua Drilling & Well Service
2255 Glendale Avenue
Sparks, Nevada 89431

Brinkerhoff Drilling Company
3040 E. Callahan
Winnemucca, Nevada 89445

Brown Bros Well Drilling
215 Jani Pl.
Sun Valley, Nevada 89431

Glen Pump & Drilling
(No longer in existance)

Kawchack
1380 Judy
Minden, Nevada 89423

McDonald
950 E. Gregg Street
Sparks, Nevada 89431

McKay Drilling, Inc.
690 Starlight Circle
Reno, Nevada 89509

Sierra Pump & Drilling
20805 Cooke Drive
Carson City, Nevada 89701

Smith-Pulati
(No longer in existance)

Williams (Paul & Sons Water Well Drilling)
747-6700

RECORD NUMBER: 1

ADDRESS: 1701 Skyline Blvd.

AREA COORDS: 12180 11450

LEGAL DISCRIPTION: T19N,R19E,527 NE NE

DRILLER: McKay

DEPTH: 203

TEMP: 75.56

TEMP. PROFILE:

COMMENTS: Depth to water 41 m, Nov. 81

RECORD NUMBER: 2

ADDRESS: 2270 Skyline Blvd.

AREA COORDS: 12350 11860

LEGAL DISCRIPTION: T19N, R19E, S27 SW SW NE NE

DRILLER: Unknown

DEPTH: 259.08

TEMP: 75.01

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 3

ADDRESS: 2190 Dant Blvd.

AREA COORDS: 12050 11990

LEGAL DISCRIPTION: T19N, R19E, S27 NE NE

DRILLER: Brinkerhoff

DEPTH: 175.3

TEMP: 76.67

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 4

ADDRESS: 2135 Richter Dr.

AREA COORDS: 12150 11700

LEGAL DISCRIPTION: T19N, R19E, S27 NENE

DRILLER: Williams

DEPTH: 198.0

TEMP: 97.22

TEMP. PROFILE: Yes

COMMENTS: Depth to water 41 m, Dec. 81

RECORD NUMBER: 5

ADDRESS: Warren Estates Test Well

AREA COORDS: 11700 11800 (approx.)

LEGAL DISCRIPTION: T19N, R19E, S26 NW NW

DRILLER: Williams

DEPTH: 211.88

TEMP: 95.0

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 6

ADDRESS: 166 Greenridge Dr.

AREA COORDS: 11700 10750

LEGAL DISCRIPTION: T19N, R19E, S22 NW NE

DRILLER: McDonald

DEPTH: 155

TEMP: 26.26

TEMP. PROFILE: Yes

COMMENTS: Depth to water 27 m, Sept. 81

RECORD NUMBER: 7

ADDRESS: 795 Manzanita Ln.

AREA COORDS: 10310 12360

LEGAL DISCRIPTION: T19N, R19E, S25 SW NW

DRILLER: McKay

DEPTH: 74.39

TEMP: 48.89

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 8

ADDRESS: 1195 Manzanita Ln.

AREA COORDS: 10480 12400

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McKay

DEPTH: 54.57

TEMP: 91.67

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 9

AREA COORDS: 10550 12450

DRILLER: Unknown

TEMP: 80

COMMENTS:

ADDRESS: 1200 Manzanita Ln.

LEGAL DISCRIPTION: T19N, R19E, S26 NE NW NE SE

DEPTH: 60.35

TEMP. PROFILE:

RECORD NUMBER: 10

AREA COORDS: 10620 12430

DRILLER: Unknown

TEMP: 65.8

COMMENTS:

ADDRESS: 1301 Manzanita Ln.

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DEPTH: 30

TEMP. PROFILE: Yes

RECORD NUMBER: 11

AREA COORDS: 10820 12450

DRILLER: McKay

TEMP: 85

COMMENTS:

ADDRESS: 1385 Manzanita Ln.

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DEPTH: 60.97

TEMP. PROFILE:

RECORD NUMBER: 12

AREA COORDS: 10890 12440

DRILLER: McKay

TEMP: 82.21

COMMENTS:

ADDRESS: 1425 Manzanita Ln.

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DEPTH: 56.40

TEMP. PROFILE:

RECORD NUMBER: 13

ADDRESS: 1460 Manzanita Ln.

AREA COORDS: 11100 12490

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McDonald

DEPTH: 45.7

TEMP: 82.2

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 14

ADDRESS: 1495 Manzanita Ln.

AREA COORDS: 11150 12490

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: Unknown

DEPTH: 30.49

TEMP: 58.4

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 15

ADDRESS: 1560 Manzanita Ln.

AREA COORDS: 11170 12490

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: Glen Pump & Drilling

DEPTH: 67.1

TEMP: 93.3

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 16

ADDRESS: 1680 Manzanita Ln.

AREA COORDS: 11200 12450

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: Brown Bros.

DEPTH: 76.2

TEMP: 75

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 17

ADDRESS: 1730 Manzanita Ln.

AREA COORDS: 11250 12500

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McKay

DEPTH: 121.95

TEMP: 94.5

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 18

ADDRESS: 1800 Manzanita Ln.

AREA COORDS: 11300 12550

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McKay

DEPTH: 99.1

TEMP: 91.0

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 19

ADDRESS: 1840 Manzanita Ln.

AREA COORDS: 11400 12600

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: Unknown

DEPTH: 228.6

TEMP: 85

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 20

ADDRESS: 1960 Manzanita Ln.

AREA COORDS: 11450 12600

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McKay

DEPTH: 94.5

TEMP: 93.3

TEMP. PROFILE:

COMMENTS: Depth to water 27 m

RECORD NUMBER: 21

ADDRESS: 2000 Manzanita Ln.

AREA COORDS: 11470 12600

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McKay

DEPTH: 99.1

TEMP: 97.2

TEMP. PROFILE: Yes

COMMENTS: Depth to water 29 m, July, 1981

RECORD NUMBER: 22

ADDRESS: 2190 Manzanita Ln.

AREA COORDS: 11500 12600

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McKay

DEPTH: 103

TEMP: 87.78

TEMP. PROFILE:

COMMENTS: Depth to water 31 m, June, 1981

RECORD NUMBER: 23

ADDRESS: 1140 Sweetwater Dr.

AREA COORDS: 10480 12280

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: A & B Contractors

DEPTH: 80.8

TEMP: 71.1

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 24

ADDRESS: 1150 Sweetwater Dr.

AREA COORDS: 10500 12280

LEGAL DISCRIPTION: T19N, R19E, S26 NE SE SE NE

DRILLER: Unknown

DEPTH: 94.5

TEMP: 77.78

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 25

AREA COORDS: 10460 12210

DRILLER: A & B Contractors

TEMP: 85

COMMENTS:

ADDRESS: 1155 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 SW SE NE

DEPTH: 96.9

TEMP. PROFILE:

RECORD NUMBER: 26

AREA COORDS: 10500 12260

DRILLER: A & B Contractors

TEMP: 85

COMMENTS:

ADDRESS: 1160 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE SE NE

DEPTH: 60

TEMP. PROFILE:

RECORD NUMBER: 27

AREA COORDS: 10500 12200

DRILLER: McDonald

TEMP: 88.9

COMMENTS:

ADDRESS: 1165 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DEPTH: 76.2

TEMP. PROFILE:

RECORD NUMBER: 28

AREA COORDS: 10600 12290

DRILLER: A & B Contractors

TEMP: 77.2

COMMENTS:

ADDRESS: 1170 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 SW SE NE

DEPTH: 54.9

TEMP. PROFILE:

RECORD NUMBER: 29

AREA COORDS: 10550 12200

DRILLER: McDonald

TEMP: 90.0

COMMENTS:

ADDRESS: 1175 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 NE SE NE

DEPTH: 50.3

TEMP. PROFILE:

RECORD NUMBER: 30

AREA COORDS: 10650 12280

DRILLER: American

TEMP: 82

COMMENTS:

ADDRESS: 1184 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 SW SW SE NE

DEPTH: 39.6

TEMP. PROFILE:

RECORD NUMBER: 31

AREA COORDS: 10700 12200

DRILLER: Unknown

TEMP: 85

COMMENTS:

ADDRESS: 1185 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 SE NW SE NE

DEPTH: 61

TEMP. PROFILE:

RECORD NUMBER: 32

AREA COORDS: 10680 12280

DRILLER: Smith-Pulati

TEMP: 86.1

COMMENTS:

ADDRESS: 1188 Sweetwater Dr.

LEGAL DISCRIPTION: T19N, R19E, S26 NE SW SE NE

DEPTH: 61

TEMP. PROFILE:

RECORD NUMBER: 33

ADDRESS: 1192 Sweetwater Dr.

AREA COORDS: 10720 12290

LEGAL DISCRIPTION: T19N, R19E, S26 NE SW SE NE

DRILLER: Unknown

DEPTH: 62.2

TEMP: 85

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 34

ADDRESS: 1196 Sweetwater Dr.

AREA COORDS: 10700 12300

LEGAL DISCRIPTION: T19N, R19E, S26 SW SW SE NE

DRILLER: A & B Contractors

DEPTH: 68.6

TEMP: 80

TEMP. PROFILE:

COMMENTS: Depth to water 11 m

RECORD NUMBER: 35

ADDRESS: 1198 Sweetwater Dr.

AREA COORDS: 10720 12320

LEGAL DISCRIPTION: T19N, R19E, S26 SW SW SE NE

DRILLER: A & B Contractors

DEPTH: 64

TEMP: 85

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 36

ADDRESS: 1204 Sweetwater Dr.

AREA COORDS: 10710 12350

LEGAL DISCRIPTION: T19N, R19E, S26 SW SW SE NE

DRILLER: McDonald

DEPTH: 70.1

TEMP: 90

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 37

ADDRESS: 1275 Sweetwater Dr.

AREA COORDS: 10740 12230

LEGAL DISCRIPTION: T19N, R19E, S26 NW SW SE NE

DRILLER: Unknown

DEPTH: 109.7

TEMP: 85

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 38A

ADDRESS: 1165 Yates Ln.

AREA COORDS: 10560 12340

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McDonald

DEPTH: 59.5

TEMP: 52.0

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 38B

ADDRESS: 1165 Yates Ln.

AREA COORDS: 10560 12340

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McKay

DEPTH: 76

TEMP: 85

TEMP. PROFILE: Yes

COMMENTS: Depth to water 4 m, Jan., 1982

RECORD NUMBER: 39

ADDRESS: 1175 Yates Ln.

AREA COORDS: 10600 12340

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: Unknown

DEPTH: Unknown

TEMP: 88

TEMP. PROFILE:

COMMENTS: Artesian

RECORD NUMBER: 40

ADDRESS: 1185 Yates Ln.

AREA COORDS: 10650 12350

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McDonald

DEPTH: 45.7

TEMP: 86.7

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 41

ADDRESS: 1350 Doral Cr.

AREA COORDS: 10750 12580

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: Unknown

DEPTH: 76.2

TEMP: 81.1

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 42

ADDRESS: 1355 Doral Cr.

AREA COORDS: 10750 12540

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: American

DEPTH: 68.6

TEMP: 75.6

TEMP. PROFILE:

COMMENTS: Depth to water less than 15 m

RECORD NUMBER: 43

ADDRESS: 1370 Doral Cr.

AREA COORDS: 10800 12600

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: McDonald

DEPTH: 39.0

TEMP: 87.8

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 44

AREA COORDS: 10890 12580

DRILLER: McKay

TEMP: 82.2

COMMENTS:

ADDRESS: 1400 Huntington Cr.

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DEPTH: 51.8

TEMP. PROFILE:

RECORD NUMBER: 45

AREA COORDS: 10890 12550

DRILLER: McKay

TEMP: 90.6

COMMENTS:

ADDRESS: 1405 Huntington Cr.

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DEPTH: 52.7

TEMP. PROFILE:

RECORD NUMBER: 46

AREA COORDS: 10890 12540

DRILLER: McKay

TEMP: 82.2

COMMENTS:

ADDRESS: 1435 Huntington Cr.

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DEPTH: 53.4

TEMP. PROFILE:

RECORD NUMBER: 47

AREA COORDS: 10900 12590

DRILLER: Ace

TEMP: 86.7

COMMENTS:

ADDRESS: 1440 Huntington Cr.

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DEPTH: 70.4

TEMP. PROFILE:

RECORD NUMBER: 48

ADDRESS: 1465 Huntington Cr.

AREA COORDS: 10950 12640

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: McKay

DEPTH: 54.3

TEMP: 91.7

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 49

ADDRESS: 1495 Huntington Dr.

AREA COORDS: 10990 12560

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: Kawchack

DEPTH: 88.7

TEMP: 73.9

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 50

ADDRESS: 1440 Bermuda Cr.

AREA COORDS: 10910 12700

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: McKay

DEPTH: 36.6

TEMP: 85.0

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 51

ADDRESS: 1465 Bermuda Cr.

AREA COORDS: 10950 12550

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: McKay

DEPTH: 55.8

TEMP: 82.2

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 52

ADDRESS: 1490 Bermuda Cr.

AREA COORDS: 10990 12650

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE

DRILLER: A & B Contractors

DEPTH: 56.4

TEMP: 88.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 53

ADDRESS: 3850 Plumas St.

AREA COORDS: 10800 11980

LEGAL DISCRIPTION: T19N, R19E, S26 NW NE

DRILLER: Aqua

DEPTH: 138.7

TEMP: 71.3

TEMP. PROFILE: Yes

COMMENTS: Depth to water less than 15 m, Jan., 1982

RECORD NUMBER: 54

ADDRESS: 4000 Plumas St.

AREA COORDS: 10780 12070

LEGAL DISCRIPTION: T19N, R19E, S26 NW NE

DRILLER: Unknown

DEPTH: 91.44

TEMP: 85.0

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 55

ADDRESS: 4280 Plumas St.

AREA COORDS: 10840 12330

LEGAL DISCRIPTION: T19N, R19E, S26 NW NE

DRILLER: Williams

DEPTH: 55.

TEMP: 82.7

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 56 | ADDRESS: 4270 Plumas St.
AREA COORDS: 10830 12320 | LEGAL DISCRIPTION: T19N, R19E, S26 NW NE
DRILLER: American | DEPTH: 52.
TEMP: 91.0 | TEMP. PROFILE:
COMMENTS:

RECORD NUMBER: 57 | ADDRESS: 4400 Plumas St.
AREA COORDS: 10820 12590 | LEGAL DISCRIPTION: T19N, R19E, S26 NW NE
DRILLER: Smith-Pulati | DEPTH: 30.
TEMP: 92.2 | TEMP. PROFILE:
COMMENTS: Formerly Artesian

RECORD NUMBER: 58 | ADDRESS: 1410 Ayershire Ct.
AREA COORDS: 10900 12330 | LEGAL DISCRIPTION: T19N, R19E, S26 NW NE
DRILLER: Aqua | DEPTH: 70.
TEMP: 93.3 | TEMP. PROFILE: Yes
COMMENTS:

RECORD NUMBER: 59 | ADDRESS: 1440 Ayershire Ct.
AREA COORDS: 10900 12350 | LEGAL DISCRIPTION: T19N, R19E, S26 NW NE
DRILLER: Unknown | DEPTH: 68.6
TEMP: 60. | TEMP. PROFILE:
COMMENTS:

RECORD NUMBER: 60

ADDRESS: 1625 Wendy Way

AREA COORDS: 10860 12250

LEGAL DISCRIPTION: T19N, R19E, S26 SW NE

DRILLER: Aqua

DEPTH: 115.85

TEMP: 58.

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 61

ADDRESS: 1640 Wendy Way

AREA COORDS: 10870 12260

LEGAL DISCRIPTION: T19N, R19E, S26 SW NE

DRILLER: Unknown

DEPTH: 76.2

TEMP: 60.

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 62

ADDRESS: 1660 Wendy Way

AREA COORDS: 10900 12260

LEGAL DISCRIPTION: T19N, R19E, S26 SW SW NE

DRILLER: Unknown

DEPTH: 201

TEMP: 82.2

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 63

ADDRESS: 1700 Wendy Way

AREA COORDS: 11040 12210

LEGAL DISCRIPTION: T19N, R19E, S26 SW SW NE

DRILLER: Unknown

DEPTH: 193.55

TEMP: 82.2

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 64

ADDRESS: 1840 Wendy Way

AREA COORDS: 10840 12200

LEGAL DISCRIPTION: T19N, R19E, S26 SW NE

DRILLER: McKay

DEPTH: 80.8

TEMP: 68.3

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 65

ADDRESS: 1855 Wendy Way

AREA COORDS: 10840 12220

LEGAL DISCRIPTION: T19N, R19E, S26 SW NE

DRILLER: McKay

DEPTH: 82.3

TEMP: 73.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 66

ADDRESS: 4042 Swanson Ln.

AREA COORDS: 11200 12200

LEGAL DISCRIPTION: T19N, R19E, S26 SW NE

DRILLER: McKay

DEPTH: 195.1

TEMP: 81.2

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 67

ADDRESS: 1880 Meadowview Ln.

AREA COORDS: 11040 12920

LEGAL DISCRIPTION: T19N, R19E, S26 SW NE

DRILLER: Brinkerhoff

DEPTH: 247.

TEMP: 70.

TEMP. PROFILE: Yes

COMMENTS: Depth to water 24 m, Jan., 1982

RECORD NUMBER: 68

ADDRESS: 1120 W. Peckham Ln.

AREA COORDS: 10600 12000

LEGAL DISCRIPTION: T19N, R19E, S26 NE NE SE NE

DRILLER: Unknown

DEPTH: 75.3

TEMP: 85.

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 69

ADDRESS: 1160 W. Peckham Ln.

AREA COORDS: 10570 12000

LEGAL DISCRIPTION: T19N, R19E, S26 NE SE NE

DRILLER: Unknown

DEPTH: 74.7

TEMP: 85.

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 70

ADDRESS: 1170 W. Peckham Ln.

AREA COORDS: 10590 12000

LEGAL DISCRIPTION: T19N, R19E, S26 NE NW SE NE

DRILLER: Unknown

DEPTH: 80.8

TEMP: 80.

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 71

ADDRESS: 1180 W. Peckham Ln.

AREA COORDS: 10700 12010

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE NE

DRILLER: McKay

DEPTH: 123.5

TEMP: 89.9

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 72

ADDRESS: 2020 Willow Tree Ln.

AREA COORDS: 11300 12300

LEGAL DISCRIPTION: T19N, R19E, S26 NW SE NE

DRILLER: Brinkerhoff

DEPTH: 183.

TEMP: 82.2

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 73

ADDRESS: 1735 Sand Point Cr.

AREA COORDS: 11200 12800

LEGAL DISCRIPTION: T19N, R19E, S26 SE SE

DRILLER: McKay

DEPTH: 76.2

TEMP: 76.67

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 74

ADDRESS: 1775 Sand Point Cr.

AREA COORDS: 11280 12820

LEGAL DISCRIPTION: T19N, R19E, S26 SE SE

DRILLER: McKay

DEPTH: 76.2

TEMP: 90.6

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 75

ADDRESS: 1785 Sand Point Cr.

AREA COORDS: 11310 12820

LEGAL DISCRIPTION: T19N, R19E, S26 SE SE

DRILLER: McKay

DEPTH: 76.2

TEMP: 88.3

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 76

ADDRESS: 5000 Lakeridge Dr.

AREA COORDS: 11390 13040

LEGAL DISCRIPTION: T19N, R19E, S26 SE SE

DRILLER: Sierra

DEPTH: 125.

TEMP: 26.67

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 77

ADDRESS: 4850 Rio Pinar Dr.

AREA COORDS: 11290 12900

LEGAL DISCRIPTION: T19N, R19E, S26 SE SW

DRILLER: McKay

DEPTH: 94.

TEMP: 75.56

TEMP. PROFILE:

COMMENTS: Depth to water 13 m, Aug., 1981

RECORD NUMBER: 78

ADDRESS: 2075 Lakeside Dr.

AREA COORDS: 10400 10450

LEGAL DISCRIPTION: T19N, R19E, S24 SE NW

DRILLER: McKay

DEPTH: 189.9

TEMP: 51.67

TEMP. PROFILE:

COMMENTS: Depth to water 10.5 m, Jan., 1982

RECORD NUMBER: 79

ADDRESS: 3835 Lakeside Dr.

AREA COORDS: 10390 11990

LEGAL DISCRIPTION: T19N, R19E, S25 NW NW

DRILLER: Williams

DEPTH: 122.

TEMP: 70.

TEMP. PROFILE:

COMMENTS: Depth to water 12 m, May, 1982

RECORD NUMBER: 80

ADDRESS: 3905 Lakeside Dr.

AREA COORDS: 10440 12100

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: Unknown

DEPTH: 141.4

TEMP: 82.2

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 81

ADDRESS: Lakeside and Peckham

AREA COORDS: 10380 12010

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: Kawchack

DEPTH: 82.3

TEMP: 60.0

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 82

ADDRESS: 4100 Lakeside Dr.

AREA COORDS: 10400 12280

LEGAL DISCRIPTION: T19N, R19E, S26 SW SW

DRILLER: McDonald

DEPTH: 135.7

TEMP: 77.78

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 83

ADDRESS: 4235 Lakeside Dr.

AREA COORDS: 10400 12350

LEGAL DISCRIPTION: T19N, R19E, S26 SE NE

DRILLER: McDonald

DEPTH: 61.

TEMP: 70.0

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 84

ADDRESS: 4595 Lakeside Dr.

AREA COORDS: 10400 12550

LEGAL DISCRIPTION: T19N, R19E, S26 NE SE

DRILLER: Brinkerhoff

DEPTH: 48.

TEMP: 54.4

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 85

ADDRESS: 2201 S. Virginia St.

AREA COORDS: 09990 10300

LEGAL DISCRIPTION: T19N, R19E, S24 NE NW NW

DRILLER: Unknown

DEPTH: 274.3

TEMP: 42.2

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 86

ADDRESS: 2707 S. Virginia St.

AREA COORDS: 09800 10800

LEGAL DISCRIPTION: T19N, R19E, S24 NE NW NE NW

DRILLER: Aqua

DEPTH: 227.9

TEMP: 53.

TEMP. PROFILE: Yes

COMMENTS: Pump tested at 750 GPM, Depth to water 7 m, Aug., 1981

RECORD NUMBER: 87

ADDRESS: 2600 Eastshore Dr.

AREA COORDS: 10200 10700

LEGAL DISCRIPTION: T19N, R19E, S24 NW SE SW NW

DRILLER: Unknown

DEPTH: 306.6

TEMP: 58.8

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 88

ADDRESS: 760 Hash Ln.

AREA COORDS: 09540 13260

LEGAL DISCRIPTION: T19N, R19E, S36

DRILLER: Unknown

DEPTH: 33.5

TEMP: 27.8

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 89

ADDRESS: 3905 Garlan Ln.

AREA COORDS: 09850 12010

LEGAL DISCRIPTION: T19N, R19E, S25 SE NW

DRILLER: Aqua

DEPTH: 92.7

TEMP: 51.5

TEMP. PROFILE: Yes

COMMENTS: Depth to water less than 15 m

RECORD NUMBER: 90

ADDRESS: 4095 Garlan Ln.

AREA COORDS: 09850 12220

LEGAL DISCRIPTION: T19N, R19E, S25 S½, NW

DRILLER: McKay

DEPTH: 67.4

TEMP: 48.33

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 91

ADDRESS: 4200 Garlan Ln.

AREA COORDS: 09810 12330

LEGAL DISCRIPTION: T19N, R19E, S25 SE, NW

DRILLER: McKay

DEPTH: 54.9

TEMP: 43.33

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 92

ADDRESS: 4255 Garlan Ln.

AREA COORDS: 09850 12360

LEGAL DISCRIPTION: T19N, R19E, S25 SE, NW

DRILLER: McKay

DEPTH: 91.2

TEMP: 50.6

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 93

ADDRESS: 4000 Jasper Ln.

AREA COORDS: 09920 12100

LEGAL DISCRIPTION: T19N, R19E, S25 S½ NW

DRILLER: McKay

DEPTH: 75.3

TEMP: 48.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 94

ADDRESS: 4030 Jasper Ln.

AREA COORDS: 09920 12120

LEGAL DISCRIPTION: T19N, R19E, S25 SE NW

DRILLER: McKay

DEPTH: 79.3

TEMP: 46.1

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 95

ADDRESS: 4155 Jasper Ln.

AREA COORDS: 09960 12350

LEGAL DISCRIPTION: T19N, R19E, S25 S½ NW

DRILLER: McKay

DEPTH: 89.9

TEMP: 48.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 96

ADDRESS: 4200 Jasper Ln.

AREA COORDS: 09920 12350

LEGAL DISCRIPTION: T19N, R19E, S25 S½ NW

DRILLER: McKay

DEPTH: 75.31

TEMP: 43.3

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 97

ADDRESS: 4290 Jasper Ln.

AREA COORDS: 09910 12390

LEGAL DISCRIPTION: T19N, R19E, S25 S½ NW

DRILLER: McKay

DEPTH: 61.6

TEMP: 43.3

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 98

ADDRESS: 4000 Warren Way

AREA COORDS: 10130 12110

LEGAL DISCRIPTION: T19N, R19E, S25 SW NW

DRILLER; McKay

DEPTH: 67.1

TEMP: 43.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 99

ADDRESS: 4100 Warren Way

AREA COORDS: 10130 12160

LEGAL DISCRIPTION: T19N, R19E, S25 SW NW

DRILLER: Unknown

DEPTH: 67.4

TEMP: 48.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 100

ADDRESS: 4210 Warren Way

AREA COORDS: 10140 12300

LEGAL DISCRIPTION: T19N, R19E, S25 SW NW

DRILLER: McKay

DEPTH: 68.0

TEMP: 48.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 101

ADDRESS: 4260 Warren Way

AREA COORDS: 10140 12330

LEGAL DISCRIPTION: T19N, R19E, S25 SW NW

DRILLER: McKay

DEPTH: 69.5

TEMP: 48.9

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 102

ADDRESS: 4295 Warren Way

AREA COORDS: 10180 12380

LEGAL DISCRIPTION: T19N, R19E, S25 SW NW

DRILLER: McKay

DEPTH: 63.7

TEMP: 47.8

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 103

ADDRESS: 4860 Warren Way

AREA COORDS: 10010 13130

LEGAL DISCRIPTION: T19N, R19E, S25 SW NW

DRILLER: McKay

DEPTH: 105.5

TEMP: 36.1

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 104

ADDRESS: 690 Starlight Cr.

AREA COORDS: 10070 12300

LEGAL DISCRIPTION: T19N, R19E, S25 SE NW

DRILLER: McKay

DEPTH: 69.5

TEMP: 54.4

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 105

ADDRESS: 970 Pinebrook Rd.

AREA COORDS: 10250 13250

LEGAL DISCRIPTION: T19N, R19E, S25 SW SW

DRILLER: McDonald

DEPTH: 121.9

TEMP: 20.55

TEMP. PROFILE: Yes

COMMENTS:

RECORD NUMBER: 106

ADDRESS: 600 Sapphire Cr.

AREA COORDS: 09980 12200

LEGAL DISCRIPTION: T19N, R19E, S25 S½ NW

DRILLER: McKay

DEPTH: 93.6

TEMP: 49.44

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER: 107

ADDRESS: NONE

AREA COORDS: 09980 12700

LEGAL DISCRIPTION: T19N, R19E, S25 NE SE

DRILLER: Unknown

DEPTH: Unknown

TEMP: 36.9

TEMP. PROFILE:

COMMENTS: ½ mile west of intersection of Kietzke and Virgina Streets

RECORD NUMBER: 108

AREA COORDS: 10050 11700

DRILLER: McDonald

TEMP: 80.0

COMMENTS:

ADDRESS: 3575 Grant Dr.

LEGAL DISCRIPTION: T19N, R19E, S25 NW NW

DEPTH: 99.1

TEMP. PROFILE:

RECORD NUMBER: 109

AREA COORDS: 10510 11610

DRILLER: McKay

TEMP: 43.3

COMMENTS:

ADDRESS: 1100 Moana Ln.

LEGAL DISCRIPTION: T19N, R19E, S26 NE NE

DEPTH: 50.3

TEMP. PROFILE:

RECORD NUMBER: 110

AREA COORDS: 09720 11700

DRILLER: McDonald

TEMP: 51.7

COMMENTS: Depth to water 18 m

ADDRESS: Moana Pool

LEGAL DISCRIPTION: T19N, R19E, S25 NE NW

DEPTH: 152.4

TEMP. PROFILE:

RECORD NUMBER: 111

AREA COORDS: 10330 11990

DRILLER: Unknown

TEMP: 81.67

COMMENTS:

ADDRESS: 955 West Peckham

LEGAL DISCRIPTION: T19N, R19E, S25 NE NE

DEPTH: 114.32

TEMP. PROFILE:

RECORD NUMBER: 112

ADDRESS: 2300 Solari

AREA COORDS: 12570 11900

LEGAL DISCRIPTION: T19N, R19E, S27 SW NE

DRILLER: McKay

DEPTH: 290

TEMP: 82.0

TEMP. PROFILE: yes

COMMENTS: Water at 73 m

RECORD NUMBER: 113

ADDRESS: 1450 Granite

AREA COORDS: 12180 11225

LEGAL DISCRIPTION: T19N, R19E, S22 SE SE

DRILLER: Williams

DEPTH: 399

TEMP: 82.0

TEMP. PROFILE:

COMMENTS: Water at 38 m

RECORD NUMBER: 114

ADDRESS: 2700 Plumas

AREA COORDS: 10780 10850

LEGAL DISCRIPTION: T19N, R19E, S23 SW

DRILLER: Anderson

DEPTH: 286

TEMP: 64.0

TEMP. PROFILE:

COMMENTS:

RECORD NUMBER:

ADDRESS:

AREA COORDS:

LEGAL DISCRIPTION:

DRILLER:

DEPTH:

TEMP:

TEMP. PROFILE:

COMMENTS:

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