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NO. 185

LOW-TEMPERATURE GEOTHERMAL ASSESSMENT
OF THE JORDAN VALLEY
SALT LAKE COUNTY, UTAH

by
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with a section on temperature-depth measurements
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LOW-TEMPERATURE GEOTHERMAL ASSESSMENT
OF THE JORDAN VALLEY
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ABSTRACT

The Utah Geological and Mineral Survey (UGMS) has been conducting research to identify low-temperature geothermal resources in Utah as per U.S. Department of Energy (DOE) Contract DE-AS07-77ET28393. This report, which is part of an area-wide geothermal research program along the Wasatch Front, is the culmination of the study conducted in the Jordan Valley, Salt Lake County, Utah.

Two known low-temperature geothermal areas (Warm Springs fault and Crystal Hot Springs) are located in the Jordan Valley, but the primary purpose of this report is to locate other low-temperature resources not previously identified. Geothermal reconnaissance techniques utilized in this study include a temperature survey and chemical analysis of wells and springs, and temperature-depth measurements in "holes of opportunity." Also, further site specific gravity modelling for the Warm Springs fault geothermal area and initial modelling for the entire valley were also conducted.

Areas identified as having potential low-temperature geothermal resources at depth are: (1) the north-central valley area; (2) an east-west portion of the central valley; and (3) a north-south oriented area extending from Draper to Midvale. Each of these areas exhibits ground-water temperatures 20⁰C or greater. Each area also has thermal wells with common ion characteristics similar to both Crystal Hot Springs and the Warm Springs fault geothermal systems. Significant concentrations of Sr, Li, B, and F are present in many of these wells.

Thermal reservoir temperatures were calculated using silica and Na-K-Ca geothermometers. Results indicate reservoir temperatures for thermal waters

range from 60^o to 100^oC. Reservoir temperatures for non-thermal water are generally less than 50^oC.

Gradients calculated from temperature-depth measurements logged in "holes of opportunity" indicate one definite area of anomalously warm temperatures. Gradients of 102^o and 103^oC/km calculated for two holes located northeast of Draper, Utah are significantly greater than the 57.8^oC/km gradient considered to be normal for the Jordan Valley by Costain and Wright (1973), and most significantly greater than the 35^oC/km considered average for the Basin and Range.

The areas delineated have low-temperature geothermal potential. However, more site specific exploration must be conducted to determine the structural controls on each system, the size and depth of any target reservoirs, and temperatures to be expected in these reservoirs.

INTRODUCTION

The Utah Geological and Mineral Survey (UGMS) has been conducting research to identify low-temperature geothermal resources in the State of Utah as per U.S. Department of Energy (DOE) contract DE-AS07-77ET28393. Prior to this study, UGMS was concentrating its investigations on known geothermal areas along the Wasatch Front from Utah County north to the Idaho/Utah State line. The concentration of the study in this region was due primarily to the number of known geothermal resources near major population centers, hopefully resulting in timely resource development.

In February, 1980 it was determined that efforts should begin in the evaluation of the area-wide geothermal resource potential for the following Wasatch Front areas: (1) Utah and Goshen Valleys in Utah County, (2) the Jordan Valley in Salt Lake County, (3) the East Shore area in Weber and Davis

Counties, (4) the lower Bear River drainage basin in Box Elder County, and (5) Cache Valley in Cache County. These areas were chosen because of inherent low-temperature geothermal potential near major population centers of the State. This report represents the study conducted in the Jordan Valley. It should be noted, however, that this study is limited in scope, and the absence of evidence for additional resources doesn't eliminate the possibility they exist. Additional exploration may establish the existence of a deep resource(s).

PHYSIOGRAPHIC SETTING

The Jordan Valley encompasses an area of approximately 400 square miles (1024 km²) in central Salt Lake County (fig. 1). This valley has substantial relief, ranging in elevation from 4200 feet (1280 m) at the Great Salt Lake to approximately 5200 feet (1585 m) where it adjoins the mountains. The east side of the valley is a transition zone between two major physiographic provinces: the Rocky Mountain province to the east and the Basin and Range province to the west.

The Jordan Valley is bounded to the east, south, and west by the Wasatch, Traverse, and Oquirrh mountain ranges, respectively, while the north end is open to the East Shore area in Davis County. An arbitrary northern boundary is an extension, to the west, of the Salt Lake salient. The Wasatch Mountains, including the Salt Lake salient, are in the Rocky Mountain physiographic province while the Traverse and Oquirrh Mountains are part of the Basin and Range.

A principal source of water to the valley is the Jordan River which flows north from Utah Valley through a gap in the Traverse Mountains referred to as the Jordan Narrows. The river continues through the entire length of the

valley, eventually entering into the Great Salt Lake. In addition to the Jordan River, other principal water sources are the creeks draining the Wasatch Mountains.

REGIONAL GEOLOGIC SETTING

Rocks of Precambrian through Pliocene Age are exposed in the mountains bordering the Jordan Valley (plate 1). In the Wasatch Mountains, sedimentary and metamorphic rocks consist of Precambrian, Paleozoic, Mesozoic, and Cenozoic sandstone, limestone, shale, conglomerate, siltstone, tuffaceous clay, tillite, quartzite, schist and gneiss. Intrusive rocks consist of early Tertiary monzonite, diorite, and granodiorite. In places these rocks are covered by Pleistocene glacial deposits as well as alluvium.

The core of the Traverse Mountains is primarily composed of the Pennsylvanian Oquirrh Formation consisting of quartzite with some calcareous sandstone and limestone. In some areas the quartzite has been broken and cemented in place - Marsell (1932) referred to this as "autoclastic breccia." Also, some Mississippian-Pennsylvanian age Manning Canyon shale and Mississippian Great Blue Limestone are present. Tertiary rocks consist of the Salt Lake Group of Slentz (1955) which generally is composed of marlstone, mudstone, siltstone, travertine, and fanglomerate. Tertiary volcanics, consisting primarily of andesite and augite-andesite porphyry composition, are also present.

Rocks of the Paleozoic Oquirrh Mountain facies are the primary units exposed in the Oquirrh Mountains. The following formations, according to Crittenden (1964), comprise the Oquirrh Mountain facies: the Great Blue Limestone, the Manning Canyon Shale, the Oquirrh Formation, the Kirkham Limestone, and the Diamond Creek Sandstone. These formations are somewhat

different in the central and northern parts of the range; units in the central area are referred to as the Bingham sequence and units to the north are the Rogers Canyon sequence. Tertiary rocks are also exposed in the Oquirrh. These include: (1) Harker's fanglomerate of Slentz's (1955) Salt Lake Group, (2) andesite and latite-andesite flows, and (3) intrusive stocks, sills and dikes of granite, monzonite, granite porphyry, and rhyolite-quartz latite.

Generally, the sediments exposed in the Jordan Valley consist of unconsolidated deposits of boulders, gravel, sand, silt, and clay deposited by streams, lakes, glaciers, wind, and mass wasting during Quaternary and Recent time. Isolated outcrops of pre-Quaternary rocks are found in areas where pediments extend from the bordering mountains. Subsurface sediments are greatly different from surface sediments in the valley. These sediments comprise the aquifers investigated as part of this study and, therefore, will be described later in detail.

REGIONAL STRUCTURAL SETTING

The Jordan Valley is at the intersection of three major tectonic elements: (1) the north-trending thrusts and folds known as the Sevier orogenic belt which extends from southern Nevada to the northwest corner of Alaska (Crittenden, 1976), (2) the east-trending Uinta Arch, and (3) north-south trending Basin and Range faulting.

Thrusting

Three episodes of thrusting have been identified in the Wasatch Mountains east of the Jordan Valley. The first two are known as the Alta and Mount Raymond thrusts and are dated at 125 and 85-90 million years old, respectively (Crittenden, 1964). The third, and most extensive, is the Charleston-Nebo

Thrust, reported to have a displacement of 40 miles (64 km²) or more from the west and is dated at 75-80 million years (Crittenden, 1964). The inferred trace of this thrust fault has been extended westward between the east Traverse Mountains and the Little Cottonwood Stock, disappearing beneath the Jordan Valley sediments where it is believed to continue to the northwest passing between Antelope and Fremont Islands, eventually connecting with its northern counterpart, the Willard-Paris thrust, east of Ogden (Crittenden, 1964). The identification of this fault explains why the Pennsylvanian rocks of the Oquirrh and Traverse Mountains differ from the rocks of the Wasatch east of the Jordan Valley and also explains why there is no visible continuation of the Uinta anticline in the Oquirrhs.

Uinta Arch

The Uinta arch is the largest structural feature within the Wasatch Range (fig. 2). It consists of a broad anticline oriented in an east-west direction forming the axis of the Uinta Mountains. East of the Jordan Valley, the anticline is exposed at the mouth of Little Cottonwood Canyon where the axis plunges approximately 30 degrees east.

Basin and Range Faulting

Another significant structural event, block faulting of the Basin and Range, occurred in the late Tertiary with the Jordan Valley being part of the eastern border. The Wasatch fault zone, which extends along the east side of the valley, separates the Basin and Range from the Wasatch Mountains. This fault zone is part of the Intermountain seismic belt, a 62.5 mile (100 km) wide zone of high seismic activity extending from northern Arizona to northwestern Montana (fig. 3).

GEOLOGY OF THE JORDAN VALLEY

Marine and Price (1964) divided the Jordan Valley into six ground-water

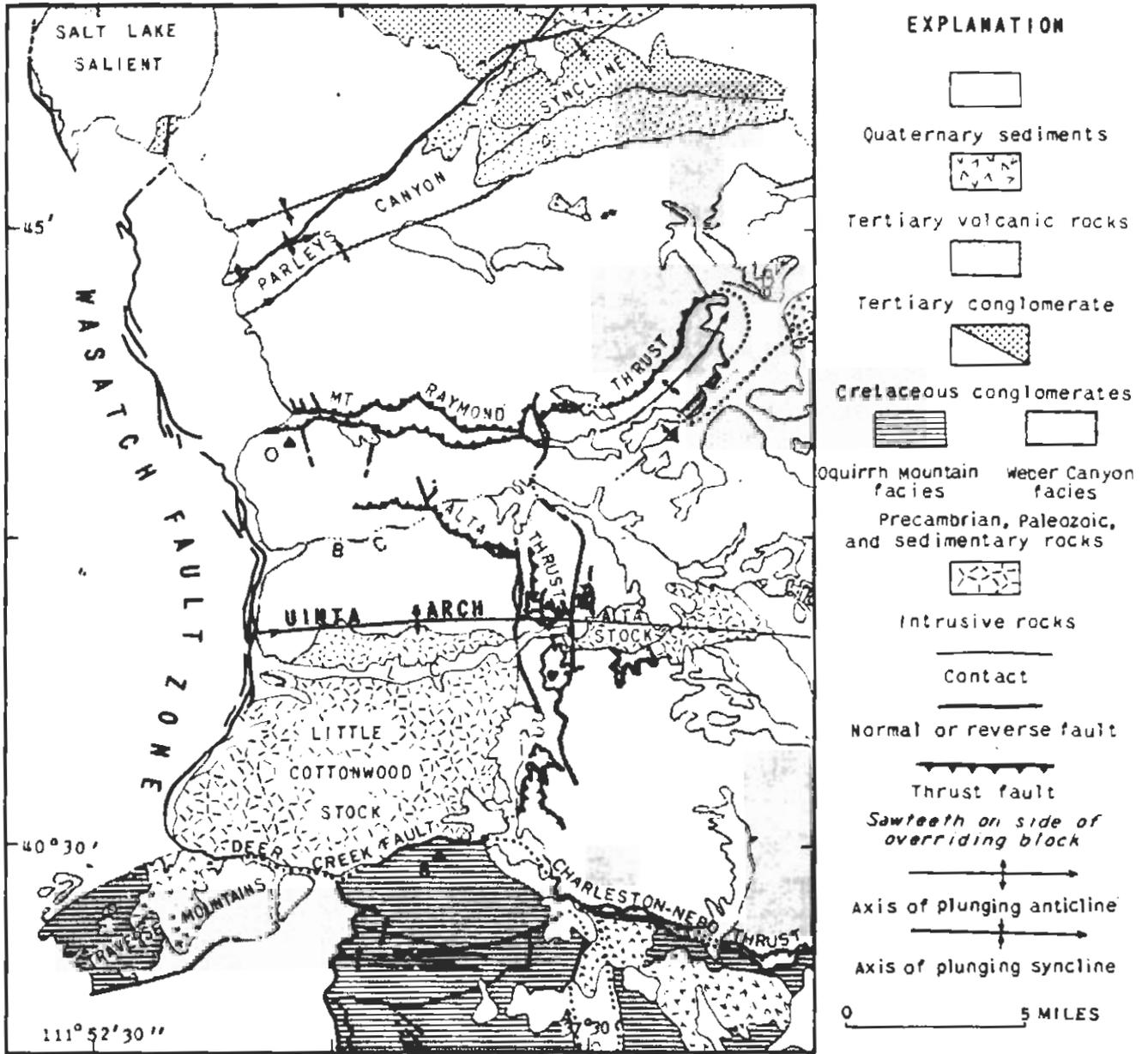


Figure 2. Generalized structure of central Wasatch Range east of Salt Lake City (from Crittenden, 1976, p. 365).

INTERMOUNTAIN SEISMIC BELT ~1850-1974

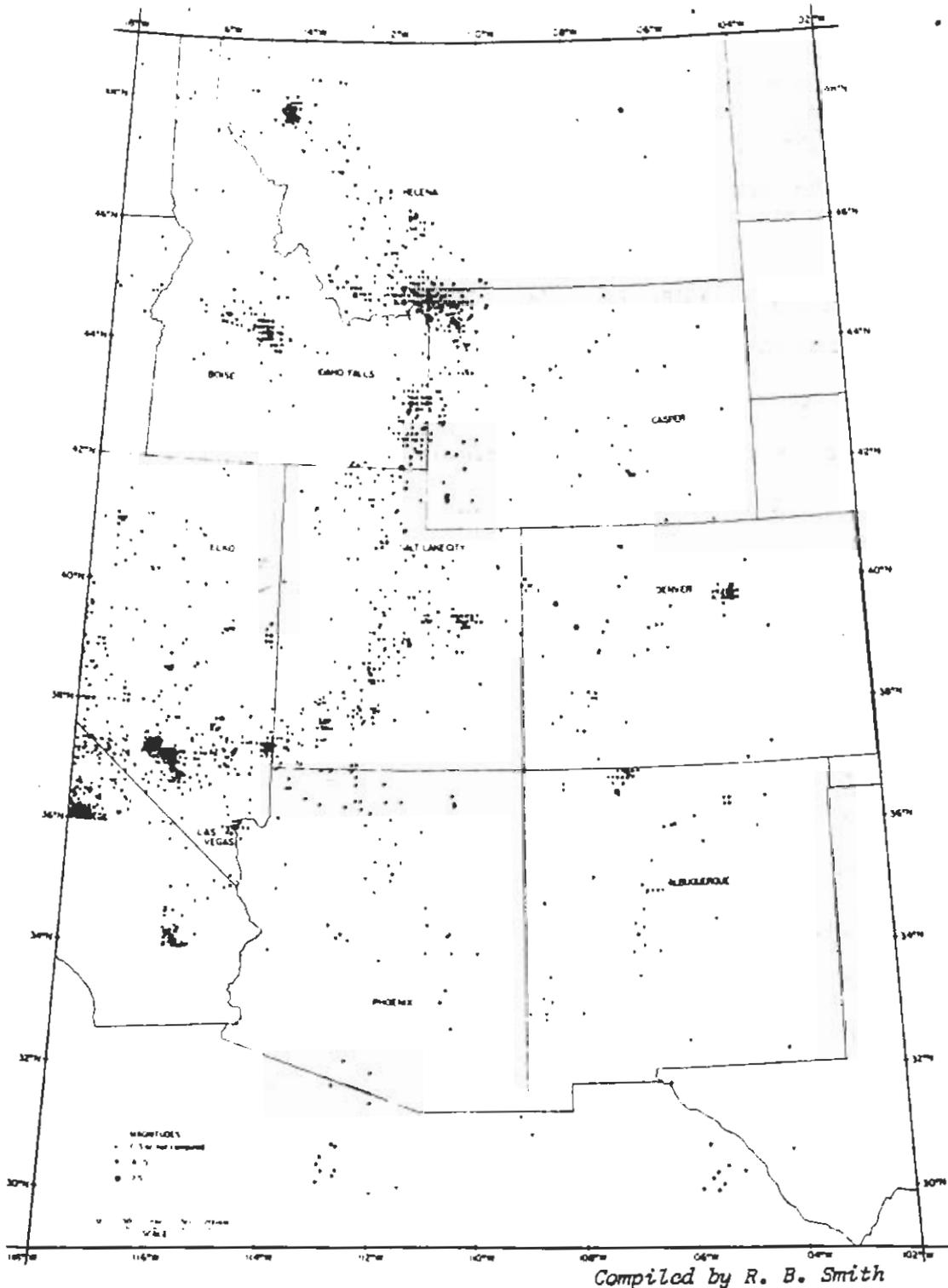


Figure 3. Epicenter map of the Intermountain seismic belt (from Arabasz and others, 1979).

districts, three of which are divided into subdistricts, based on geologic characteristics of driller's logs and well cuttings (fig. 1). The following is a brief description of the geologic materials characteristic for each of these areas:

East Bench District

The East Bench district is bounded to the north, south, and west by the East Bench fault and to the east by the Wasatch Mountains (fig. 1). South of Emigration Creek, a pediment extends approximately 1 mile (1.6 km) west of the range front and is primarily composed of sandstone, limestone, and shale of Jurassic and Triassic age. In most areas, this pediment is only a few feet below the surface and is covered by channel sands and gravels. In other areas of the district the sediments consist predominantly of boulders, gravel, sand, silt, and clay. The sources of this material are primarily mudflows as well as channel, colluvial and flood-plain deposits. Thicknesses range from less than 3.28 feet (1 m) in the area of the pediment to as much as 700 feet (213 m) in the alluvial fans at the mouths of Parleys and Mill Creek Canyons.

East Lake Plain District

The East Lake Plain district is bounded to the east by the East Bench fault, to the west by the Jordan River, to the north by the Salt Lake salient and to the south by an abandoned channel of Big Cottonwood Creek (fig. 1). This district is divided into three subdistricts which are as follows:

East Lake Plain Subdistrict--The East Lake Plain subdistrict is composed principally of lake bottom clays with intercalated, discontinuous lenses of gravel. In places, these sediments are modified by recent flood-plain deposits of the Jordan River as well as by the broad alluvial fans of City, Emigration, Parleys, and Mill Creeks. These deposits are underlain at depth by sediments of the Lake Bonneville Group which, in turn, are underlain by

pre-Lake Bonneville deposits. Underlying these unconsolidated sediments are Tertiary limestone or shale. Shale was encountered in a well in sec. 12, T. 1 S., R. 1 W. at 1,168 feet (356 m).

City Creek Fan Subdistrict--The City Creek Fan subdistrict sediments are pre-Lake Bonneville alluvial fan material consisting primarily of well-sorted boulders and gravel. The Wasatch Formation underlies this subdistrict at a depth of approximately 500 feet (152 m).

North Bench Subdistrict--The North Bench subdistrict consists of interfaced pre-Lake Bonneville mud-rock flows, Lake Bonneville deposits, and Recent mud-rock flows. To the east and south, these deposits grade into the City Creek Fan subdistrict and Lake Plain subdistrict deposits, respectively. Generally, the deposits consist of boulders, gravel and clay.

Cottonwoods District

The Cottonwoods district is bounded to the north by an abandoned channel of Big Cottonwood Creek and the East Bench fault, to the east by the Wasatch fault zone, to the south by Dry Creek, and to the west by the Jordan River (fig. 1). Sediments in the district have been derived from a number of sources, which are as follows: (1) glacial outwash and till, (2) lake deposits, including spits and deltas, and (3) alluvium and colluvium. The sediments consist of gravel and sand which predominate near the mountain front with clay increasing toward the Jordan River. Depth to bedrock ranges from a few feet at the Bonneville shore level to more than 3000 feet (915 m) beneath the Jordan River (Everitt, 1979; and Meiji Resource Consultants, 1983).

Southeast District

The Southeast district is bounded to the north by Dry Creek, to the east by the Wasatch fault zone, to the south by the Traverse Mountains and to the

west by the Jordan River (fig. 1). A pediment, formed on the Oquirrh Formation, extends northwest from the East Traverse Mountains into the valley and is covered by lakeshore sand and gravel. In the Jordan Narrows, gravel and clay have been logged to a depth of approximately 150 feet (46 m), and are underlain by the Salt Lake Group of Slentz (1955). In most other areas of the district, unconsolidated sediments consist of Lake Bonneville spit sand and gravel and alluvial fan gravel, sand, and clay. Depth to bedrock is from less than 1000 feet (305 m) on the pediment to greater than 2000 feet (710 m) at the Jordan River (Everitt, 1979; and Meiji Resource Consultants, 1983).

West Slope District

The West Slope district is bounded to the south by the Traverse Mountains, to the west by the Oquirrh Mountains, to the north by a physiographic break in slope, to the northeast by the Granger fault scarp, and to the east by the Jordan River (fig. 1). This district includes a broad alluvial-pediment slope formed primarily on rocks of the Salt Lake Formation and has been divided into two subdistricts which are as follows:

North Pediment Subdistrict--The North Pediment subdistrict consists of a thin layer of alluvial or lacustrine deposits overlying the lower units of the Salt Lake Group. Bedrock is considered to range from less than 1000 feet (305 m) to more than 3000 feet (915 m) in this subdistrict (Everitt, 1979; and Meiji Resource Consultants, 1983).

South Fan Subdistrict--Deposits in the South Fan subdistrict consist primarily of gravel, boulders, and clay of the Harker's fanglomerate and the Camp Williams units of the Salt Lake Group (Slentz, 1955). The two units are, in turn, underlain by the Jordan Narrows unit. Depth to bedrock varies from less than 305 meters (1000 feet) to more than 915 meters (3000 feet) in this area (Everitt, 1979).

Northwest Lake Plain District

The Northwest Lake Plain district is bordered to the east by the Jordan River, to the south by the Oquirrh Mountains and the change in slope caused by the north boundary of the pediment extending east from the Oquirrhs, to the west and northwest by the Great Salt Lake, and arbitrarily to the north by the Salt Lake/Davis County Line (fig. 1). The district is covered by Lake Bonneville bottom deposits. The underlying sediments are such that the district is divided into four subdistricts which are as follows:

Northwest Lake Plain Subdistrict--The Northwest Lake Plain subdistrict consists of several thousand feet of lake clays with interbedded thin sand lenses. This unit is generally thought to extend to a depth of 2300 feet (700 m) at which point approximately 500 feet (152 m) of interbedded sand and andesite could be encountered which, in turn, is underlain by sand to 3500 feet (1067 m). The Wasatch Formation is thought to be present below this depth.

North Oquirrh Subdistrict--The North Oquirrh subdistrict consists of lake clay and silt, which thickens from a feather edge at the Oquirrh Mountains to approximately 450 feet (137 m) at the Great Salt Lake. The clay and silt are underlain by a coarse angular gravel ranging from 150 to 450 feet (46 to 137 m) in thickness. The gravel is, in turn, underlain by the Oquirrh Formation.

South Margin Subdistrict--The South Margin subdistrict is underlain by approximately 100 feet (30 m) of lake clay which, in turn, is underlain by 200 to 300 feet (61 to 91 m) of alternating and variable thicknesses of gravel and clay beds which are underlain by Oquirrh Formation.

Mid-Jordan Subdistrict--The Mid-Jordan subdistrict is underlain primarily by flood plain deposits of the Jordan River. The maximum thickness of unconsolidated deposits penetrated is 775 feet (236 m). No wells are known to have penetrated bedrock.

STRUCTURE OF THE JORDAN VALLEY

Faulting

The Joroan Valley is part of the Wasatch Front Valley physiographic subprovince of the Basin and Range physiographic province. The initial episode of block faulting which resulted in the elongated, parallel, north-south oriented mountain ranges with intervening basins, of which the Jordan Valley is one, occurred in Late Eocene (Eardley, 1955). Eardley (1955) has reported a second episode of block faulting which occurred in the Pliocene. A number of faults in the surficial valley deposits indicate that faulting has also occurred in Recent time although no major earthquakes have been recorded since historical time.

The Wasatch fault zone (the major zone of recent faulting) separates the Jordan Valley from the Wasatch Range from Corner Creek, sec. 3, T. 3 S., R. 1 E., to Mount Olympus, sec. 14, T. 2 S, R. 1 E., (plate 1). North of this location the Recent faulting (East Bench fault) extends to the northwest to sec. 33, T. 1 N., R. 1 E. (Van Horn, 1969) (plate 1). A number of faults have been located in excavations in northern Salt Lake City which indicate a possible continuation of a branch of the East Bench fault to the northwest, eventually adjoining the Warm Springs fault system located at the base of the Salt Lake Salient. Van Horn (1972) has mapped another fault that continues around the base of Mount Olympus and then northwest along the base of the range front approximately 4 miles (6.4 km), to sec. 15, T. 1 S., R. 1 E. (plate 2). Movement on this fault is thought to have occurred more than 5000 years ago (Van Horn, 1972). North of this point, Van Horn (1969) considers the faulting to have occurred prior to 3,000,000 years ago. An older branch of this fault (pre-5000 years old according to Van Horn, 1972) continues from sec. 3, T. 1 S., R. 1 E., northeast to sec. 33, T. 1 N., R. 1 E., there rejoining the younger fault segment.

The East Bench fault forms the eastern boundary of a visible inner graben in the Jordan Valley. The western boundary of this inner graben is what Marine and Price (1964) have mapped as the Jordan Valley fault zone, which is approximately 1 mile (1.62 km) wide, and includes the Granger fault to the west and the Taylorsville fault to the east (plate 2). This fault zone is oriented northwest-southeast and extends from approximately sec. 11, T. 2 S., R. 1 W., in the south to sec. 17, T. 1 S., R. 1 W., to the north.

Evidence of other faulting that occurred prior to Recent time is also apparent in the Jordan Valley. The Traverse Mountains are separated from the valley by a normal fault referred to by Marine and Price (1964) as the Steep Mountain fault (plate 2). Normal faulting has also been mapped by Slentz (1955) along the base of the Oquirrh Mountains between the Pennsylvanian Oquirrh Formation and the Tertiary Harker's fanglomerate from the Traverse Mountains to just south of Bacchus (plate 2). Slentz (1955) reports that, in places, the fanglomerate is downfaulted to the east and in other areas the fault is buried beneath the fanglomerate. Tooker and Roberts (1961) have mapped Sevier Orogeny thrust faulting at the north end of the Oquirrh Mountains (plate 2). Also, Van Horn (1975) has located a number of additional faults beneath the valley sediments based on geophysical investigations; these fault locations are speculative and have not been included on plate 2.

Geophysical Investigations

Site Specific Gravity Surveys--Detailed gravity surveys were conducted by UGMS on two known low- temperature geothermal resource areas in the Jordan Valley: the Warm Springs fault geothermal system and Crystal Hot Springs. The Warm Springs fault geothermal system is located at the western edge of the Salt Lake Salient at the northern end of the valley (fig. 4). The gravity survey consisted of 12 east-west oriented gravity lines with individual

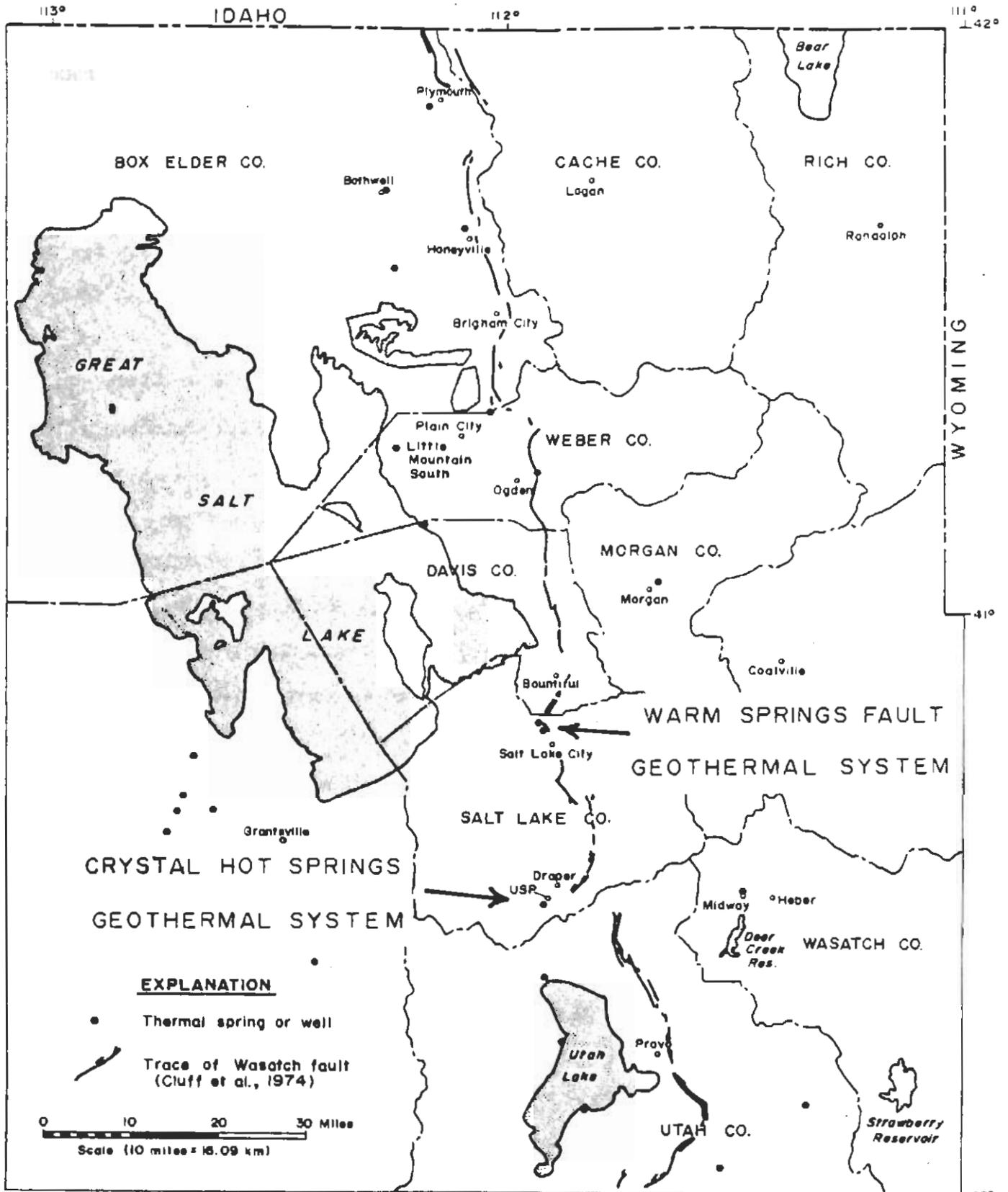


Figure 4. Location of the Warm Springs fault and Crystal Hot Springs geothermal systems, Salt Lake County, Utah.

station spacings of 500 to 1000 feet (152 to 304 m). Individual gravity lines were spaced from 0.25 to 0.75 miles (0.4 to 1.2 km) apart. One gravity profile was modeled using a three dimensional program. The modeling indicates, from east to west, two faults, a deep alluvium-filled graben and a horst block; the easternmost fault corresponds to the Warm Springs fault. The model indicates the downthrown block of the Warm Spring fault to the west is covered by approximately 328 feet (100 m) of alluvium (Murphy and Gwynn, 1979b). The Hobo Springs fault (the second fault to the west) is also downthrown to the west and borders the aforementioned graben. This graben has an estimated depth of 4000 feet (1220 m).

Crystal Hot Springs is located in southern Jordan Valley, southwest of the town of Draper (fig. 4). An area-wide gravity survey was conducted by orienting profiles perpendicular to the East Traverse and Wasatch Mountain ranges. Profiles were spaced at nearly 0.5 mile (0.8 km) intervals with approximately 1000 feet (304 m) intervals between individual stations. The area-wide survey provided a regional setting upon which to base a more detailed gravity grid to better delineate the structure beneath the springs (Utah Energy Office, 1981). The detailed grid consisted of 290 gravity stations, spaced at 350 feet (107 m) intervals, centered on the thermal springs.

The regional gravity surface resulting from the area-wide gravity survey indicates normal range-front fault segments bordering the west and north edges of the Wasatch and Traverse Mountain ranges, respectively (Utah Energy Office, 1981). Furthermore, this report states that in the vicinity of the thermal springs, these faults trend almost east-west and abruptly terminate at a gravity high to the south. In other areas, the presence of northeast trending faults is indicated.

Modeling of the data suggests Crystal Hot Springs is located between two range front faults striking roughly east-northeast, and dipping to the northwest (Utah Energy Office, 1981). Drill hole data have indicated a third range front fault to the northwest. The report also points out that the structure between the southernmost two range front faults is quite complex, consisting of a number of small, tilted fault blocks.

The detailed gravity surveys indicate that the Jordan Valley is very complex structurally, consisting of smaller scale bedrock horsts and grabens beneath unconsolidated valley sediments within the valley-wide graben. Work by Meiji Resource Consultants, (1983), Everitt (1979), and Arnow and Mattick (1968) also indicate a complex graben system within the Jordan Valley.

Valley-Wide Gravity Surveys--A gravity survey over the entire study area which consisted of 800 stations along 40 profiles at 0.25 to 0.5 mile (0.4 to 0.8 km) intervals was conducted due to the structural complexity of the Jordan Valley. This survey was designed to compliment the two site specific surveys and the work previously conducted by Cook and Berg (1961). The result of incorporating this data with the work previously done can be seen in the "Complete Bouguer Gravity Anomaly Map" of Jordan Valley, Utah by Adhidjaja and others (1981). This map indicates a number of major bedrock fault blocks may be present in the Jordan Valley. This could be significant because the borders of these fault blocks could provide conduits for geothermal water.

Valley-Wide Gravity Modeling--Meiji Resource Consultants (1983) were contracted by the UGMS to model existing gravity data for the Jordan Valley to better determine the structural regime throughout the valley as well as to further investigate the Warm Springs fault geothermal system. Major buried features in the valley include: (1) the downfaulted western extension of the Cottonwood Stock in the southern valley; (2) an east-west oriented mid-valley

bedrock ridge; and (3) Precambrian bedrock high at the northern end of the valley. Further modeling of the warm springs fault zone indicates this area may represent the western boundary of a gravity slide block.

Aeromagnetic Surveys--An aeromagnetic survey, 9.5 miles (15.4 km) in length (north-south), 6 miles (9.7 km) in width (east-west) and centered on Crystal Hot Springs, was flown to detail the complex magnetic surface of the area. The Utah Energy Office (1981) report concluded that the observed magnetic anomaly results from a series of intrusive and extrusive bodies that trend east-northeast and range in depth from 7500 feet (2887 m) to within 350 feet (107 m) of the surface. These bodies are thought to be intrusive at depth, but shallower levels may be either intrusive dikes and sills or extrusive flows (Utah Energy Office, 1981). The report also noted that many of the stacked prisms used to model the intrusives shared common edges which could indicate the presence of deep seated structures. One of these deep seated structures is present just north of the thermal springs and may be coincident with faults delineated on the basis of gravity data (Utah Energy Office, 1981). Results of this survey and preliminary modeling provide an understanding of the distribution of the magnetic susceptibility in the subsurface and a major normal range front fault north of the springs (Utah Energy Office, 1981).

GROUND WATER

Ground water in the Jordan Valley occurs in: (1) a large artesian aquifer, (2) a deep unconfined aquifer, (3) a shallow unconfined aquifer overlying the (artesian) confined aquifer, and (4) in local, perched unconfined aquifers (fig. 5). All are hydraulically interconnected to some extent, but the deep unconfined aquifer directly recharges the large artesian

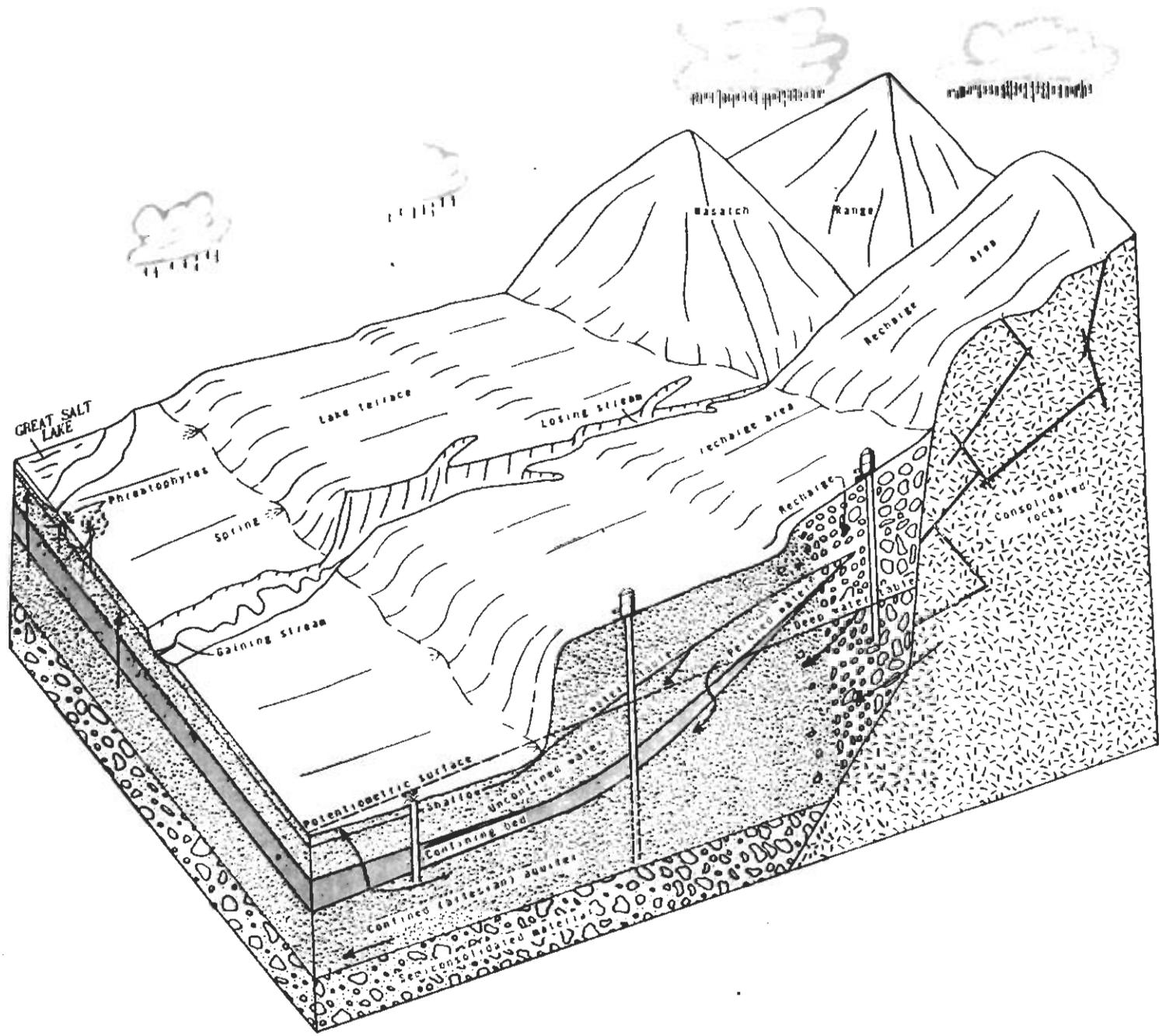


Figure 5. Ground water under unconfined, artesian, and perched conditions in the Jordan Valley, Utah (modified after Hely and others, 1971).

aquifer forming the principal ground-water reservoir (Hely and others, 1971). The shallow unconfined aquifer overlies the confining layer for the artesian aquifer while the locally perched aquifers are in areas overlying the deep unconfined reservoir. This confining layer generally consists of clay, silt and fine sand, ranging in thickness from 40 to 100 feet (12 to 30 m), and lying between 50 and 150 feet (15 and 46 m) below the surface (Hely and others, 1971). The shallow, unconfined aquifer extends over the same area as the confined aquifer while the perched aquifers are found primarily east of Midvale and west of Riverton overlying the deep unconfined aquifer (fig. 6).

Principal Aquifer

The deep unconfined aquifer in the Jordan Valley is a principal recharge source for the artesian aquifer. The line dividing these two aquifers can only be approximately located due to shifts caused by response to changing rates of recharge and discharge (Hely and others, 1971) (fig. 6).

The artesian aquifer consists of Quaternary deposits of interbedded clay, silt, sand, and gravel, all hydraulically interconnected; thin beds and lenses of fine-grained material up to 20 feet (6 m) thick tend to confine water in each of the many individual beds of sand and gravel. The fine-grained material is slightly to moderately permeable and discontinuous, thereby allowing movement of water between the various permeable beds of sand and gravel (Hely and others, 1971). This confined aquifer attains a maximum thickness of more than 1000 feet (305 m) in the northern part of the valley (Hely and others, 1971). For the most part this aquifer is underlain by Tertiary and pre-Tertiary deposits. In some areas the Tertiary deposits are permeable enough to yield water to wells (Hely and others, 1971).

Recharge and Movement

Recharge to the Jordan Valley ground-water system comes from the following sources: (1) seepage from bedrock fractures in the adjoining mountains, (2)

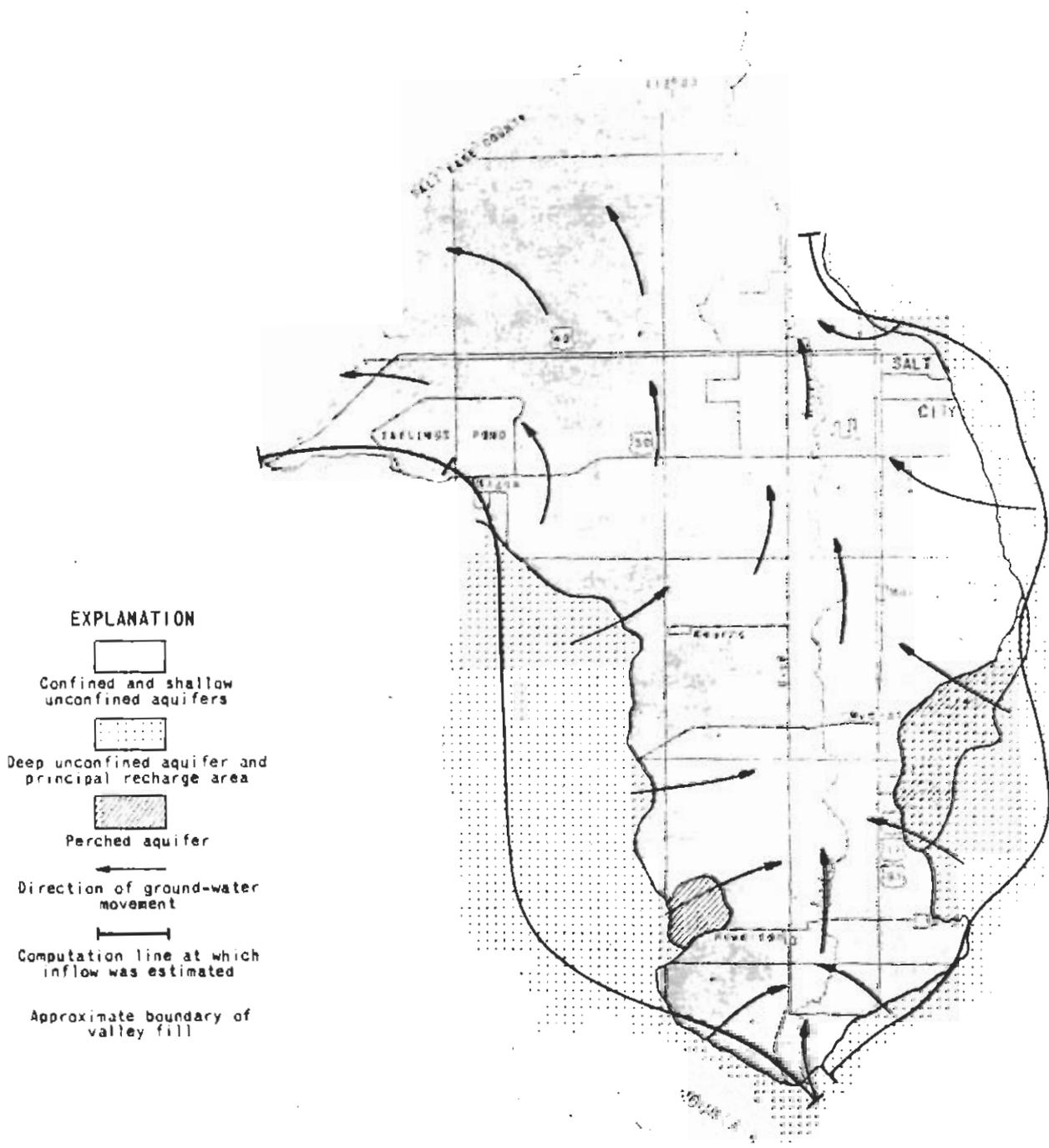


Figure 6. Approximate areas in which ground water occurs in confined, shallow unconfined, deep unconfined, and perched aquifers in the Jordan Valley, Utah (from Hely and others, 1971).

underflow in channel fill draining the adjacent canyons, (3) underflow from Utah Valley to the south through the Jordan Narrows and the East Shore area to the northwest of the Salt Lake salient, (4) seepage from creek channels and the Jordan River, (5) seepage from unlined canals, (6) migration upward through fault systems, (7) direct precipitation, (8) seepage from irrigation, and (9) seepage from tailings ponds.

Ground-water movement in the principal aquifer is generally northward toward the Great Salt Lake. Ground water migrates laterally toward the Jordan River from both the east and west sides of the valley and, subsequently, migrates to the north (fig. 6).

WARM SPRINGS FAULT GEOTHERMAL SYSTEM

The Warm Springs fault geothermal system is represented by an area approximately 3 miles (4.9 km) in length and 0.75 miles (1.2 km) in width. Included within this strip are Beck Hot Springs, Wasatch Warm Springs, Hobo Warm Springs, and Clark Warm Springs as well as two shallow warm water wells pumped by the Monroc Corporation. Discharge temperatures in this system range from 27°C (Clark Warm Springs) to 55°C (Beck Hot Springs).

Murphy and Gwynn (1979b) report this geothermal system is controlled by water circulating to depth and, subsequently, migrating up the Warm Springs and Hobo fault systems. This report also indicates that major springs tend to occur at the intersections of these major faults with older, minor structures striking roughly perpendicular (east-west). Meiji Resource Consultants (1983) indicate the Salt Lake salient may be a gravity slide block with the Warm Springs fault zone representing the western boundary of this block. Meiji Resource Consultants (1983) also suggest the glide plane could provide conduits for recharge to the geothermal system.

CRYSTAL HOT SPRINGS GEOTHERMAL SYSTEM

The Crystal Hot Springs geothermal system has been investigated and reported on by Murphy and Gwynn (1979a), the Utah Energy Office (1981), and Morrison-Knudson Company, Inc. (1982). Results of these studies indicate Crystal Hot Springs is located between two range-front faults with fractured Paleozoic quartzite (at depth) leaking warm water into the springs through overlying unconsolidated material. Temperatures between 55^o and 84^oC have been measured at the springs. A geothermal production well for the Utah State prison, drilled into the fractured Paleozoics, encountered temperatures from 85^o to 90^oC. Morrison-Knudson (1982) reports that isotopic data indicate the geothermal water is meteoric in origin, from moderate to high elevations within the Wasatch Range; this water circulates to depth, is heated and rises to the surface by convection.

UTAH ROSES FLORAL GREENHOUSE GEOTHERMAL PROJECT

Utah Roses, Inc., greenhouse facility is located, 14 miles (22.6 km) south of Salt Lake City, in Sandy, Utah. The high cost of heating this facility initiated an effort to develop a low-temperature geothermal resource at this location. Utah Roses, Inc. applied for and was selected to receive funding for such a project under the Department of Energy Project Opportunity Notice (PON ET-78-N-03-2047).

Initially, a target well depth of 4000 feet (1220 m) was envisioned to intercept a hot water aquifer thought to exist between 3000 and 4000 feet (915 and 1220 m). Hopefully, 50^oC water at 600 gpm (37.8 l/s) could be produced. Actually, the hole was extended to 5009 feet (1527 m) and 49^oC water at 200 gpm (12.6 l/s) was achieved. Lawrence Berkeley Laboratory and the Idaho National Engineering Laboratory (1981) indicate the problems which were encountered with this project:

"The Utah Roses project illustrates problems that can be expected when small-scale projects are implemented with a limited budget in a highly developed area. The site selection was based on space heating requirements at an existing greenhouse structure. This limited site selection to an economical piping distance from the greenhouse. In addition, land ownership further restricted site selection to the developer's existing property. No surficial manifestation of a geothermal resource was evident on the Utah Roses property reducing the odds of a usable shallow depth resource. The geology, hydrology, and geophysical surveys were oriented toward a regional interpretation. No site-specific surveys to delineate lithology, structure, or hydrology were accomplished. One site was considered as good as any other, since exploration and drilling was restricted to the Utah Roses property. However, this approach should be questioned, since any geothermal system at this locale would be fracture controlled. A site-specific-resistivity survey and local-gradient drilling should have been the minimum accomplished. A target model was apparently not developed due to land ownership restrictions and the limited site-specific data. The probability of drilling one well to successfully find a resource was low."

TEMPERATURE SURVEY

An attempt was made to measure temperatures in wells that intercepted the principal aquifer. Where no wells intercepting the principal aquifer were available or accessible, shallower wells were used, although these are few in number. Temperatures were recorded at 214 locations by UGMS personnel with a Yellow Springs Instrument (YSI) Model 33 Temperature-Conductivity meter. An additional 9 temperatures were obtained from local municipal water

departments, and 15 temperatures were provided by the Kennecott Copper Corporation. Of the 214 locations measured by UGMS, five were springs with the balance consisting of pumped or flowing wells. Temperatures ranged from 7.5^o to 85^oC.

Nathenson and others (1982) define low-temperature geothermal resources as being no lower than 10^oC above the mean annual air temperature at the surface, increasing by 25^oC/Km with depth to a maximum of 90^oC. The mean annual air temperature in the Jordan Valley is considered to be 10^oC and the average Basin and Range temperature gradient is considered to be 35^oC/Km. Therefore, temperatures 20^oC and greater are considered to have low-temperature geothermal potential and will be referred to as thermal water. Based on this criterion, six general areas as well as three isolated wells have recorded water temperatures indicative of possible low-temperature resources. Two of these areas, the Warm Spring fault geothermal area and Crystal Hot Springs are previously known because of warm water at the surface. The remaining four general areas are not evident at the surface. These areas are: (1) the north-central valley area, (2) the area immediately north of the Oquirrh Mountains, (3) an east-west oriented portion of the central valley in the vicinity of Taylorsville, Murray, and Holladay, and (4) a north-south oriented area extending from Draper to Midvale, Utah. These areas can be identified in plate 3.

Temperatures in the northcentral valley area range from 20^o to 28^oC and are spread over a fan-shaped area covering approximately 33 square miles (85 km²). The north Oquirrh area, located immediately north of the Oquirrh Mountains, has temperatures ranging from 21^o to 29^oC. Thermal temperatures were measured in three wells located north and northwest of Taylorsville in the central valley area. These wells produced temperatures

ranging from 20^o to 21^oC. Two wells with temperatures of 24^o and 22^oC are located in Holladay.

A temperature of 24^oC was measured in a well in the Midvale area. Two wells in the Sandy City area had temperatures of 21^o and 26^oC. A third well drilled by Utah Roses to a depth of 5009 feet (1527 m) produced a temperature of 48^oC. Wells in Draper and 1.7 miles (2.8 km) to the northwest in Crescent have temperatures of 26^o and 22^oC, respectively.

Other Isolated Warm Temperatures

A temperature of 21^oC was recorded for a well approximately 1.25 miles (2 km) southwest of Kearns, Utah. A temperature of 21^oC was also recorded for a well at the mouth of Rose Canyon in southwestern Jordan Valley. Both of these wells are located on plate 3.

WATER CHEMISTRY

One hundred and ninety-nine water samples were collected and analyzed in the Jordan Valley as part of this study. See plate 4 for sample locations. The on-site analyses consisted of: (1) pH, (2) alkalinity, and (3) conductivity. A Corning-Orion Model 407A/F specific ion meter in conjunction with an Orion gel-filled Model 91-05 combination pH electrode was used to measure pH. Three readings were taken and the average was recorded as the final value. A YSI Model 33 Temperature-Conductivity Meter was used to measure conductivity. Alkalinity was measured using a Hach Alkalinity Model AL-AP test kit.

Three (two 570 ml. and one 65 ml.) polyethylene bottles were filled at each sampling location with water filtered through a GeoFilter Peristaltic Pump - Model #004 using a 0.45 micron filter paper. This water was subsequently analyzed at the University of Utah Research Institute/Earth

Science Laboratory (WURI/ESL). The 65 ml. bottle was acidified with reagent grade HNO_3 to a final concentration of 20% HNO_3 for cation analysis of elements presented in table 1 by an APL Inductivity Coupled Plasma Quantometer (ICPQ). A 570 ml. bottle was acidified with concentrated HCl to a final concentration of 1% HCl for SO_4 analysis. The remaining bottle was unacidified and the water was analyzed for Cl, F, and total dissolved solids (TDS). Results of the analyses are presented in table 2.

The Jordan Valley exhibits complex ground-water chemistry which is attributable to complicated stratigraphy, structure, irrigation and mining practices, as well as geothermal activity. This chemistry is further complicated because samples were collected at the well head and many times individual wells were screened and/or completed at or to various depths within the aquifer. However, some general chemical characteristics are evident.

The total dissolved solids (TDS) content of ground water in the principal aquifer in the Jordan Valley is composed primarily of four common cations, three common anions, and silica (SiO_2). The cations consist of calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg); the anions are bicarbonate (HCO_3), sulfate (SO_4), and chloride (Cl). Other elements present within detectable limits in at least some samples were: iron (Fe), boron (B), lithium (Li), fluorine (F), zinc (Zn), phosphorous (P), tin (Sn), lead (Pb), chromium (Cr), barium (Ba), tungsten (W), and manganese (Mn).

The chemical quality of ground water depends on the quality of recharge, composition and physical properties of sediments through which it passes, and the duration of the contact with such sediments (Hely and others, 1971). Generally, ground water in the principal aquifer east of the Jordan River is of lower TDS (higher quality) than to the west. This results from recharge with lower TDS from streams and bedrock in the Wasatch Mountains to the east

Table 1: Limits of quantitative detection (LQD) for solution analysis by the University of Utah Research Institute/Earth Science Lab Inductively Coupled Plasma Quantometer.

<u>Element</u>	<u>Concentration (mg/l)</u>
Na	1.25
K	2.50
Ca	0.250
Mg	0.500
Fe	0.025
Al	0.625
Si	0.250
Ti	0.125
P	0.625
Sr	0.013
Ba	0.625
V	1.25
Cr	0.050
Mn	0.250
Co	0.025
Ni	0.125
Cu	0.063
Mo	1.25
Pb	0.250
Zn	0.125
Cd	0.063
As	0.625
Sb	0.750
Bi	2.50
Sn	0.125
W	0.125
Li	0.050
Be	0.005
B	0.125
Zr	0.125
La	0.125
Ce	0.250
Th	2.50

LQD concentrations represent the lowest reliable analytic values for each element. Precision at the LQD is approximately \pm 100% of the given value with a confidence level of 95%.

Table 2. Water analysis from wells and springs in the Jordan Valley, Salt Lake County, Utah.

(u - elements not present or not present in detectable concentrations.)

Sample #		R-1	R-2	R-3	R-4	R-5	R-6	R-7
Location		(D-1-1)7aca 40°45'01" 111°52'38"	(D-1-1)20bab 42°43'30" 111°51'57"	(D-1-1)35bbb 40°41'43" 111°48'47"	(D-1-1)10dab 40°44'47" 111°49'08"	(D-1-1)9bab 40°45'16" 111°50'49"	(D-1-1)22cda 40°42'53" 111°49'29"	(D-1-1)19bac 40°43'22" 111°53'62"
Temp.	°C	13	17	14	13	14	13	14
pH		7.32	6.92	7.05	7.15	6.90	7.15	7.15
TDS	mg/l	634	718	562	210	448	580	696
HCO ₃	mg/l	295	243	243	168	268	435	295
Na	mg/l	45	40	15	9	25	46	25
K	mg/l	u	3	u	u	u	u	3
Ca	mg/l	92	96	105	52	77	103	106
Mg	mg/l	38	40	34	10	28	29	36
Fe	mg/l	u	u	0.03	u	u	u	u
SiO ₂	mg/l	7	15	11	6	13	13	13
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Str	mg/l	0.90	1.64	1.11	0.24	0.65	1.43	1.46
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	0.4
Zn	mg/l	u	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	0.1	u	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	u	u	u	u	u
F	mg/l	0.2	0.4	0.3	0.2	0.2	0.2	0.4
Cl	mg/l	53	35	24	23	38	99	28
SO ₄	mg/l	164	279	198	31	102	94	278

Table 2. (continued.)

Sample #		R-8	R-9	R-10	R-11	R-12	R-13	R-14
Location		(D-1-1)4cbd 40°45'32" 111°50'55"	(D-1-1)28dca 40°41'55" 111°50'22"	(D-2-1)5dca 40°40'17" 111°51'29"	(D-2-1)4cda 40°40'14" 111°50'37"	(D-2-1)4acb 40°40'41" 111°50'32"	(D-1-1)31aad 40°41'39" 111°52'21"	(D-3-1)19bba 40°33'03" 111°53'12"
Temp.	°C	13	16	24	22	15	13	22
pH		7.28	6.96	6.91	6.92	7.02	7.30	6.75
TDS	mg/l	552	686	618	554	902	552	2022
HCO ₃	mg/l	337	278	382	330	452	330	400
Na	mg/l	29	23	45	39	77	32	220
K	mg/l	u	3	3	u	3	u	28
Ca	mg/l	86	105	97	82	111	84	252
Mg	mg/l	32	41	31	31	46	32	69
Fe	mg/l	u	u	u	u	u	u	0.22
SiO ₂	mg/l	13	13	11	9	11	11	19
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.88	1.68	1.12	1.03	1.33	1.14	3.54
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	0.7	0.7	0.6	u	u
Zn	mg/l	u	u	0.2	0.4	0.3	u	0.3
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	u	u	0.37
B	mg/l	u	u	u	u	u	u	0.3
F	mg/l	0.2	0.4	0.3	0.3	0.3	0.3	0.6
Cl	mg/l	66	23	79	67	121	56	350
SO ₄	mg/l	128	293	139	135	227	154	736

Table 2. (continued.)

Sample #		R-15	R-16	R-17	R-18	R-19	R-20	R-21
Location		(D-3-1)29cbc 40°31'38" 111°52'15"	(D-3-1)31abb 40°31'18" 111°52'48"	(C-2-1)36ddb 40°35'49" 111°53'41"	(D-2-1)30dbc 40°36'52" 111°52'50"	(D-3-1)7acc 40°34'26" 111°52'47"	(D-3-1)6cdc 40°35'07" 111°54'16"	(D-2-1)33dca 40°35'55" 111°50'21"
Temp.	°C	24	15	15	14	15	18	12
pH		7.15	7.00	7.18	7.27	7.16	7.20	7.30
TDS	mg/l	1002	282	246	152	704	700	236
HCO ₃	mg/l	295	330	157	122	313	153	168
Na	mg/l	267	14	20	9	88	107	12
K	mg/l	18	9	u	u	4	4	u
Ca	mg/l	59	42	36	23	92	75	47
Mg	mg/l	11	20	11	9	31	23	12
Fe	mg/l	0.37	1.02	u	u	u	u	u
SiO ₂	mg/l	24	30	11	11	13	13	9
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	0.9	u	u	u	u	u
Sr	mg/l	1.13	0.43	0.29	0.19	0.38	0.80	0.28
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	0.5	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.7	0.1	u	u	u	0.2	0.1
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.36	u	u	u	u	u	u
B	mg/l	0.5	u	u	u	0.1	u	u
F	mg/l	0.8	0.4	0.3	0.3	0.3	0.2	0.6
Cl	mg/l	400	14	41	15	121	290	12
SO ₄	mg/l	58	u	27	16	159	16	24

Table 2. (continued.)

Sample #		R-22	R-23	R-24	R-25	R-26	R-27	R-28
Location		(D-3-1)4dbc 40°35'08" 111°50'34"	(D-2-1)3acd 40°40'46" 111°49'11"	(D-2-1)4adc 40°40'35" 111°50'10"	(D-3-1)6bad 40°35'31" 111°52'54"	(D-3-1)12bdc 40°34'24" 111°47'18"	(D-3-1)15ccc 40°33'10" 111°49'51"	(D-2-1)3adba 40°36'07" 111°49'16"
Temp.	°C	11	12	14	13	10	11	12
pH		7.38	6.98	7.24	7.50	6.98	6.98	7.16
TDS	mg/l	192	384	598	302	178	184	170
HCO ₃	mg/l	137	278	295	138	138	153	122
Na	mg/l	12	16	26	12	11	12	8
K	mg/l	u	u	3	3	u	u	u
Ca	mg/l	48	65	93	49	32	32	35
Mg	mg/l	9	26	39	11	7	9	8
Fe	mg/l	0.17	0.03	u	0.04	u	u	u
SiO ₂	mg/l	13	6	11	11	9	13	9
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.21	0.87	1.30	0.30	0.29	0.23	0.27
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	1.2	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	u	u	u	u	u
F	mg/l	0.2	0.4	0.4	0.2	0.3	0.2	0.3
Cl	mg/l	15	24	37	65	21	12	15
SO ₄	mg/l	10	94	213	12	77	14	27

Table 2. (continued.)

Sample #		R-29	R-30	R-31	R-32	R-33	R-34	R-35
Location		(D-2-1)33abd 40°36'23" 111°50'17"	(D-3-1)4bbb 40°35'39" 111°51'07"	(D-2-1)30dda 40°36'43" 111°52'18"	(C-3-1)1cac 40°35'07" 111°54'16"	(C-2-1)24bcd 40°37'57" 111°54'17"	(D-4-1)5bcd 40°30'07" 111°52'03"	(D-4-1)6bch 40°29'57" 111°53'08"
Temp.	°C	12	12	14	26	16	13	16
pH		7.25	7.15	7.25	7.35	7.15	7.35	6.98
TDS	mg/l	190	218	182	422	393	720	1592
HCO ₃	mg/l	153	168	138	142	173	330	400
Na	mg/l	9	14	13	121	56	42	207
K	mg/l	u	u	u	4	u	11	15
Ca	mg/l	33	36	28	21	43	119	174
Mg	mg/l	8	9	10	8	19	31	64
Fe	mg/l	u	u	u	u	u	u	u
SiO ₂	mg/l	11	11	9	11	11	30	34
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.23	0.25	0.23	0.52	0.60	1.07	1.28
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	0.2
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	u	u	0.15
B	mg/l	u	u	u	u	u	u	0.3
F	mg/l	0.3	0.3	0.3	0.4	0.3	0.3	0.2
Cl	mg/l	13	18	22	160	86	154	292
SO ₄	mg/l	23	18	23	20	76	126	501

Table 2. (continued.)

Sample #		R-36	R-37	R-38	R-39	R-40	R-41	R-42
Location		(D-2-1)31bdc 40°36'13" 111°53'07"	(D-3-1)8acc 40°34'25" 111°51'40"	(D-3-1)8bbc 40°34'42" 111°52'15"	(D-3-1)8baa 40°34'50" 111°51'51"	(D-3-1)17aac 40°33'50" 111°51'23"	(D-3-1)32aaa 40°31'17" 111°51'10"	(C-1-1)35caa 40°41'19" 111°55'14"
Temp.	°C	13	18	21	16	18	14	20
pH		7.25	7.34	6.95	7.36	7.28	6.96	7.45
TDS	mg/l	536	428	1688	186	262	705	374
HCO ₃	mg/l	348	168	184	168	184	330	295
Na	mg/l	58	77	354	12	40	59	36
K	mg/l	3	u	7	u	u	5	u
Ca	mg/l	72	44	123	27	37	126	48
Mg	mg/l	27	9	27	7	8	26	16
Fe	mg/l	u	u	u	u	u	u	0.15
SiO ₂	mg/l	11	15	13	13	15	17	17
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.42	0.48	1.92	0.21	0.38	0.78	0.83
Ba	mg/l	u	u	0.8	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	0.3	u	u	u	u
F	mg/l	0.7	0.2	0.2	0.2	0.2	0.2	0.4
Cl	mg/l	78	134	800	21	59	134	36
SO ₄	mg/l	102	15	27	6	10	152	81

Table 2. (continued.)

Sample #		R-43	R-45	R-46	R-47	R-48	R-49	R-50
Location		(C-2-1)1dbb 40°40'24" 111°53'55"	(D-2-1)7ddb 40°39'21" 111°52'29"	(C-2-1)12ccd 40°39'13" 111°54'24"	(D-2-1)17dda 40°38'57" 111°51'49"	(D-2-1)22cac 40°37'41" 111°49'41"	(D-2-1)23bbc 40°38'07" 111°48'43"	(C-2-1)23dad 40°37'42" 111°54'40"
Temp.	°C	18	13	17	12	10	11	15
pH		7.35	7.39	6.45	6.92	7.05	7.05	6.95
TDS	mg/l	324	420	212	124	154	245	494
HCO ₃	mg/l	173	122	100	103	123	140	192
Na	mg/l	34	39	35	7	6	8	59
K	mg/l	u	3	u	u	u	u	3
Ca	mg/l	48	66	25	26	31	53	64
Mg	mg/l	17	25	11	9	9	18	28
Fe	mg/l	0.03	u	u	u	u	u	u
SiO ₂	mg/l	17	11	9	9	6	6	11
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.84	0.46	0.36	0.19	0.20	0.48	0.71
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	u	u	u	u	u
F	mg/l	0.3	0.3	0.3	0.2	0.2	0.1	0.2
Cl	mg/l	23	72	44	9	12	26	127
SO ₄	mg/l	109	82	45	19	25	50	93

Table 2. (continued.)

Sample #	R-51	R-52	R-53	R-54	R-55	R-56	R-58	
Location	(D-2-1)20cab 40°37'53" 111°51'56"	(C-2-1)13dcb 40°38'41" 111°53'53"	(C-2-1)12bad 40°39'56" 111°54'05"	(C-2-1)12aaa 40°39'58" 111°53'33"	(D-2-1)17cd 40°38'31" 111°51'52"	(D-1-1)4cbc 40°45'32" 111°50'58"	(D-3-1)14caa 40°33'29" 111°48'24"	
Temp.	°C	15	16	17	17	11	13	11
pH		6.91	6.90	6.57	6.55	6.39	6.80	6.66
TDS	mg/l	138	156	154	216	180	524	250
HCO ₃	mg/l	120	144	143	143	168	327	192
Na	mg/l	9	12	17	22	10	30	10
K	mg/l	u	u	u	u	u	u	u
Ca	mg/l	19	22	30	34	40	99	45
Mg	mg/l	8	9	12	13	12	39	9
Fe	mg/l	u	u	u	u	u	u	u
SiO ₂	mg/l	9	9	11	13	9	13	13
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.18	0.21	0.41	0.45	0.27	1.13	0.42
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	u	u	u	u	u
F	mg/l	0.3	0.2	0.2	0.2	0.2	0.2	0.1
Cl	mg/l	12	17	17	16	15	67	16
SO ₄	mg/l	16	22	44	64	32	172	23

Table 2. (continued.)

Sample #		R-59	R-60	R-61	R-62	R-63	R-64	R-65
Location		(D-3-1)14dbb 40°33'28" 111°48'11"	(B-2-2)35cda 40°51'28" 112°02'13"	(B-1-2)2dac 40°50'47" 112°01'40"	(B-1-2)8abc 40°50'18" 112°05'20"	(B-1-2)36baa 40°47'00" 112°00'56"	(B-1-2)28ddd 40°47'03" 112°03'48"	(B-1-2)21acd 40°48'23" 112°04'06"
Temp.	°C	11	16	27	19	26	23	22
pH		6.90	8.39	8.05	8.00	7.40	7.62	7.90
TDS	mg/l	178	1158	522	928	3812	1950	654
HCO ₃	mg/l	200	751	292	234	234	217	317
Na	mg/l	11	377	147	262	990	484	205
K	mg/l	u	u	3	u	17	12	5
Ca	mg/l	52	4	11	22	180	73	14
Mg	mg/l	10	6	3	16	57	42	6
Fe	mg/l	u	0.19	u	0.24	0.51	0.19	0.12
SiO ₂	mg/l	13	21	24	19	34	47	41
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.53	0.14	0.41	0.82	6.37	3.46	0.50
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.6	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	0.07	0.08	0.14	0.35	0.19	0.07
B	mg/l	u	0.7	0.3	0.5	0.5	0.4	0.4
F	mg/l	0.2	3.6	2.1	1.6	1.3	1.2	2.1
Cl	mg/l	17	287	134	432	2060	989	222
SO ₄	mg/l	25	u	u	4	42	3	u

Table 2. (continued.)

Sample #		R-66	R-67	R-68	R-69	R-70	R-71	R-73
Location		(D-4-1)6cab 40°29'59" 111°52'55"	(B-1-1)5odd 40°50'35" 111°58'08"	(D-4-1)6caa 40°29'59" 111°52'55"	(D-4-1)6aad 40°30'16" 111°52'23"	(D-1-1)7aac 40°45'07" 111°52'35"	(C-1-1)8ada 40°45'02" 111°58'08"	(C-1-1)14abd 40°44'14" 111°54'57"
Temp.	°C	16	28	79	13	15	14	12
pH		7.33	7.70	7.01	7.71	7.20	6.99	6.92
TDS	mg/l	1060	1047	1242	242	735	344	428
HCO ₃	mg/l	359	259	334	234	376	351	317
Na	mg/l	178	298	79	46	55	70	65
K	mg/l	16	12	17	10	3	3	3
Ca	mg/l	92	49	195	23	123	32	45
Mg	mg/l	43	10	49	6	44	13	22
Fe	mg/l	u	0.08	0.05	0.03	0.04	0.31	0.21
SiO ₂	mg/l	34	51	39	30	15	16	15
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.60	1.51	1.74	0.41	1.16	0.50	0.62
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	0.10	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	0.2	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.11	0.14	0.13	0.11	u	u	u
B	mg/l	0.3	0.4	0.1	u	u	u	u
F	mg/l	0.4	1.4	0.2	0.6	0.3	0.3	0.3
Cl	mg/l	212	482	221	29	96	26	22
SO ₄	mg/l	296	u	394	14	158	25	103

Table 2. (continued.)

Sample #		R-74	T-1	T-3	T-4	T-5	T-6	T-7
Location		(B-2-2)36bad 40°46'53" 111°54'08"	(C-1-1)14dcd 40°43'40" 111°54'57"	(C-1-1)15cad 40°43'49" 111°56'26"	(C-1-1)23cbd 40°42'54" 111°55'28"	(C-1-1)26ccc 40°41'53" 111°55'36"	(C-1-1)25cca 40°41'54" 111°54'18"	(C-1-2)36bbb 40°41'41" 112°01'21"
Temp.	°C	17	13	14	13	15	14	14
pH		7.40	6.90	6.68	6.89	6.85	7.45	6.70
TDS	mg/l	3338	362	638	1052	1244	284	1212
HCO ₃	mg/l	401	259	217	217	334	217	476
Na	mg/l	686	39	51	52	122	13	185
K	mg/l	18	u	4	9	6	u	4
Ca	mg/l	238	53	70	126	130	56	100
Mg	mg/l	67	21	32	65	59	19	58
Fe	mg/l	u	0.39	0.19	1.21	0.04	0.24	u
SiO ₂	mg/l	14	13	15	18	14	11	35
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	2.87	0.73	0.95	1.42	1.30	0.66	1.00
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	0.3	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.18	u	u	0.06	u	u	0.11
B	mg/l	0.4	u	u	u	u	u	0.4
F	mg/l	0.3	0.4	0.3	0.2	0.3	0.3	0.4
Cl	mg/l	1417	17	178	220	276	15	235
SO ₄	mg/l	455	104	101	314	360	69	317

Table 2. (continued.)

Sample #		T-8	T-9	T-10	T-11	T-12	T-13	T-14
Location		(C-1-2)22aac 40°43'20" 112°02'50"	(C-1-2)21bcd 40°43'07" 112°04'45"	(C-1-1)24ada 40°43'15" 111°53'27"	(C-1-1)27ccc 40°41'49" 111°56'49"	(C-1-1)25abc 40°43'27" 111°53'58"	(C-1-1)2cda 40°45'30" 111°55'15"	(C-1-1)7abc 40°45'07" 111°59'25"
Temp.	°C	11	14	13	13	16	12	17
pH		7.20	6.72	7.05	7.12	7.18	7.65	7.22
TDS	mg/l	982	1272	662	1632	332	414	394
HCO ₃	mg/l	284	351	317	417	250	484	200
Na	mg/l	269	331	35	281	28	94	61
K	mg/l	9	13	u	7	u	5	3
Ca	mg/l	34	56	109	129	48	25	39
Mg	mg/l	17	27	37	77	15	15	15
Fe	mg/l	1.58	0.04	0.19	0.04	0.12	0.29	0.14
SiO ₂	mg/l	44	35	11	25	14	19	17
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.63	0.79	1.51	1.40	0.68	0.37	0.75
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.11	0.13	u	0.13	u	u	u
B	mg/l	0.3	0.3	u	0.4	u	0.2	u
F	mg/l	0.9	0.5	0.3	0.3	0.3	0.5	0.5
Cl	mg/l	346	324	41	366	15	28	39
SO ₄	mg/l	136	249	238	433	76	u	125

Table 2. (continued.)

Sample #		Y-15	Y-16	Y-17	Y-18	D-1	D-2	D-3
Location		(C-1-2)31aaa 40°41'45" 112°06'04"	(C-1-2)35bad 40°41'40" 112°02'05"	(C-1-1)6bcc 40°45'50" 112°00'16"	(C-1-1)30adc 40°42'19" 111°59'29"	(C-3-1)31baa 40°31'17" 111°59'47"	(C-3-1)32aba 40°31'18" 111°58'19"	(C-3-1)34bda 40°31'05" 111°56'21"
Temp.	°C	16	15	20	13	14	15	16
pH		7.35	7.04	8.00	7.29	7.28	7.71	7.22
TDS	mg/l	926	1432	1160	1738	490	714	1070
HCO ₃	mg/l	259	401	167	376	292	459	292
Na	mg/l	132	185	321	348	38	74	74
K	mg/l	11	13	4	15	5	7	4
Ca	mg/l	60	106	48	107	80	129	155
Mg	mg/l	48	56	25	86	23	33	46
Fe	mg/l	0.17	0.16	0.18	0.03	0.24	u	u
SiO ₂	mg/l	14	37	21	38	36	36	28
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.80	1.08	1.68	1.68	0.46	0.67	0.84
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.8	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.09	0.07	0.07	0.16	u	u	u
B	mg/l	0.2	0.3	0.3	0.4	u	0.2	u
F	mg/l	0.5	0.2	0.9	0.4	0.2	0.3	0.13
Cl	mg/l	241	350	572	421	111	95	244
SO ₄	mg/l	219	359	20	449	40	135	180

Table 2. (continued.)

Sample #		D-4	D-5	D-6	D-8	D-9	D-10	D-11
Location		(C-4-1)12bca 40°29'20" 111°54'24"	(C-4-1)12bca 40°29'22" 111°54'21"	(C-4-1)12bbd 40°29'25" 111°54'20"	(C-3-2)33ddd 40°30'34" 112°03'51"	(C-4-2)3cdc 40°29'36" 112°03'24"	(C-4-2)3ccd 40°29'37" 112°03'30"	(C-3-2)25ddd 40°31'22" 112°00'19"
Temp.	°C	85	38	54	18	8	14	14
pH		7.60	7.26	6.16	7.28	6.85	6.85	7.26
TDS	mg/l	1710	1720	1700	316	712	646	610
HCO ₃	mg/l	355	459	480	213	417	313	292
Na	mg/l	376	347	370	46	62	52	37
K	mg/l	56	53	55	5	10	8	4
Ca	mg/l	133	146	139	43	122	115	90
Mg	mg/l	33	32	32	6	36	27	32
Fe	mg/l	u	u	6.94	u	u	0.07	u
SiO ₂	mg/l	47	77	45	20	47	47	24
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	3.69	3.86	3.72	0.82	0.74	0.65	1.01
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	0.4	1.0	0.4	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	0.2	u	0.9	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	1.57	1.34	1.58	u	u	u	u
B	mg/l	1.3	1.1	1.4	u	0.1	u	u
F	mg/l	2.6	2.5	2.4	0.2	0.3	0.3	0.1
Cl	mg/l	722	673	708	54	131	140	117
SO ₄	mg/l	67	74	62	25	85	45	65

Table 2. (continued.)

Sample #		D-12	D-13	D-14	D-15	D-16	D-17	D-18
Location		(C-4-2)2cbc 40°29'51" 112°02'31"	(C-4-2)1bbb 40°30'26" 112°01'24"	(C-3-1)3lccb 40°30'38" 112°00'16"	(C-3-1)3cad 40°35'09" 111°56'21"	(C-3-1)3lccb 40°30'50" 112°00'16"	(C-4-1)5bbb 40°30'26" 111°59'07"	(C-3-1)3lbbd 40°31'03" 111°59'56"
Temp.	°C	14	15	14	13	14	13	14
pH		7.16	7.17	7.14	7.28	7.17	7.23	7.13
TDS	mg/l	636	988	830	846	1020	802	864
HCO ₃	mg/l	355	334	316	230	271	376	293
Na	mg/l	51	58	59	59	51	77	49
K	mg/l	7	8	8	3	8	7	6
Ca	mg/l	114	153	133	121	166	130	132
Mg	mg/l	31	39	33	45	41	32	35
Fe	mg/l	0.04	u	u	u	u	u	u
SfO ₂	mg/l	43	41	39	20	39	39	34
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.67	0.91	0.74	0.62	0.87	0.70	0.68
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.4	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	0.1	0.1
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	u	u	u
B	mg/l	u	u	u	u	u	0.2	u
F	mg/l	0.3	0.3	0.3	0.2	0.1	0.3	0.2
Cl	mg/l	136	246	196	193	273	159	232
SO ₄	mg/l	54	74	69	171	88	93	50

Table 2. (continued.)

Sample #		D-19	D-21	D-22	D-23	D-25	D-26	D-27
Location		(C-3-1)30daa 40°31'40" 111°58'32"	(C-3-1)27acd 40°31'51" 111°56'07"	(C-3-1)12cad 40°34'12" 111°54'07"	(C-3-1)14adc 40°33'32" 111°54'50"	(C-2-1)25cbb 40°37'00" 111°54'30"	(C-2-1)28bcc 40°37'04" 111°57'59"	(C-3-1)8dda 40°34'04" 111°58'04"
Temp.	°C	14	15	17	15	16	16	16
pH		7.03	6.96	7.03	7.13	7.14	7.13	6.55
TDS	mg/l	816	1262	1060	604	400	1510	2895
HCO ₃	mg/l	334	66	293	250	202	459	730
Na	mg/l	54	103	124	103	58	285	87
K	mg/l	u	4	6	6	3	7	4
Ca	mg/l	125	178	129	55	45	109	422
Mg	mg/l	37	53	45	26	20	60	200
Fe	mg/l	u	u	u	0.03	u	u	u
SiO ₂	mg/l	19	22	15	24	11	30	28
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.65	0.92	0.57	0.90	0.41	0.54	1.46
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	4.3
Sn	mg/l	0.2	u	0.3	0.3	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	0.05	u	0.11	u
B	mg/l	u	0.1	0.2	0.2	u	0.5	u
F	mg/l	0.2	0.2	0.2	0.3	0.3	0.3	0.1
Cl	mg/l	108	411	204	144	73	237	189
SO ₄	mg/l	162	247	302	105	93	489	1258

Table 2. (continued.)

Sample #		D-28	D-29	D-30	D-31	D-32	D-33	D-35
Location		(C-3-1)16bdb 40°33'38" 111°57'37"	(C-3-1)20abb 40°33'01" 111°58'28"	(C-2-1)9dcc 40°39'12" 111°57'25"	(C-3-1)1cbb 40°35'12" 111°54'30"	(C-3-1)16bdb 40°33'41" 111°57'55"	(C-3-1)20cca 40°32'22" 111°58'53"	(C-3-1)29abc 40°32'01" 111°58'32"
Temp.	°C	14	14	17	48	15	14	14
pH		7.05	7.00	7.13	7.75	6.85	6.85	7.05
TDS	mg/l	1558	1296	1978	2609	1754	1618	1498
HCO ₃	mg/l	438	417	271	147	438	370	459
Na	mg/l	115	145	238	754	81	53	73
K	mg/l	7	3	13	5	4	3	3
Ca	mg/l	209	146	161	55	267	262	261
Mg	mg/l	91	51	116	17	94	83	78
Fe	mg/l	0.04	u	u	0.04	0.07	u	u
SiO ₂	mg/l	26	19	30	19	21	19	19
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	1.23	0.51	2.07	2.18	1.06	0.89	1.01
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.2	u	u	u	0.5	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	0.3	u	u	u	u	u
Li	mg/l	0.07	u	0.16	0.07	u	u	u
B	mg/l	0.2	0.3	0.3	2.3	u	u	u
F	mg/l	0.2	0.1	0.5	0.8	0.1	0.1	0.2
Cl	mg/l	205	71	536	654	201	228	237
SO ₄	mg/l	590	529	517	934	655	532	521

Table 2. (continued.)

Sample #		D-36	D-37	D-38	D-39	D-40	D-41	D-42
Location		(C-3-1)30aba 40°32'12" 111°59'30"	(C-3-1)30bab 40°32'09" 111°59'51"	(C-3-1)22dda 40°32'23" 111°55'45"	(C-3-1)14bbc 40°33'47" 111°55'40"	(C-3-1)26add 40°31'52" 111°54'37"	(C-3-1)25bbb 40°32'11" 111°54'26"	(C-3-1)24bac 40°32'56" 111°54'15"
Temp.	°C	14	14	16	17	15	17	17
pH		6.95	7.15	7.20	7.35	7.45	7.26	6.95
TDS	mg/l	1328	1086	576	672	904	576	2130
HCO ₃	mg/l	355	292	165	165	313	250	355
Na	mg/l	55	44	73	53	229	78	246
K	mg/l	3	3	3	3	12	6	28
Ca	mg/l	230	179	92	82	47	57	240
Mg	mg/l	68	47	29	36	13	25	80
Fe	mg/l	0.03	u	u	u	1.00	0.05	1.09
SiO ₂	mg/l	21	19	19	15	21	19	19
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	1.07	0.97	0.60	0.61	0.72	0.74	3.42
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	0.3	u	1.1
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.2	0.1	u	0.9	0.1	0.7	0.2
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	u	0.32	u	0.25
B	mg/l	u	u	u	u	0.4	u	0.4
F	mg/l	0.2	0.1	0.2	0.2	0.6	0.3	0.6
Cl	mg/l	199	267	184	191	317	126	385
SO ₄	mg/l	464	220	80	88	85	94	780

Table 2. (continued.)

Sample #		D-43	D-44	D-45	D-46	D-48	D-49	D-50
Location		(C-3-1)7cbb 40°34'18" 112°00'13"	(C-2-2)25cba 40°36'59" 112°01'16"	(C-2-1)20bab 40°38'17" 111°58'49"	(C-2-1)6abc 40°40'45" 111°59'41"	(C-3-1)31aaa 40°31'16" 111°59'10"	(C-3-1)32cdc 40°30'29" 111°58'44"	(C-4-1)5acb 40°30'10" 111°58'33"
Temp.	°C	16	15	18	19	12	16	13
pH		7.31	7.18	7.25	7.13	7.22	7.22	7.25
TDS	mg/l	452	930	584	1638	688	532	788
HCO ₃	mg/l	230	209	292	209	326	250	376
Na	mg/l	44	98	64	158	69	39	75
K	mg/l	3	3	6	8	3	9	7
Ca	mg/l	61	102	66	167	117	68	125
Mg	mg/l	26	48	38	102	27	25	31
Fe	mg/l	0.13	u	u	u	u	u	u
SiO ₂	mg/l	21	21	28	30	24	54	36
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.41	0.66	0.59	3.54	0.55	0.50	0.65
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.5	0.6	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	0.06	u	u	u	u
B	mg/l	u	u	0.1	u	u	u	0.2
F	mg/l	0.3	0.3	0.5	0.7	0.1	0.2	0.3
Cl	mg/l	112	320	104	542	98	113	95
SO ₄	mg/l	52	55	90	254	138	26	134

Table 2. (continued.)

Sample #		D-51	D-52	D-53	D-55	D-56	D-57
Location		(C-4-1)4aaa 40°30'27" 111°56'57"	(C-2-2)16adc 40°38'46" 112°03'55"	(C-3-2)12cdd 40°34'09" 112°01'03"	(C-4-2)9abc 40°29'23" 112°04'11"	(C-3-1)25aba 40°32'12" 111°53'43"	(C-4-1)15cbc 40°28'08" 111°56'49"
Temp.	°C	15	14	17	21	19	19
pH		7.15	7.30	7.24	7.35	7.24	7.65
TDS	mg/l	1132	456	374	310	1072	278
HCO ₃	mg/l	326	215	215	191	263	191
Na	mg/l	77	57	32	26	209	48
K	mg/l	5	4	3	7	25	8
Ca	mg/l	176	58	59	46	89	46
Mg	mg/l	46	19	23	17	22	10
Fe	mg/l	u	u	u	u	0.34	0.18
SiO ₂	mg/l	28	39	24	19	21	19
Tl	mg/l	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u
Sr	mg/l	0.87	0.32	0.24	0.96	1.69	0.29
Ba	mg/l	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	0.3
Pb	mg/l	u	u	u	u	u	u
Zn	mg/l	u	0.4	u	u	u	u
Sn	mg/l	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u
Li	mg/l	u	u	u	u	0.31	u
B	mg/l	u	u	u	u	0.3	u
F	mg/l	0.1	0.3	0.2	0.4	0.8	0.3
Cl	mg/l	263	99	90	60	365	99
SO ₄	mg/l	187	30	48	24	129	10

Table 2. (continued.)

Sample #		D-58	D-59	D-60	D-61	D-62	D-64	D-65
Location		(C-3-1)2adc 40°35'22" 111°54'49"	(C-2-1)2bcc 40°40'35" 111°55'38"	(C-3-2)2cda 40°35'03" 112°02'00"	(C-2-1)36bac 40°35'23" 111°54'11"	(C-2-1)25dac 40°36'47" 111°53'39"	(C-2-1)2daa 40°40'28" 111°54'38"	(C-2-1)12bbb 40°40'00" 111°54'27"
Temp.	°C	21	15	16	17	24	15	18
pH		7.65	7.34	7.28	7.05	7.35	7.38	7.24
TDS	mg/l	858	1676	666	340	148	234	348
HCO ₃	mg/l	167	326	181	191	143	167	167
Na	mg/l	219	188	42	42	33	13	34
K	mg/l	7	3	3	3	u	u	u
Ca	mg/l	35	212	89	41	18	41	42
Mg	mg/l	15	76	33	15	8	16	16
Fe	mg/l	u	0.13	u	u	u	u	u
SiO ₂	mg/l	9	15	24	11	11	13	13
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.96	2.59	0.39	0.37	0.30	0.52	0.66
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.1	u	u	u	u	u	u
B	mg/l	0.2	0.2	u	u	u	u	u
F	mg/l	0.4	0.1	0.2	0.2	0.3	0.3	0.3
Cl	mg/l	336	360	194	63	19	14	36
SO ₄	mg/l	94	572	38	65	29	37	100

Table 2. (continued.)

Sample #	D-66	D-67	D-68	D-69	D-70	D-71	D-72	
Location	(C-2-1)3cdd 40°40'05" 111°56'23"	(C-2-1)11ccc 40°39'14" 111°55'41"	(C-2-1)17bab 40°39'08" 111°58'43"	(C-2-1)18cbb 40°38'43" 112°00'10"	(C-2-2)24bbb 40°38'16" 112°01'24"	(C-4-2)10dbd 40°29'01" 112°02'59"	(C-3-2)36bcb 40°31'06" 112°01'21"	
Temp.	°C	21	19	17	16	21	15	19
pH		7.17	7.13	7.31	7.09	7.04	7.03	7.22
TDS	mg/l	756	312	434	802	499	588	562
HCO ₃	mg/l	143	143	191	239	239	215	215
Na	mg/l	117	35	64	95	52	38	34
K	mg/l	5	u	5	7	10	7	4
Ca	mg/l	66	43	43	90	56	91	98
Mg	mg/l	38	16	21	46	27	21	27
Fe	mg/l	u	u	u	u	0.03	u	u
SiO ₂	mg/l	34	13	32	36	58	43	34
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	1.38	0.67	0.37	0.76	0.79	0.55	0.45
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	0.4	0.2
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	0.05	0.07	u	u	u
B	mg/l	u	u	u	0.1	u	u	u
F	mg/l	0.3	0.3	0.6	0.5	0.5	0.2	0.2
Cl	mg/l	255	40	65	250	103	163	83
SO ₄	mg/l	157	100	54	80	40	37	135

Table 2. (continued.)

Sample #		D-73	D-74	D-80	D-81	D-82	D-83	D-84
Location		(C-2-2)13cdd 40°38'20" 112°00'53"	(C-4-1)14cdc 40°27'58" 111°55'24"	(C-3-2)34aaa 40°31'17" 112°02'35"	(C-3-2)34dcb 40°30'40" 112°03'08"	(C-2-1)2abc 40°40'47" 111°55'08"	(C-2-1)10aad 40°39'56" 111°55'46"	(C-2-1)13dad 40°38'34" 111°53'28"
Temp.	°C	19	15	12	12	12	19	14
pH		7.22	7.43	7.25	7.15	7.70	7.70	7.21
TDS	mg/l	724	884	1450	1460	2080	650	824
HCO ₃	mg/l	215	353	397	355	397	129	313
Na	mg/l	66	127	93	76	282	108	115
K	mg/l	5	9	5	3	8	3	5
Ca	mg/l	76	102	253	238	222	64	101
Mg	mg/l	51	41	68	70	95	27	34
Fe	mg/l	u	u	u	u	0.45	0.11	u
SiO ₂	mg/l	28	24	24	17	15	17	13
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.88	0.81	0.94	0.69	2.21	1.25	0.50
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	0.09	0.10	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	u	u	u	0.3
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.05	0.08	u	u	0.11	u	u
B	mg/l	u	0.2	u	u	0.4	u	0.2
F	mg/l	0.4	0.5	0.2	0.2	0.2	0.4	0.5
Cl	mg/l	230	89	239	69	433	205	159
SO ₄	mg/l	61	217	409	642	685	164	188

Table 2. (continued.)

Sample #	D-85	D-86	D-87	D-88	D-89	D-90	D-91	
Location	(C-2-1)21aad 40°38'07" 111°56'59"	(C-2-1)27cac 40°36'51" 111°56'28"	(C-2-1)33cad 40°35'59" 111°57'29"	(C-2-1)34daa 40°36'07" 111°55'44"	(C-2-1)35ddd 40°35'46" 111°54'35"	(C-4-2)10aab 40°29'35" 112°02'43"	(C-2-2)1cab 40°40'24" 112°01'08"	
Temp.	°C	14	15	14	15	16	15	15
pH		6.90	7.22	7.21	7.04	7.50	7.26	7.26
TDS	mg/l	3055	1360	695	1250	430	584	610
HCO ₃	mg/l	438	292	397	292	184	250	313
Na	mg/l	334	140	121	128	67	38	92
K	mg/l	40	9	4	5	3	5	5
Ca	mg/l	345	174	92	164	57	96	65
Mg	mg/l	134	64	31	53	14	21	31
Fe	mg/l	0.04	0.03	u	u	u	0.03	0.03
SiO ₂	mg/l	30	26	24	26	13	36	34
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	2.40	0.76	0.39	0.68	0.50	0.40	0.50
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	0.09	u	u	u	u	u	0.09
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.3	0.2	0.1	0.1	u	0.6	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.32	0.10	u	0.06	u	u	0.08
B	mg/l	0.6	0.2	0.2	u	u	u	0.2
F	mg/l	0.2	0.2	0.3	0.2	0.2	0.3	0.6
Cl	mg/l	526	356	123	292	109	120	143
SO ₄	mg/l	1200	293	149	280	61	29	81

Table 2. (continued.)

Sample #		D-92	D-93	D-96	D-97	D-98	D-100	D-101
Location		(C-2-2)1aab 40°40'54" 112°00'26"	(C-2-2)1ladc 40°39'43" 112°01'37"	(C-3-1)2bcc 40°35'22" 111°55'40"	(C-3-1)5adc 40°35'18" 111°58'13"	(C-3-1)2abaa 40°32'08" 111°55'15"	(C-3-1)32dcb 40°30'36" 111°58'33"	(C-3-1)32adc 40°30'54" 111°58'16"
Temp.	°C	16	15	15	15	16	12	13
pH		7.21	7.62	7.05	7.53	7.16	7.31	7.53
TDS	mg/l	880	405	1045	680	1115	804	630
HCO ₃	mg/l	250	202	230	376	209	397	355
Na	mg/l	103	44	76	145	101	78	90
K	mg/l	6	4	4	4	5	5	3
Ca	mg/l	104	51	147	61	157	149	108
Mg	mg/l	47	20	49	16	50	36	26
Fe	mg/l	0.07	0.06	0.10	u	u	u	u
SiO ₂	mg/l	34	26	19	30	28	26	19
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.77	0.25	0.59	0.21	0.68	0.61	0.44
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	0.11	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	0.8	u	u	0.3	0.4	0.2	0.2
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.09	u	u	u	u	u	u
B	mg/l	0.2	0.2	u	0.3	u	u	0.1
F	mg/l	0.5	0.3	0.2	0.4	0.2	0.1	0.2
Cl	mg/l	272	70	262	93	334	170	100
SO ₄	mg/l	102	69	195	146	159	107	134

Table 2. (continued.)

Sample #	D-102	D-103	D-104	D-105	D-106	D-108	D-109
Location	(C-3-1)35cab 40°30'48" 111°55'20"	(C-3-1)35bbb 40°31'16" 111°55'40"	(C-4-1)4bda 40°30'15" 111°57'26"	(C-4-1)4dcc 40°29'37" 111°57'24"	(C-4-1)5add 40°30'03" 111°58'04"	(C-4-1)5bcd 40°30'04" 111°58'52"	(C-4-1)8bab 40°29'32" 111°58'46"
Temp.	°C	15	16	13	15	14	16
pH		7.25	7.06	7.26	7.25	7.35	7.34
TDS	mg/l	1650	1010	788	716	778	532
HCO ₃	mg/l	501	230	376	480	397	230
Na	mg/l	217	73	62	77	68	51
K	mg/l	17	5	3	8	6	8
Ca	mg/l	179	169	137	111	132	77
Mg	mg/l	73	52	38	34	35	20
Fe	mg/l	2.08	u	u	u	u	u
SiO ₂	mg/l	36	26	19	41	34	49
Ti	mg/l	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u
Sr	mg/l	0.74	0.74	0.55	0.54	0.56	0.39
Ba	mg/l	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u
Mn	mg/l	0.8	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u
Zn	mg/l	0.2	u	u	u	u	0.2
Sn	mg/l	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u
Li	mg/l	0.15	u	u	u	u	u
B	mg/l	0.4	u	u	0.3	0.2	0.4
F	mg/l	0.3	0.1	0.1	0.2	0.3	0.3
Cl	mg/l	347	291	134	83	104	147
SO ₄	mg/l	435	184	152	125	144	33

Table 2. (continued.)

Sample #		D-110	D-111	D-114	D-115	D-117	D-118	D-119
Location		(C-4-1)8add 40°29'11" 111°58'10"	(C-4-1)8abb 40°29'34" 111°58'33"	(C-4-1)9ccc 40°20'48" 111°57'58"	(C-4-1)10bda 40°29'18" 111°56'22"	(C-4-1)10dbc 40°28'58" 111°56'09"	(C-4-1)10ccc 40°28'48" 111°56'49"	(C-4-1)11acc 40°29'12" 111°55'06"
Temp.	°C	17	16	15	16	17	17	17
pH		7.34	7.26	7.03	7.14	7.05	7.64	7.14
TDS	mg/l	484	628	462	1000	1330	836	892
HCO ₃	mg/l	230	397	220	376	355	292	355
Na	mg/l	44	57	43	77	139	100	119
K	mg/l	7	10	6	14	17	11	9
Ca	mg/l	70	112	79	126	193	116	100
Mg	mg/l	26	30	20	52	80	38	46
Fe	mg/l	u	u	0.04	u	0.14	0.04	1.07
SiO ₂	mg/l	47	47	43	47	34	45	19
Ti	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	0.37	0.51	0.35	1.45	2.20	0.64	0.77
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	u	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	0.4	u	0.2	1.8	u	u
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	u	u	u	0.07	0.13	0.07	0.09
B	mg/l	u	0.2	u	u	0.3	0.2	0.2
F	mg/l	0.3	0.2	0.3	0.4	0.4	0.3	0.7
Cl	mg/l	126	98	122	213	319	176	169
SO ₄	mg/l	46	100	64	160	295	168	195

Table 2. (continued.)

Sample #		D-120	D-121	D-122	D-123	D-124	D-125	D-126
Location		(C-4-1)11adc 40°29'14" 111°54'45"	(C-4-1)11dab 40°29'08" 111°55'00"	(C-4-1)12daa 40°29'05" 111°53'34"	(C-4-1)13ccb 40°27'58" 111°54'29"	(C-4-1)15bcb 40°28'27" 111°56'48"	(C-4-1)15aad 40°28'33" 111°55'50"	(C-4-1)22dba 40°29'49" 111°56'30"
Temp.	°C	29	38	17	17	17	16	15
pH		7.15	6.30	7.46	7.64	7.28	7.15	7.35
TDS	mg/l	1560	1308	286	312	545	1090	520
HCO ₃	mg/l	355	520	165	271	220	438	292
Na	mg/l	316	257	23	23	37	194	50
K	mg/l	47	39	u	5	7	12	5
Ca	mg/l	124	143	40	46	77	107	81
Mg	mg/l	36	35	18	22	19	62	23
Fe	mg/l	u	14.36	u	0.04	u	u	u
SiO ₂	mg/l	42	24	15	15	50	24	45
Tl	mg/l	u	u	u	u	u	u	u
P	mg/l	u	u	u	u	u	u	u
Sr	mg/l	3.87	3.40	0.15	0.45	0.43	1.40	0.51
Ba	mg/l	u	u	u	u	u	u	u
Cr	mg/l	u	u	u	u	u	u	u
Mn	mg/l	u	0.3	u	u	u	u	u
Pb	mg/l	u	u	u	u	u	u	u
Zn	mg/l	u	u	u	0.3	0.3	u	0.4
Sn	mg/l	u	u	u	u	u	u	u
W	mg/l	u	u	u	u	u	u	u
Li	mg/l	0.93	0.53	u	u	0.06	0.12	u
B	mg/l	0.8	0.5	u	u	u	0.3	u
F	mg/l	2.3	1.8	0.2	1.0	0.6	0.4	0.5
Cl	mg/l	618	531	36	38	93	233	72
SO ₄	mg/l	94	45	35	48	82	272	81

Table 2. (continued.)

Sample #		D-127	BECKS	HOB0	WASATCH
Location		(C-4-1)23bac 40°27'39" 111°55'19"	(B-1-1)14dcb 40°48'57" 111°55'05"	(B-1-1)23acc 40°48'24" 111°55'05"	(B-1-1)25bdb 40°47'32" 111°54'03"
Temp.	°C	15	55	32	39
pH		7.50	6.45	6.89	7.28
TDS	mg/l	510	15730	13365	4116
HCO ₃	mg/l	233	313	313	313
Na	mg/l	73	5167	3999	977
K	mg/l	9	172	137	40
Ca	mg/l	60	727	606	240
Mg	mg/l	36	103	101	52
Fe	mg/l	u	0.16	0.03	0.05
SiO ₂	mg/l	19	28	26	11
Tl	mg/l	u	u	u	u
P	mg/l	u	u	u	u
Sr	mg/l	0.73	17.60	14.20	4.66
Ba	mg/l	u	u	u	u
Cr	mg/l	u	0.06	0.06	u
Mn	mg/l	u	u	u	u
Pb	mg/l	u	u	u	u
Zn	mg/l	u	u	u	u
Sn	mg/l	u	u	u	u
W	mg/l	u	u	u	u
Li	mg/l	0.06	2.63	2.04	0.45
B	mg/l	0.1	2.9	2.4	0.7
F	mg/l	0.8	2.9	2.5	1.5
Cl	mg/l	90	8150	6660	1781
SO ₄	mg/l	116	936	900	489

relative to recharge from bedrock, streams and irrigation canals in the Oquirrh Mountains to the west. Tables 3, 4, and 5 from Hely and others (1971) exhibit this fact.

Due to the complex chemistry, the volume of samples collected, and the basis for this report, the Jordan Valley has been divided into six areas irrespective of ground-water divisions mentioned previously. Each area includes warm water sampled, to provide comparisons for evaluation of the aqueous chemistries with cold aquifer waters. Plate 4 depicts the six areas designated A, B, C, D, E, and F.

Area A

Area A is located in northern Jordan Valley and comprises parts of the Northwest Lake Plain, East Lake Plain, and East Bench ground-water districts. Included in area A are the north central valley, north Oquirrh, and Warm Springs fault warm areas (plate 4). Permission was not obtained to sample the wells in the north Oquirrh area, therefore no chemistry values are available.

Total dissolved solids--Analysis of water samples collected in area A indicate the ground water is quite diverse. Total dissolved solids (TDS) concentrations range from 344 to 15,730 mg/l. The wide range of values is indicative of the complicated hydrologic regime. The Warm Springs fault geothermal area has values ranging from 4116 to 15,740 mg/l, which are considered to be the result of deep circulation of the source water (the warm water being more chemically reactive with the reservoir rocks), the chemical makeup of the reservoir rocks, as well as the residence time of the water. Sample R-74 is not in the warm springs area but the high TDS values (3338 mg/l) may be influenced by the warm springs regime. Low TDS values from wells sampled in the East Bench and East Lake Plain districts of area A (210/735 mg/l) are closer to the recharge areas allowing for less residence time within

Table 3: Total dissolved solids (TDS) content from major Wasatch streams in Salt Lake County, Utah (from Hely and others, 1971).

Stream or area of recharge	Dissolved solids (milligrams per liter)	
	Average high flow	Average low flow
Little Cottonwood Creek	99	137
Big Cottonwood Creek	153	227
Mill Creek	345	458
Parleys Creek	312	414
Emigration Creek	378	520
Red Butte Creek	305	440
City Creek	209	245

Low flow is considered to be indicative of bedrock recharge water quality.

Table 4: Total dissolved solids (TDS) content from major streams and canals draining the Oquirrh Mountains in Salt Lake County, Utah (from Hely and others, 1971).

	Dissolved solids (milligrams per liter)
Utah Lake Distributing Co. and Utah and Salt Lake Canals ¹	1,120
Provo Reservoir Canal ²	231
Rose Creek	426
Butterfield Creek	985
Keystone Gulch ³	1,310
Bingham Creek	44,400

¹These canals divert water from the Jordan River in the Jordan Narrows.

²Diverts water from the Provo River in Utah County.

³Mascotte Tunnel is the source of this water.

Table 5: Total dissolved solids content of water from wells near Herriman, Lark, Copperton, and in Barneys Canyon thought to be indicative of recharge through bedrock from the Oquirrh Mountains (from Hely and others, 1971).

	Dissolved solids (milligrams per liter)
(C-3-2) 4adb-1	1,120
5aac-1	636
5acb-1	719
17cac-1	1,070
20bdd-1	1,460
32baa-1	408
34daa-1	533
(C-4-2) 6acc-1	870

the aquifer. The remaining samples located within the Northwest Lake Plain district have TDS values ranging from 344 to 3012 mg/l. This is the major ground-water discharge area for the Jordan Valley, therefore waters are from a number of sources and residence times are quite varied. A number of wells have water temperatures above 20°C which could also contribute to the highly variable TDS values.

Common Ion Analyses--Common ion analyses indicate two main types of water are present in area A (fig. 7). Type I waters are thermal and consist of Becks, Hobo and Wasatch Hot Springs as well as samples from six water wells. Type I waters are sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) and sodium-calcium chloride (Na-Ca Cl) in character, slightly acidic to basic, and slightly to very saline with respect to TDS. All samples are enriched with Na and K with respect to other cations and Cl with respect to other anions present. Type II waters are calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃), and calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO₃-Cl-SO₄) in character, slightly acidic to slightly basic, and dilute to slightly saline. Type II waters are enriched in Ca with respect to other cations and Cl or HCO₃ with respect to other anions present. Type II waters are reflective of recharge from the Wasatch Mountains to the east and the relatively short residence time in the hydrologic regime. Eight other samples were collected and analyzed which are not included in either type I or type II. These samples are sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃), sodium-calcium bicarbonate-chloride-sulfate (Na-Ca HCO₃-Cl-SO₄) and sodium bicarbonate-chloride-sulfate (Na HCO₃-Cl-SO₄) in character, slightly acidic to basic, and dilute to slightly saline. The diversity of these waters are reflective of the long residence time within the aquifer, the various

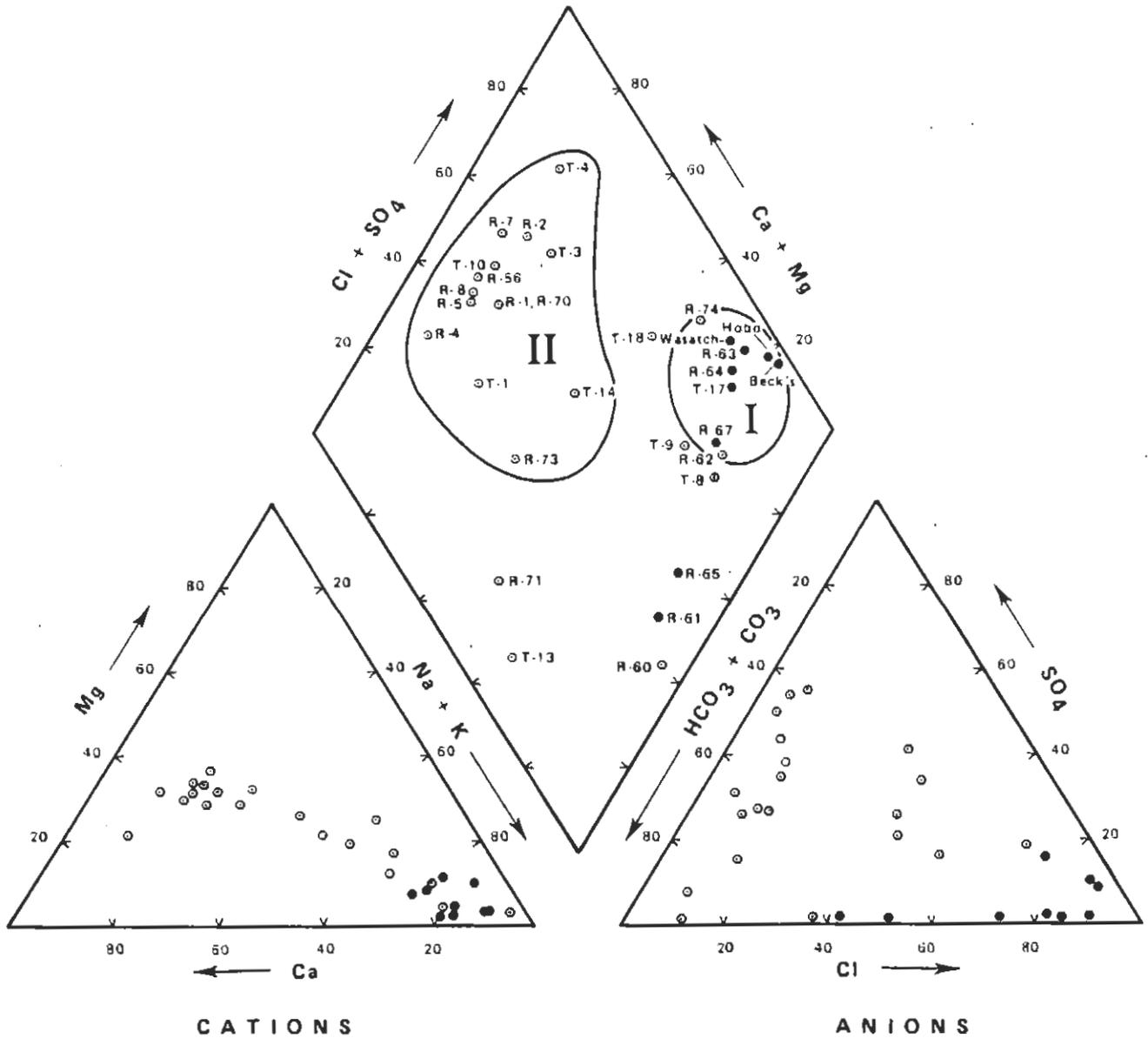


Figure 7. Piper diagram of common ions from samples collected in area "A" on plate 4 in the Jordan Valley, Salt Lake County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Darkened symbols indicate samples with temperatures $\geq 20^\circ C$. Roman numerals indicate classification of water types.

recharge areas within the valley and underflow through the Jordan Narrows from Utah Valley to the south.

Sodium is a common ion which can be indicative of thermal waters as is demonstrated by samples collected at Becks, Hobo and Wasatch Hot Springs. Sodium concentrations for these three warm springs are 5167, 3999, and 977 mg/l, respectively. Sodium concentrations for the remaining samples included in type I are from 262 to 990 mg/l. Concentrations for type II range from 9 to 65 mg/l (significantly lower than type I) and are considered indicative of non-thermal water. The remaining samples have Na concentrations which are quite varied, ranging from 70 to 377 mg/l.

Chloride is a second common ion which, in significant concentrations, can be indicative of thermal water. This is demonstrated by the concentrations of Cl in Becks, Hobo and Wasatch Hot Springs which were 8150, 6660, and 1781 mg/l, respectively. In other samples included in type I Cl values range from 432 to 2060 mg/l. Concentrations of Cl for type II range from 17 to 220 mg/l; concentrations in the remaining samples range from 26 to 421 mg/l. It should be pointed out that 421 mg/l of Cl for sample T-18 is less than the 432 mg/l concentration of Cl in sample R-62 for type I.

Silica--Silica concentrations in area A ranged 6 to 51 mg/l and are irrespective of temperature. Wasatch Warm Springs has a temperature of 39°C with a SiO₂ value of 11 mg/l while water sample T-8 had a temperature of 11°C and a SiO₂ content of 44 mg/l.

Trace Elements--Certain elements may be helpful in qualitatively distinguishing thermal from non-thermal water in area A. These elements are Li, B, and F. Only F was present in detectable limits in all samples. However, all three elements are present in detectable concentrations in sufficient samples to indicate some trends possibly related to thermal sources.

Lithium values range from undetectable to 2.63 mg/l for all samples collected. For those samples included in type I in figure 7, Li values range from 0.07 (T-17) to 2.63 mg/l (Becks Hot Spring). Concentrations for all type I samples, excepting T-17, are 0.18 mg/l or greater. Lithium is undetectable in all samples included in type II with the exception of T-4 (0.06 mg/l). Lithium values for all remaining samples range from undetectable to 0.16 mg/l.

Boron ranges from undetectable to 2.9 mg/l for all samples collected. Concentrations for type I waters range from 0.3 to 2.9 mg/l; concentrations for type II are all below detectable limits, if present. All remaining samples had values ranging from undetectable (R-71) to 0.7 mg/l (R-60).

Fluorine concentrations range from 0.2 to 3.6 mg/l. Type I concentrations range from 0.3 to 2.9 mg/l; type II are from 0.2 to 0.5 mg/l. The highest concentration is 3.6 mg/l for sample R-60 not included in types I or II. Samples R-61 and R-65, also not included, have 2.1 mg/l of F which is significant. Concentrations for all other samples range from 0.3 to 0.9 mg/l.

Area B

Area B is located in western Jordan Valley and comprises part of the west slope ground-water district. Included in area B is one thermal well (D-70) with a water temperature of 21°C.

Total Dissolved Solids--Total dissolved solid concentrations for D-70 is 499 mg/l. Concentrations for waters less than 20°C range from 374 to 2895, indicative of recharge from the Oquirrh Mountains increasing in TDS further from the recharge area.

Common Ion Analyses--Common ion analyses indicate one general type of water in area B with a calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO₃-Cl-SO₄) to calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃) character (fig. 8). This water is slightly acidic to

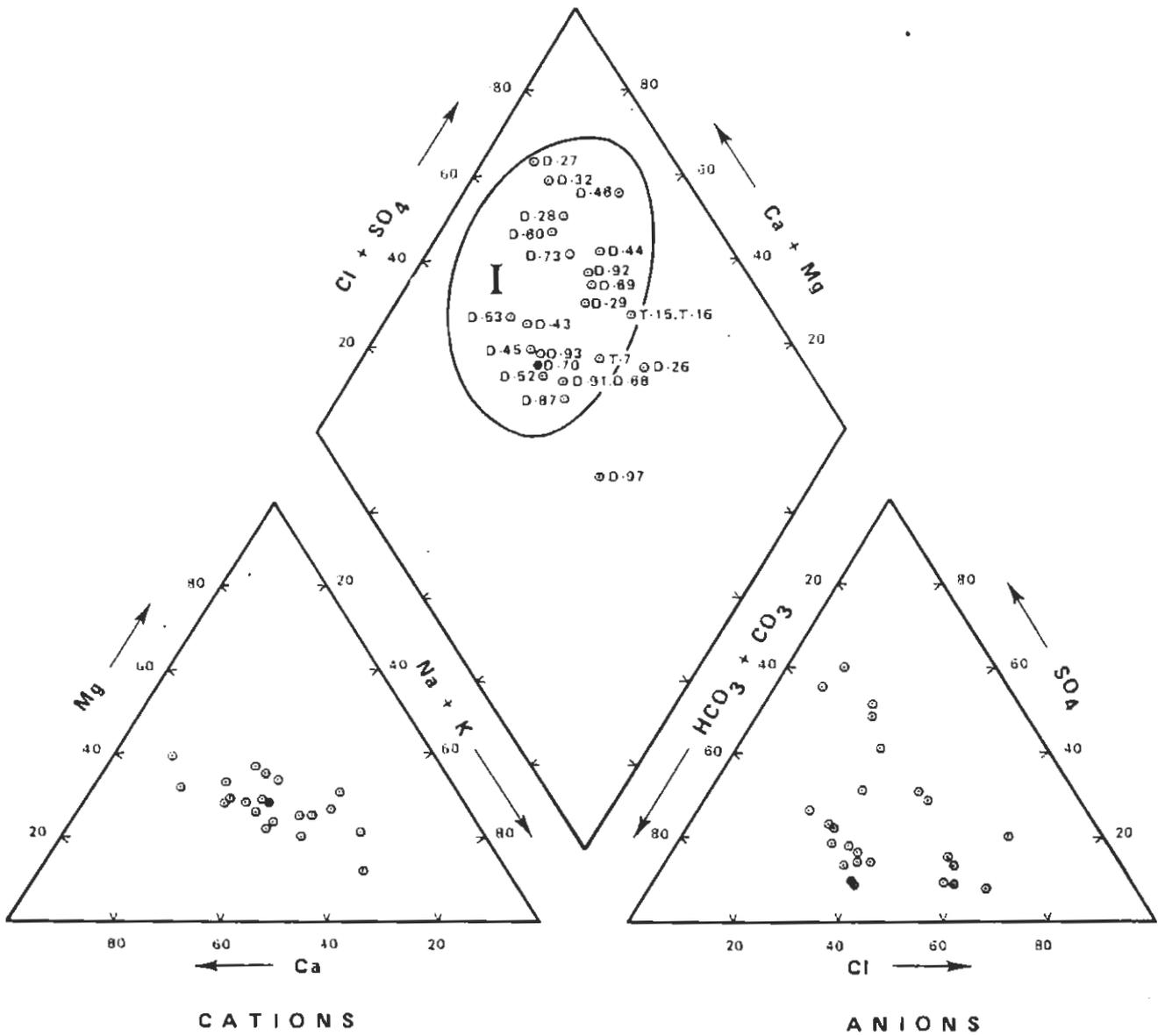


Figure 8. Piper diagram of common ions from samples collected in area "B" on plate 4 in the Jordan Valley, Salt Lake County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Darkened symbols indicate samples with temperatures $\geq 20^\circ C$. Roman numerals indicate classification of water types.

slightly basic, dilute to slightly saline, enriched in Ca or Ca plus Mg to other cations present, and enriched either in HCO_3 or SO_4 to other anions. Interestingly, D-70 is included with this water.

Two samples were collected in this area, however, which are not included within type I. Sample D-26 is sodium-calcium chloride-sulfate-bicarbonate ($\text{Na-Ca Cl-SO}_4\text{-HCO}_3$) in character, slightly basic, slightly saline, and enriched in Na and HCO_3 to other cations and anions present, respectively. Sample D-97, by comparison, is sodium-calcium bicarbonate-chloride-sulfate ($\text{Na-Ca HCO}_3\text{-Cl-SO}_4$) in character, slightly basic, dilute, and enriched in Na and HCO_3 .

Sodium concentrations range from 32 to 285 mg/l but are not correlative with temperature. The higher concentrations, however, are located in the central valley areas and could be indicative of residence time and mixing with other waters. Chloride concentrations range from 70 to 542 mg/l and, as with Na, are not correlative with temperature.

Silica--Silica concentrations for non-thermal waters in area B range from 19 to 36 mg/l. The concentration for thermal sample D-70 is 58 mg/l. The significantly higher concentration of SiO_2 in D-70 could be indicative of a thermal source. The significant decrease of SiO_2 in D-73 may be indicative of dilution resulting from mixing with non-thermal waters downgradient from D-70 which also reduced the temperature from 21° to 19°C .

Trace Elements--Lithium concentrations for non-thermal water in area B range from undetectable to 0.11 mg/l. Lithium is undetectable in D-70, as is B. Boron concentrations range from undetectable to 0.5 mg/l for all non-thermal water in area B. However, F is present within detectable limits in all wells sampled and ranges from 0.1 to 0.7 mg/l. D-70 exhibited no anomalous concentration of F (0.5 mg/l).

Area C

Area C is located in east-central Jordan Valley and includes portions of the East Lake Plain, East Bench, Cottonwoods, Northwest Lake Plain and West Slope ground-water districts (plate 4). Included in area C is the central valley warm area with wells ranging in temperature from 20^o to 24^oC, and extending from the Taylorsville area on the west into the Holladay area to the east.

Total Dissolved Solids--Total dissolved solid concentrations for samples in area C range from 124 to 3055 mg/l. The wide range is indicative of low TDS waters from the east mixing with waters higher in TDS that have either been in the ground-water system for a longer period of time and/or migrated from the Oquirrh Mountains where initial concentrations are greater. Total dissolved solid concentrations for waters from wells being recharged from the East Bench area and located primarily east of the Jordan River range from 212 to 902 mg/l; the remaining wells in the area located primarily west of the Jordan River have concentrations ranging from 756 to 3055 mg/l.

Common Ion Analyses--Common ion analyses indicate two main types of water in area C (fig. 9). Type I consists of water relatively low in TDS located east of the Jordan River and originating primarily in the Wasatch Mountains. These waters are calcium-magnesium chloride-sulfate-bicarbonate (Ca-Mg Cl-SO₄-HCO₃), calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃), and calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO₃-SO₄) in character, slightly acidic to slightly basic, and dilute. All samples are enriched in Ca with respect to other cations present and in HCO₃ or Cl with respect to other anions. Type II waters are primarily higher in TDS and are located west of the Jordan River. These waters are calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃) in

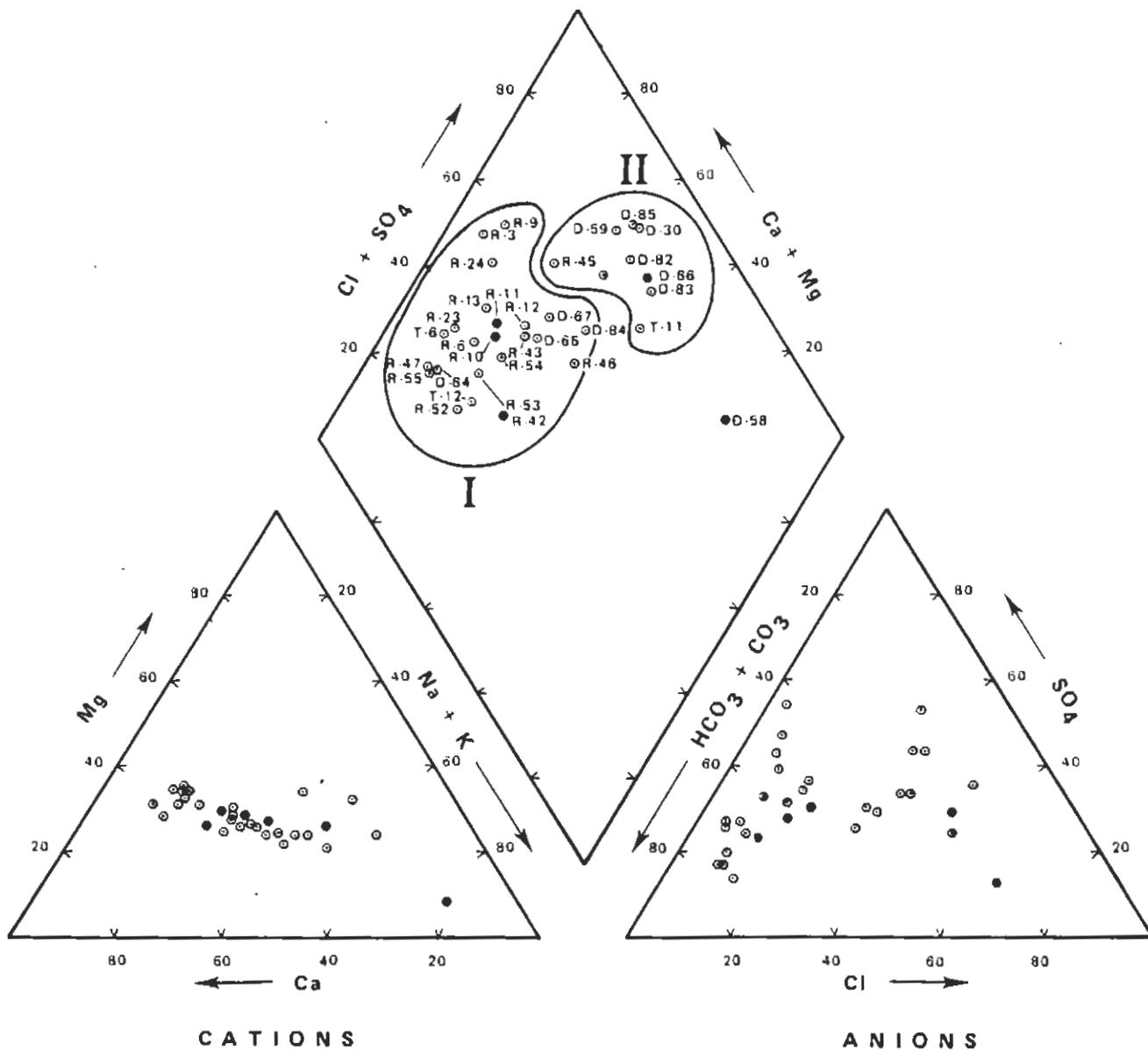


Figure 9. Piper diagram of common ions from samples collected in area "C" on plate 4 in the Jordan Valley, Salt Lake County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Darkened symbols indicate samples with temperatures $\geq 20^\circ C$. Roman numerals indicate classification of water types.

character, slightly basic with the exception of sample D-85 which is slightly acidic. All type II water is dilute to moderately saline. Type II water is enriched in Ca plus Mg with respect to other cations and with Cl with respect to other anions. In addition to the two major types of water, one other sample (D-58) exhibited a significantly different chemistry (fig. 9). Sample D-58 is sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, basic, and dilute. D-58 is enriched in Na and Cl with respect to cations and anions present, respectively. This sample is 21°C.

Sodium concentrations for samples from this area have no direct correlation with temperature with the exception of D-58 (219 mg/l). Type I samples have Na concentrations that range from 7 to 115 mg/l, indicative of dilute waters recharged from the Wasatch Mountains. Sodium concentrations for type II range from 108 to 334 mg/l, indicative of the higher TDS waters common west of the Jordan River.

Other than sample D-58 (336 mg/l), chloride concentrations also are not indicative of warmer waters. Chloride concentrations for type I ranged from 9 to 159 mg/l, representative of dilute, low TDS waters from the Wasatch. Concentrations for type II range from 205 to 526 mg/l, significantly higher than type I, but not unexpected for high TDS waters.

Silica--Silica concentrations in area C range from 6 to 34 mg/l. Sample D-66 has a concentration of 34 mg/l with a 21°C temperature. However, all other SiO₂ concentrations are irrespective of temperature. Silica values are higher for type II water where concentrations range from 15 to 34 mg/l; type I silica concentrations range from 6 to 17 mg/l; D-58 has a concentration of 9 mg/l.

Trace Elements--Lithium is present in detectable limits in samples D-85, D-30, D-82, T-11 and D-58, whereas B is present in all of the aforementioned

samples as well as D-59 and D-84. Lithium concentrations range from 0.1 to 0.32 mg/l. All of the samples above, excluding D-84, are located west of the Jordan River and with the exception of D-58 (21°C) are less than 15°C. Fluorine is present in all samples in relatively low concentrations (0.1 to 0.5 mg/l). No correlation between F concentrations and temperature is evident.

Area D

Area D is located in the east-central portion of the Jordan Valley, immediately south of area C, and includes portions of the Cottonwoods and West Slope ground-water districts (plate 4). Area D includes a portion of the warm area extending from Draper to Midvale (plate 3). Included are two wells with temperatures of 21°C (R-38) and 26°C (R-32) near Sandy City, a 5009 foot (165 m) deep geothermal well (D-31) with a recorded temperature of 48°C, and an isolated well with a temperature of 24°C (D-62) located in Midvale (plate 4).

Total Dissolved Solids--Total dissolved solids for water well samples in area D range from 138 to 1688 mg/l; the geothermal well (D-31) produced a concentration of 2609 mg/l. The range of values is indicative of low TDS waters from the Wasatch (178 mg/l for R-26) migrating downgradient, subsequently increasing in concentration due to residence time within the aquifer as well as mixing with higher TDS waters in the central part of the valley.

Common Ion Analyses--Common ion analyses indicate three main types of waters are present in area D (fig. 10). Type I consists of those waters low in TDS, originating in the Wasatch Mountains, and located primarily east of the Salt Lake Meridian (State Street). These waters are primarily calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO₃-Cl-SO₄) in character, the exception being R-49 which is calcium-magnesium bicarbonate-chloride-sulfate (Ca-Mg HCO₃-Cl-SO₄) in character. Type I

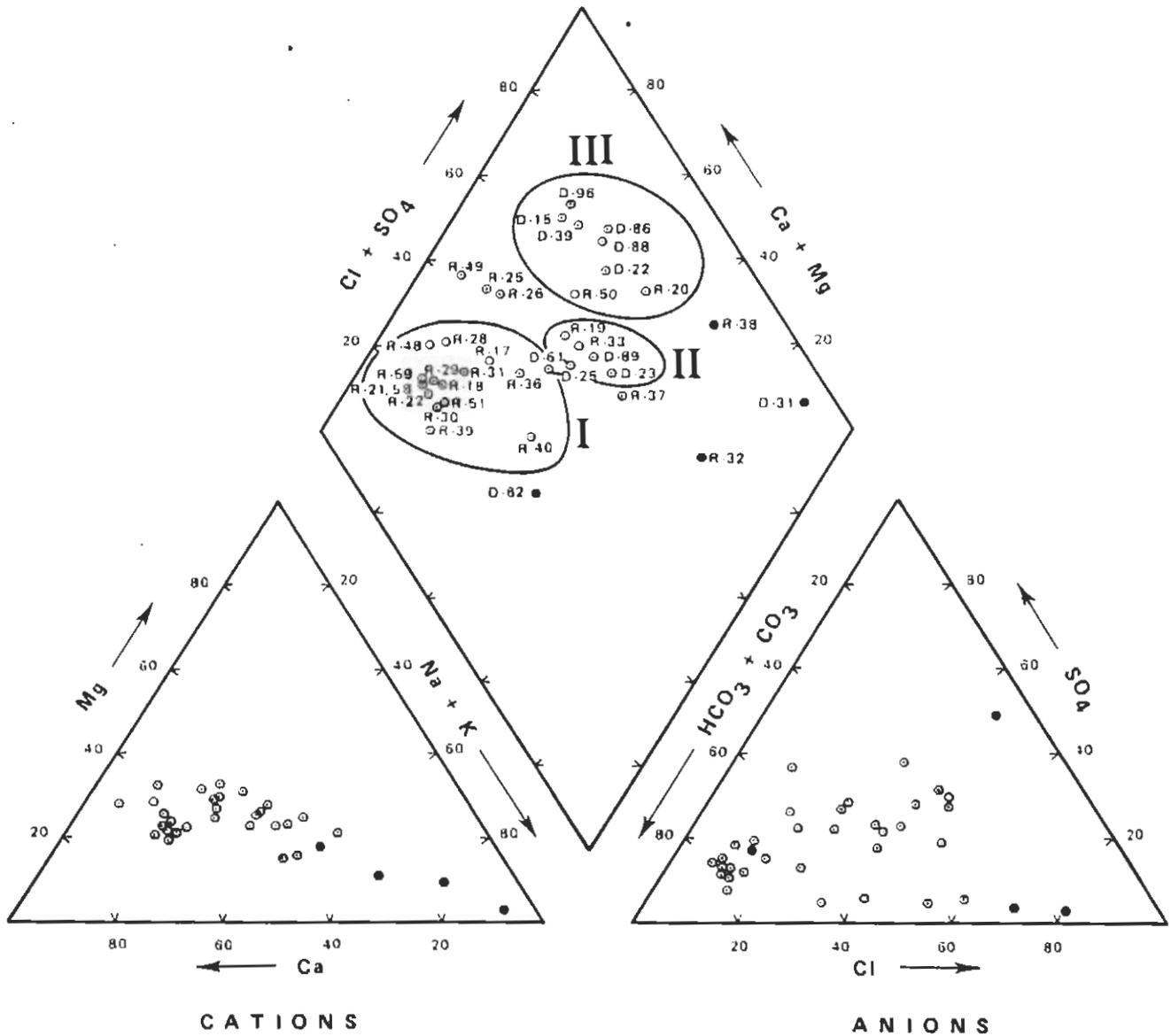


Figure 10. Piper diagram of common ions from samples collected in area "D" on plate 4 in the Jordan Valley, Salt Lake County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Darkened symbols indicate samples with temperatures $\geq 20^{\circ}C$. Roman numerals indicate classification of water types.

water is slightly acidic to slightly basic, dilute ranging in TDS from 138 to 536 mg/l, and enriched in Ca and HCO_3 to other cations and anions present, respectively.

Type II water located downgradient from type I is calcium-sodium chloride-sulfate-bicarbonate ($\text{Ca-Na Cl-SO}_4\text{-HCO}_3$) in character, slightly acidic to slightly basic, and dilute to slightly saline with TDS concentrations ranging from 393 to 1060 mg/l. All type II water is enriched in Ca with respect to other cations and Cl with respect to anions.

Type III water is located west of the Jordan River in a zone of mixing with water from the south and west. This water is also calcium-sodium chloride-sulfate-bicarbonate ($\text{Ca-Na Cl-SO}_4\text{-HCO}_3$) in character but is higher in TDS, with concentrations ranging from 672 to 1360 mg/l (dilute to slightly saline). All type III water is slightly basic as well as enriched in Ca and Cl with regard to other cations and anions present, respectively.

Thermal water exhibited chemistries not consistent with types I, II, or III (fig. 10). Sample D-62 is calcium-sodium bicarbonate-chloride-sulfate ($\text{Ca-Na HCO}_3\text{-Cl-SO}_4$) in character, slightly basic, and dilute. Unlike type I, however, this sample is enriched in Na with respect to other cations present. Samples R-32 and R-38 are both sodium-calcium chloride-sulfate-bicarbonate ($\text{Na-Ca Cl-SO}_4\text{-HCO}_3$) in character. R-32 is slightly basic, dilute and enriched in SO_4 with respect to other cations. With respect to anions, however, R-32 is enriched in Cl. Sample R-38 is slightly acidic, slightly saline, and enriched in Na and Cl with respect to other cations and anions present. However, D-31, the deep (5009 ft or 1527 m) well, is sodium-calcium chloride-sulfate (Na-Ca Cl-SO_4) in character and is considered indicative of deep basin chemistry. Water from D-31 is basic, slightly saline with a TDS value of 2609 mg/l, highly enriched in Na and SO_4 with respect to other cations and anions.

Sample R-37 is non-thermal but also is not included in types I, II, or III. This sample is sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, slightly basic, dilute, and enriched in Na and HCO₃ with respect to cations and anions.

Sodium concentrations are somewhat indicative of warmer waters in this area. With the exception of D-62 (33 mg/l), Na concentrations range from 121 to 754 mg/l for all thermal water. Sodium concentrations for all other samples range from 8 to 128 mg/l.

Chloride concentrations are not as indicative of thermal water. Again, not including D-62 (19 mg/l), water 20°C and warmer has Cl concentrations ranging from 19 to 800 mg/l. Sample R-38 provides the greatest concentration of Cl. Concentrations of Cl for type I range from 12 to 78 mg/l indicative of recharge from the Wasatch Mountains. Concentrations for types II and III range from 63 to 356 mg/l; these higher values are to be expected in the central valley due to longer residence times for the water as well as mixing with waters from other recharge areas.

Silica--Silica concentrations in area C range from 6 to 26 mg/l. Concentrations for thermal samples range from 11 to 19 mg/l. No correlation with temperature is evident, but higher values are noted for water in types II and III.

Trace Elements--Lithium and B are present within detectable limits in only four samples. Fluorine is present in all samples but only ranges from 0.1 to 0.7 mg/l.

Area E

Area E is located in southwestern Jordan Valley and is included in the West Slope ground-water district (plate 4). Included within area C is one thermal well identified as D-55 with a temperature of 21°C.

Total Dissolved Solids--Total dissolved solids (TDS) concentrations for the thermal well is 310 mg/l. Concentrations for the non-thermal wells range from 462 to 5262 mg/l.

Common Ion Analyses--Common ion analyses for area E indicates one general type of water, including D-55, ranging from calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO₃-Cl-SO₄) to calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃) in character (fig. 11). This water is slightly acidic to slightly basic, dilute to slightly saline, and enriched primarily in Ca with respect to other cations and either HCO₃, SO₄, or Cl to other anions present.

Sodium concentrations range from 34 to 93 mg/l; concentrations of Cl are from 47 to 273 mg/l. Concentrations of Na and Cl for D-55 are 26 mg/l and 60 mg/l, respectively, indicating no apparent relationship exists between concentrations of these ions and thermal water.

Silica--Silica concentrations range from 17 to 54 mg/l for all non-thermal water. The concentration for D-55 is 18 mg/l, indicating no difference between thermal and non-thermal water.

Trace Elements--Lithium is undetectable in all samples analyzed. Of the nine samples with detectable B, concentrations range from 0.1 to 0.4 mg/l. Sample D-55 contains no detectable B. Fluorine, however, is detectable in all samples. Concentrations for non-thermal samples range from 0.1 to 0.3 mg/l. The concentration for D-55 is 0.4 mg/l can be indicative of warmer water at depth. This is, however, the only chemical constituent that even slightly indicates some thermal potential for the area.

Area F

Area F is located in southeastern Jordan Valley and comprises parts of the Southeastern and West Slope ground-water districts (plate 4). Included in

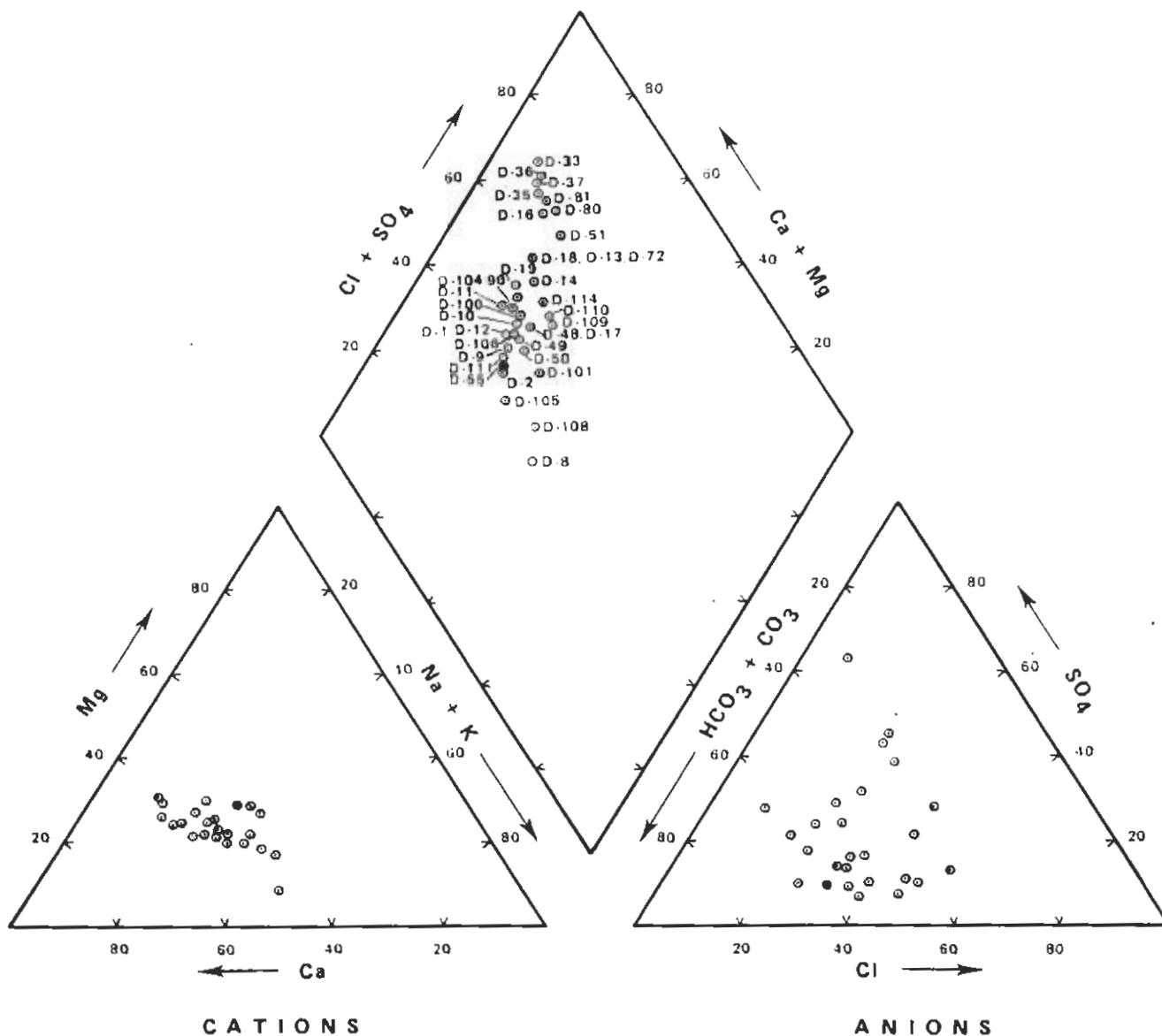


Figure 11. Piper diagram of common ions from samples collected in area "E" on plate 4 in the Jordan Valley, Salt Lake County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Darkened symbols indicate samples with temperatures $\geq 20^{\circ}C$. Roman numerals indicate classification of water types.

area F is Crystal Hot Springs and two isolated thermal water wells. The samples from these wells are designated R-14 and R-15 (plate 4).

Total Dissolved Solids--Total dissolved solid concentrations for waters in area F range from 242 to 2130 mg/l. Total dissolved solids for those waters designated as thermal range from 278 to 2130 mg/l. Concentrations for all other water in the area range from 242 to 1330 mg/l. Total dissolved solids are generally greater than for areas C and D to the north due primarily to significant mixing in this part of the valley; recharge occurs from the east and west Traverse Mountains, the Wasatch Mountains, the Oquirrh Mountains, underflow from Utah Valley, inflow from a number of irrigation canals and the Jordan River, and from Crystal Hot Springs. Total dissolved solid concentrations for Crystal Hot Springs and vicinity (892 to 1720 mg/l), however, are quite low when compared to concentrations at the Warm Springs geothermal area.

Common Ion Analyses--Generally, common ion analyses indicate two main types of water, thermal and non-thermal (fig. 12). Non-thermal waters can be divided into two groups. Type I is calcium-sodium bicarbonate (Ca-Na HCO₃) and calcium-sodium bicarbonate-chloride-sulfate (Ca-Na HCO₃-Cl-SO₄) in character, slightly acidic to slightly basic, and dilute. All samples are enriched in Ca and HCO₃ with respect to all other cations and anions present. Type II is calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃) and calcium-sodium chloride (Ca-Na Cl) in character, slightly acidic to slightly basic, and dilute to slightly saline. All samples are enriched in Ca + Mg with respect to all other cations. Anion enrichment consisted of either Cl or Cl + SO₄. All thermal waters, with the exception of R-14, are sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, acidic to basic and slightly saline. Thermal

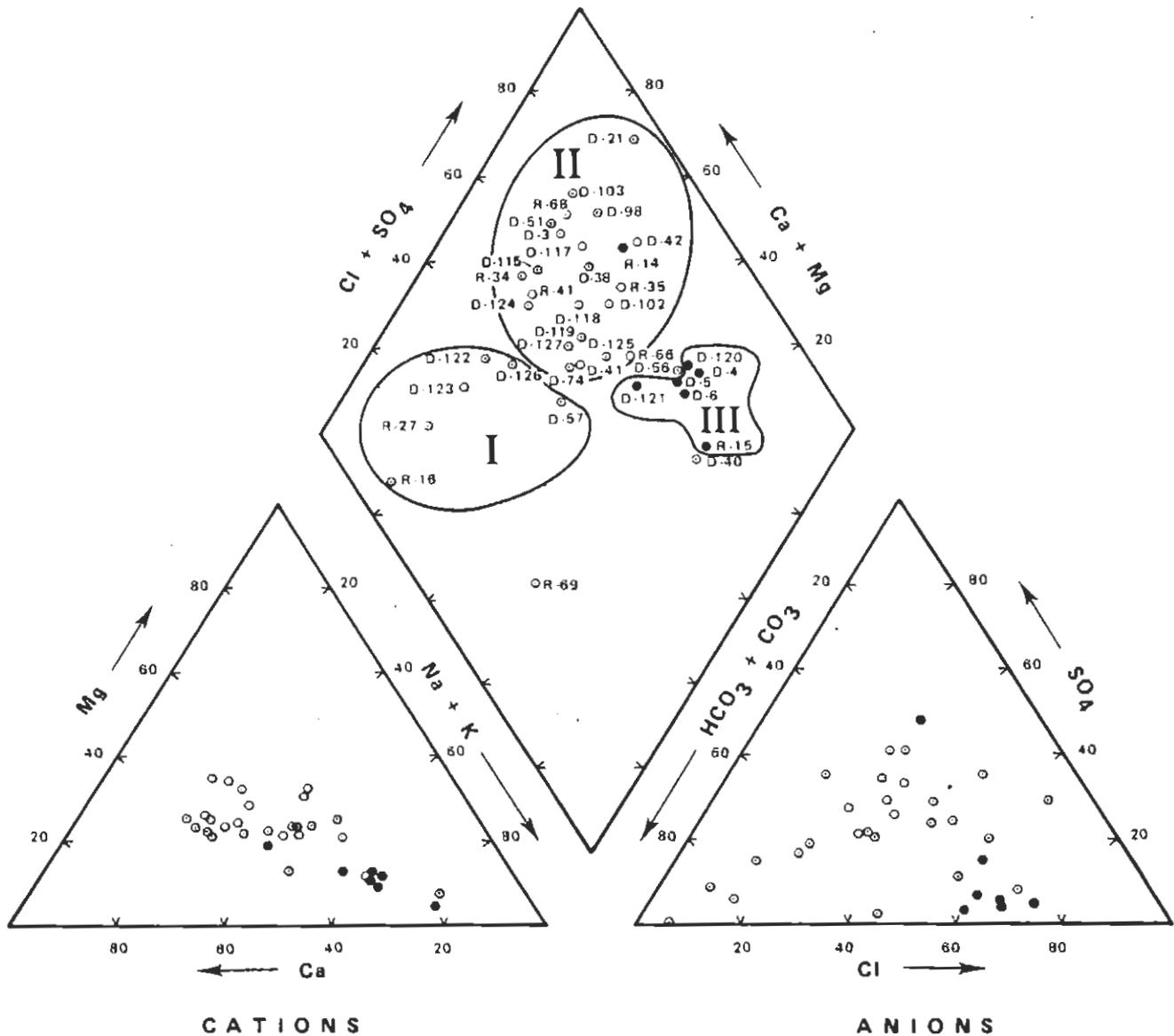


Figure 12. Piper diagram of common ions from samples collected in area "F" on plate 4 in the Jordan Valley, Salt Lake County, Utah. Chemical constituents are plotted as percentage of total milliequivalents. Darkened symbols indicate samples with temperatures $\geq 20^{\circ}C$. Roman numerals indicate classification of water types.

waters are enriched in Na with respect to other cations and Cl with respect to other anions. Sample R-14 is somewhat anomalous with a temperature of 22°C and a calcium-sodium chloride-sulfate-bicarbonate (Ca-Na Cl-SO₄-HCO₃) character. This sample is slightly acidic, slightly saline, and enriched in Ca and HCO₃ to other cations and anions present, respectively. Three other samples, D-56, D-40, and R-69, are not included with the aforementioned types. Samples D-56 and D-40 are similar chemically to R-15, but are not thermal. Sample R-69, being not chemically similar to any other waters sampled in this area, is sodium-calcium bicarbonate-chloride-sulfate (Na-Ca HCO₃-Cl-SO₄) in character, basic, dilute, and enriched in Na and HCO₃ to other cations and anions present, respectively.

Sodium for thermal waters in area F ranges from 48 to 376 mg/l, the highest concentrations being associated with Crystal Hot Springs. Sodium concentrations for non-thermal water range from 12 to 207 mg/l.

Chloride concentrations range from 99 to 722 mg/l for thermal waters. Again, higher values are associated with Crystal Hot Springs. Non-thermal waters have Cl concentrations ranging from 12 to 411 mg/l.

Silica--Silica concentrations for thermal waters in area F range from 19 to 77 mg/l. The highest value is detected in sample D-5, one of the Crystal Hot Springs. Silica concentrations for non-thermal waters range from 15 to 50 mg/l; generally, these values are higher than most non-thermal waters from the remainder of the valley.

Trace Elements--Lithium is not present within detectable limits for all thermal waters sampled from area F. However, in those warm waters where Li is detectable, concentrations range from 0.36 to 1.58 mg/l. Where Li is detected in non-thermal waters, concentrations range from 0.08 to 0.32 mg/l.

Boron is also not detectable in all thermal waters; where detected,

however, concentrations range from 0.3 to 1.4 mg/l. In non-thermal water, B is present in concentrations up to 0.4 mg/l.

Fluorine is present in all samples tested. Concentrations for thermal and non-thermal waters range from 0.3 to 2.6 mg/l and 0.1 and 1.0 mg/l, respectively. All F concentrations greater than 1.0 mg/l are for samples collected in the vicinity of and including Crystal Hot Springs.

CHEMICAL GEOTHERMOMETRY

Chemical geothermometers have been calculated for all water samples collected and analyzed in the Jordan Valley. Geothermometers considered applicable and used in this study are: 1) silica (quartz conductive and chalcedony); and 2) sodium-potassium-calcium (Na-K-Ca). Equations, from Fournier (1981), expressing the temperature dependence of selected geothermometers, are presented below:

Quartz (conductive):

$$t(^{\circ}\text{C}) = \frac{1309}{5.19 - \log \text{SiO}_2} - 273.15$$

Chalcedony:

$$t(^{\circ}\text{C}) = \frac{1032}{4.69 - \log \text{SiO}_2} - 273.15$$

$$\text{Na-K-Ca: } t(^{\circ}\text{C}) = \frac{1647}{\log (\text{Na/K}) + B [\log \text{Ca}^{1/2}/\text{Na}) + 2.06] + 2.47} - 273.15$$

where: B = 1/3 for t greater than 100°C

B = 4/3 for t less than 100°C

SiO₂, Na, K, and Ca concentrations are in mg/l

The reliability of SiO₂ and Na-K-Ca geothermometers depends upon five assumptions (Fournier and others, 1974). These assumptions are:

1. temperature-dependent reactions occur at depth,

2. all constituents involved in the temperature-dependent reactions are sufficiently abundant,
3. water-rock chemical equilibrations occur at the reservoir temperature,
4. little or no equilibration or change in composition occurs at lower temperatures as the water flows from the reservoir to the surface, and
5. the hot water coming from deep in the system does not mix with cooler, shallow ground water.

Realistically, most low temperature thermal systems occur in hydrologic regimes which preclude all/some of these assumptions. Also, Fournier and Potter (1979) present data which indicate the Na-K-Ca geothermometer gives anomalously high results for waters rich in Mg. They derived a temperature correction to accommodate this occurrence. The conditions which dictate when this correction can be used are as follows:

- (1) Na-K-Ca temperature equal to or greater than 70°C, and
- (2) R equal to or less than 50

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

Mg, Ca, and K are in equivalent units of concentration. When these conditions are met, a graphical method presented in their paper is used to obtain a corrected temperature.

Conditions in most of the Jordan Valley are not favorable for at least some of the above assumptions and, therefore, expected geothermometer temperatures at depth could be somewhat spurious. This is especially true of mixing; identified warm water areas in the Jordan Valley, with the exception of Crystal Hot Springs, result from mixing of hotter water with cool water from near-surface aquifers. The effect of dilution on Na-K-Ca geothermometer

is generally negligible if higher temperature geothermal water is much more saline than the diluting water (Fournier, 1981). Fournier (1981) also indicates, however, that if the warm water component is 30 percent or less, the effects of mixing should be considered. Anomalous results with the Na-K-Ca geothermometer can also be expected if the waters are rich in Mg (Fournier and Potter, 1979). Therefore, the Mg-correction must be utilized in this situation. However, as with other geothermometers, the Mg-corrected Na-K-Ca geothermometer is subject to error related to possible continued water-rock reaction as ascending water cools and, therefore, must be used with caution (Fournier, 1981).

Quartz is the most stable and least soluble polymorphic form of silica within the temperature and pressure range found in low-temperature geothermal systems (Fournier, 1981). Fournier (1981) also states that ground waters, which have not attained temperatures greater than 80^o to 90^oC, have silica concentrations greater than those predicted by the solubility of quartz which could indicate these low-temperature waters have equilibrated with chalcedony. Fournier (1977) suggests that if the Na-K-Ca geothermometer indicates a temperature of less than 100^oC, the silica content of the water is a function of chalcedony solubility. For temperatures greater than 100^oC, the silica temperature should be calculated assuming the silica content is a function of quartz solubility. In Iceland, Arnorsson (1975) found that when undissociated silica is less than 60 mg/l, the silica temperature refers to equilibrium with chalcedony and between 60 and 250 mg/l, it has not been determined whether chalcedony or quartz governs the amount of silica in the system. Due to the lack of consensus regarding which form of silica governs concentrations from temperatures between 100^o and 180^oC, both chalcedony and quartz temperatures will be given. When ascending warm

water becomes diluted by cooler water, a new water rock chemical equilibrium may or may not be attained after mixing. If chemical equilibrium is not attained, direct application of the silica geothermometer will give a temperature that is too low and, therefore, mixing must be accounted for (Fournier, 1981). To be compatible with the chemical analysis, the geothermometry results will be discussed within the framework of the six areas (A, B, C, D, E, and F) depicted in plate 4.

Area A

Na-K-Ca (Mg corrected) temperatures for those waters designated as non-thermal in area A range from 19⁰ to 50⁰C and are presented in table 6. A number of samples contain no detectable K which precludes this method. Two samples, T-8 and T-9, have R values greater than 50 which suggests that water temperatures at depth at these locations are similar to the recorded temperatures of 11⁰ and 14⁰C, respectively. Chalcedony values range from -9⁰ to 66⁰C for all samples. Good agreement between the two geothermometers has not been obtained on all samples, but the range of temperatures is similar, suggesting that, with depth, non-thermal water in this part of the Jordan Valley is less than 50⁰C.

Temperatures calculated by the Na-K-Ca (Mg corrected) method for thermal waters range from 33⁰ to 92⁰C. In sample R-62, K is undetectable, therefore precluding this method. Becks and Hobo hot springs provide the highest expected temperatures with depth. Chalcedony temperatures range from 10⁰ to 73⁰C, but only R-63 and R-67 provide good agreement with the Na-K-Ca geothermometer. Good agreement with the quartz geothermometer is obtained for samples from Becks and Hobo hot springs as well as water well samples R-61, T-17, and R-51. This may indicate these waters equilibrated with quartz and not chalcedony. Mixing models (Fournier, 1977; Truesdell and

Table 6: Chemical geothermometers with magnesium correction where applicable and surface temperatures for fluids in (°C) for samples in area "A" on Plate 4 in the Jordan Valley, Salt Lake County, Utah.

SAMPLE	TEMPERATURE	QTZ (COND)	CHALCEDONY	Na-K-Ca	Na-K-Ca (Mg-correction)
T-1	13	48	15	*	*
T-3	14	53	21	39	+
T-4	13	60	27	50	+
T-8	11	96	66	112	R > 50
T-9	14	86	55	99	39
T-10	13	42	10	*	*
T-13	12	62	29	41	+
T-14	17	57	25	43	+
T-18	13	89	59	89	R > 50
R-1	13	53	21	*	*
R-2	17	53	21	25	+
R-4	13	24	-9	*	*
R-5	14	48	15	*	*
R-7	14	48	15	20	+
R-8	13	48	15	*	*
R-9	16	48	15	19	+
R-56	13	48	15	*	*
R-60	16	65	33	*	*
R-62	19	62	29	*	*
R-70	15	53	21	23	+
R-71	14	55	23	48	+
R-73	12	53	21	41	+
R-74	17	51	18	85	64
Becks H.S.	55	77	45	178	99
Hobo H.S.	32	74	42	168	87
Wasatch H.S.	39	42	10	119	70
R-61	27	70	39	76	73
R-63	26	85	54	94	56
R-64	23	99	69	94	33
R-65	22	93	62	92	48
R-67	28	103	73	98	78
T-17	20	65	33	63	63

* K not present or not present in detectable concentrations which precludes the use of the Na-K-Ca geothermometer.

R > 50 indicates the underground water temperature is probably equal to the measured temperature.

+ Na-K-Ca temperature less than 70°C; therefore, the Mg correction does not apply.

Fournier, 1977) have been applied to all thermal samples as well as R-74 in an effort to determine what temperature could be expected if mixing is taken into account. Reasonable results have been achieved for Becks and Wasatch hot springs as well as JVR-61. The mixing model (Fournier, 1977) for Becks Hot Spring indicates a maximum temperature of 110°C can be expected with the cold water component being 59 percent. This revised quartz temperature is in agreement with the Na-K-Ca temperature of 92°C. Wasatch Hot Springs mixing model provided a temperature of 50°C to be expected at depth and a 30 percent cold water component. Again, the second confirmation mixing model (Truesdell and Fournier, 1977) indicates quartz equilibrium and not chalcedony with a maximum temperature of 54°C. The Na-K-Ca temperature of 66°C is consistent. The mixing model (Fournier, 1977) for sample R-61 provides a temperature of 80°C with an 85 percent cold water component. This is comparable with the Na-K-Ca (Mg-corrected) temperature of 73°C. The second mixing model (Truesdell and Fournier, 1977) indicates a temperature of 93°C can be expected at depth but with chalcedony as the equilibrium phase.

Mixing models conducted on all other samples were inconclusive. Either unreasonably high temperatures and fractions of cold water resulted or concentrations of SiO₂ are such that the method cannot be implemented.

Area B

Na-K-Ca (Mg-corrected) temperatures for non-thermal waters in area B range from 15 to 62°C (table 7). Sample T-15 has an R value greater than 50 which indicates the temperature at depth is similar to the recorded temperature of 16°C. Chalcedony values range from 18°C to 57°C and exhibit, with the exception of samples D-27 and D-91, good agreement with the Na-K-Ca temperatures, indicating non-thermal waters at depth in this area are less than 60°C.

Table 7: Chemical geothermometers with magnesium correction where applicable and surface temperatures for fluids in (°C) for samples in area "B" on Plate 4 in the Jordan Valley, Salt Lake County, Utah.

SAMPLE	TEMPERATURE	QTZ (COND)	CHALCEDONY	Na-K-Ca	Na-K-Ca (Mg-correction)
T-7	14	86	55	44	+
T-15	16	51	18	81	R > 50
T-16	15	88	57	77	42
D-26	16	79	48	62	+
D-27	16	77	45	15	+
D-28	14	74	42	42	+
D-29	14	62	29	28	+
D-32	15	65	33	21	+
D-43	16	79	18	33	+
D-44	15	65	33	31	+
D-45	18	77	45	53	+
D-46	19	79	48	52	+
D-52	14	91	59	43	+
D-53	17	70	39	31	+
D-60	16	70	39	26	+
D-68	17	82	51	56	+
D-69	16	87	56	55	+
D-73	19	77	45	46	+
D-87	14	70	39	42	+
D-91	15	85	54	52	+
D-92	16	85	54	49	+
D-93	15	74	42	43	+
D-97	15	85	51	51	+
D-70	21	109	79	69	+

R > 50 indicates the underground water temperature is probably equal to the measured temperature.

+ Na-K-Ca temperature less than 70°C; therefore, the Mg correction does not apply.

The Na-K-Ca (Mg-corrected) temperature for D-70 (thermal sample) is 69°C. The chalcedony temperature for D-70 was 79°C and is in concordance with the Na-K-Ca geothermometer. Silica mixing models attempted on D-70, proved inconclusive because of non-agreement between the two methods applied.

Area C

Na-K-Ca (Mg-corrected) temperatures for non-thermal waters in area C range from 19°C to 52°C (table 8). A number of samples contain no detectable K which precludes this method. Sample D-30 has an R value greater than 50, indicating the temperature to be expected at depth at this location is similar to the recorded temperature of 17°C. Although chalcedony temperatures range from 3°C to 48°C, agreement is not obtained with Na-K-Ca temperatures for all individual samples. The range of temperatures, however, is similar, suggesting, as in area A, that non-thermal water at depth in this part of the Jordan Valley is less than 50°C. In certain samples, quartz and Na-K-Ca temperatures are similar.

Potassium is not detectable in two of the five thermal samples in area C, therefore precluding the use of the Na-K-Ca geothermometer. Temperatures for the remaining three samples are 26°C, 49°C, and 54°C. The 54°C temperature determined for D-66 is consistent with the 54°C chalcedony temperature determined for this sample. Chalcedony temperatures for the remaining samples range from 3°C to 25°C while quartz temperatures range from 36°C to 85°C; the 85°C temperature is for D-66. The mixing model (Fournier, 1977) applied to the thermal samples indicate all samples have a greater than 90 percent cold-water component. This could affect the Na-K-Ca temperatures significantly, resulting in lower computed temperatures (Fournier, 1981). None of the mixing models provide temperatures considered reasonable. The mixing model (Fournier, 1977) applied to two non-thermal but

Table 8: Chemical geothermometers with magnesium correction where applicable and surface temperatures for fluids in (°C) for samples in area "C" on Plate 4 in the Jordan Valley, Salt Lake County, Utah.

SAMPLE	TEMPERATURE	QTZ (COND)	CHALCEDONY	Na-K-Ca	Na-K-Ca (Mg-correction)
T-5	15	51	18	47	+
T-6	14	42	10	*	*
T-11	13	72	40	59	+
T-12	16	51	18	*	*
R-3	14	42	10	*	*
R-9	16	48	15	19	+
R-12	15	42	10	28	+
R-13	13	42	10	*	*
R-23	12	24	-9	*	*
R-24	14	42	10	*	*
R-43	18	57	25	*	*
R-45	13	42	10	31	+
R-46	17	36	3	*	*
R-47	12	36	3	*	*
R-52	16	36	3	*	*
R-53	17	42	10	*	*
R-54	17	48	15	*	*
R-55	11	36	3	*	*
D-30	17	79	48	71	R > 50
D-59	15	53	21	25	+
D-64	15	48	15	*	*
D-65	18	48	15	*	*
D-67	19	48	15	*	*
D-82	12	53	21	52	+
D-83	19	57	25	40	+
D-84	14	48	15	46	+
D-85	24	42	10	26	+
R-11	22	36	3	*	*
R-42	20	57	25	*	*
D-58	21	36	3	83	49
D-66	21	85	54	54	+

* K not present or not present in detectable concentrations which precludes the use of the Na-K-Ca geothermometer.

R > 50 indicates the underground water temperature is probably equal to the measured temperature.

+ Na-K-Ca temperature less than 70°C; therefore, the Mg correction does not apply.

fairly warm samples (D-65 and D-67) result in temperatures of 110° and 100°C , respectively. Again, the mixing model indicates cold-water components in excess of 90 percent. A second mixing model (Truesdell and Fournier, 1977) is in agreement with these temperatures and indicates the SiO_2 equilibrated with quartz. Both samples contain no detectable K, so use of the Na-K-Ca geothermometer is not possible.

Area D

Na-K-Ca (Mg-corrected) temperatures for those non-thermal waters with detectable K range from 24° to 61°C (table 9). It should be noted that 19 out of the 31 non-thermal samples collected in this area have K concentrations below detectable limits. Chalcedony temperatures for those samples with undetectable K range from 0° to 21°C ; temperatures for the remaining non-thermal samples range from 10° to 42°C . As with other areas, good agreement is not obtained between the two geothermometers for each individual sample, but the range of temperatures is fairly consistent, indicating non-thermal water temperatures at depth are not more than 50°C , and at most locations are much less.

Four samples collected in area D had temperatures 20°C or greater. Sample D-31 is somewhat anomalous aside from the fact that a 48°C temperature was recorded at the well head. This sample is from the Utah Roses, Inc. well and the temperature is to be expected considering the normal geothermal gradient ($35^{\circ}\text{C}/\text{km}$) for the Basin and Range physiographic province. The chemistry from this well may be indicative of deep basin water. Therefore, geothermometer results for this sample are somewhat spurious. The Na-K-Ca (Mg-corrected) temperature is 62°C ; the chalcedony and quartz temperatures are 29° and 62°C , respectively. These temperatures are not unreasonable, and indicate the 48°C measured

Table 9: Chemical geothermometers with magnesium correction where applicable and surface temperatures for fluids in (°C) for samples in area "D" on Plate 4 in the Jordan Valley, Salt Lake County, Utah.

SAMPLE	TEMPERATURE	QZ (COND)	CHALCEDONY	Na-K-Ca	Na-K-Ca (Mg-correction)
R-17	15	42	10	*	*
R-18	14	42	10	*	*
R-20	18	48	16	44	+
R-21	12	36	3	*	*
R-22	11	48	16	*	*
R-25	13	42	10	26	*
R-26	10	36	3	*	*
R-28	12	36	3	*	*
R-29	12	42	10	*	*
R-30	12	42	10	*	*
R-31	14	36	3	*	*
R-33	16	42	10	*	*
R-36	13	42	10	*	*
R-37	18	53	21	*	*
R-39	16	48	16	*	*
R-40	18	53	21	*	*
R-48	10	24	-9	*	*
R-49	11	24	-9	*	*
R-50	15	42	10	35	+
R-51	15	24	3	*	*
R-58	11	48	16	*	*
R-59	11	48	16	*	*
D-15	13	62	29	24	+
D-22	17	53	21	47	+
D-23	15	70	39	61	+
D-25	16	42	10	40	+
D-39	17	53	21	30	+
D-61	17	42	10	39	+
D-86	15	74	42	54	+
D-88	15	74	42	38	+
D-89	16	48	16	38	+
D-96	15	62	29	30	+
R-32	26	42	10	70	+
R-38	21	46	15	62	+
D-31	48	62	29	76	64
D-62	24	42	10	*	*

* K not present or not present in detectable concentrations which precludes the use of the Na-K-Ca geothermometer.

+ Na-K-Ca temperature less than 70°C; therefore, the Mg correction does not apply.

is near to the maximum temperature. A silica mixing model (Truesdell and Fournier, 1977) indicates a maximum temperature of 72°C and equilibration with quartz.

Of the three remaining thermal samples, D-62 has undetectable K which precludes use of the Na-K-Ca geothermometer. The chalcedony and quartz geothermometers provide temperatures of 10°C and 42°C, respectively but the low concentration of SiO₂ precludes the use of mixing models. Samples R-32 and R-38 have Na-K-Ca (Mg-corrected) temperatures of 70°C and 62°C, respectively. Chalcedony temperatures are 10°C (R-32) and 15°C (R-38); both are below actual measured temperatures which eliminates use of this geothermometer. The quartz geothermometer provides temperatures of 42°C and 48°C for R-32 and R-38, respectively. These temperatures are more realistic, and are more consistent with the Na-K-Ca temperatures. The very low silica value for R-32 precluded the use of mixing models. Mixing models (Truesdell and Fournier, 1977; Fournier, 1977) applied to R-38, however, result in temperatures of 53°C and 60°C, 85 percent dilution from non-thermal water, and equilibration with quartz. These temperatures are reasonable, but indicate only moderate thermal waters are to be expected at depth.

Area E

Na-K-Ca (Mg-corrected) temperatures for non-thermal waters in area E range from 12°C to 56°C (table 10). In sample D-19 the K concentration is below detectable limits, thereby eliminating this geothermometer. Chalcedony temperatures range from 25°C to 76°C, a slightly higher range than determined with the Na-K-Ca geothermometer. This higher range is a reflection of greater concentrations of silica for this area as compared with other parts of the valley. Although agreement is not achieved between geothermometers for

Table 10: Chemical geothermometers with magnesium correction where applicable and surface temperatures for fluids in ($^{\circ}\text{C}$) for samples in area "E" on Plate 4 in the Jordan Valley, Salt Lake County, Utah.

SAMPLE	TEMPERATURE	QTZ (COND)	CHALCEDONY	Na-K-Ca	Na-K-Ca (Mg-correction)
D-1	14	87	56	40	+
D-2	15	87	56	46	+
D-8	18	63	31	53	+
D-9	8	99	69	56	+
D-10	14	99	69	49	+
D-11	14	70	39	32	+
D-12	14	95	64	45	+
D-13	15	93	62	45	+
D-14	14	91	60	47	+
D-16	14	91	60	42	+
D-17	13	91	60	47	+
D-18	14	85	54	34	+
D-19	14	62	29	*	*
D-33	16	62	29	12	+
D-35	14	62	29	14	+
D-36	14	65	33	14	+
D-37	14	62	29	16	+
D-48	13	70	39	26	+
D-49	16	105	76	59	+
D-50	13	87	56	47	+
D-72	19	88	54	30	+
D-80	12	70	39	28	+
D-81	12	57	25	16	+
D-90	15	88	57	37	+
D-100	13	74	42	36	+
D-101	13	62	29	29	+
D-104	13	62	29	23	+
D-106	14	85	54	41	+
D-108	14	91	60	54	+
D-109	16	101	71	56	+
D-110	17	99	69	53	+
D-11	16	99	69	56	+
D-114	15	95	64	47	+
D-55	21	62	29	56	+

* K not present or not present in detectable concentrations which precludes the use of the Na-K-Ca geothermometer.

+ Na-K-Ca temperature less than 70°C ; therefore, the Mg correction does not apply.

all samples, generally a similar trend is evident; higher temperatures with one geothermometer compared with higher temperatures for the other geothermometer within respective ranges.

Sample D-55 is the only thermal sample from area E. The Na-K-Ca (Mg-corrected) temperature of 56°C is not indicative of any significant low-temperature resource in the area. Furthermore, the 29°C chalcedony temperature is at the lower end of the non-thermal temperature range. The quartz temperature of 62°C , however, indicates silica within this sample may have equilibrated with quartz and not chalcedony. Mixing models are not feasible because the low SiO_2 concentration.

Area F

Na-K-Ca (Mg corrected) temperatures for non-thermal waters in area F range from 29° to 75°C (table 11). Samples R-27, D-105, and D-122 have K concentrations below detectable limits, precluding the use of this geothermometer. Chalcedony temperatures range from 16° to 72° . Agreement between geothermometers is not obtained on all samples, but as with other areas previously discussed, the range of temperatures is similar. The upper limits of the range of these temperatures are higher than in other parts of the valley which may be a result of the interaction with the material through which the water migrates and not a result of mixing with thermal waters at depth.

Temperatures calculated with the Na-K-Ca (Mg-corrected) geothermometer for thermal waters in area F range from 61° to 81°C . With the exceptions of R-14 and R-15, these samples are all from Crystal Hot springs or wells in the immediate vicinity. Sample D-4 is, in fact, from a well that intercepts the geothermal reservoir that feeds the springs. The reservoir temperature measured in this well is 85°C . This temperature is consistent with the

Table 11: Chemical geothermometers with magnesium correction where applicable and surface temperatures for fluids in (°C) for samples in area "F" on Plate 4 in the Jordan Valley, Salt Lake County, Utah.

SAMPLE	TEMPERATURE	QTZ (COND)	CHALCEDONY	Na-K-Ca	Na-K-Ca (Mg-correction)
R-16	15	79	48	59	+
R-27	11	48	16	*	*
R-34	13	79	48	55	+
R-35	16	85	54	57	+
R-41	14	57	25	36	+
R-66	16	85	54	41	+
R-68	15	91	60	64	+
R-69	13	79	48	87	74
D-3	16	77	45	29	+
D-21	15	67	35	29	+
D-38	16	62	29	30	+
D-40	15	65	33	96	65
D-41	17	62	29	58	+
D-42	17	62	29	88	56
D-51	15	77	45	33	+
D-56	19	65	33	181	60
D-57	19	62	29	66	+
D-74	15	70	39	63	+
D-98	16	78	47	37	+
D-102	15	87	56	34	+
D-103	16	74	42	33	+
D-105	15	93	62	53	+
D-115	16	99	69	67	+
D-117	17	85	54	70	54
D-118	16	97	67	64	+
D-119	17	62	29	63	+
D-122	17	53	21	*	*
D-123	17	53	21	45	+
D-124	17	102	72	175	60
D-125	16	70	39	75	39
D-126	15	97	67	42	+
D-127	15	62	29	68	+
R-14	22	62	29	86	65
R-15	24	70	39	159	81
D-4	85	99	69	200	73
D-5	38	123	95	199	79
D-6	54	97	67	199	77
D-120	29	94	63	197	61
D-121	38	70	39	193	68

* K not present or not present in detectable concentrations which precludes the use of the Na-K-Ca geothermometer.

+ Na-K-Ca temperature less than 70°C; therefore, the Mg correction does not apply.

Na-K-Ca (Mg-corrected) and chalcedony temperatures for this sample and also with the spring sample (D-5) and State forestry well sample (D-6). See table 11 for these calculated geothermometer temperatures. Two other samples, D-120 from a small pond formed from the same geothermal system and D-121 from a water well removed from the actual system, have geothermometer temperatures somewhat lower. However, mixing models for D-121 resulted in temperatures of 95^o (Fournier, 1977) and 94^o (Truesdell and Fournier, 1977), which are very close to the maximum determined temperature for the reservoir. These mixing models also indicate silica has equilibrated with quartz and fluids sampled contain 70 percent cool water. Mixing models applied to D-120, D-5, and D-6 also provide unacceptable results.

Na-K-Ca (Mg-corrected) results for R-14 and R-15 are 65^o and 81^oC, respectively. Chalcedony temperatures are exceptionally low, but quartz temperatures are similar to the Na-K-Ca (Mg-corrected) results, with values of 62^oC (R-14) and 70^oC (R-15). Mixing models applied to sample R-14 result in a temperature of 82^oC, 90 percent mixing of non-thermal water, and equilibrium with quartz. Applying the same mixing models to R-15 results in temperatures between 135^o and 145^oC and 94 percent mixing with non-thermal waters. However, the chalcedony modifications of Sonderegger and Donovan (1981) provide a more reasonable temperature of 85^oC.

TEMPERATURE-DEPTH MEASUREMENTS

Temperature-depth measurements, and the subsequent temperature gradients derived thereof, are useful in exploration for geothermal resources since they can allow for detection of thermal anomalies (Laughlin, 1982). Temperature gradients are affected by heat flow and thermal conductivity. Heat flow is the conductive transfer of heat from the earth's interior and, therefore, the

surface expression of geothermal conditions at depth. For a given heat flow, the temperature gradient is inversely proportional to the thermal conductivity of the material through which the heat is being transmitted by conduction (Kappelmeyer and Haenel, 1974). At shallow depths, temperature gradients are affected by surface conditions such as temperature and precipitation. These effects are eliminated below 98 ft (30 m) in depth (Kappelmeyer and Haenel, 1974). Also, temperature measurements are strongly influenced by the movement of ground water (sometimes to depths of hundreds of feet or meters) and it should always be recognized that temperature gradients are meaningful only for conductive heat transfer and that vertical, as well as horizontal, convection can upset the extrapolation of temperature information (Laughlin, 1982; and Lumb, 1981).

The Jordan Valley is an area of highly convective heat flow due to the influx of cool water from the mountainous recharge areas. Stable, conductive thermal gradients are difficult to obtain in such areas, and results must be considered local rather than regional. Although the average Basin and Range gradient is considered to be approximately $35^{\circ}\text{C}/\text{km}$, Costain and Wright (1973) calculated a gradient of $57.7^{\circ}\text{C}/\text{km}$ from a gradient hole drilled in the Jordan Valley near Salt Lake City. Costain and Wright (1973) attributed this high gradient to what is believed to be the low thermal conduction of the relatively unconsolidated Lake Bonneville deposits encountered in the hole. Because all of the holes logged for this study are in these relatively unconsolidated deposits, only gradients greater than $60^{\circ}\text{C}/\text{km}$ are considered anomalous.

Temperature-depth measurements have been completed in 30 "holes of opportunity" in the Jordan Valley (plate 5). "Holes of opportunity" are pre-existing holes available and conducive to temperature-depth logging.

Unfortunately, as can be seen plate 5, good coverage is not obtained throughout the valley because of the non-availability of suitable holes. Location of these holes by longitude and latitude, elevation interval of gradient calculation, and calculated gradient are presented in table 12. Temperature-depth profiles are presented in figures 13 to 25. Logs of each hole are presented in Appendix C. Temperatures in these holes were measured with a thermistor probe connected by a four-wire configuration to a digital ohmmeter. A Fenwal K212E thermistor probe with a nominal resistance of 10,000 ohms at 20°C, power dissipation of 50 m WK⁻¹ in still waters, and a response time of 5 seconds, was used. Temperature readings were taken at 5 meter intervals in air and 2.5 meter intervals in water, after the temperature stabilized at each position. Gradients were calculated using linear regression with standard error.

Gradients resulting from these temperature-depth measurements range from negative to 103°C/km. Comparison with the background gradients indicate one definite area of elevated temperature and a second area that may be indicative of abnormally warm temperature.

The area of most significant elevated temperature is located northeast of Draper, Utah and is delineated by temperature-depth hole locations JVG-19, JVG-17, and JVG-5 (fig. 16 and plate 5). Gradients calculated for JVG-19 and JVG-5 were 102°C and 103°C/km, respectively (table 12). These gradients are significantly greater than the 57.8°C/km gradient determined by Costain and Wright (1973), and most significantly greater than the 35°C/km considered average for the Basin and Range. The third gradient (JVG-17) is only 47°C/km between the depths of 129 and 159 meters. However, last two data points (at 149 and 159 meters) indicate an increase in the gradient to more than 80°C/km. All three of these temperature-depth profiles are, to

Table 12: Geothermal gradient data for 30 "holes of opportunity" logged in the Jordan Valley, Salt Lake County, Utah

Site	N. Lat.	W. Long.	Elev (m)	Depth Water (m)	Depth Range (m)	Gradient (°C/km)	Gradient Class
JVG-1	40°39'07"	111°52'29"	1311 \pm 2	flowing	30 - 83	13 \pm 2	isothermal
JVG-2	40°36'06"	111°49'20"	1424 \pm 2	122	24 - 268	26 \pm 3	tentative
JVG-3	40°34'19"	111°52'22"	1370 \pm 1	15	43 - 65	23 \pm 6	tentative
JVG-4	40°32'37"	111°50'39"	1453 \pm 2	100	64 - 218	4 \pm 6	isothermal
JVG-5	40°31'48"	111°51'51"	1384 \pm 2	34	20 - 43	103 \pm 51	air
JVG-6	40°34'12"	111°55'11"	1332 \pm 1	5	20 - 45	47 \pm 2	good
JVG-7	40°26'56"	111°56'11"	1445 \pm 3	16	20 - 95	33 \pm 5	good
JVG-8	40°29'02"	112°04'17"	1646 \pm 6	33	18 - 57	58 \pm 16	fair
JVG-9	40°30'47"	112°04'29"	1598 \pm 3	41	19 - 128	64 \pm 7	good
JVG-10	40°39'40"	112°05'12"	1503 \pm 3	30	24 - 79	18 \pm 5	fair
JVG-11	40°28'27"	112°04'20"	1659 \pm 6	30	49 - 159	46 \pm 9	good
JVG-12	40°40'04"	111°58'11"	1334 \pm 1	11	19 - 89	34 \pm 6	good
JVG-13	40°39'48"	112°04'43"	1486 \pm 3	29	19 - 49	18 \pm 7	tentative
JVG-14	40°39'16"	111°57'58"	1360 \pm 1	less than 29	29 - 89	16 \pm 5	tentative
JVG-15	40°41'07"	111°55'42"	1296 \pm 1	1	19 - 57	24 \pm 2	fair

Table 12 (Continued)

Site	N. Lat.	W. Long.	Elev (m)	Depth Water (m)	Depth Range (m)	Gradient (°C/km)	Gradient Class
JVG-16	40°35'58"	111°51'30"	1398 _± 6	no water	99 - 145	negative	
JVG-17	40°32'44"	111°52'04"	1384 _± 2	45	129 - 159	47 _± 22	tentative
JVG-18	40°35'55"	111°50'22"	1433 _± 3	115	99 - 217	negative	
JVG-19	40°33'26"	111°52'56"	1348 _± 1	21	29 - 89	102 _± 6	good
JVG-20	40°37'29"	112°02'40"	1540 _± 3	80	99 - 179	40 _± 4	good
JVG-21	40°32'08"	111°56'52"	1364 _± 1	15	39 - 68	27 _± 1	tentative
JVG-22	40°34'55"	111°59'48"	1438 _± 1	38	39 - 159	65 _± 10	good
JVG-23	40°37'51"	111°55'23"	1303 _± 1	4	29 - 65	25 _± 5	fair
JVG-24	40°40'06"	111°58'23"	1348 _± 1	26	29 - 219	56 _± 6	good
JVG-25	40°29'54"	112°03'41"	1585 _± 6	105	29 - 159	52 _± 7	good
JVG-26	40°36'16"	111°49'19"	1415 _± 2	91	19 - 169	negative	
JVG-27	40°46'52"	111°53'12"	1335 _± 3	82	19 - 89	negative	
JVG-28	40°41'01"	111°48'14"	1463 _± 6	115	29 - 119	50 _± 9	air
JVG-29	40°41'53"	111°48'00"	1476 _± 2	88	29 - 79	80 _± 31	air
JVG-30	40°40'55"	111°48'20"	1421 _± 6	no water	18 - 95	negative	

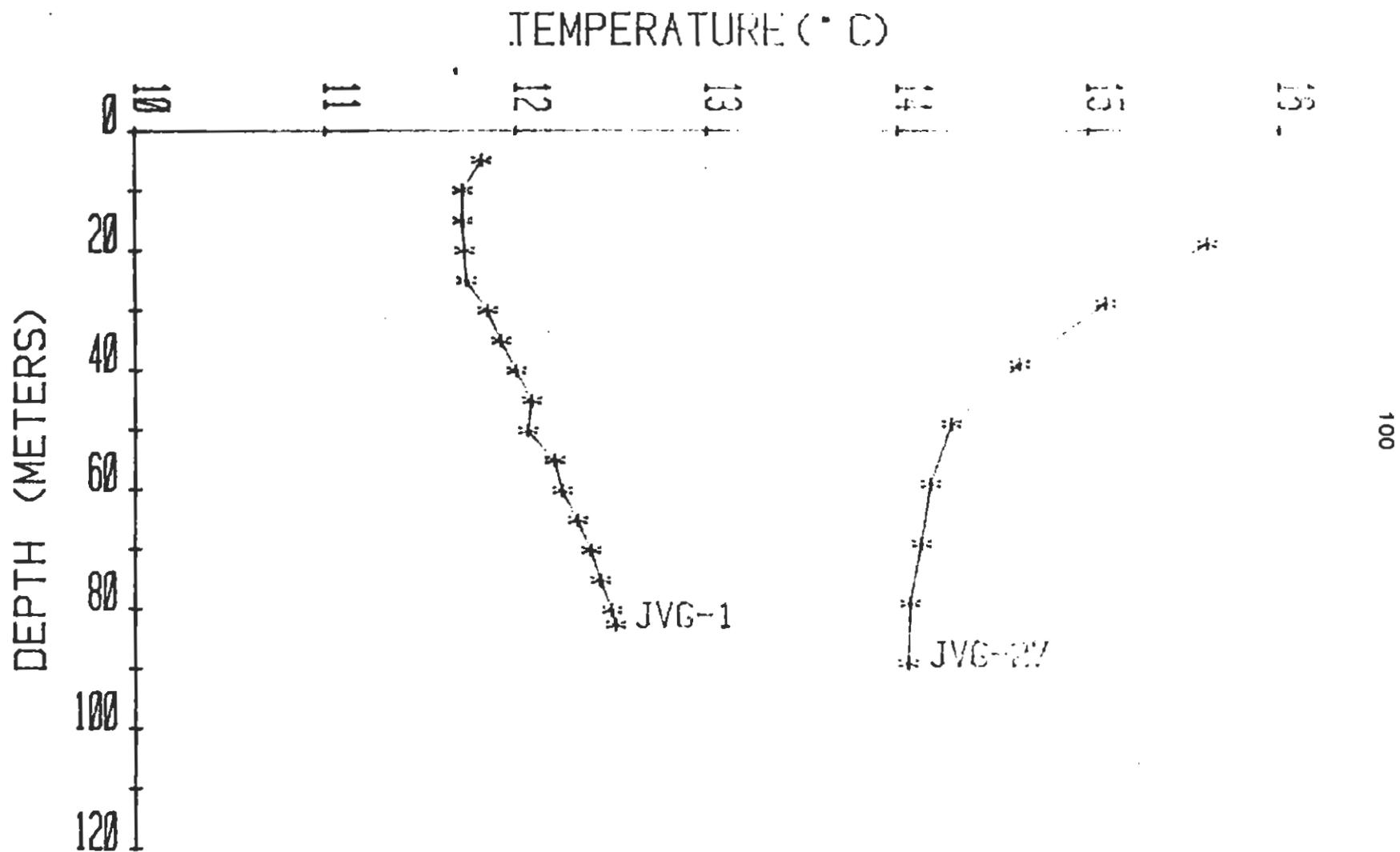


Figure 13. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

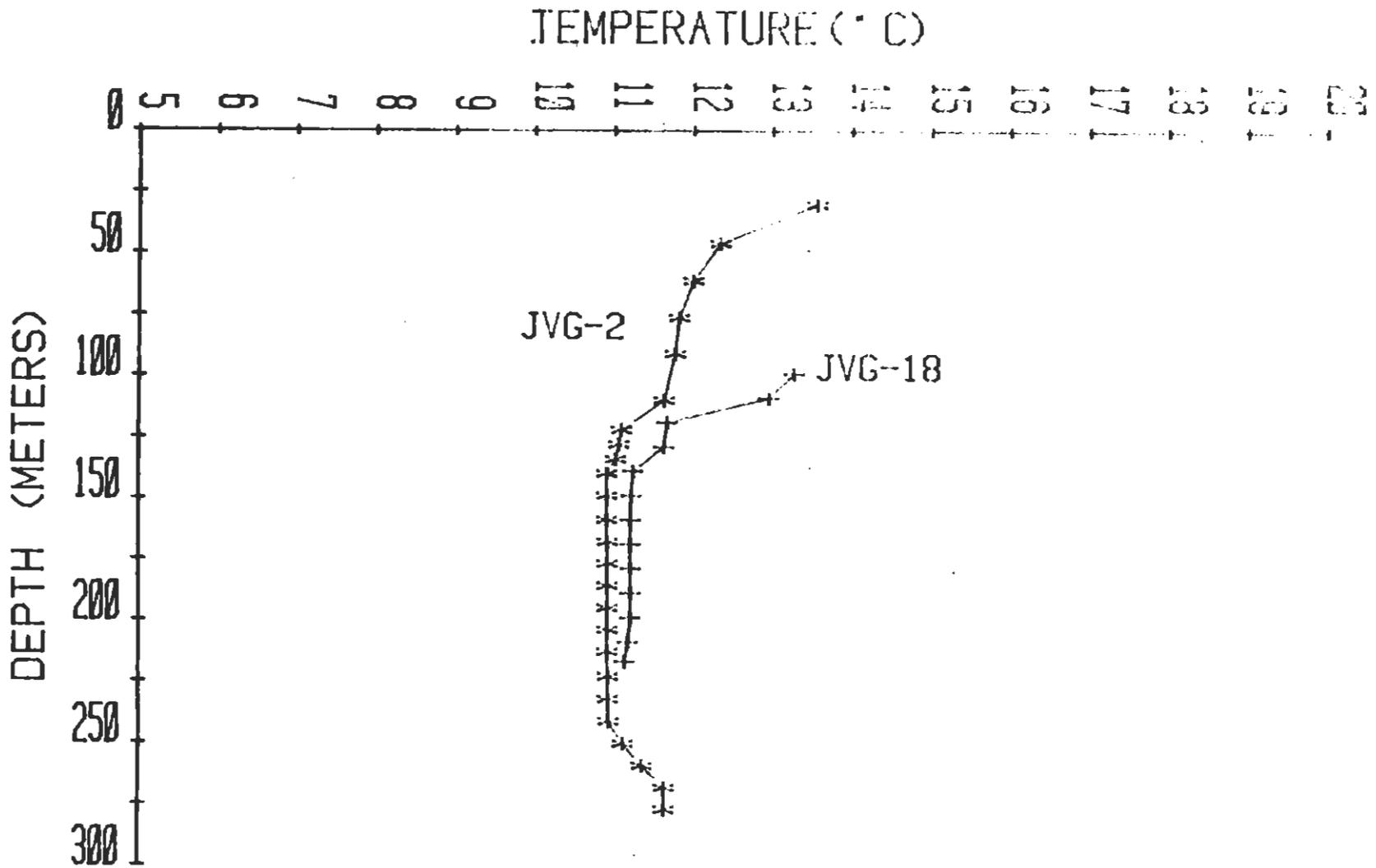


Figure 14. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

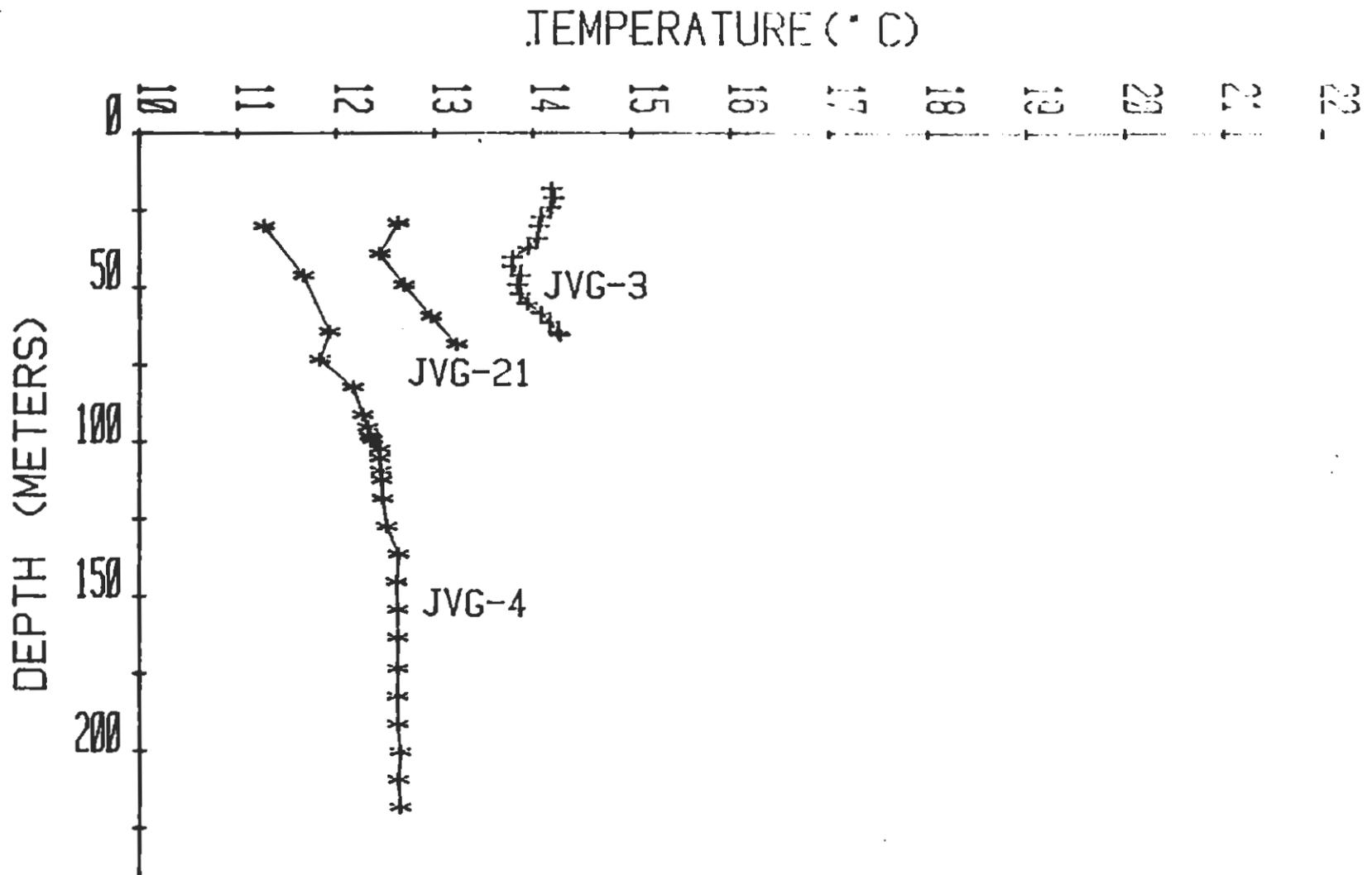


Figure 15. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

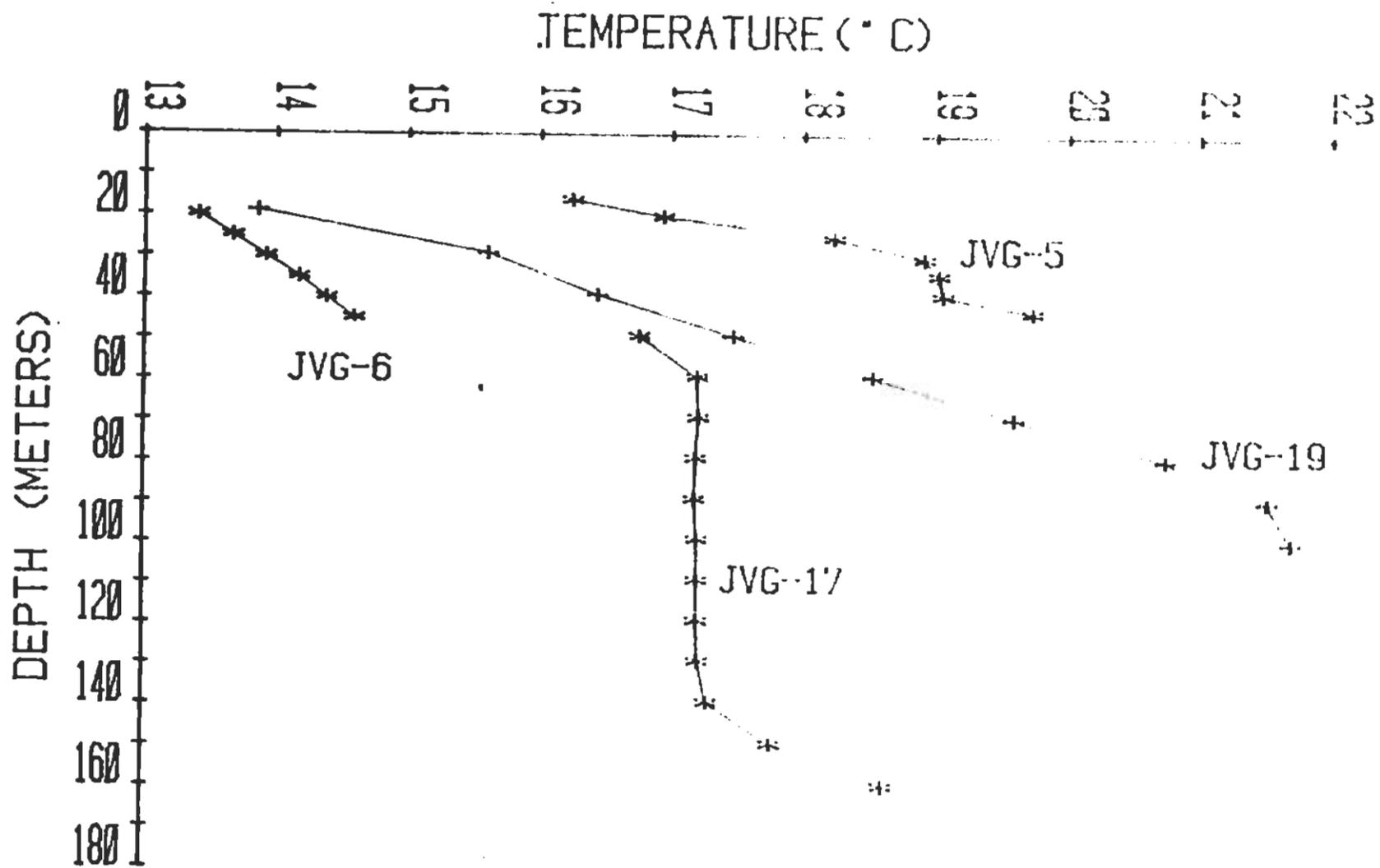


Figure 16. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

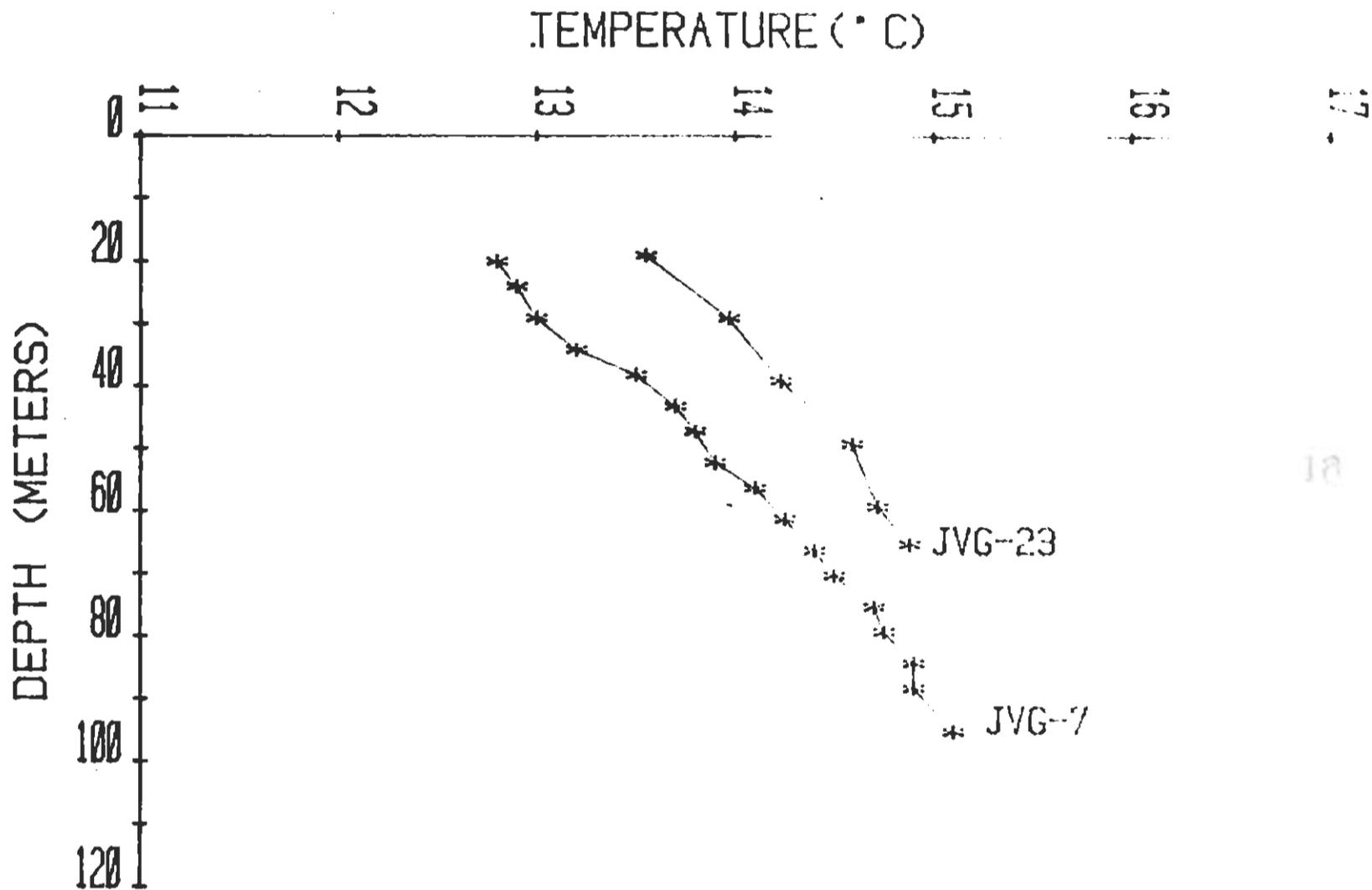


Figure 17. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

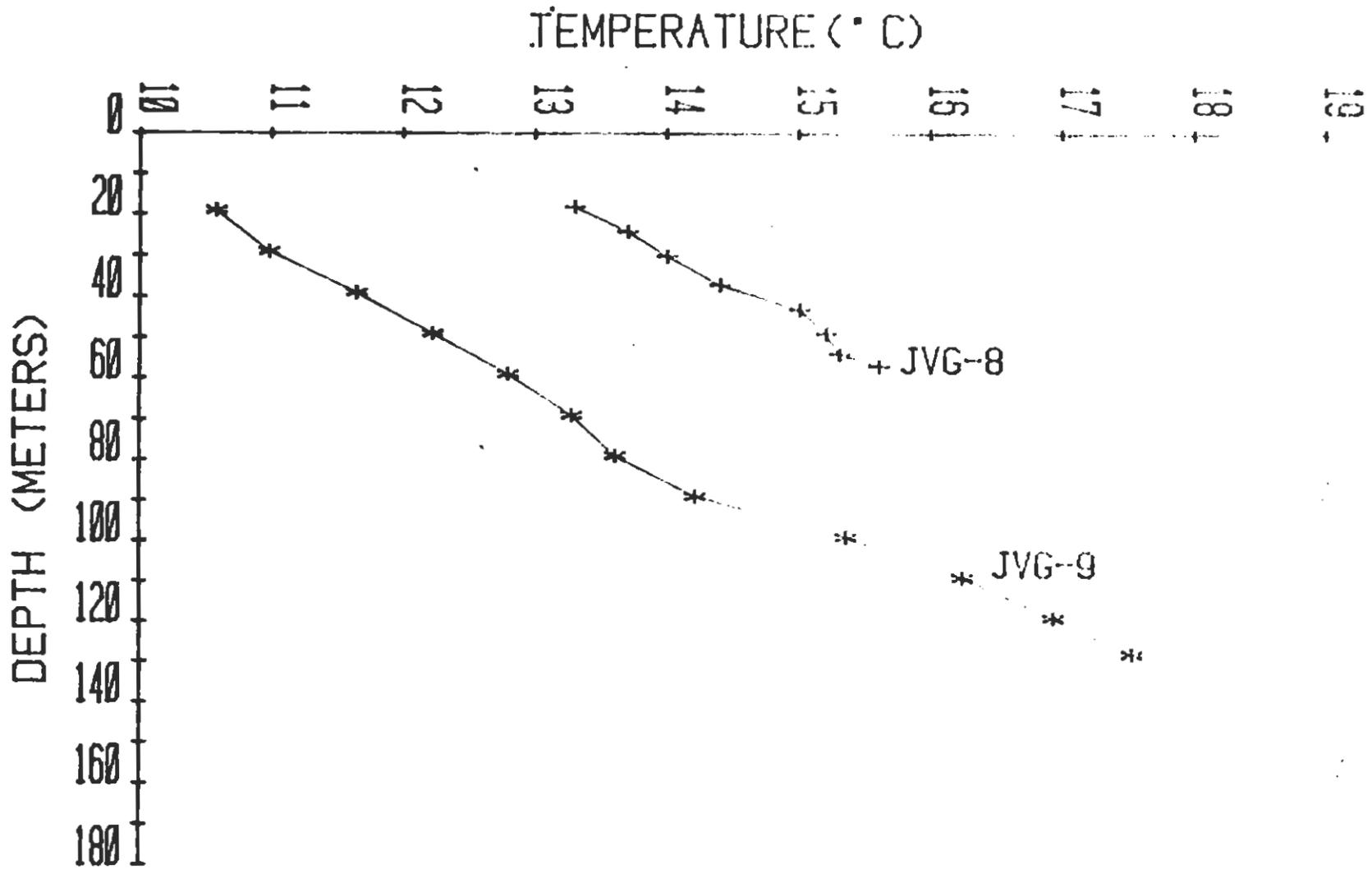


Figure 18. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

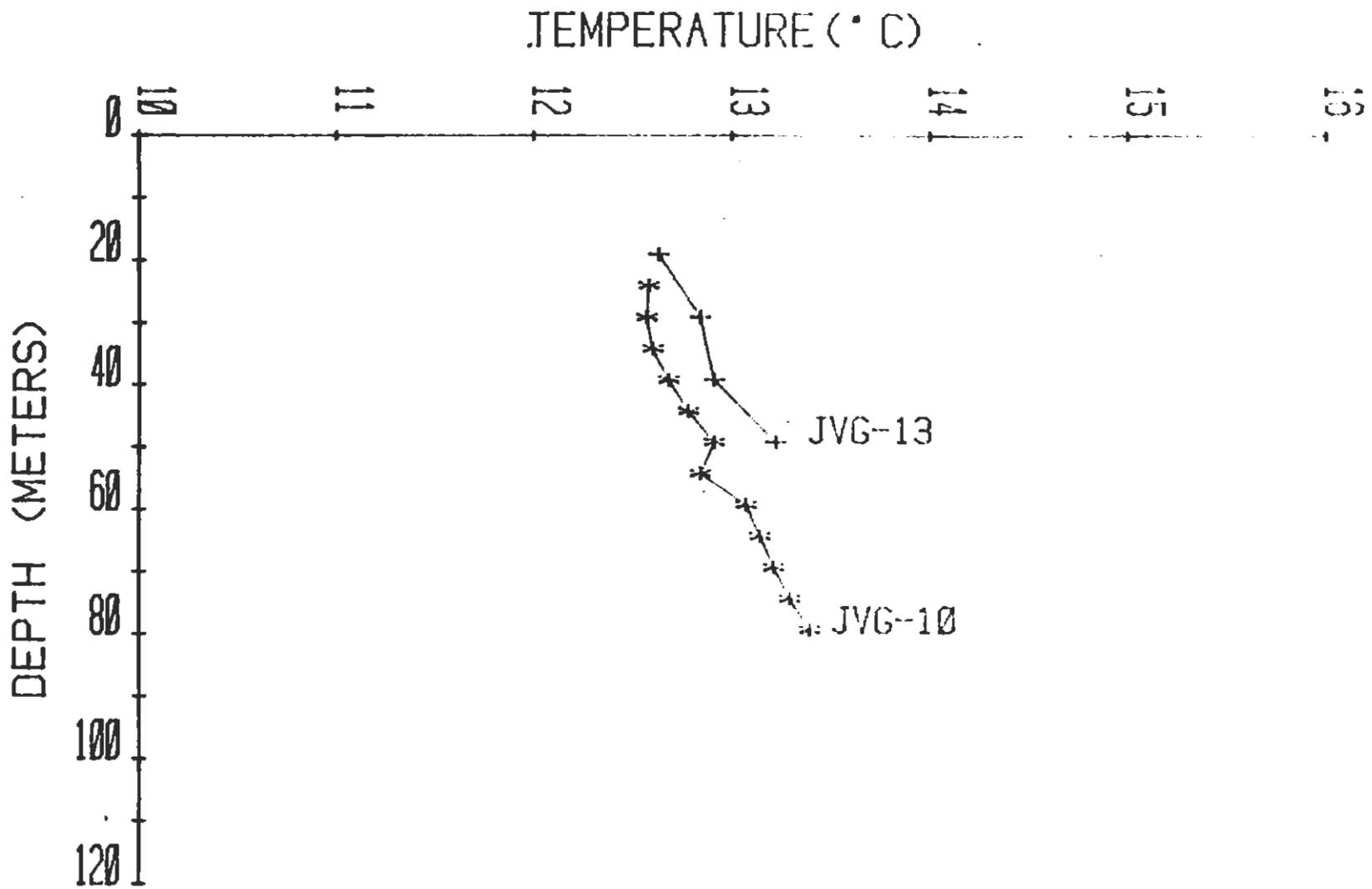


Figure 19. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

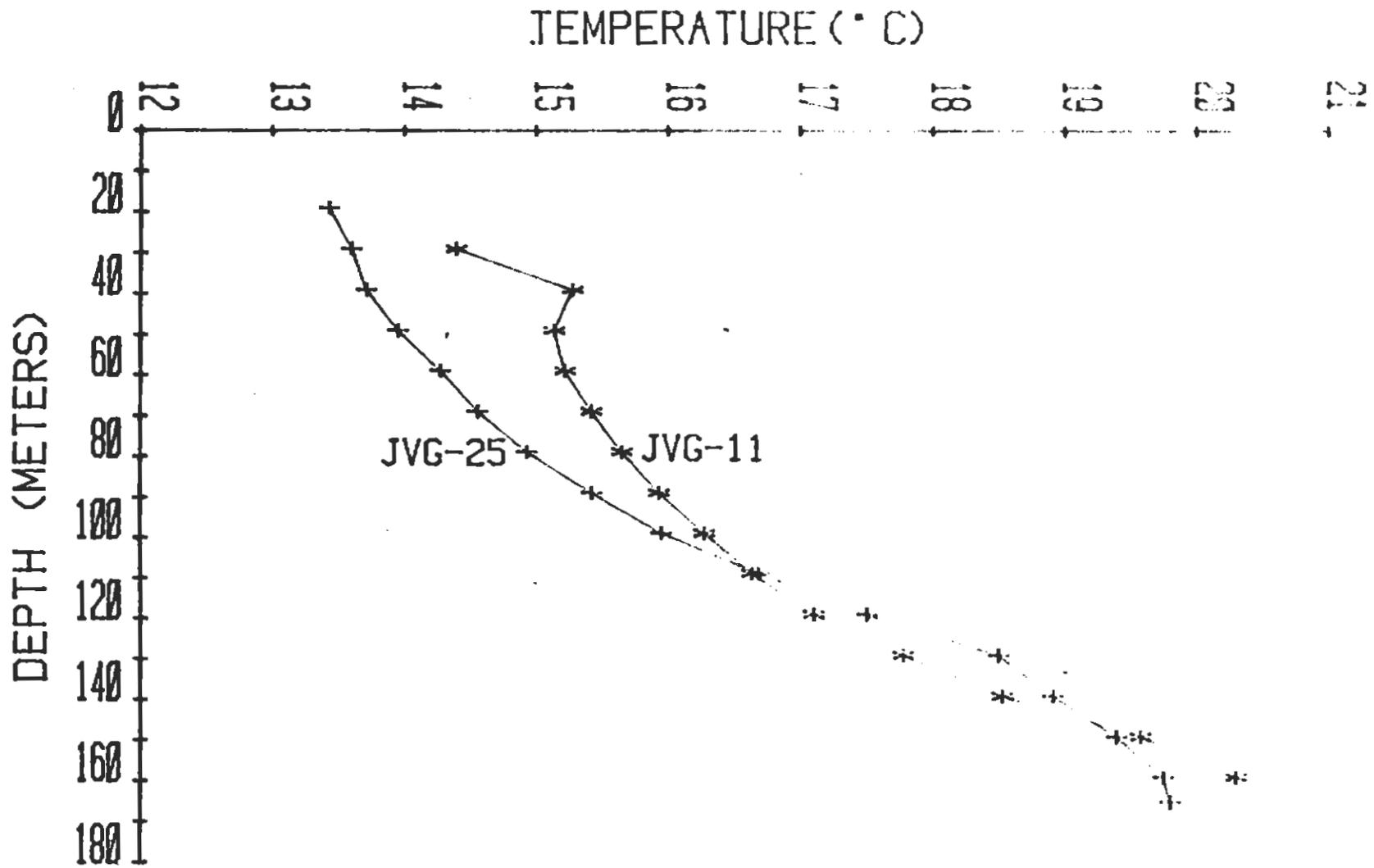


Figure 20. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

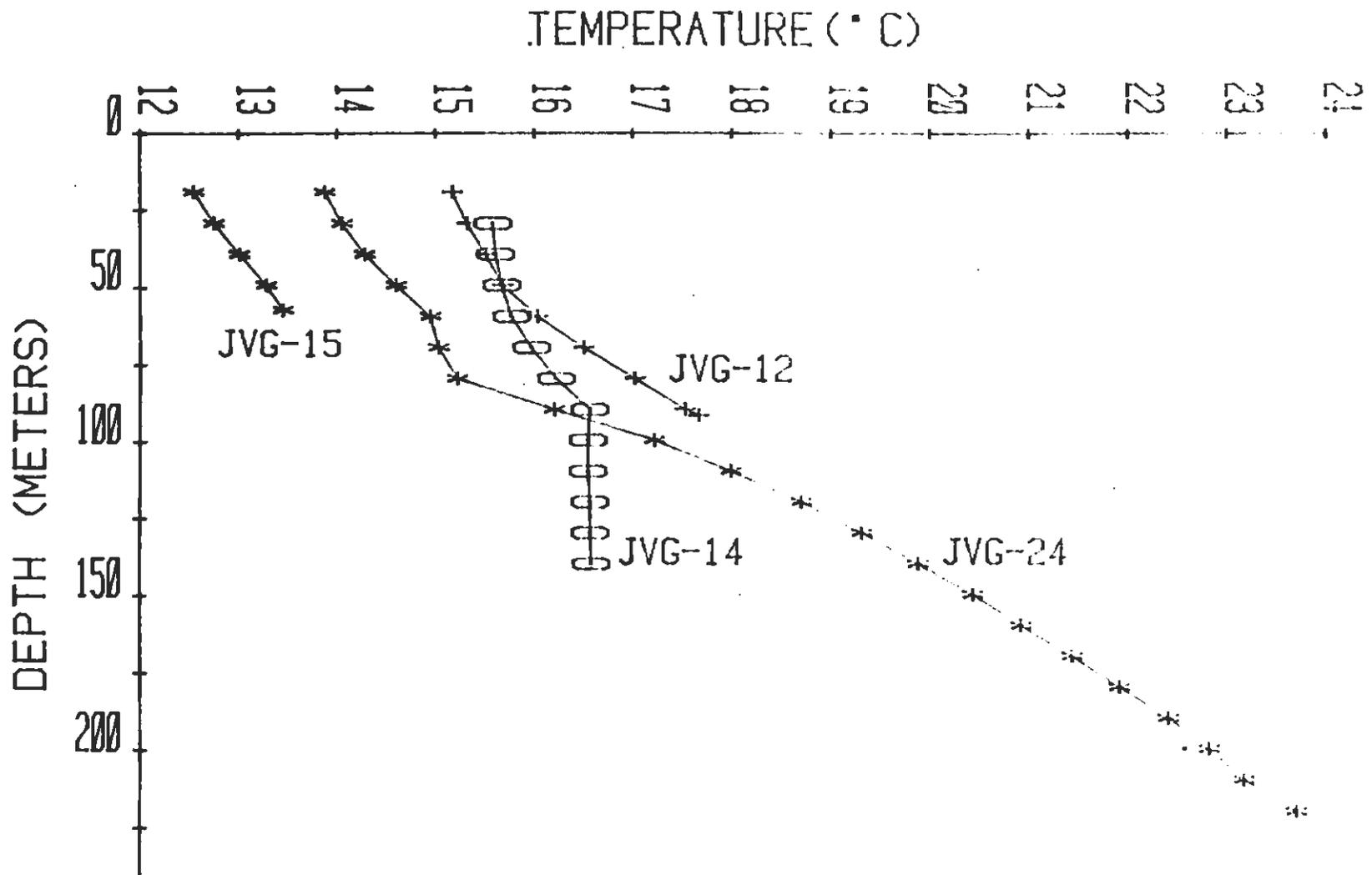


Figure 21. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

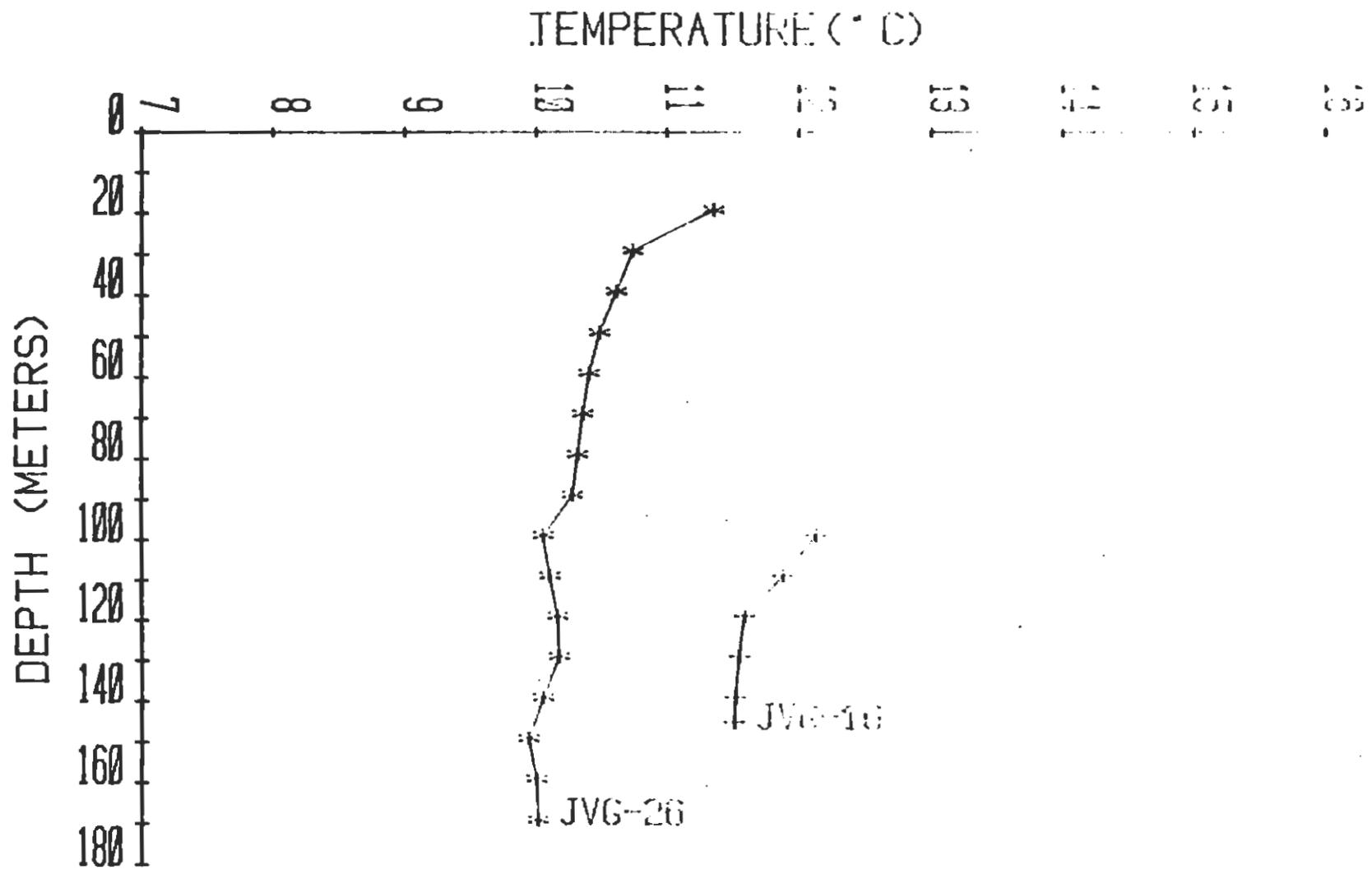


Figure 22. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

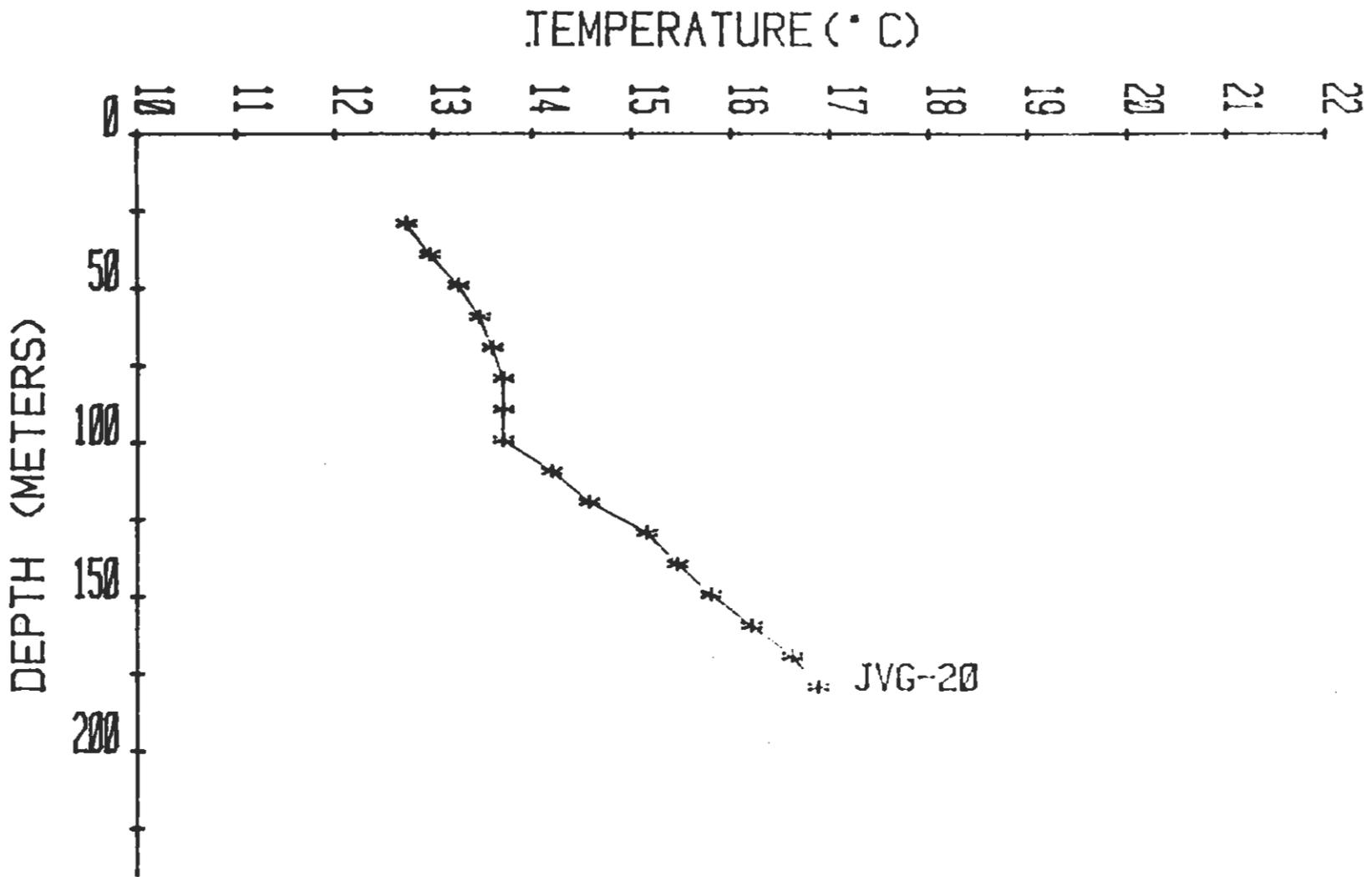


Figure 23. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

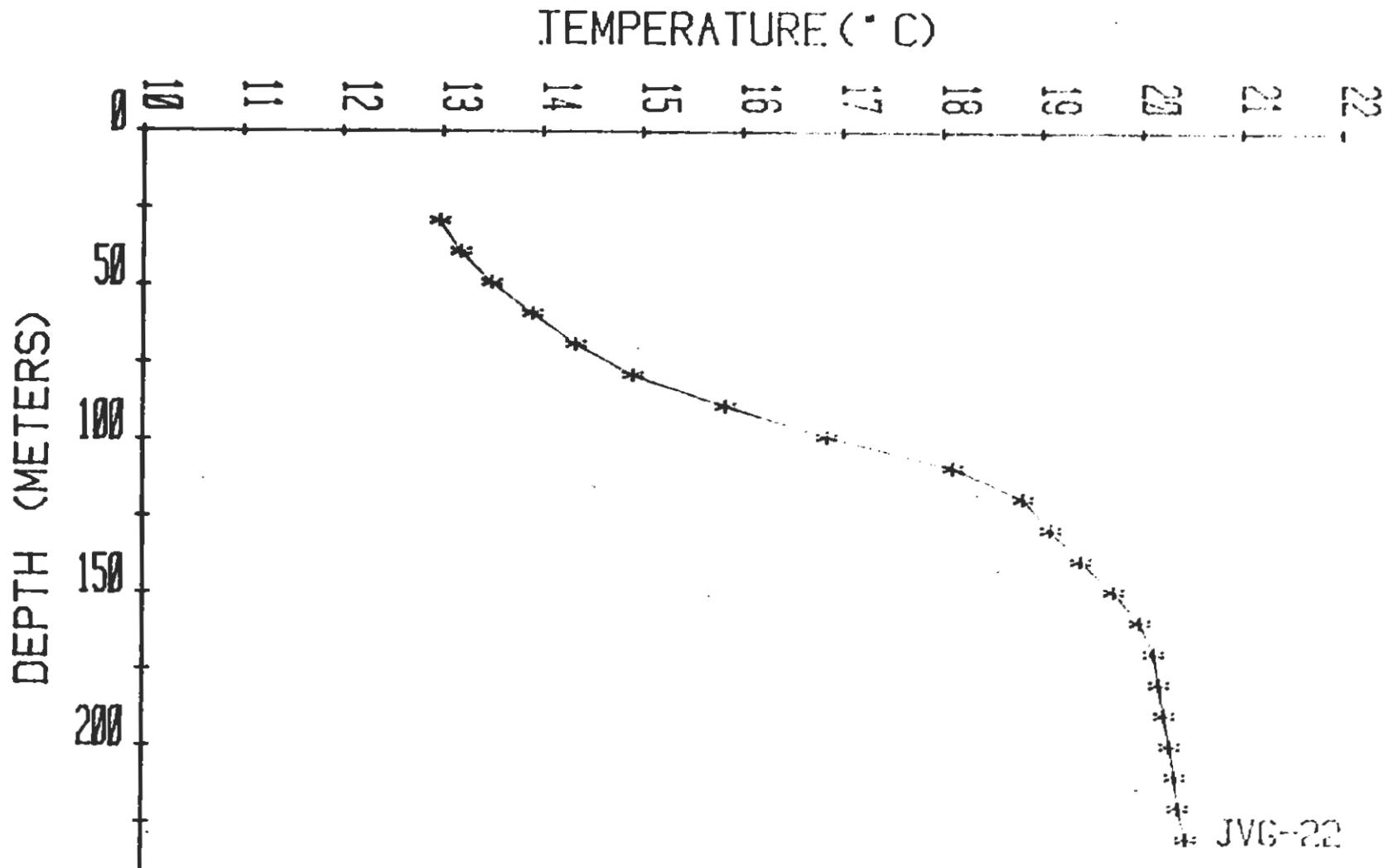


Figure 24. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

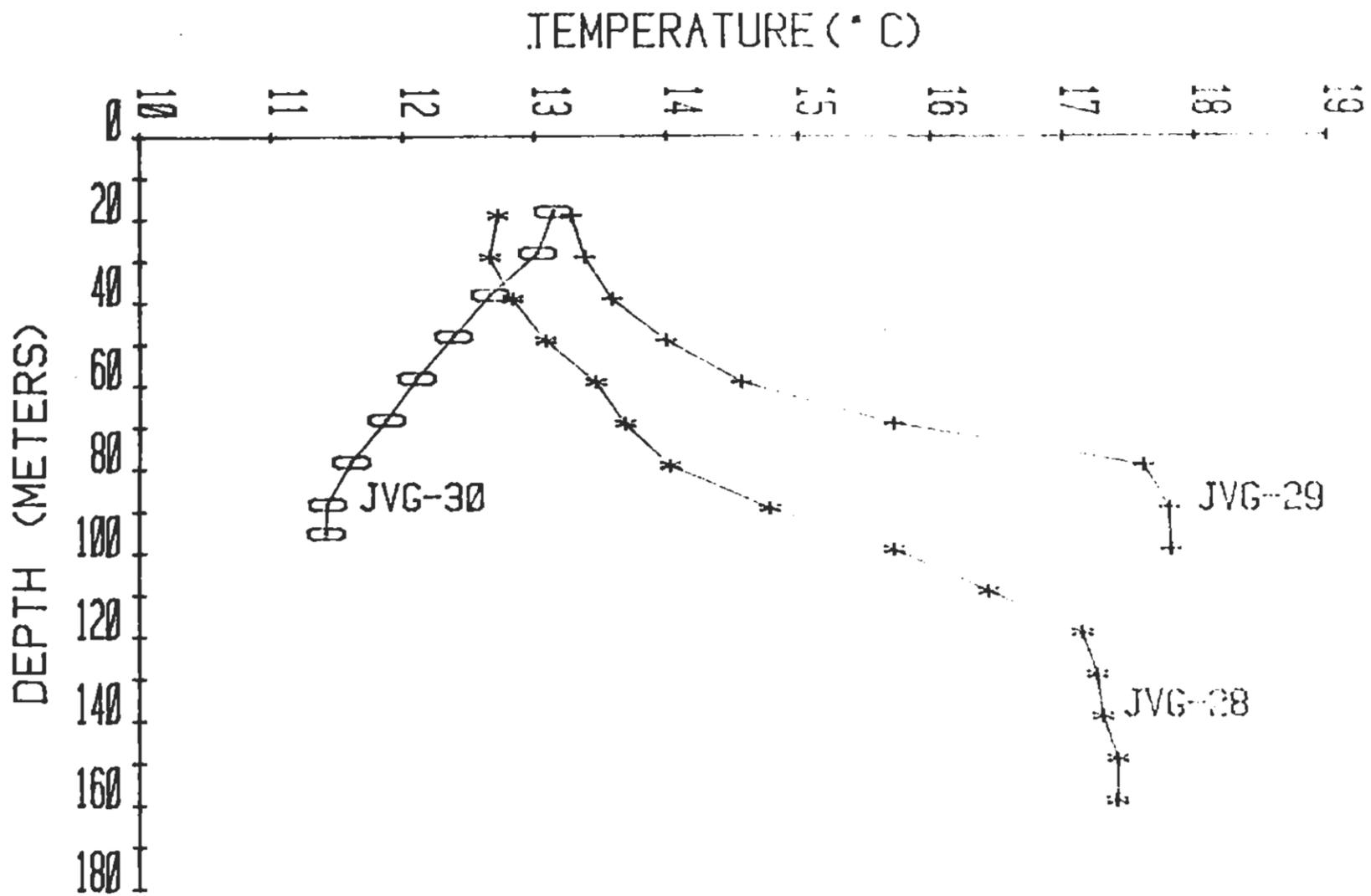


Figure 25. Temperature-depth profiles logged in "holes of opportunity" in the Jordan Valley, Salt Lake County, Utah. Locations are presented on Plate 5.

some extent, affected by near surface disturbance.

The second area that has some indications of a thermal anomaly is depicted by gradient hole locations JVG-9, JVG-25, JVG-11 and JVG-8 located west and southwest of Herriman, Utah (figs. 18 and 20; plate 5). Locations JVG-8 and JVG-9 resulted in gradients of 58° and $64^{\circ}\text{C}/\text{km}$, respectively (table 12). JVG-11 and JVG-25 have gradients of 46° and $52^{\circ}\text{C}/\text{km}$ which are not significant when compared to the suggested background gradient of $57.8^{\circ}\text{C}/\text{km}$ (table 12). Also, the profiles from which these two gradients are derived indicate a significant amount of convective interference, possibly due to the near surface cold water aquifer. However, these two profiles have bottom hole temperatures of 20.27° (JVG-11) and 19.77°C (JVG-25), which indicate some low-temperature geothermal potential.

Four other "holes of opportunity" have characteristics that merit discussion. JVG-22, located approximately 6 miles (9.7 km) west of Sandy City, Utah has a gradient of $65^{\circ}\text{C}/\text{km}$ (table 12; fig. 22; plate 5). Furthermore, this well has a bottom hole temperature of 20.44°C . A second hole, JVG-24, located approximately 1 mile (1.6 km) northwest of Kearns, Utah has a gradient of $56^{\circ}\text{C}/\text{km}$ and a bottom hole temperature of 23.70°C (fig. 21, table 12; plate 5). A second hole, JVG-12 (fig. 21), located approximately 0.6 miles (1 km) to the east, has a bottom hole temperature of 17.6°C at 91 meters of depth; the gradient for this hole projected downward results in a temperature of nearly 24°C at 219 m which is consistent with JVG-24. JVG-29 located between the mouths of Parleys and Mill Creek canyons on plate 5 has a calculated gradient of $80^{\circ}\text{C}/\text{km}$ down to a depth of 79 meters (table 12; fig. 25). Temperatures, however, were measured in air which makes this gradient highly speculative. The remaining two temperatures logged in this hole were measured in water, but indicate an isothermal gradient possibly

reflecting convection from recharge in the Wasatch Mountains. The bottom hole temperature of 17.8°C is higher, however, than expected from an area so near the Wasatch Mountains. The remainder of the holes logged in the Jordan Valley reflect low or negative gradients and/or isothermal conditions which indicate no thermal potential or thermal conditions that are totally masked by near surface aquifers and/or convection between aquifers at the well site.

SUMMARY AND CONCLUSIONS

Prior to this study, two low-temperature geothermal systems were known to exist in the Jordan Valley: (1) the Warm Springs fault geothermal system, and (2) Crystal Hot Springs. Furthermore, Utah Roses, Inc., drilled a 5009 ft (1527 m) geothermal well in Sandy, Utah and encountered 48°C water at 200 gpm (12.6 L/S). Both the Warm Springs fault system and Crystal Hot Springs manifest themselves at the surface as springs. Utah Roses, Inc.'s well attempted to intercept a fracture-controlled system at depth which had no surface expression. The purpose of this study is to detect other low-temperature geothermal systems not presently known and to, if possible, expand the information on the two known systems.

Results of the studies previously conducted in the Warm Springs fault area and at Crystal Hot Springs, as well as other sites along the Wasatch Front, indicate low-temperature thermal systems are convective, resulting from deep circulation of meteoric water. Site specific gravity surveys and modeling at both Crystal Hot Springs and the Warm Springs fault systems further enhance this theory. The Crystal Hot Springs results are presented in a report published by the Utah Energy Office (1981) and will not be elaborated on further in this report. Further modeling of the gravity survey conducted at

the Warm Springs fault geothermal system, indicates the Salt Lake salient may be a gravity slide block with the slide plane possibly providing a permeable conduit within the deep convective system. Figure 26 presents a proposed model for this system.

Water temperatures measured throughout the valley indicate four areas of thermal ground water that may be indicative of low-temperature thermal anomalies at depth. These areas are: (1) the north-central valley located in area A on plate 4; (2) the area immediately north of the Oquirrh Mountains also found in area A; (3) an east-west oriented portion of the central valley located in area C; and (4) a north-south oriented area extending from Draper to Midvale located in areas D and F.

The elevated temperatures recorded for the area north of the Oquirrh Mountains are provided by the Kennecott Copper Corporation. Permission was not received, however, to sample these wells for chemical analysis and, therefore, no further information can be presented at this time.

Chemical analysis of both the Warm Springs fault and Crystal Hot Springs geothermal systems indicate thermal waters in the Jordan Valley are either sodium-calcium chloride (Na-Ca Cl) or sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character. Chemical analyses of these systems indicate thermal waters are slightly to very saline, have elevated concentrations of Sr, and have significant concentrations of Li, B, and F. Each thermal area has certain wells with chemical characteristics that are similar to the Warm Springs and Crystal Hot Springs areas. Results of common ion analyses of thermal samples from area A indicates R-63, R-64, and T-17 are similar to thermal waters in the Warm Springs fault geothermal system. These waters are sodium-calcium chloride (Na-Ca Cl) to sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, slightly to

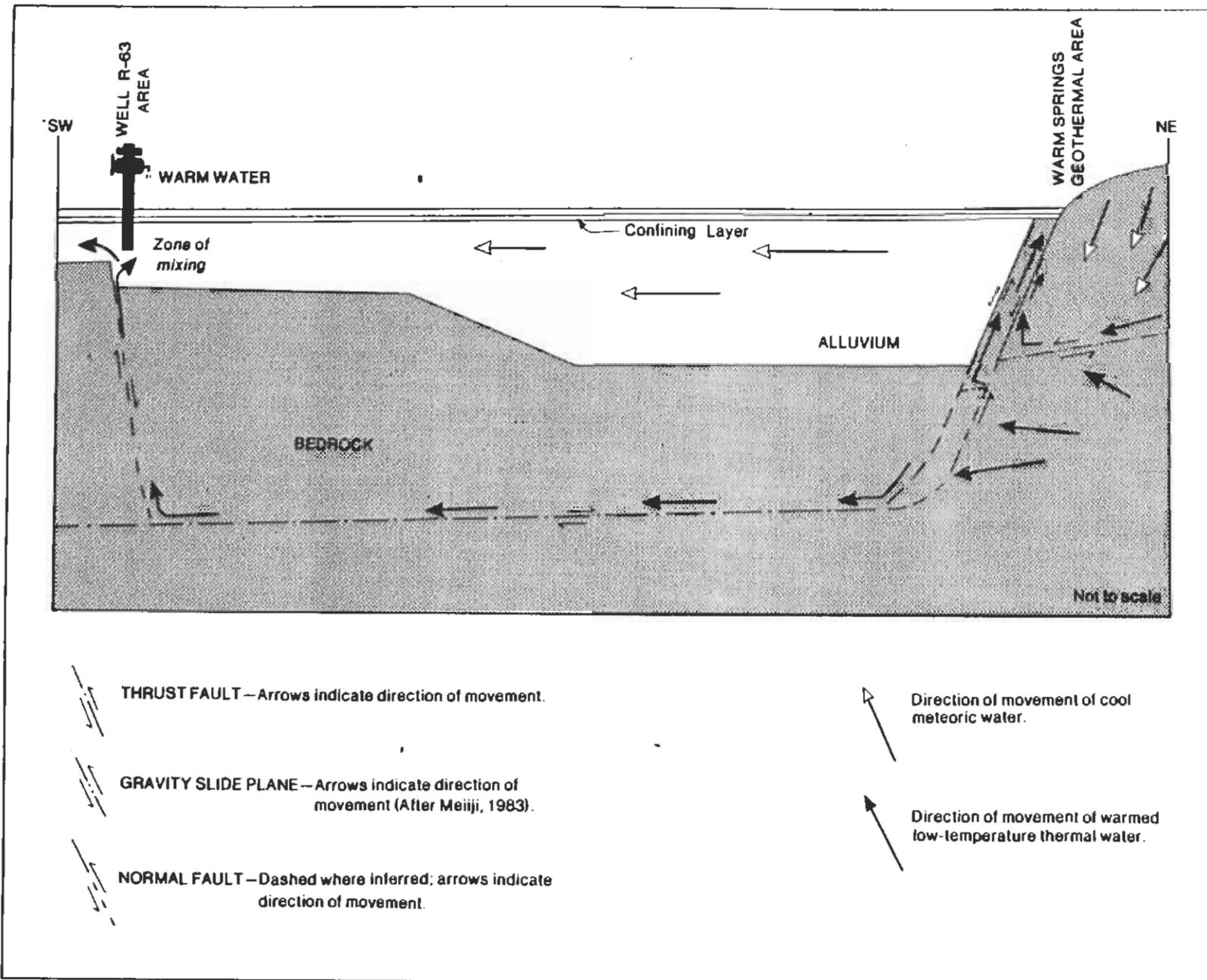


Figure 26. Model to account for the proposed thermal anomalies at the Warm Springs fault geothermal system and the area to the southwest, generally defined by samples R-63, R-64, and T-17 on Plate 4.

moderately saline, and have significant concentrations of Sr, B, Li, and F. Samples R-63 and R-64 have high concentrations of Mg, indicating water-rock reactions may be occurring during upward flow as the water cools (Fournier, 1981). Therefore, the Mg corrected Na-K-Ca temperature for these two samples may be low. The Na-K-Ca temperature of 94⁰C may be more accurate. T-17 provided a temperature of 63⁰C. All of these temperatures indicate low-temperature geothermal potential at depth.

Samples R-63, R-64, and T-17 are located 5 to 8 miles (3.1 to 4.9 km) west of the Warm Springs geothermal system. These wells are in an area where two faults are indicated to exist (Van Horn, 1975). The similarity, chemically, with the Warm Springs system indicates these waters may be from the same source but migrated further west, possibly along a thrust plane, eventually moving up normal faults as presented by Van Horn (1975). A model of this proposed system is presented in figure 26.

Sample R-74 is less than 20⁰C but is sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, moderately saline, and contains significant concentrations of Sr, Li, B, and F. This well may be receiving lateral flow from the Warm Springs system to the north or may be part of a southern extension of this system. The low temperature can be accounted for by dilution from cool water flowing out of City Creek Canyon. The high Mg concentration in this sample indicates the Mg-correction for the Na-K-Ca temperature may be low and the 85⁰C temperature more realistic.

Sample R-67 is also sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, slightly saline, with significant concentrations of Sr, Li, B, and F. Na-K-Ca (Mg-correction) geothermometer results indicate a reservoir temperature of 78⁰C can be expected, which is consistent with other thermal samples from the area.

The two remaining thermal samples, R-61 and R-65, as well as sample R-60 (16°C) are significantly different chemically from all other waters in area A. The reason for this has not been determined at this time and is beyond the scope of this report. Possibly, as suggested by Marine and Price (1964), the heat warming these waters may be the result of exothermic reactions within the organic clays in the area.

Five samples have temperatures greater than 20°C in the central valley in area C, but only sample D-58 is chemically similar to the other known geothermal systems in the valley. Sample D-58 is sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃), in character, dilute, with significant concentrations of Li. The well is located immediately east (< 0.25 miles or 0.40 km) and downgradient from the Jordan Valley fault zone (plate 2). Therefore, the warm water may be migrating from depth through this zone and mixing with cooler, shallower, ground water prior to being intercepted by the well. A temperature-depth hole located approximately 3 miles (4.9 km) to the west provides a 56°C/km gradient with a bottom hole temperature of 23.7°C. Chemical geothermometry provides no significant temperatures for D-58 or any other thermal sample from this area. A model depicting the geothermal system is presented in figure 27. The source of heat for the other thermal samples in area C is not understood at this time.

Temperatures greater than 20°C were recorded for 6 wells located between Draper and Midvale in areas D and F on plate 4. Four of these samples are included in area D, but only 3 have chemical characteristics similar to the known geothermal systems. Utah Roses, Inc.'s geothermal well is included with these three wells.

Utah Roses' (D-31) sample is sodium-calcium chloride (Na-Ca Cl) in character, slightly saline, with a significant concentration of B, and

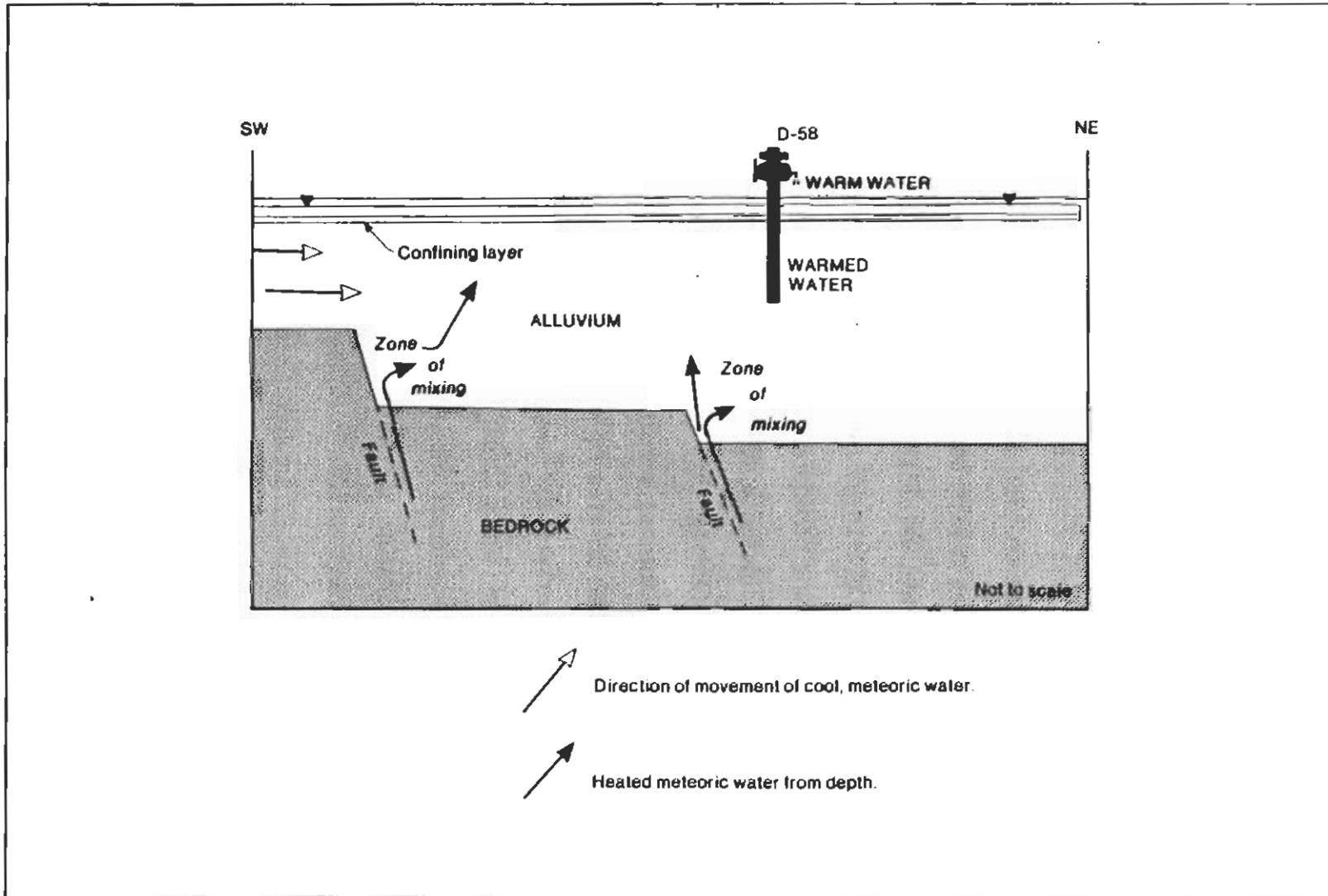


Figure 27. Model to account for thermal anomaly from well D-58 west of the Jordan Valley fault zone.

detectable concentrations of Sr, Li, and F. Sample R-32 is located a few hundred feet southeast of D-31 but was only drilled to a depth of 800 feet (244 m) whereas D-31 was drilled to 5009 feet (1527 m). Chemical analysis indicates R-38 is sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, slightly saline, with detectable concentrations of Sr, B, and F. Chemical geothermometry indicates a reservoir temperature of 62°C. The structural control on this system is not understood at this time. The third well in area D with some low-temperature thermal characteristics is R-32. This water is also sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, but is dilute with low concentrations of Sr and F and non-detectable concentrations of Li and B. Geothermometry, however, indicates a 70°C expected reservoir temperature. Again, the structural controls for this system are not understood at this time.

Sample R-15, one of two thermal samples not included with Crystal Hot Springs and vicinity measured in area F, exhibits significant low-temperature geothermal chemical characteristics. Sample R-15 is sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, slightly saline, with significant concentrations of Sr, Li, B, and F. The 81°C Na-K-Ca (Mg-corrected) temperature is reasonable and higher than most non-thermal geothermometer temperatures for samples from this area. Two other non-thermal samples (D-40 and U-56) located in the same general area as R-15, exhibit certain chemical characteristics which can be indicative of low-temperature geothermal potential. Both samples are sodium-calcium chloride-sulfate-bicarbonate (Na-Ca Cl-SO₄-HCO₃) in character, and have significant concentrations of Li, B, and F. Geothermometers indicate reservoir temperatures of 65° to 67°C can be expected. The low temperatures for these samples may be the result of dilution and cooling from

cooler aquifers. The other thermal sample (R-14), also located in this area, has a high concentration of Mg which precludes use of the Mg-corrected Na-K-Ca geothermometer. The 86°C pre-Mg-corrected temperature, however, is significant, and agrees with the Na-K-Ca temperature for R-15. According to Fournier (1981), dilution has little effect on the Na-K-Ca geothermometer if the thermal water is much more saline than the diluting water. R-14 has a TDS concentration of 2022 mg/l, whereas TDS for a well further up-gradient is only 184 mg/l. Therefore, the 86°C Na-K-Ca temperature may be realistic. Sample R-14 also has significant concentrations of Sr, Li, B, and F. This area, characterized by sample locations R-14, R-15, D-4U, and D-56, also has two temperature-depth holes with calculated gradients of 102° and 103°C/km. Structural controls for this area are not fully understood at this time, but speculation indicates the source of the warm water is the result of a deep convective system.

All of the areas discussed have characteristics which indicate low-temperature geothermal potential. However, much more site specific exploration must be conducted to determine the structural controls on each system, the size and depth of target reservoirs, and temperatures to be expected in these reservoirs. Furthermore, this study is limited in scope. Only geothermal anomalies affecting the near-surface unconsolidated aquifers are identified. The absence of evidence does not eliminate the possibility additional resources exist. Further exploration may establish a deep resource(s) heretofore not identified.

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Appendix A
Well- and Spring-Numbering System

APPENDIX A

WELL AND SPRING-NUMBERING SYSTEM

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake Base Line and Meridian, and these quadrants are designated by uppercase letters as follows: A, northeast; B, northwest; C, southwest; and D, southeast. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section, — generally 10 acres (4-hm^2); the quarters of each subdivision are designated by lowercase letters as follows: a, northeast; b, northwest; c, southwest; and d, southeast. The number after the letters is the serial number of the well or spring within the 10-acre (4-hm^2) tract; the letter "S" preceding the serial number denotes a spring. Thus (C-36-16) 36abd-1 designated the first well constructed or visited in the SE1/4 SE1/4 NE1/4 sec. 36, T. 36 S., R. 16 W. If a well or spring cannot be located within a 10-acre (4-hm^2) tract, one or two location letters are used and the serial number is omitted. Other sites where hydrologic data were collected are numbered in the same manner, but three letters are used after the section number and no serial number is used. The numbering systems is illustrated in figure A1.

Sections within a township

Tracts within a section

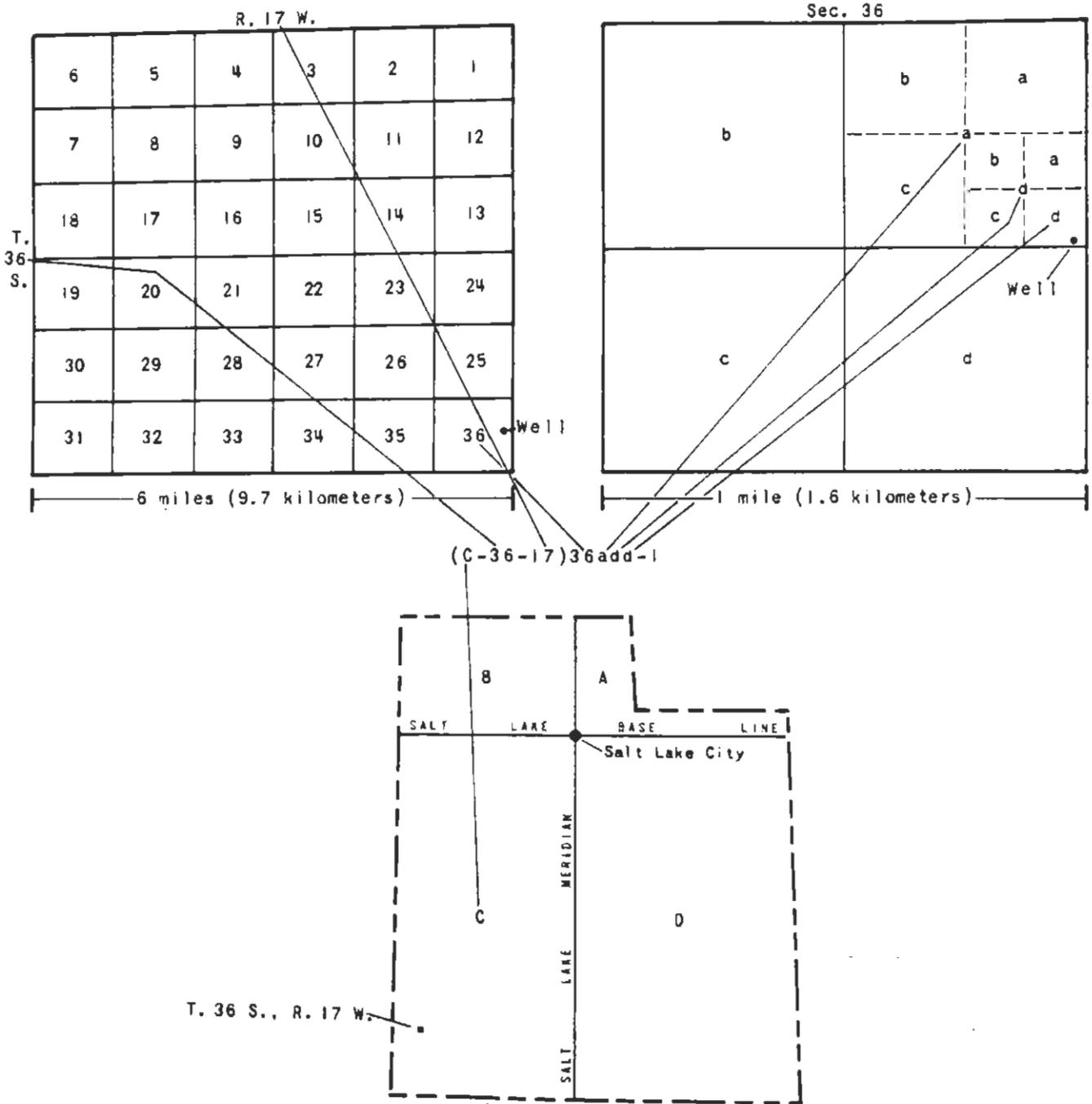


Figure A-1. Well-, and spring-, and other data site-numbering system used in Utah.

Appendix B
Conversion Factors

CONVERSION FACTORS

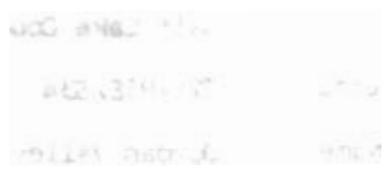
Water temperatures are reported in degrees centigrade ($^{\circ}\text{C}$) in the report. Water temperatures can be converted from ($^{\circ}\text{C}$) to ($^{\circ}\text{F}$) by the following equation: $^{\circ}\text{F} = 1.8 (^{\circ}\text{C}) + 32$.

Chemical concentrations are given in milligrams per liter (mg/l) which is a unit expressing the solute per unit volume (liter) of water.

Gradients are given in $^{\circ}\text{C}/\text{km}$ and can be converted to ($^{\circ}\text{F}$)/100 ft by the following conversion: $18.22^{\circ}\text{C}/\text{km} = 1^{\circ}\text{F}/100 \text{ ft}$. Depths to logging points are given in meters (m) and can be converted to feet by the following conversion: $3.28 \text{ ft} = 1 \text{ m}$.

Appendix C
Thermal Gradient Data

Area Salt Lake County, Utah
Cadastral T2S/R1E/S7dab
Site Name Jordan Valley JVG-1



Latitude	40° 39' 07" N.	Depth to Water	Flowing
Longitude	111° 52' 29" W.	Depth Range (Grad. Calc.)	30 - 83 m
Elevation	1311 ± 2 meters	Gradient	13 ± 2 °C/km

Drilling Completed By: 6-20-20

Thermal Logging Date: 5-23-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
0	11.79				
5	11.82				
10	11.72				
15	11.72				
20	11.73				
25	11.74				
30	11.85				
35	11.92				
40	12.00				
45	12.08				
50	12.06				
55	12.20				
60	12.24				
65	12.32				
70	12.39				
75	12.44				
80	12.50				
83	12.52				

Area Salt Lake County, Utah
Cadastral T2S/R1E/S34
Site Name Jordan Valley JVG-2

Latitude 40° 36' 06" N. Depth to Water 122 m
Longitude 111° 49' 20" W. Depth Range 240.9 - 268.3 m
(Grad. Calc.)
Elevation 1424 ± 2 meters Gradient 26 ± 3 °C/km

Drilling Completed By: 4-23-80

Thermal Logging Date: 11-3-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
15.2	15.36				
30.5	13.55				
45.7	12.33				
61.0	11.99				
76.2	11.81				
91.5	11.76				
109.8	11.62				
122.0	11.08				
128.0	11.05				
134.1	11.01				
140.2	10.90				
149.4	10.90				
158.5	10.90				
167.7	10.91				
176.8	10.91				
186.0	10.91				
195.1	10.91				
204.3	10.91				
213.4	10.91				
222.6	10.92				
231.7	10.92				
240.9	10.93				
250.0	11.11				
259.1	11.35				
268.3	11.63				
277.4	11.63				

Area Salt Lake County, Utah
Cadastral T3S/R1E/S7caa
Site Name Jordan Valley JVG-3

Latitude	40° 34' 19" N.	Depth to Water	15 m
Longitude	111° 52' 22" W.	Depth Range (Grad. Calc.)	42.7 - 65.1 m
Elevation	1370 ± 2 meters	Gradient	23 ± 6 °C/km

Drilling Completed By: 10-10-52

Thermal Logging Date: 10-23-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
6.1	15.49				
9.1	13.95				
12.2	13.84				
15.2	14.04				
18.3	14.19				
21.3	14.21				
24.4	14.18				
27.4	14.08				
30.5	14.06				
33.5	14.04				
36.6	13.95				
39.6	13.79				
42.7	13.79				
45.7	13.87				
48.8	13.84				
51.8	13.87				
54.9	13.94				
57.9	14.08				
61.0	14.17				
64.0	14.25				
65.1	14.27				

Area Salt Lake County, Utah
Cadastral T3S/R1E/S21caa
Site Name Jordan Valley JVG-4

Latitude	40° 32' 37" N.	Depth to Water	100 m
Longitude	111° 50' 39" W.	Depth Range (Grad. Calc.)	64.0 - 218.3 m
Elevation	1453 ± 2 meters	Gradient	4 ± 2 °C/km

Drilling Completed By: 10-28-61

Thermal Logging Date: 10-8-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
30.5	11.27				
45.7	11.67				
64.0	11.93				
73.2	11.83				
82.3	12.17				
91.5	12.27				
94.5	12.32				
97.6	12.34				
99.4	12.37				
102.4	12.44				
105.5	12.44				
108.5	12.45				
111.6	12.46				
117.7	12.47				
126.8	12.51				
136.0	12.63				
145.1	12.61				
154.3	12.62				
163.4	12.62				
172.6	12.62				
181.7	12.62				
190.9	12.62				
200.0	12.75				
209.1	12.63				
218.3	12.65				

Area Salt Lake County, Utah
Cadastral T3S/R1E/S29bdb
Site Name Jordan Valley JVG-5



Latitude	40° 31' 48" N.	Depth to Water	34 m
Longitude	111° 51' 51" W.	Depth Range (Grad. Calc.)	20.4 - 43.3 m
Elevation	1384 ± 2 meters	Gradient	103 ± 51°C/km

Drilling Completed By: 10-23-62

Thermal Logging Date: 7-17-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
5.2	14.20				
6.7	12.77				
11.3	15.01				
15.9	16.24				
20.4	16.93				
25.0	18.22				
29.6	18.90				
34.1	19.01				
38.7	19.04				
43.3	19.72				

Area Salt Lake County, Utah
Cadastral T3S/R1W/S11cad
Site Name Jordan Valley JVG-6

Latitude	40° 34' 12" N.	Depth to Water	5 m
Longitude	111° 55' 11" W.	Depth Range (Grad. Calc.)	20 - 45 m
Elevation	1332 ± 1 meters	Gradient	47 ± 2°C/km

Drilling Completed By: 7-8-78

Thermal Logging Date: 6-17-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
5	12.12				
10	12.42				
15	13.04				
20	13.41				
25	13.67				
30	13.92				
35	14.17				
40	14.38				
45	14.59				

Area Salt Lake County, Utah
 Cadastral T4S/R1W/S27abb
 Site Name Jordan Valley JVG-7



Latitude	40° 26' 56" N.	Depth to Water	16 m
Longitude	111° 56' 11" W.	Depth Range (Grad. Calc.)	19.8 - 95.5 m
Elevation	1445 ± 3 meters	Gradient	33 ± 5°C/km

Drilling Completed By: 8-16-72

Thermal Logging Date: 7-10-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
10.7	13.1				
15.2	13.2				
19.8	12.8				
24.4	12.9				
30.5	13.1				
35.1	13.3				
39.6	13.5				
45.7	13.8				
50.3	13.9				
54.9	14.1				
59.5	14.2				
65.5	14.4				
70.1	14.5				
74.7	14.7				
79.3	14.8				
85.4	14.9				
94.5	15.1				

Area Salt Lake County, Utah
Cadastral T4S/R2W/S9caa
Site Name Jordan Valley JVG-8

Latitude 40° 29' 02" N. Depth to Water 33 m
Longitude 112° 04' 17" W. Depth Range 18.3 - 57.0 m
(Grad. Calc.)
Elevation 1646 ± 6 meters Gradient 58 ± 16°C/km

Drilling Completed By: 4-14-76

Thermal Logging Date: 6-27-80

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
12.2	13.1				
18.3	13.3				
24.4	13.7				
30.5	14.0				
35.1	14.3				
39.6	14.4				
45.7	15.1				
50.3	15.2				
54.9	15.3				
57.0	15.6				

Area Salt Lake County, Utah
Cadastral T3S/R2W/S33cad
Site Name Jordan Valley JVG-9



Latitude 40° 30' 47" N. Depth to Water 41 m
Longitude 112° 04' 25" W. Depth Range (Grad. Calc.) 19 - 128 m
Elevation 1598 ± 3 meters Gradient 64 ± 7°C/km

Drilling Completed By: 7-8-71

Thermal Logging Date: 5-29-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	10.53				
19	10.58				
29	10.98				
39	11.64				
49	12.22				
59	12.79				
69	13.27				
79	13.60				
89	14.21				
99	15.35				
109	16.23				
119	16.92				
128	17.52				

Area Salt Lake County, Utah
Cadastral T2S/R2W/S8acd
Site Name Jordan Valley JVG-10

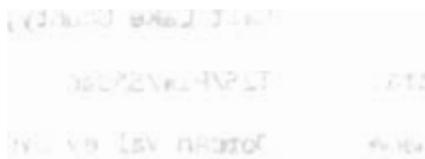
Latitude 40° 39' 40" N. Depth to Water 30 m
Longitude 112° 05' 12" W. Depth Range (Grad. Calc.) 34 - 79 m
Elevation 1503 ± 3 meters Gradient 18 ± 5°C/km

Drilling Completed By: 6-81

Thermal Logging Date: 7-10-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
24	12.58				
29	12.57				
34	12.60				
39	12.68				
44	12.78				
49	12.91				
54	12.84				
59	13.07				
64	13.14				
69	13.21				
74	13.29				
79	13.39				

Area Salt Lake County, Utah
Cadastral T4S/R2W/S9bad
Site Name Jordan Valley JVG-11



Latitude 40° 28' 27" N. Depth to Water 30 m
Longitude 112° 04' 20" W. Depth Range (Grad. Calc.) 49 - 159 m
Elevation 1659 ± 6 meters Gradient 46 ± 9°C/km

Drilling Completed By: 6-81 (cleaned)

Thermal Logging Date: 7-13-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	22.77				
19	17.36				
29	14.39				
39	15.27				
49	15.13				
59	15.21				
69	15.41				
79	15.64				
89	15.92				
99	16.26				
109	16.62				
119	17.09				
129	17.76				
139	18.51				
149	19.55				
159	20.27				

Area Salt Lake County, Utah
Cadastral T2S/R1W/S5dac
Site Name Jordan Valley JVG-12

Latitude	40° 40' 04" N.	Depth to Water	11 m
Longitude	112° 04' 20" W.	Depth Range (Grad. Calc.)	19 - 89 m
Elevation	1334 ± 1 meters	Gradient	34 ± 6°C/km

Drilling Completed By: 11-20-77

Thermal Logging Date: 7-22-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	16.97				
19	15.17				
29	15.32				
39	15.51				
49	15.68				
59	16.03				
69	16.50				
79	17.02				
89	17.53				
91	17.67				

Area Salt Lake County, Utah
Cadastral T2S/R2W/S9bca
Site Name Jordan Valley JVG-13

Latitude 40° 39' 48" N. Depth to Water 29 m
Longitude 112° 04' 43" W. Depth Range (Grad. Calc.) 19 - 49 m
Elevation 1486 ± 3 meters Gradient 18 ± 7°C/km

Drilling Completed By: 5-39

Thermal Logging Date: 8-4-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	12.78				
19	12.63				
29	12.84				
39	12.91				
49	13.22				

Area Salt Lake County, Utah
Cadastral T2S/R1W/S9ccc
Site Name Jordan Valley JVG-14

Latitude	40 ⁰ 39' 16" N.	Depth to Water	less than 29 m
Longitude	111 ⁰ 57' 58" W.	Depth Range (Grad. Calc.)	29 - 89 m
Elevation	1360 ± 1 meters	Gradient	16 ± 5°C/km

Drilling Completed By: 1966

Thermal Logging Date: 8-6-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
29	15.58				
39	15.61				
49	15.67				
59	15.77				
69	15.97				
79	16.22				
89	16.56				
99	16.54				
109	16.54				
119	16.56				
129	16.56				
139	16.57				

Area Salt Lake County, Utah
Cadastral T1S/R1W/S34dda
Site Name Jordan Valley JVG-15

Latitude 40° 41' 07" N. Depth to Water 1 m
Longitude 111° 55' 42" W. Depth Range (Grad. Calc.) 19 - 57 m
Elevation 1296 ± 1 meters Gradient 24 ± 2°C/km

Drilling Completed By: 1-31-71

Thermal Logging Date: 8-7-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	12.11				
19	12.55				
29	12.75				
39	13.01				
49	13.28				
57	13.45				

Area Salt Lake County, Utah
Cadastral T2S/R1E/S32dbd
Site Name Jordan Valley JVG-16

Latitude	40° 35' 58" N.	Depth to Water	No water found
Longitude	111° 51' 30" W.	Depth Range (Grad. Calc.)	99 - 145 m
Elevation	1398 ± 6 meters	Gradient	Negative

Drilling Completed By: 1-22-68

Thermal Logging Date: 8-11-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
99	12.11				
109	11.86				
119	11.57				
129	11.53				
139	11.50				
145	11.49				

Area Salt Lake County, Utah
Cadastral T3S/R1E/S20bcd
Site Name Jordan Valley JVG-17

Latitude	40° 32' 44" N.	Depth to Water	45 m
Longitude	111° 52' 04" W.	Depth Range (Grad. Calc.)	129 - 159 m
Elevation	1384 ± 2 meters	Gradient	47 ± 22°C/km

Drilling Completed By: 7-21-76

Thermal Logging Date: 8-12-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
49	16.75				
59	17.19				
69	17.20				
79	17.18				
89	17.17				
99	17.19				
109	17.19				
119	17.19				
129	17.20				
139	17.27				
149	17.75				
159	18.59				

Area Salt Lake County, Utah
Cadastral T2S/R1E/S33dca
Site Name Jordan Valley JVG-18

Latitude 40° 35' 55" N. Depth to Water 115 m
Longitude 111° 50' 22" W. Depth Range (Grad. Calc.) 99 - 217 m
Elevation 1433 ± 3 meters Gradient Negative

Drilling Completed By: 9-1-77

Thermal Logging Date: 8-13-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
99	13.26				
109	12.94				
119	11.66				
129	11.62				
139	11.23				
149	11.21				
159	11.20				
169	11.20				
179	11.20				
189	11.20				
199	11.20				
209	11.17				
217	11.13				

Area Salt Lake County, Utah
Cadastral T3S/R1E/S18cba
Site Name Jordan Valley JVG-19

Latitude	40° 33' 26" N.	Depth to Water	21 m
Longitude	111° 52' 56" W.	Depth Range (Grad. Calc.)	29 - 89 m
Elevation	1348 ± 1 meters	Gradient	102 ± 6°C/km

Drilling Completed By: 3-9-59

Thermal Logging Date: 8-14-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	13.58				
19	13.86				
29	15.60				
39	16.43				
49	17.46				
59	18.51				
69	19.58				
79	20.73				
89	21.50				
99	21.68				

Area Salt Lake County, Utah
Cadastral T2S/R2W/S22ddd
Site Name Jordan Valley JVG-20

Latitude 40° 37' 29" N. Depth to Water 80 m
Longitude 112° 02' 40" W. Depth Range 99 - 179 m
(Grad. Calc.)
Elevation 1540 ± 3 meters Gradient 40 ± 4°C/km

Drilling Completed By: 1-12-63

Thermal Logging Date: 8-17-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	13.99				
19	12.70				
29	12.72				
39	12.96				
49	13.25				
59	13.46				
69	13.59				
79	13.70				
89	13.70				
99	13.70				
109	14.19				
119	14.57				
129	15.15				
139	15.46				
149	15.80				
159	16.21				
169	16.62				
179	16.88				

Area Salt Lake County, Utah
Cadastral T3S/R1W/S21daa
Site Name Jordan Valley JVG-21



Latitude	40° 32' 08" N.	Depth to Water	15 m
Longitude	112° 56' 52" W.	Depth Range (Grad. Calc.)	39 - 68 m
Elevation	1364 ± 1 meters	Gradient	27 ± 1°C/km

Drilling Completed By: 1933
Thermal Logging Date: 8-18-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	19.13				
19	14.35				
29	12.63				
39	12.44				
49	12.69				
59	12.96				
68	13.22				

Area Salt Lake County, Utah
Cadastral T3S/R1W/S6cdd
Site Name Jordan Valley JVG-22

Latitude	40° 34' 55" N.	Depth to Water	38 m
Longitude	111° 59' 58" W.	Depth Range (Grad. Calc.)	39 - 159 m
Elevation	1438 ± 1 meters	Gradient	65 ± 10°C/km

Drilling Completed By: 3-15-78

Thermal Logging Date: 8-19-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	19.10				
19	14.55				
29	12.96				
39	13.17				
49	13.48				
59	13.89				
69	14.32				
79	14.89				
89	15.82				
99	16.83				
109	18.09				
119	18.79				
129	19.07				
139	19.37				
149	19.70				
159	19.96				
169	20.10				
179	20.15				
189	20.20				
199	20.25				
209	20.30				
219	20.33				
229	20.41				
231	20.44				

Area Salt Lake County, Utah
 Cadastral T2S/R1W/S5ccd
 Site Name Jordan Valley JVG-24

Latitude 40° 40' 06" N. Depth to Water 26 m
 Longitude 111° 58' 23" W. Depth Range 29 - 219 m
 (Grad. Calc.)
 Elevation 1348 ± 1 meters Gradient 56 ± 6°C/km

Drilling Completed By: 4-4-78

Thermal Logging Date: 8-25-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	20.18				
19	13.88				
29	14.05				
39	14.28				
49	14.60				
59	14.95				
69	15.03				
79	15.22				
89	16.20				
99	17.22				
109	17.99				
119	18.70				
129	19.31				
139	19.88				
149	20.43				
159	20.92				
169	21.44				
179	21.92				
189	22.41				
199	22.82				
209	23.17				
219	23.70				

Area Salt Lake County, Utah
Cadastral T4S/R2W/S3cbc
Site Name Jordan Valley JVG-25

Latitude	40 ⁰ 29' 54" N.	Depth to Water	105 m
Longitude	112 ⁰ 03' 41" W.	Depth Range (Grad. Calc.)	29 - 159 m
Elevation	1585 ± 6 meters	Gradient	52 ± 7 ⁰ C/km

Drilling Completed By: 7-2-79

Thermal Logging Date: 8-26-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	13.34				
19	13.43				
29	13.60				
39	13.71				
49	13.95				
59	14.27				
69	14.55				
79	14.92				
89	15.41				
99	15.94				
109	16.67				
119	17.49				
129	18.48				
139	18.89				
149	19.37				
159	19.72				
160	19.77				

Area Salt Lake County, Utah
Cadastral T2S/R1E/S34acb
Site Name Jordan Valley JVG-26

Latitude	40° 36' 16" N.	Depth to Water	91 m
Longitude	112° 49' 19" W.	Depth Range (Grad. Calc.)	19 - 169 m
Elevation	1415 ± 2 meters	Gradient	Negative

Drilling Completed By: 5-1-78

Thermal Logging Date: 8-31-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	13.42				
19	11.35				
29	10.73				
39	10.60				
49	10.47				
59	10.39				
69	10.34				
79	10.30				
89	10.26				
99	10.04				
109	10.09				
119	10.15				
129	10.16				
139	10.04				
149	9.93				
159	9.99				
169	10.00				

Area Salt Lake County, Utah
Cadastral T1N/R1E/S31cca
Site Name Jordan Valley JVG-27

Latitude	40° 46' 21" N.	Depth to Water	82 m
Longitude	111° 53' 12" W.	Depth Range (Grad. Calc.)	19 - 89 m
Elevation	1335 ± 3 meters	Gradient	Negative

Drilling Completed By: 1-81

Thermal Logging Date: 9-3-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	16.72				
19	15.62				
29	15.09				
39	14.64				
49	14.28				
59	14.17				
69	14.12				
79	14.06				
89	14.05				

Area Salt Lake County, Utah

Cadastral T1S/R1E/S35dccc

Site Name Jordan Valley JVG-28

Latitude	40° 41' 01" N.	Depth to Water	115 m
Longitude	111° 48' 14" W.	Depth Range (Grad. Calc.)	29 - 119 m
Elevation	1463 ± 6 meters	Gradient	50 ± 9°C/km

Drilling Completed By: 1-65

Thermal Logging Date: 9-3-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	14.53				
19	12.72				
29	12.66				
39	12.83				
49	13.08				
59	13.46				
69	13.68				
79	14.02				
89	14.77				
99	15.71				
109	16.42				
119	17.13				
129	17.24				
139	17.28				
149	17.39				
159	17.38				

Area Salt Lake County, Utah
Cadastral T1S/R1E/S26ddc
Site Name Jordan Valley JVG-29

Latitude	40° 41' 53" N.	Depth to Water	88 m
Longitude	111° 48' 00" W.	Depth Range (Grad. Calc.)	29 - 79 m
Elevation	1476 ± 2 meters	Gradient	80 ± 31°C/km

Drilling Completed By: 6-52

Thermal Logging Date: 9-4-81

Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
9	13.42				
19	13.28				
29	13.38				
39	13.58				
49	13.99				
59	14.56				
69	15.71				
79	17.60				
89	17.79				
99	17.80				

Area Salt Lake County, Utah
 Cadastral T2S/R1E/S2bbb
 Site Name Jordan Valley JVG-30

Latitude	40° 40' 55" N.	Depth to Water	No water found
Longitude	111° 48' 20" W.	Depth Range (Grad. Calc.)	18 - 95 m
Elevation	1421 ± 6 meters	Gradient	Negative

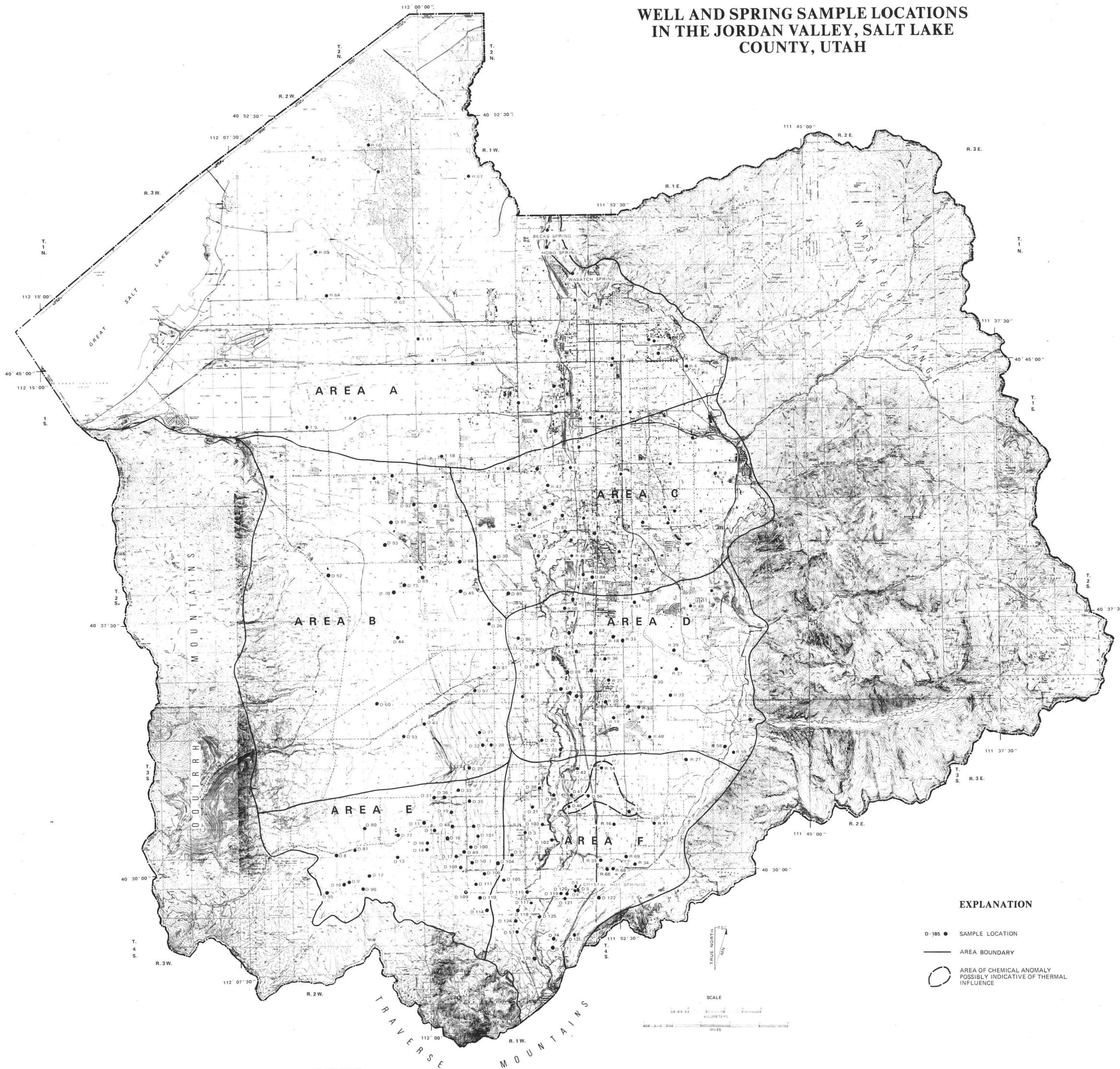
Drilling Completed By: 12-17-50

Thermal Logging Date: 9-4-81

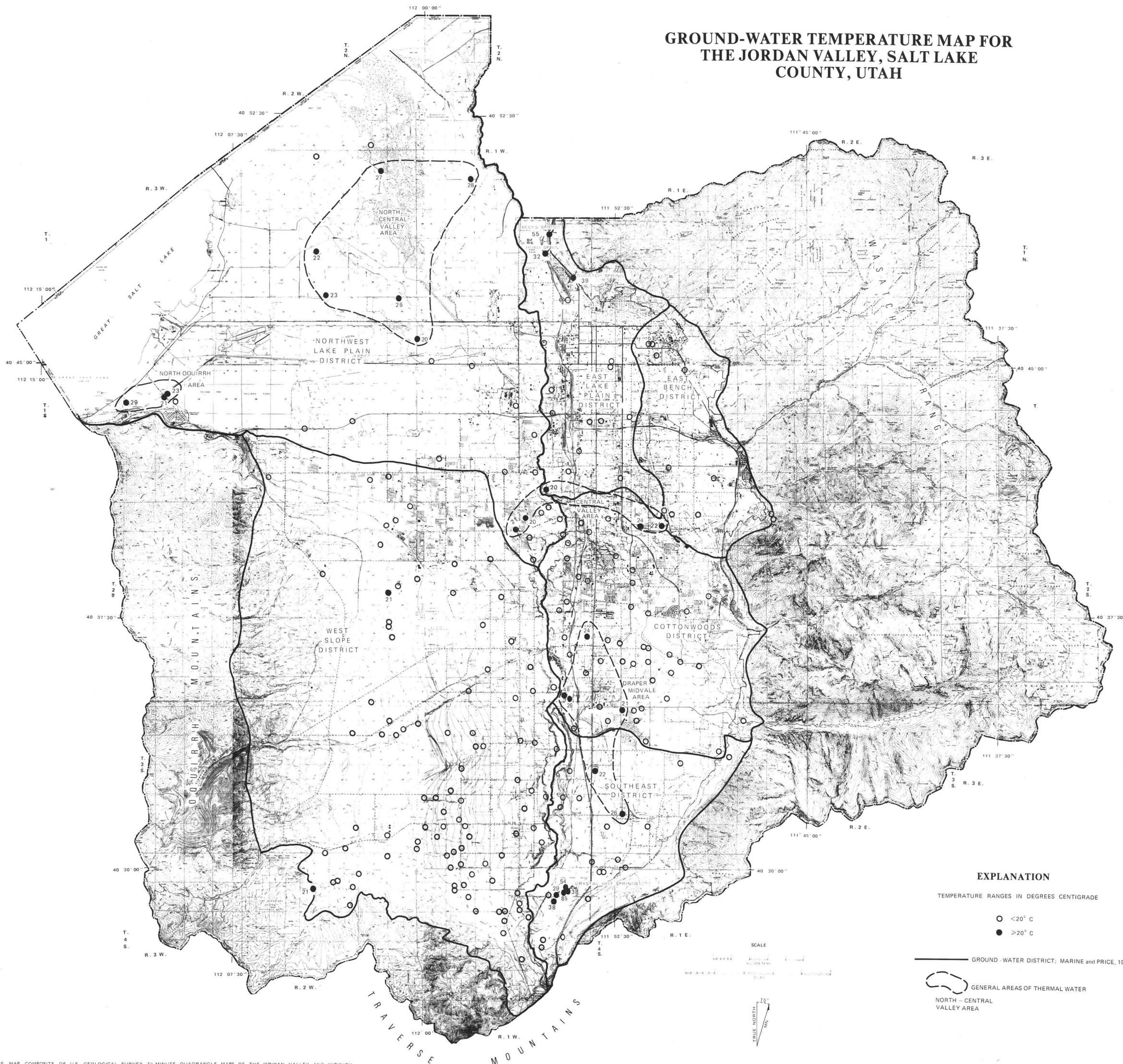
Depth (m)	T (C)	Depth (m)	T (C)	Depth (m)	T (C)
8	13.33				
18	13.14				
28	13.02				
38	12.66				
48	12.38				
58	12.10				
68	11.87				
78	11.60				
88	11.42				
95	11.41				



WELL AND SPRING SAMPLE LOCATIONS IN THE JORDAN VALLEY, SALT LAKE COUNTY, UTAH



GROUND-WATER TEMPERATURE MAP FOR THE JORDAN VALLEY, SALT LAKE COUNTY, UTAH



EXPLANATION

TEMPERATURE RANGES IN DEGREES CENTIGRADE

- <20° C
- >20° C

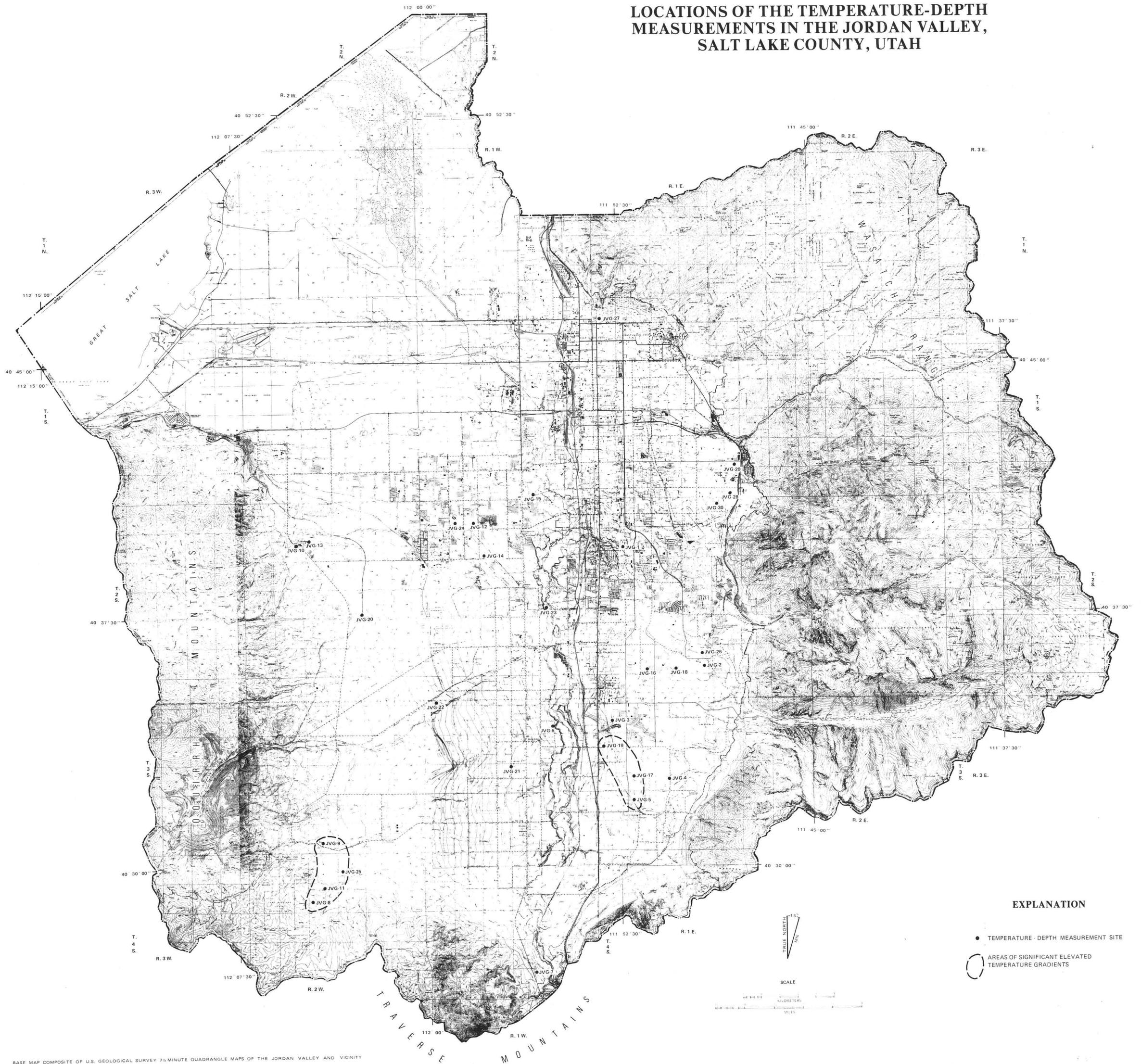
— GROUND-WATER DISTRICT; MARINE and PRICE, 1964

○ GENERAL AREAS OF THERMAL WATER
○ NORTH-CENTRAL VALLEY AREA

SCALE



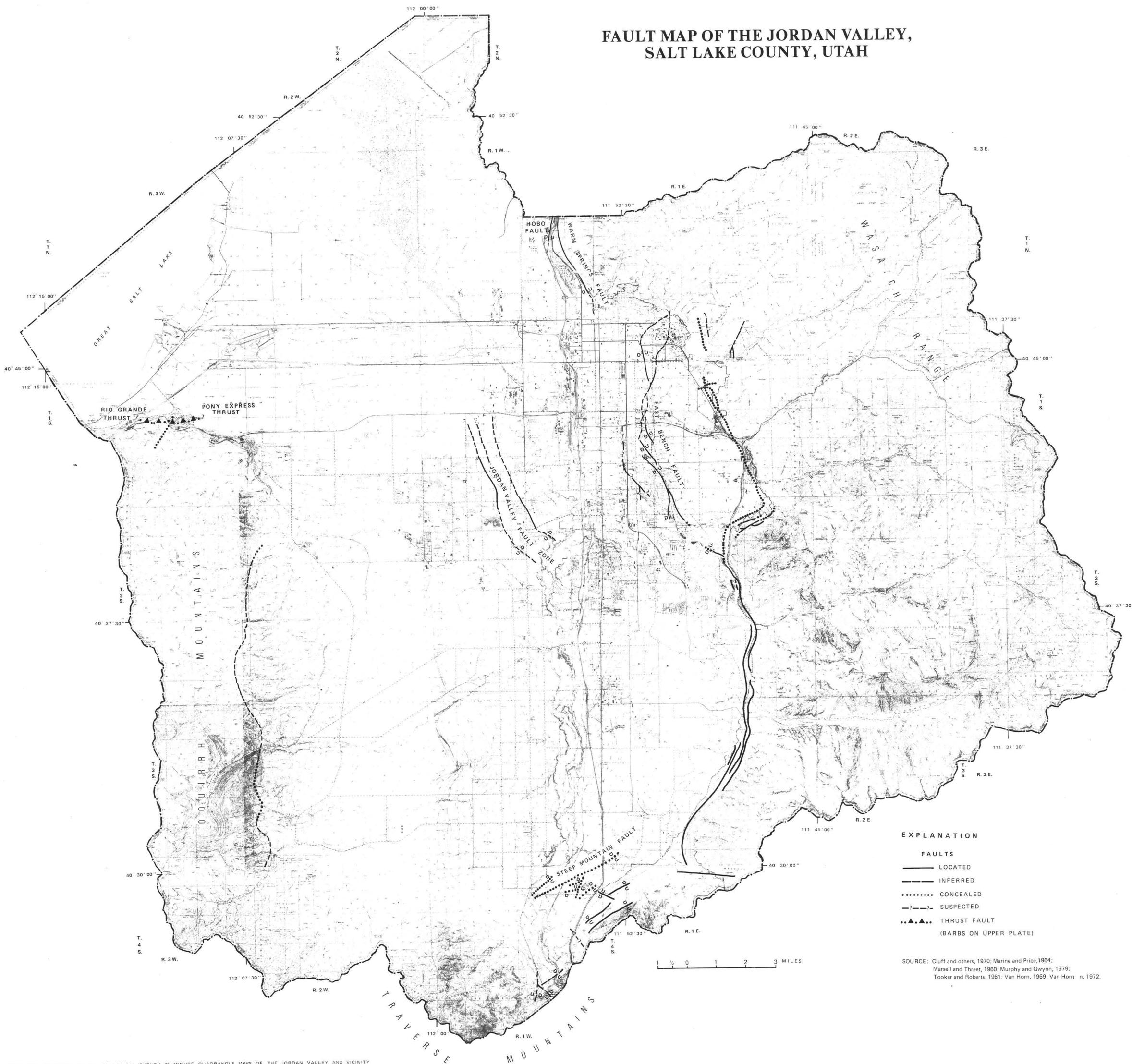
LOCATIONS OF THE TEMPERATURE-DEPTH MEASUREMENTS IN THE JORDAN VALLEY, SALT LAKE COUNTY, UTAH



EXPLANATION

- TEMPERATURE-DEPTH MEASUREMENT SITE
- AREAS OF SIGNIFICANT ELEVATED TEMPERATURE GRADIENTS

FAULT MAP OF THE JORDAN VALLEY, SALT LAKE COUNTY, UTAH



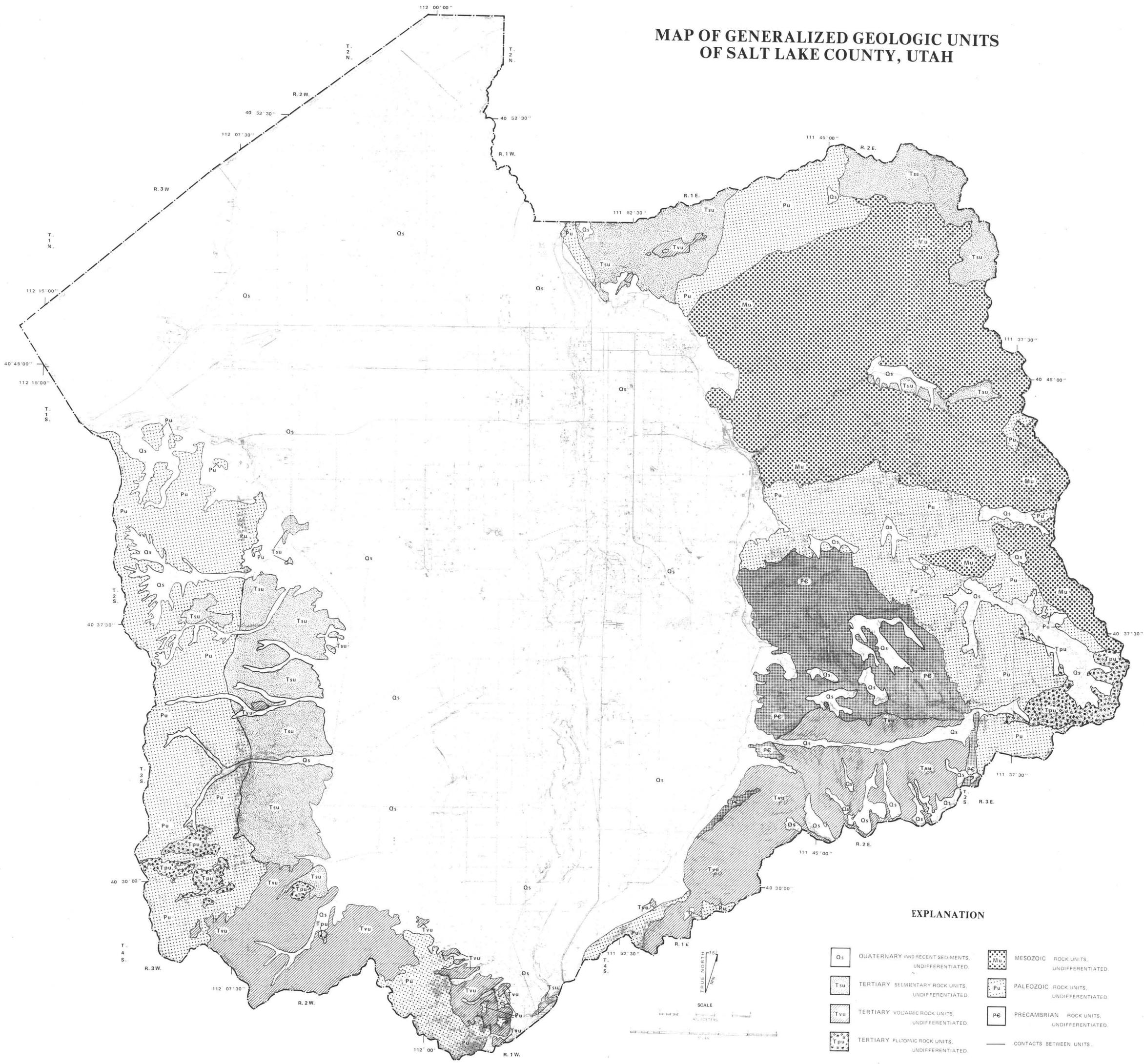
EXPLANATION

FAULTS

- LOCATED
- - - INFERRED
- CONCEALED
- ? - ? - SUSPECTED
- ▲▲▲ THRUST FAULT
(BARBS ON UPPER PLATE)

SOURCE: Cluff and others, 1970; Marine and Price, 1964;
 Marsell and Threut, 1960; Murphy and Gwynn, 1979;
 Tooker and Roberts, 1961; Van Horn, 1969; Van Horn, n, 1972.

MAP OF GENERALIZED GEOLOGIC UNITS OF SALT LAKE COUNTY, UTAH



EXPLANATION

- | | | | |
|-----|--|----|---|
| Qs | QUATERNARY AND RECENT SEDIMENTS, UNDIFFERENTIATED. | Mu | MESOZOIC ROCK UNITS, UNDIFFERENTIATED. |
| Tsu | TERTIARY SEDIMENTARY ROCK UNITS, UNDIFFERENTIATED. | Pu | PALEOZOIC ROCK UNITS, UNDIFFERENTIATED. |
| Tvu | TERTIARY VOLCANIC ROCK UNITS, UNDIFFERENTIATED. | Pc | PRECAMBRIAN ROCK UNITS, UNDIFFERENTIATED. |
| Tpu | TERTIARY PLUTONIC ROCK UNITS, UNDIFFERENTIATED. | — | CONTACTS BETWEEN UNITS. |

SOURCE: Davis, 1983; Marsell, R. E. and Threet, R. L., 1960; Stokes, 1963.