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PROGRESS REPORT ON THE GEOTHERMAL ASSESSMENT OF THE JORDAN VALLEY, SALT LAKE COUNTY, UTAH

by

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May, 1981

DISCLAIMER

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ABSTRACT

Two known geothermal areas have been investigated previously by Murphy and Gwynn (1979) in the Jordan Valley, Salt Lake County, Utah. These two reports indicate meteoric water is being circulated to depth and heated by the ambient temperature derived from normal heat flow. This warm water subsequently migrates upward along permiable fault zones.

The gravity survey conducted in the valley indicates a number of fault blocks are present beneath the unconsolidated valley sediments (Plate II). The faults bounding these blocks could provide conduits for the upward migration of warm water.

Four areas of warm water wells, in addition to the two known geothermal areas, have been delineated in the valley (Plate III). However, the chemistry of the Jordan Valley is quite complex and at this time is not fully understood in regard to geothermal potential (Plates IV and V).

Thick sequences of unconsolidated valley fill could conceal geothermal areas due to lateral dispersion or dilution within the principal aquifer, as well as retardation of warm water flow allowing time for cooling prior to discharge in wells or springs. Other areas are possibly diluted and cooled by high quality, ground water recharge from snow melt in the Wasatch Range.

INTRODUCTION

The Utah Geological and Mineral Survey (UGMS) has been conducting research to advance the utilization of 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 Valley 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 of the state, 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 of the following Wasatch Front Valleys: (1) Utah Valley, (2) Jordan Valley; (3) Ogden Valley; (4) Bear River Valley; (5) Malad Valley, and (6) Cache Valley. These areas were decided upon because of their inherent low temperature geothermal potential and because they encompass the three major population centers of the state. The initial major effort in this assessment study was concentrated in the Jordan Valley because of the inclusion of Salt Lake City, the major population center.

PHYSIOGRAPHIC SETTING

The Jordan Valley encompasses an area of approximately 1024 square kilometers (400 square miles) in north-central Utah in central Salt Lake County (figure 1). This valley has substantial relief, ranging in elevation from 1280 meters (4200 feet) at the Great Salt Lake to approximately 1585 meters (5200 feet) where adjoining the mountains. The east side of the valley is a boundary 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 Ogden Valley with an arbitrary boundary being an extension of the Salt Lake salient which is an intermediate fault block that extends west from the Wasatch Mountains into the valley for approximately 6.4 km (4 miles), (figure 1). The Wasatch Mountains, including the Salt Lake salient, are part of the Rocky Mountain physiographic province while the Traverse and Oquirrh Mountains are part of the Basin and Range province.

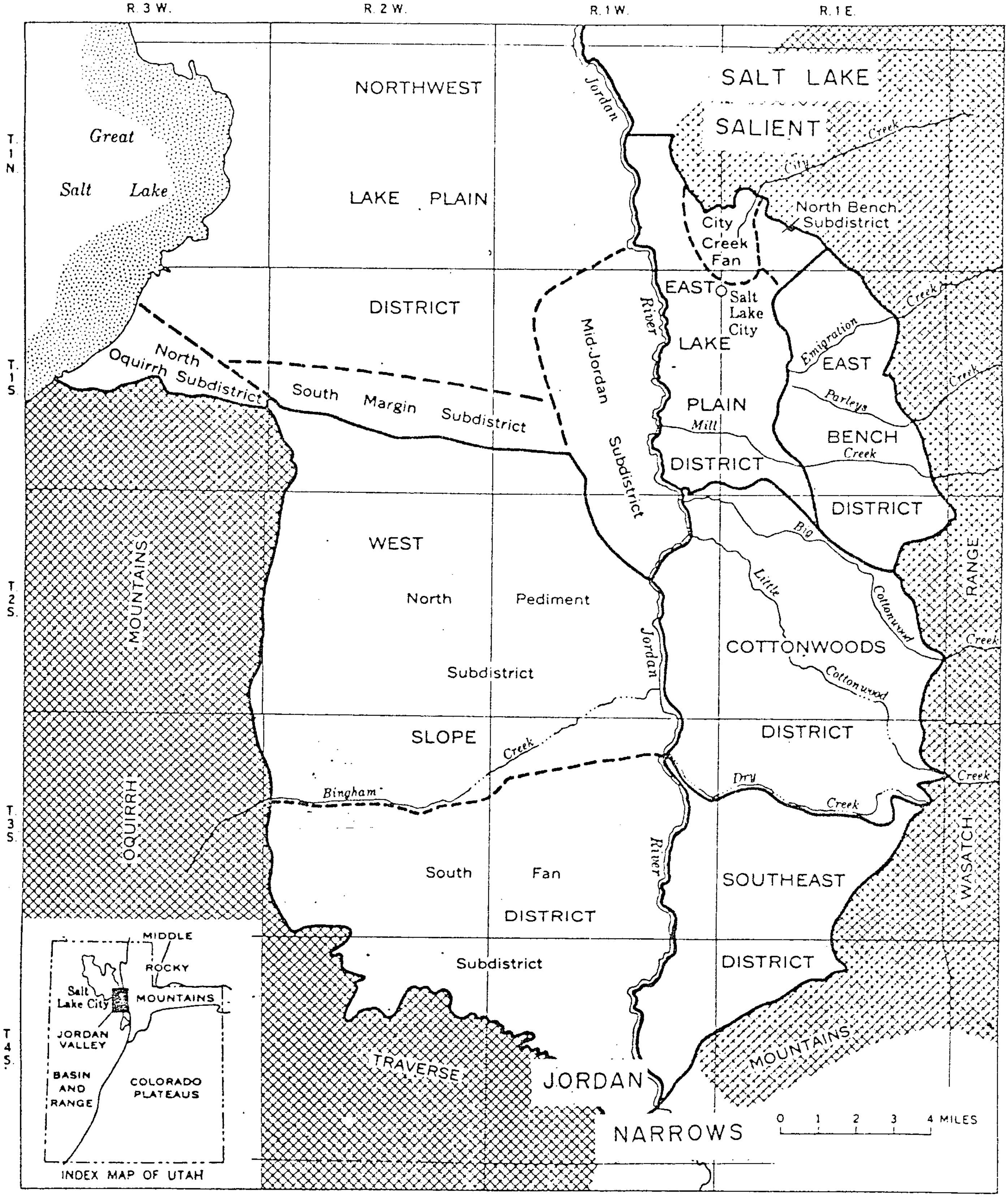

Figure 1. Index map of the Jordan Valley, Utah, showing ground-water districts and subdistricts (modified from Marine and Price, 1964)

A principal water source to the Jordan Valley is the Jordan River which flows north from Utah Valley through a gap in the Traverse Mountains referred to as the Jordan Narrows and continues through the entire length of the valley, eventually entering into the Great Salt Lake. In addition to the Jordan River, the other principal water sources are the creeks draining the Wasatch Mountains (figure 1).

REGIONAL GEOLOGIC SETTING

Rocks of Pre-Cambrian through Pliocene Age are exposed in the mountains bordering the Jordan Valley. In the Wasatch Mountains, sedimentary and metamorphic rocks consist of Pre-Cambrian, Paleozoic, Mesozoic, and Cenozoic sandstone, limestone, shale, conglomerate, siltstone, tuffaceous clay, tillite, quartzite, shist and gneiss. Intrusive rocks consist of early Tertiary monzonite, diorite and granodiorite, and in places 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, 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 where units in the central area are referred to as the Bingham sequence while units to the north are the Rogers Canyon sequence. Tertiary rocks, also, are exposed in the Oquirrhs. 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 differ greatly from surface sediments in the valley and will therefore be described later in detail, since they comprise the aquifers tapped by the wells investigated for the geothermal assessment study.

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), the north-south trending Basin and Range faulting.

Thrusting

Three episodes of thrusting have been discovered in the Wasatch Mountains east of the Jordan Valley. The first two are known as the Alta and Mount Raymond thrusts 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 64 kilometers (40 miles) or more from the west and 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. It then passes 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 Pennsylvania 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 (figure 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 100 kilometer (62.5 mile) wide zone of high seismic activity extending from northern Arizona to northwestern Montana (figure 3). Seismic studies indicate the zone is an active rift system with the tensional axis oriented in an east-west direction (Murphy, 1979).

GEOLOGY OF THE JORDAN VALLEY

Marine and Price (1964) divided the Jordan Valley into six ground water districts, three of which are divided into a total of nine subdistricts based on geologic characteristics of driller's logs and well cuttings (figure 1). The following is a brief description of their account of the geologic materials characteristic of 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 (figure 1). South of Emigration Creek a pediment extends approximately 1.6 Kilometers (1 mile) 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 mud rock flows as well as channel, colluvial and flood-plain deposits. Thicknesses of these materials range from less than 1 meter (3.28 feet) in the area of the pediment to as much as 213 meters (700 feet) 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 (figure 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 Creek, Emigration Creek, Parleys Creek and Mill Creek. 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 Section 12, T. 1 S., R. 1 W at 356 meters (1,168 feet).

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 152 meters (500 feet).

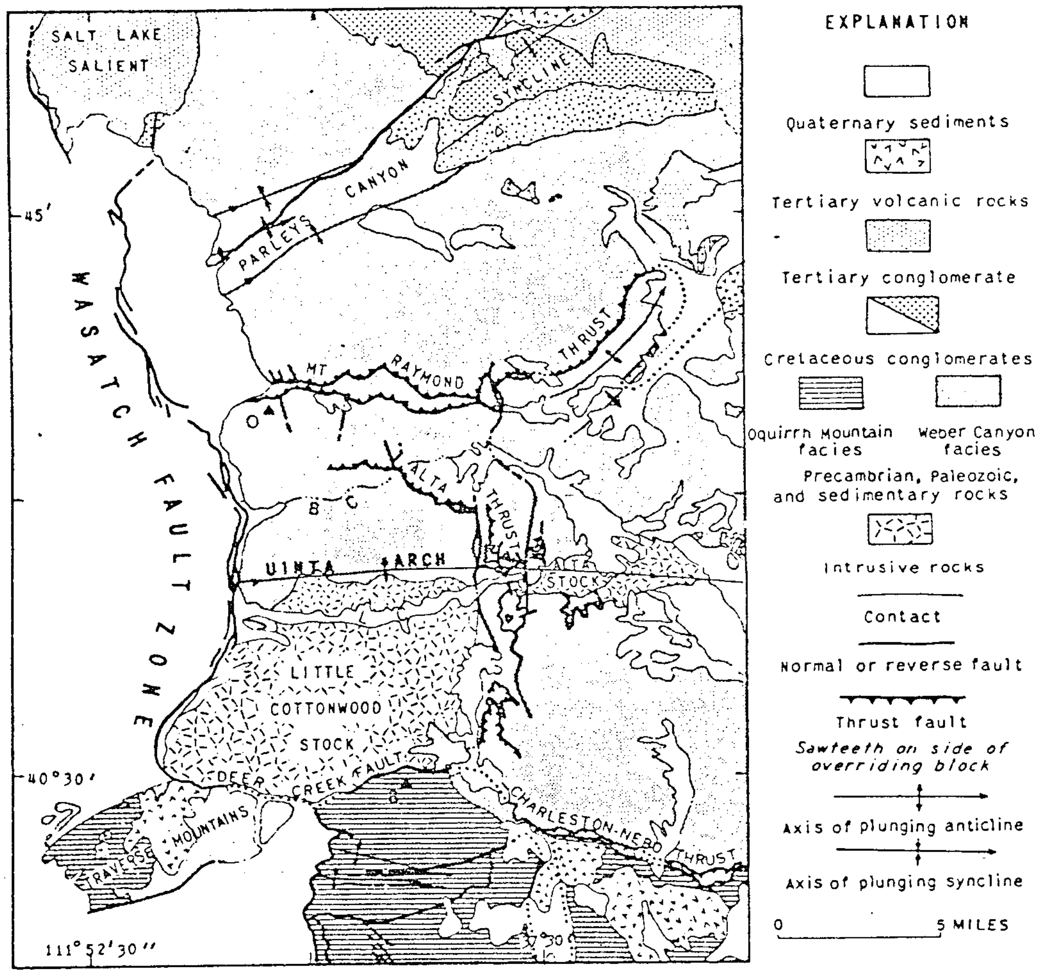

Figure 2. Generalized structure of central Wasatch Range east of Salt Lake City (from Crittenden, 1976, p. 365)

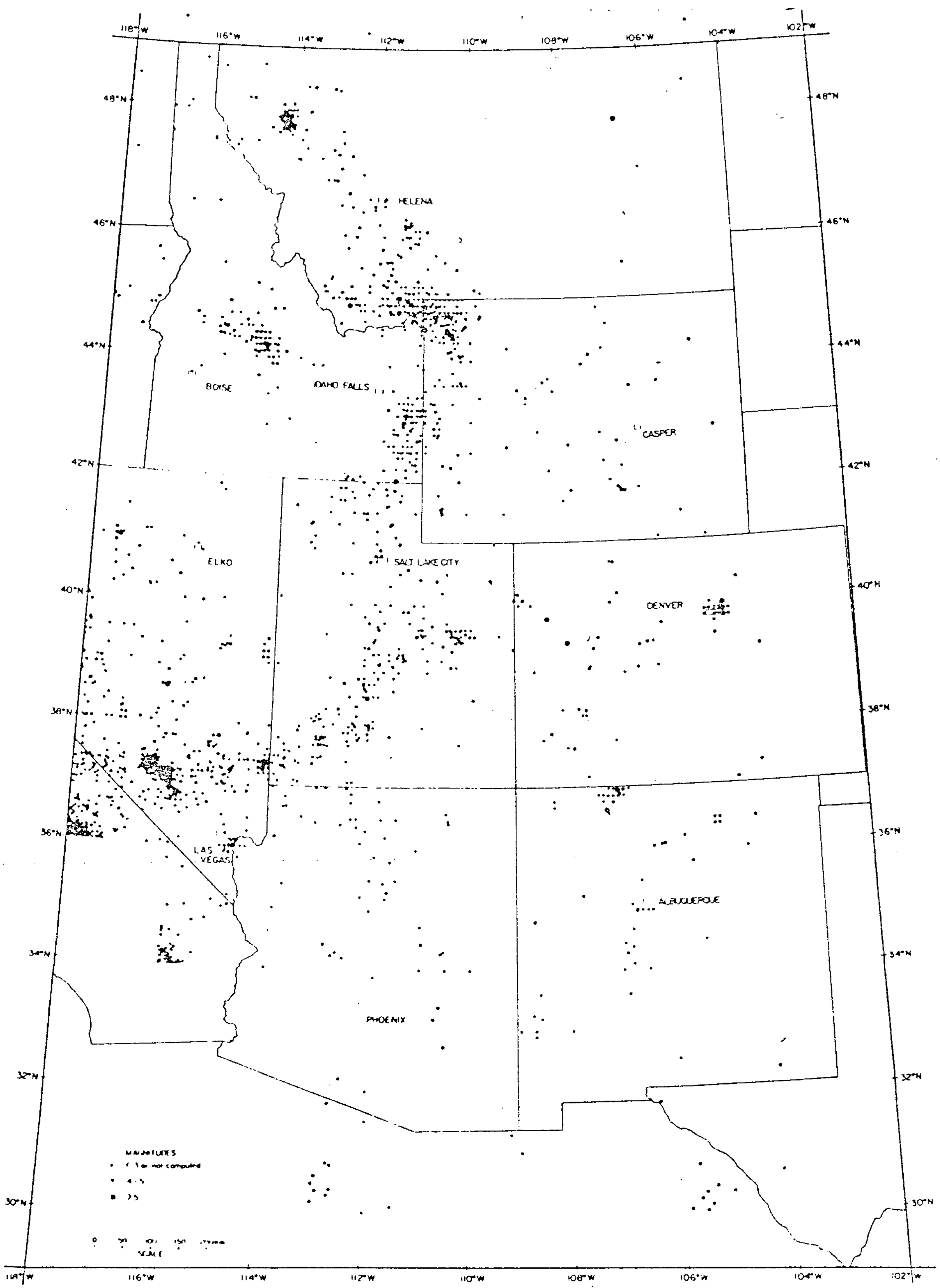

Figure 3. Epicenter map of the Intermountain seismic belt (from Arabasz and others, 1979)

North Bench Subdistrict

The North Bench subdistrcit 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 (figure 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 primarily consist of gravel and sand. The gravel and sand predominate near the mountain front with the clay increasing toward the Jordan River. Depth to bedrock ranges from a few feet at the Bonneville shore level to more than 3000 feet beneath the Jordan River (Everitt, 1979).

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 (figure 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 46 meters (150 feet), 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 sands and gravel and alluvial fan gravel, sand and clays. Depth to bedrock is from less than 305 meters (1000 feet) on the pediment to greater than 710 meters (2000 feet) at the Jordan River (Everitt, 1979).

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 (figure 1). This district includes a broad alluvial-pediment slope formed primarily on rocks of the Salt Lake Formation of Slenz (1955) 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 305 meters (1000 feet) to more than 915 meters (3000 feet) in this subdistrict (Everitt, 1979).

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 of 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 Davis County Line (figure 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 700 meters (2300 feet) at which point approximately 152 meters (500 feet) of interbedded sand and andesite could be encountered which in turn is underlain by sand to 1067 meters (3500 feet). 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 thins to the south toward the Oquirrh Mountains while thickening to the north to approximately 137 meters (450 feet) at the Great Salt Lake. The clay and silt are underlain by a coarse angular gravel ranging from 46 to 137 meters (150 to 450 feet) in thickness. The gravel is, in turn, underlain by the Oquirrh formation.

South Margin Subdistrict

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

Mid-Jordan Subdistrict

The Mid-Jordan Subdistrict is underlain primarily by flood plain deposits of the Jordan River. Bedrock is known to be at a depth greater than 229 meters (750 feet) in this subdistrict; no known wells have penetrated bedrock in this area.

STRUCTURE OF THE JORDAN VALLEY

Faulting

The Jordan 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 has reported a second episode of block faulting which occured in the Pliocene. Also, a number of faults in the surficial valley deposits indicate that faulting has occurred in Recent time although no major earthquakes have been recorded in historical time.

The "Wasatch Fault Zone" (the major zone of recent faulting) in the Jordan Valley separates the Wasatch Range from the valley from Corner Creek, section 3, T. 3 S., R. 1 E., to Mount Olympus, section 14, T. 2 S, R. 1 E., (Plate I). North of this location the recent faulting (East Bench Fault) extends to the northwest (Plate I). 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, north approximately 6.4 kilometers (4 miles), to section 15, T. 1 S., R. 1 E. (Plate I). Movement on this fault is thought to have occurred more than 5,000 years ago (Van Horn, 1972). North of this point, Van Horn (1969) considered the faulting to have occurred prior to 3,000,000 years ago. The East Bench fault continues to section 33, T. 1 N., R. 1 E. (Van Horn, 1969). An older branch of this fault (pre-5,000 years old according to Van Horn, 1972) continues from section 3, T. 1 S., R. 1 E., northeast to section 33, T. 1 N., R. 1 E., thereby rejoining the younger fault segment. 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 northwest, eventually adjoining the Warm Springs fault system located at the base of the Salt Lake salient.

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 wide, and includes the Granger fault to the west and the Taylorsville fault to the east (Plate I). This fault zone is oriented northwest-southeast and extends from approximately section 11, T. 2 S., R. 1 W., in the south to section 17, T. 1 S., R. 1 W., to the north. Evidence of other faulting that occurred prior to recent time is apparent in the Jordan Valley to the south and west.

The Traverse Mountains are separated from the valley by a normal fault referred to by Marine and Price (1964) (Plate I) as the Steep Mountain fault. 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 I). Slentz (1955) reports that in places the fanglomerate is down-faulted to the east and in other areas the fault is buried beneath the fanglomerate.

Tooker and Roberts (1961) have mapped Sevier Orogony thrust faulting at the north end of the Oquirrh Mountains (Plate I). Also, Van Horn (1975) has mapped 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 I).

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 the Crystal Hot Springs geothermal system. The Warm Springs fault geothermal system is located at the western edge of the Salt Lake salient in the northern end of the valley (figure 4). The gravity survey consisted of 12 east-west oriented gravity lines with individual station spacings of 152 to 304 meters (500 to 1000 feet). Individual gravity lines were spaced from 0.4 to 1.2 km (0.25 to 0.75 miles) apart. One gravity profile was modeled using a three dimensional modeling 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 100 meters (328 feet) of alluvium (Murphy & Gwynn, 1979). 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 1220 meters (4000 feet).

The Crystal Hot Springs geothermal system is located in the southern part of the Jordan Valley, southwest of the town of Draper (figure 4). An areawide gravity survey was conducted by orienting profiles perpendicular to the East Traverse and Wasatch Mountain ranges. Profiles were spaced at nearly 0.8 kilometer (0.5 mile) intervals with approximately 304 meter (1000 feet) intervals between individual stations. The area-wide survey provided a regional setting on which to base a more detailed gravity grid to better delineate the structure beneath the springs (Murphy, 1981). The detailed grid consisted of 290 gravity stations, spaced 350 feet apart and was 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 (Murphy, 1981). Murphy (1981) states that in the vicinity of the thermal springs, these faults trend almost east-west and abruptly terminate 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 (Murphy, 1981). Drill hole data has indicated a third range front fault to the northwest. Murphy (1981) 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 Everitt (1979) and Arnow and Mattick (1968) also indicate a complex graben system within the Jordan Valley.

Valley-Wide Gravity Surveys

The structural complexity of the Jordan Valley initiated a gravity survey over the entire study area which consisted of 800 stations along 40 profiles at 0.4 to 0.8 kilometer (0.25 to 0.5 mile) intervals. This survey was designed to compliment the two site specific surveys and the work previously done by Cook and Berg (1961). The result of incorporating this data with the work previously done can be seen in the "Complete Bouguer Gravity Map" presented as Plate II. This map indicates that a number of major bedrock fault blocks may be present in the Jordan Valley. This could be significant because the borders of these aforementioned fault blocks could be conduits for geothermal water. Plate II indicates significant gravity lows in the Jordan Valley which could correspond to structural grabens whereas the

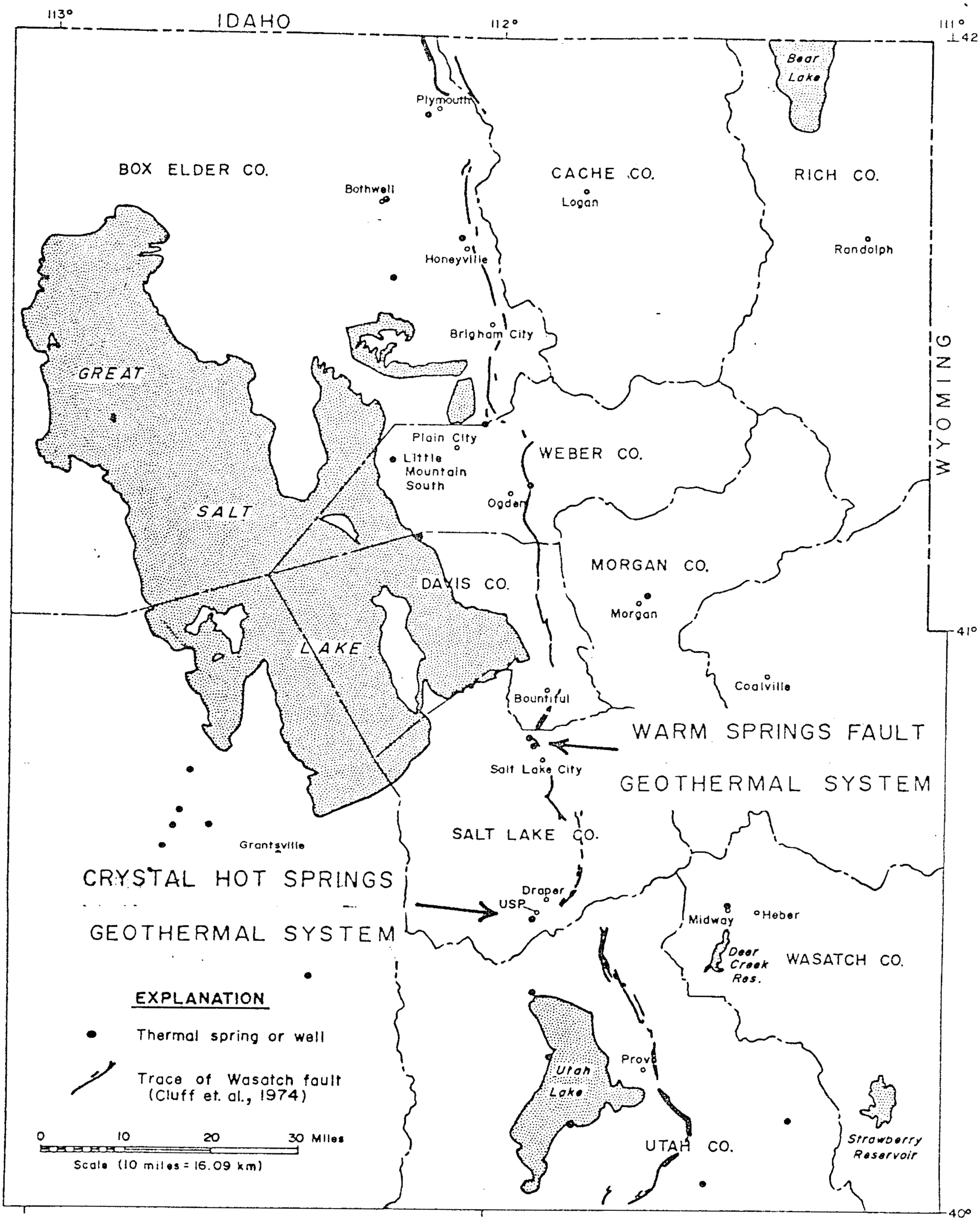

Figure 4. Location of the Warm Springs fault and Crystal Hot Springs geothermal systems, Salt Lake County, Utah

intervening gravity highs could indicate structural bedrock horsts.

Aero Magnetic Surveys

An aeromagnetic survey, 9.5 miles in length (north-south), 6 miles in width (east-west) and centered on Crystal Hot Springs, was flown to detail the complex magnetic surface of the area. Smith (1980) concluded that the resulting magnetic anomaly results from a series of magnetically susceptible intrusive and extrusive bodies that trend east-northeast and vary in depth from 2887 meters (7500 feet) to within 107 meters (350 feet) of the surface. The lower portions of the bodies are thought to be intrusive while the uppper levels may be either intrusive dikes and sills or extrusive flows (Murphy, 1981). Smith (1980) 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 (Murphy, 1981). Results of this survey and preliminary modeling by Smith (1980) provides an understanding of the distribution of the magnetic susceptibility in the subsurface and a major normal range front fault north of the springs (Murphy, 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. All are hydraulically interconnected to some extent, but the large artesian aquifer directly recharges the deep artesian aquifer forming the principal groundwater 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, varying in thickness from 12 to 30 meters (40 to 100 feet), and lying between 15 and 46 meters (50 and 150 feet) 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 (figure 5).

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) (figure 5).

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 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 305 meters (1000 feet) in the northern part of the valley (Hely and others, 1971). For the most part his aquifer is underlain by Tertiary and pre-Tertiary deposits. In some areas the Tertiary deposits are permiable 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) underflow in channel fill draining the adjacent canyons, (3) underflow from Utah Valley to the south through the Jordan Narrows and Ogden Valley 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.

Groundwater movement in the principal aquifer is generally northward toward the Great Salt Lake. Groundwater migrates laterally toward the Jordan River from both the east and west sides of the valley and subsequently migrates to the north (figure 5).

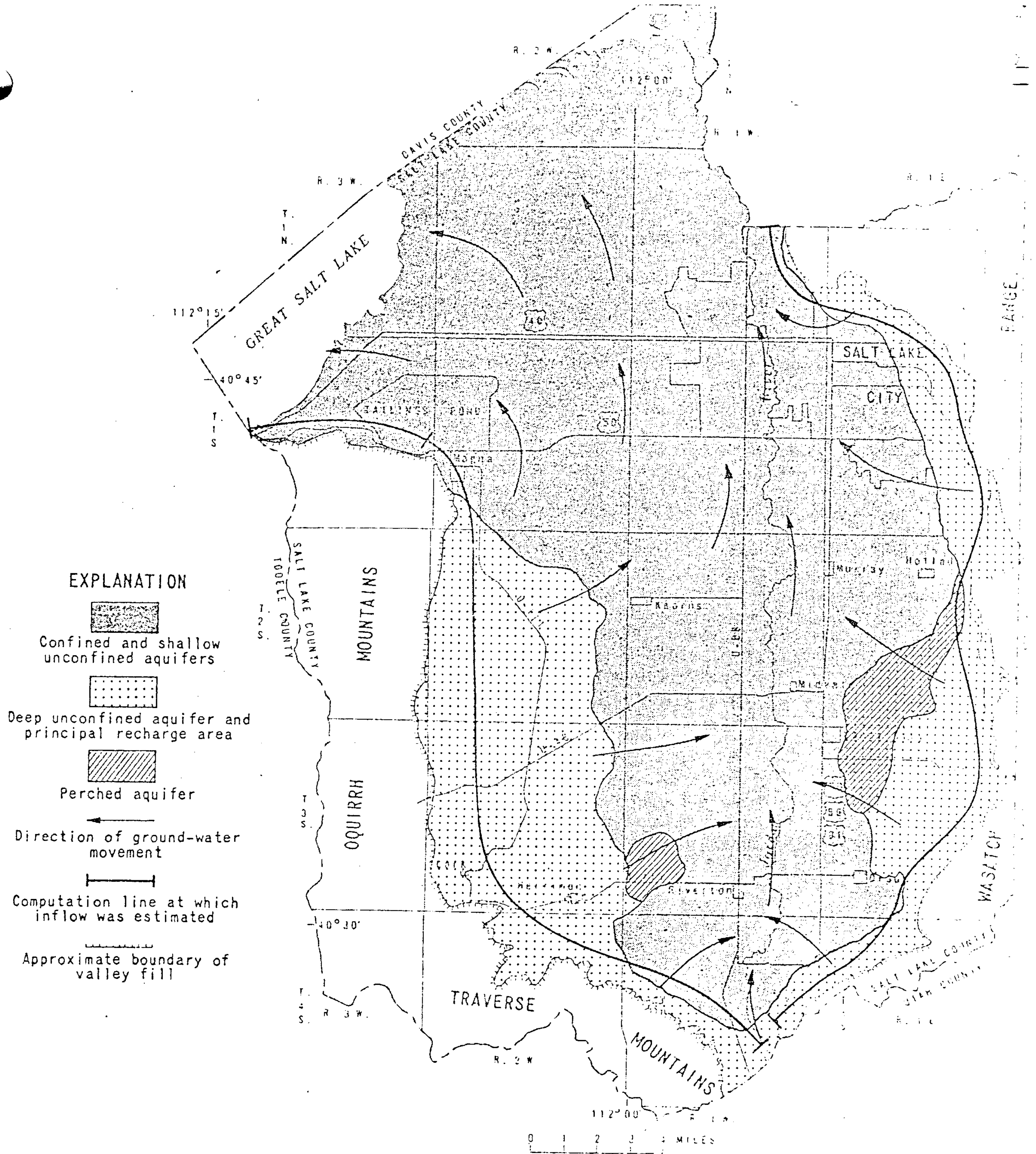

Figure 5. Approximate areas in which ground water occurs in confined, shallow unconfined, deep unconfined, and perched aquifers in Jordan Valley (from Hely and others, 1971)

Temperature

An attempt was made to measure/sample wells that intercepted the principal aquifer. Where no wells of this type were available or accessible, shallower wells were used although these are few in number. Temperatures were recorded at 214 locations by Utah Geological and Mineral Survey (UGMS) personnel, 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, 5 were springs and the balance consisted of pumped or flowing wells.

Temperatures, both measured and acquired, range from 7.5° to 85°C; 182 of the 238 total measured range from 10.4° to 17.4°C. These temperatures are slightly higher than those of Marine and Price (1964) who found most temperatures between 7.8° and 59.4°C. This result is not unexpected since this study was designed to define potential geothermal areas and much data was collected in areas thought to be of above average temperature. Also, test wells have been drilled at Crystal Hot Springs, intercepting warmer water at depth, thereby increasing the upper limit to 85°C from the 59.4°C that had previously been measured in the surface ponds at this location.

Areas of Warm Water

Seventy-six percent (182 out of 238) of all temperatures measured or acquired in the Jordan Valley were 17.4°C or lower. For this reason, 18.0°C was designated as the low temperature limit in trying to delineate anomalously warm areas for further investigation. The result indicates six general areas of potential low temperature geothermal water in addition to a few isolated wells. These general areas are: (1) the northcentral valley area, (2) the area immediately north of the Oquirrh Mountains, (3) the Warm Springs fault geothermal area, (4) an east-west section of the central valley in the vicinity of Kearns, Murray and Holladay, (5) an area between Sandy City and Draper in the southeastern part of the valley, and (6) an area in the extreme southern part of the valley, including Crystal Hot Springs. These areas are presented in Plate III.

Northcentral Valley Area

Temperatures in this vicinity range from 19.3° to 28.1°C and are spread over a fan-shaped area covering approximately 85 square kilometers (33 sw. mi.). First indications from gravity surveys suggest this area is bordered by faulting which could, in turn, structurally control the location of warm water encountered in wells. If this is occurring, groundwater must be circulating to a minimum depth of 0.5 kilometers (0.3 miles) for the Basin and Range geothermal gradient to heat the water to the temperature recorded at the well heads. Marine and Price (1964) suggest an alternative theory of ground water reactions with the organic clays in the area, with the resulting temperature being a product of exothermic reactions.

North Oquirrh Area

This area, located immediately north of the Oquirrh Mountains, ranged in temperature from 21° to 29°C (Plate III). A possible source of this anomaly could be water circulating at depth and migrating up the Pony Express and Rio Grande thrust faults. The minimum depth of circulation is estimated to be 0.5 kilomters (0.3 miles).

Warm Springs Fault Area

The Warm Spring Fault geothermal system is located immediately west of the Salt Lake salient (Plate III). According to Murphy and Gwynn (1979) this system is controlled by water circulating to a minimum depth of 1.5 to 2.0 kilometers (0.9 to 1.2 miles) and migrating up the Warm Springs and Hobo fault systems. They indicate that the major springs tend to occur at the intersections of these major faults with older, minor structures striking roughly perpendicular. An anomalously warm well (19.4°C) is located approximately 1.6 kilometers (1 mile) south of the Warm Springs fault. This anomaly could result from a continuation of the Warm Springs or Hobo fault systems to the south.

Central Valley Area

A temperature of 18.8°C was recorded approximately 3.2 kilometers (2 miles) north of Kearns while two warm temperatures (18.5° and 21.0°C) were recorded approximately 2.4 kilometers (1.5 miles) to the southwest. The warm temperature recorded to the north could be controlled by the Jordan Valley fault zone. The two wells to the southwest were drilled to depths of between 305 and 335 meters (1000 to 1100 feet) in an area where wells are known to be receiving water from permeable zones in Tertiary deposits. These wells were drilled to a significantly greater depth than other, cooler wells in the area therefore indicating that the normal geothermal gradient may be producing these anomalously warm temperatures.

A second group of warm temperatures were measured in wells located in the Murray area (Plate III). Six wells produced temperatures ranging from 18° to 21°C.

Two wells with temperatures of 23.8° and 22.1°C are located in the Holladay area (Plate III). This anomaly may be attributable to warm water rising from depths of at least 0.5 kilometers (0.3 miles) along the East Bench fault.

Sandy City -- Draper Area

Warm water was encountered in 9 wells located in the general area between Sandy City and Draper, Utah (Plate III). Six of these wells are located south of Sandy City and trend in a west-northwest direction with temperatures ranging from 18.0° to 48°C. The anomalous temperatures in two of these wells can be attributed to the normal thermal gradient.

Three other warm wells are located randomly in and northwest of Draper (Plate III). These wells produce water with temperatures of 19.2°, 21.7° and 23.7°C. Insufficient data is available at this time to speculate as to the source of this water.

Crystal Hot Springs Area

Five warm temperatures ranging from 28.5° to 85.0°C were measured at and in the vicinity of Crystal Hot Springs. Murphy and Gwynn (1979) and Murphy (1981) studied this area extensively and conclude that it is located between two range front faults, is underlain by smaller fault blocks and is supplied by warm water circulating to a minimum depth of 2.5 kilometers (1.55 miles). This water is heated by the normal geothermal gradient and rises along permeable fault zones and infiltrates into well-fractured quartzite located beneath the site.

Other Isolated Warm Temperatures

A temperature of 23.5°C was measured approximately 2.4 kilometers (1.5 miles) north of Sandy City. This temperature cannot be accounted for by the normal Basin and Range geothermal gradient and does not seem to be related to other anomalous temperatures in the area.

Three other anomalous temperatures were measured in the southwest part of the valley (Plate III). Locations of these wells were approximately 3.2 kilometers (2 miles) southeast of Crystal Hot Springs, just east of Herriman and in Rose Canyon (Plate III). The 18.6°C temperature recorded southwest of Crystal Hot Springs and the 21.0°C temperature measured in Rose Canyon can be accounted for by the normal geothermal gradient. At this time no explanation is available for the 19.0°C temperature recorded east of Herriman.

Chemistry

The Jordan Valley exhibits a complex ground water chemistry which is attributable to complicated stratigraphy and structure as well as low temperature geothermal activity within the area. Despite this inherent complexity, however, trends are apparent in this system which are indicative of anomalous chemistry that may be associated with geothermal activity.

A definite trend in the ground water seems evident from the Jordan Narrows north to Sandy City (Plate IV). Generally, the water in this area contains approximately equal amounts of sodium, calcium and magnesium cations with predominantly sulfate and chloride anions.

Four isolated locations are indicative of ground water high in sodium and chloride (Plate V). Three of these locations are in the area where Corner Creek, Little Cottonwood Creek and Big Cottonwood Creek plumes should predominate. However, due to the fairly deep graben present in this area (Everitt, 1979), the ground water is thought to circulate quite deep, increasing in temperature and dissolution time and consequently accumulating predominantly sodium and chloride ions. The fourth location is on the edge of this basin but exhibits similar chemistry. This could be caused by the deep circulation of geothermal ground water through a highly faulted area (Murphy and Gwynn, 1979).

The central part of the Jordan Valley displays chemistry typical of ground water in a resistate system. The groundwater contains approximately equal amounts of sodium, calcium and magnesium cations with predominantly sulfate and chloride anions (Plate IV). Total dissolved solids are greater than 1600 ppm (Plate V). These chemical conditions may be the result of the structural conditions within this portion of the valley; a possible explanation is as follows: The "Complete Bouguer Gravity Map" (Plate II) suggests this area is structurally complex. Plate II indicates that an east-west striking normal fault downdropped on the south is present, extending east from Bacchus approximately 6.4 kilometers (4 miles). This fault is truncated by a north-south oriented fault, downdropped on the east, which extends northward through the valley (Plate II). The increase in bedrock elevation to the north through this part of the Jordan Valley causes a decrease in the rate of groundwater migration and an increase in time of dissolution. East of Bacchus, the groundwater could be interacting with geothermal water migrating upward from depth along the fault system, thereby increasing in total dissolved solids.

Further north, a sharp transitional boundary exists, where the ground water changes to a predominantly sodium chloride system (Plate IV). This transition zone roughly parallels the stratigraphic change from the pediment located in the West Slope groundwater district to the Lake Bonneville clays of the Northwest Lake Plain groundwater district. The change in chemistry reflects the influence of the Great Salt Lake and the ion exchange capacity of the lake clays located in this area.

The chemistry of the groundwater in the north-central part of the valley is predominantly a sodium chloride system, but displays a significant increase in bicarbonate while exhibiting a decrease in calcium, magnesium, sulfate and total dissolved solids (Plates IV and V). Plate II indicates this area is a horst bounded by grabens to the north, south and west. A seismic reflection survey conducted by the U. S. G. S. also shows this area to be a bedrock high (Mower, 1968). According to Hely and others (1971), the low - total dissolved solids is caused by the migration of high quality water from the Ogden Valley to the north. The significance of the chemistry in relation to the warm water measured in this area is not understood at this time.

The area east of the Jordan River, extending from the Salt Lake salient south to Corner Canyon is recharged by high quality water from the canyons in the Wasatch Range. This results in low total dissolved solids and no significant anamalous water chemistry (Plates IV and V). This high quality water could mask any obvious chemical indication of possible geothermal activity in this area of the valley. The temperature map, however, does indicate warm temperatures both east and west of Murray (Plate III).

SUMMARY OF FINDINGS

Prior to the study of area-wide, low-temperature geothermal resources in the Jordan Valley, Murphy and Gwynn (1979) conducted studies of two known geothermal areas: (1) the Warm Springs fault, and (2) Crystal Hot Springs. These studies indicate meteoric water is being circulated to depth and heated by the ambient temperature derived from normal heat flow. This warm water migrates upward along permeable fault zones. Study of these two geothermal areas has proven important to the present investigation by providing insight into the controlling mechanism of low-temperature geothermal resources.

The present study being conducted in the Jordan Valley has provided a complete Bouguer gravity map in addition to water temperature and chemistry for 238 wells and springs (Plates II, III, IV, and V). Results of the gravity survey indicate a number of fault blocks are buried beneath valley sediments (Plate II). Since previous work has indicated that warm water migrates upward along permeable fault zones, the common borders of these horsts and grabens could provide conduits for warm water.

Water temperatures measured in the valley have provided further insight into areas of geothermal potential (Plate III). Four areas, in addition to the two known geothermal sites have warm water wells. These areas are designated as the: (1) Northcentral Valley area, (2) North Oquirrh area, (3) Central Valley area, and (4) Sandy City - Draper area.

The chemistry of the Jordan Valley is quite complex and not fully understood in regard to geothermal potential. Further investigation is required to discern the significance of the anomalies noted.

The two known geothermal areas are located where bedrock is within 305 meters (1000 feet) of the surface. In other areas of the valley, bedrock is covered by hundreds of meters (thousands of feet) of unconsolidated sediment which could conceal warm water anomalies due to lateral dispersion or dilution within the principal aquifer. Areas of low permeability could retard warm water flow, thereby allowing for cooling of the water prior to discharge in wells or springs. The area of the valley east of the Jordan River receives considerable cool, high quality ground water recharge from snow melt in the Wasatch Range. This water could appreciably cool possible warm water as well as notably improve the water quality of geothermal resources in that area.'

FUTURE INVESTIGATIONS

Jordan Valley geothermal assessment has provided insight into the direction of future investigations to complete the study. The following is additional work to be undertaken within the following year.

(1) Gravity modeling to define the structure and geology in specific areas indicative of geothermal potential.
(2) Testing of geothermometry models to determine possible reservoir temperatures in areas with warm water wells.
(3) Gradient logging where accessible throughout the valley.
(4) Further investigation of the chemistry to determine, if possible, correlations between warm water and ion concentrations or types.

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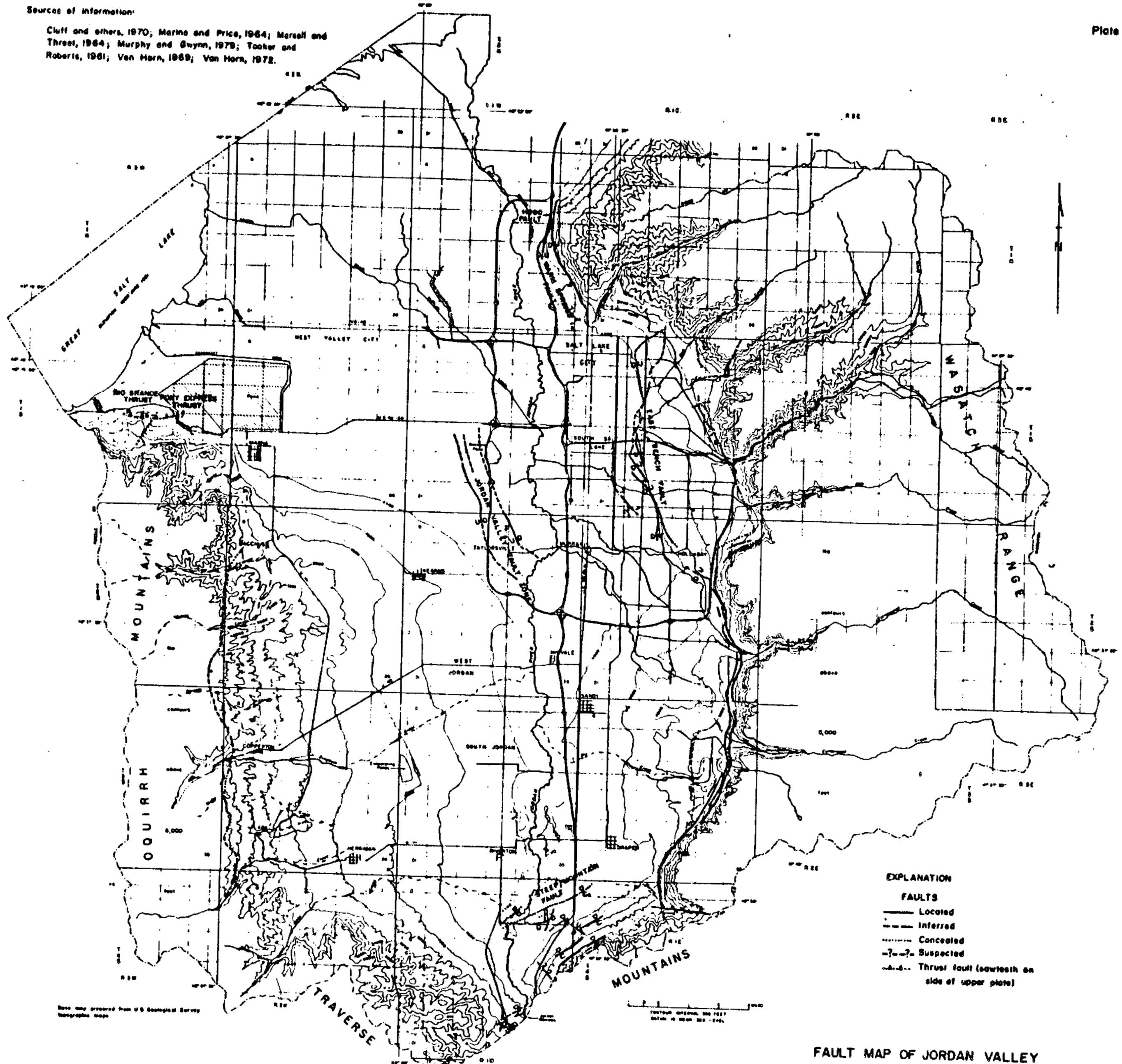
Sources of information:

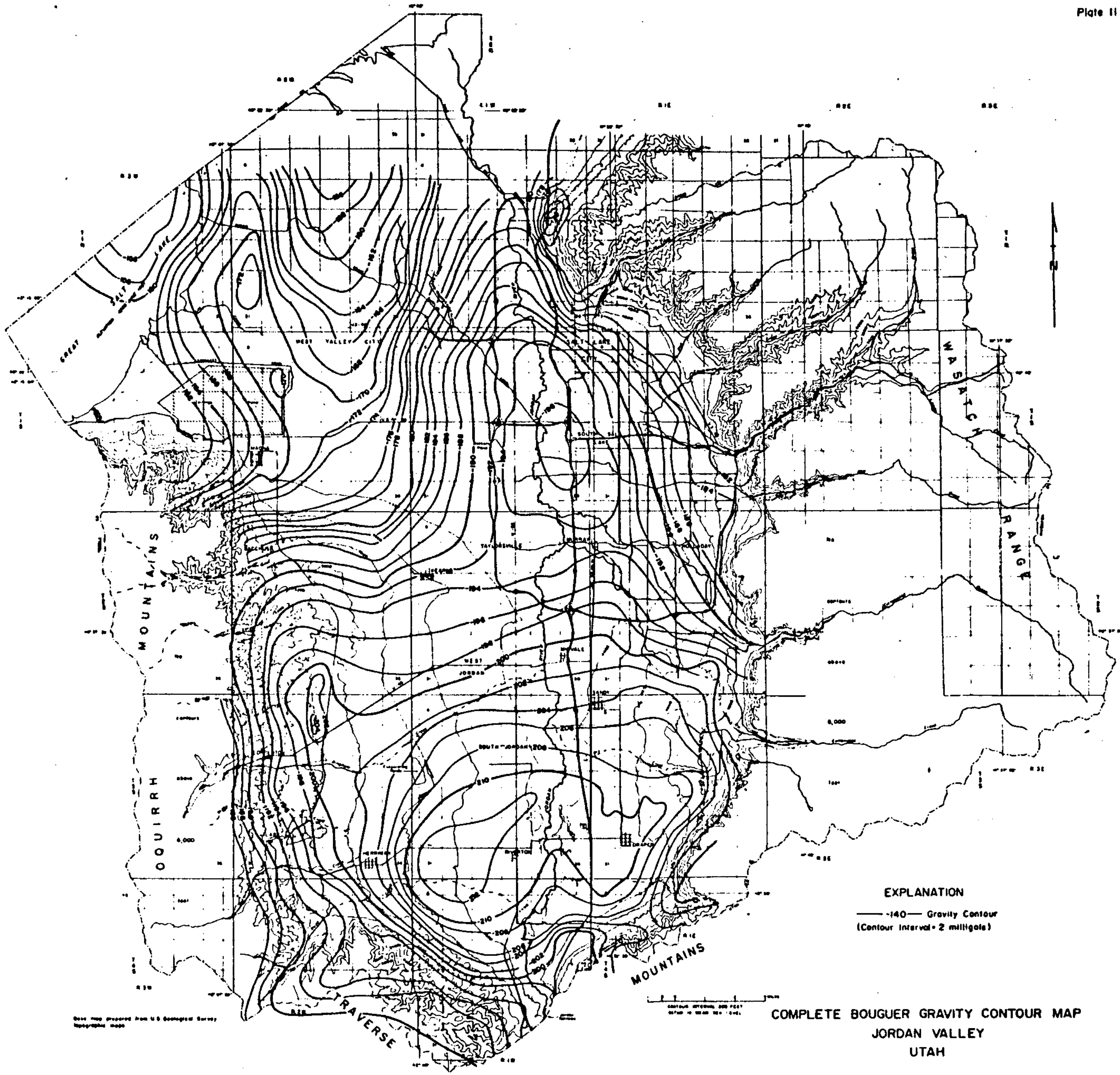
Cluff and others, 1970; Marine and Price, 1964; Marsell and Threet, 1964; Murphy and Gwynn, 1979; Tooker and Roberts, 1961; Van Horn, 1969; Van Horn, 1972.

Plate I



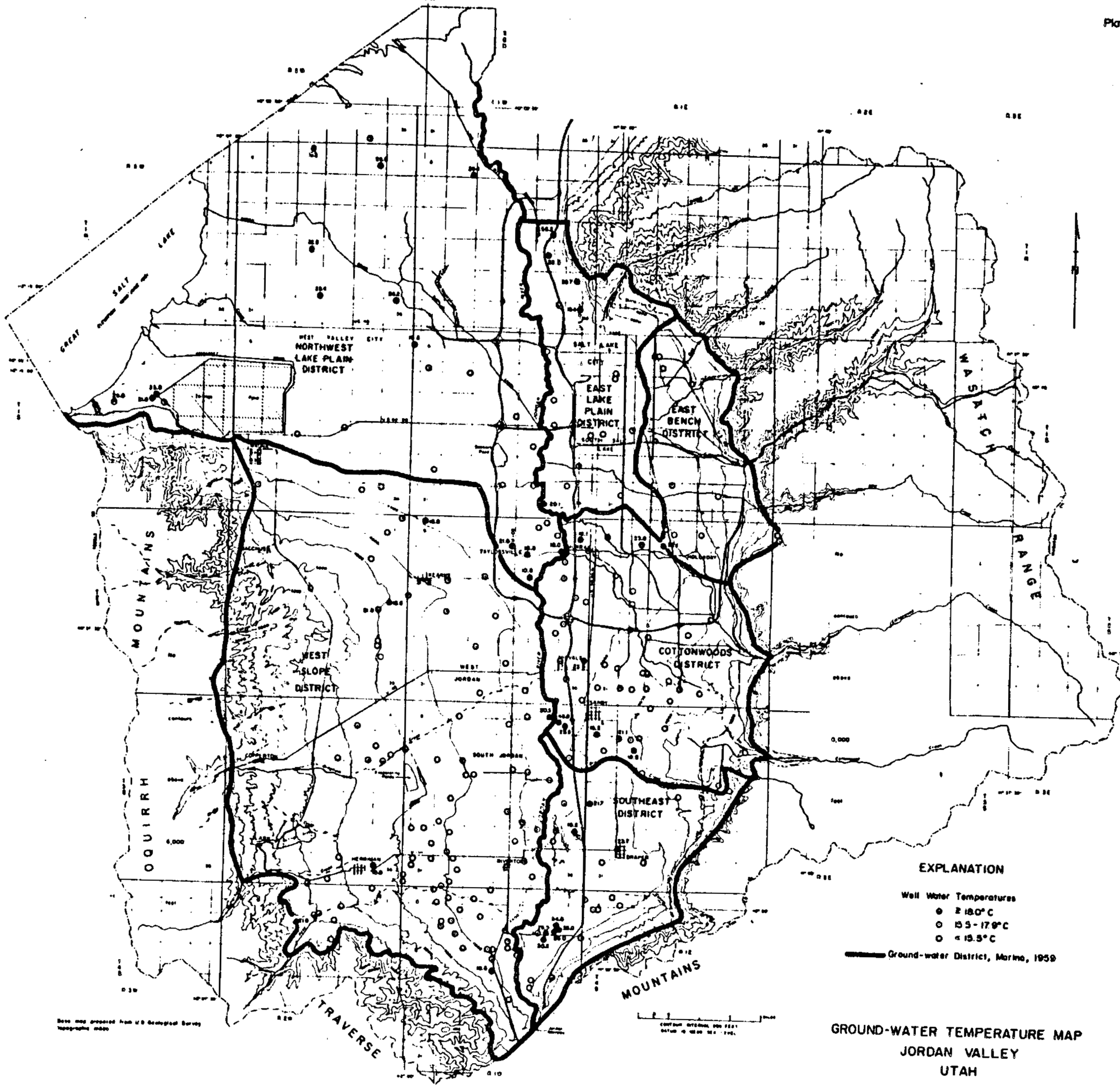
FAULT MAP OF JORDAN VALLEY
UTAH

Plate II



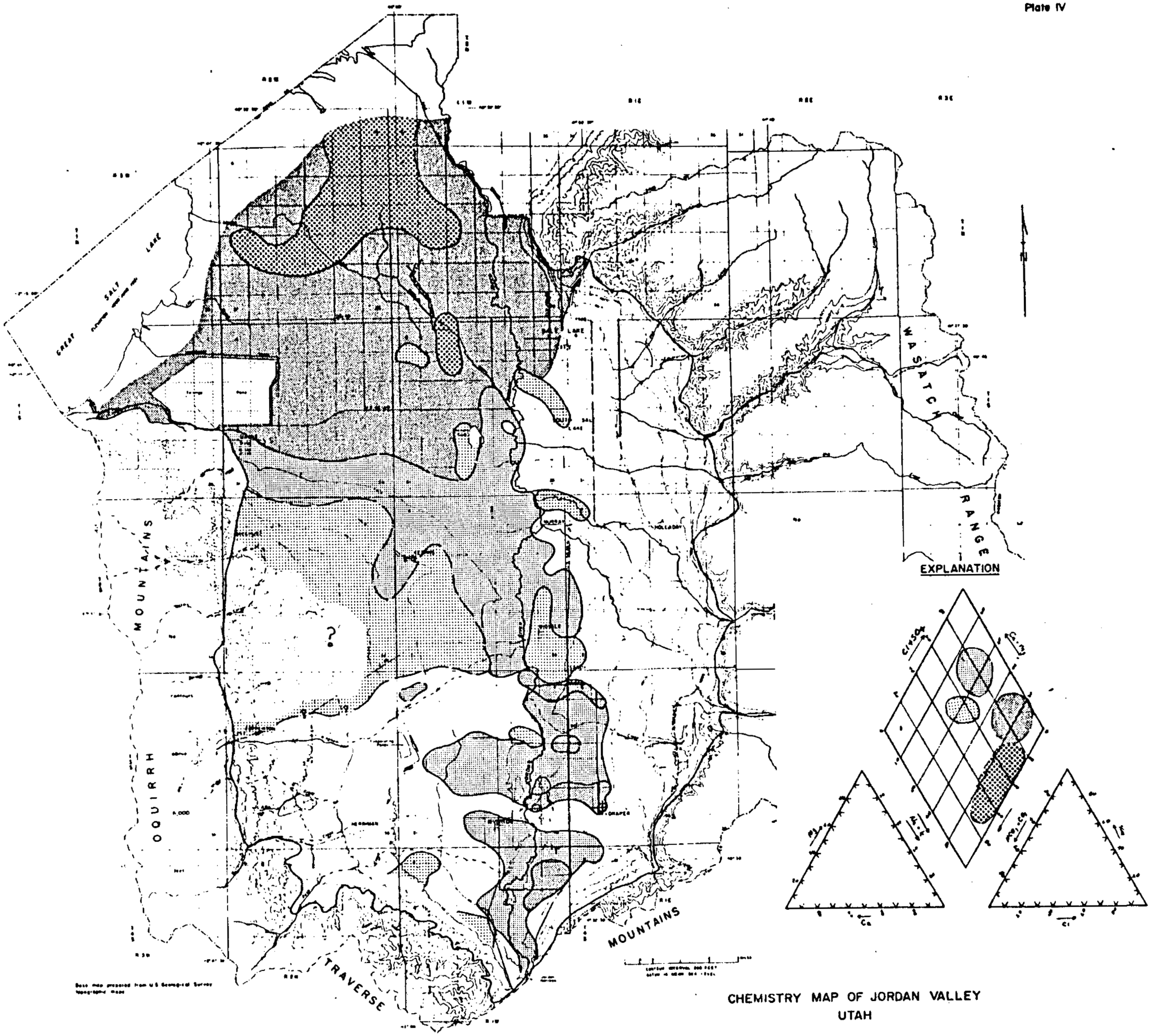
COMPLETE BOUGUER GRAVITY CONTOUR MAP
JORDAN VALLEY
UTAH

Plate III



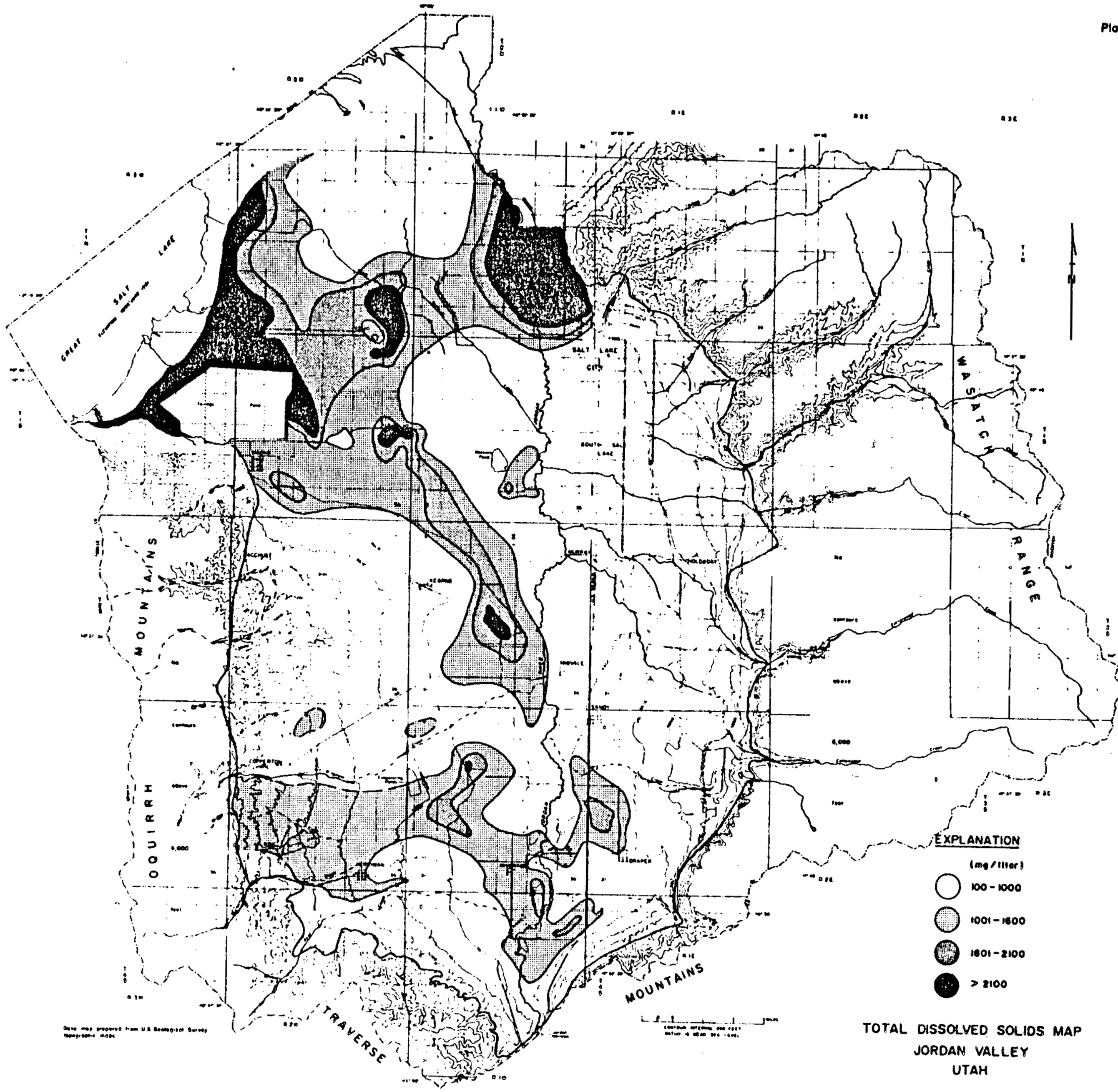
GROUND-WATER TEMPERATURE MAP
JORDAN VALLEY
UTAH

Plate IV



CHEMISTRY MAP OF JORDAN VALLEY
UTAH

Plate V



TOTAL DISSOLVED SOLIDS MAP
JORDAN VALLEY
UTAH

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