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SUMMARY OF LOW-TEMPERATURE
GEOTHERMAL STUDIES CONDUCTED BY THE
UTAH GEOLOGICAL AND MINERAL SURVEY
FROM JULY 1, 1977 TO DECEMBER 31, 1984

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INTRODUCTION

The Utah Geological and Mineral Survey (UGMS) has conducted research to advance the utilization of low-temperature geothermal resources in the State of Utah under U.S. Department of Energy/Division of Geothermal Energy (presently the Division of Geothermal and Hydropower Technologies) (DOE/DGE) contract DE-AS07-77ET 28393 (originally EG-77-S-1679) since July 1, 1977. The following is a summary of the areas investigated and the results obtained.

STATE-WIDE STUDIES

The Geothermal Resources of Utah map (Murphy, 1980) identified 327 thermal wells and springs in Utah with temperatures greater than 20°C. All but 13 of these wells and springs are located in the western half of Utah. In addition to individual well and spring locations, Known Geothermal Resource Areas (KGRA), as designated by the U.S. Department of the Interior, are located on this map. KGRA's are defined either by geologic criteria or competitive interest. Utah has nine such areas (fig. 1). Also designated are areas of significant lateral extent, favorable for discovery and development of water less than 90°C.

"Thermal Waters of Utah" by Goode (1978) depicts 16 areas in western and central Utah that yield slightly warm (16°C to 19°C), warm (19°C to 34°C), or hot (35°C and above) water. Also included are records of approximately 1500 wells and springs with temperatures greater than 16°C. These records include location, ownership, temperature, yield, depth (of wells), geologic unit, and chemical analyses.

SITE-SPECIFIC STUDIES

The UGMS has conducted investigations at Udy (Belmont) Hot Springs, Crystal (Madsen) Hot Springs, Utah Hot Springs, Little Mountain Hot Springs, Warm Springs fault geothermal area, Crystal Hot Springs and the Midway Hot Springs area (fig. 1). These areas were studied because of their proximity to metropolitan areas, with homes and industry as potential users. These investigations provided information on each system, established a data base to aid potential users in making informed decisions, and provided a model applicable to other Utah geothermal systems.

The methods employed to investigate these individual systems included: gravity and aeromagnetic surveys with subsequent modeling; shallow ground-water temperature surveys; aqueous chemical sampling and analysis; gradient hole drilling; and production hole drilling. Results of the individual studies indicate that all individual areas studies, with the exception of Midway, are convective systems with a deep circulation of meteoric water within a region of high heat flow (Murphy and Gwynn, 1979a, b, c). Water moves downward through permeable rocks and heated. It reaches fault zones of high permeability that provide conduits for the warmed water to rise rapidly to the surface with minimal heat loss. Thermal gradient, depth of descent, rate of ascent, and degree of mixing with non-thermal water are the main factors influencing the temperature of fluids observed. Figure 2 depicts this model. The source of warmed water for the Midway geothermal area is not fully understood (Kohler, 1979).

Figure 2. Diagram depicting a general model of the origin of low-temperature geothermal water in Utah.

AREA-WIDE STUDIES

The UGMS has conducted surveys in Cache Valley, north-central Box Elder County, and the Escalante Valley as well as in all valleys along the Wasatch Front since 1980. The purpose of these studies was to detect geothermal systems not presently known, as well as expand the information on geothermal systems previously investigated by Murphy and Gwynn (1979a, b, c).

Exploration methods employed for these investigations include: (1) a literature search; (2) gravity surveying and modeling, (3) aqueous chemistry analysis of wells and springs; (4) temperature measurement of wells and springs; and (5) temperature-depth measurements in "holes of opportunity." Results of these studies, to date, indicate all of the geothermal systems encountered are convective, resulting from deep circulation of meteoric water as was previously described. All geothermal systems appear to produce only low- to moderate-temperature water and thus are restricted to those types of uses. The following is a brief discussion about the individual valley areas or counties investigated.

Escalante Valley

This study by Klauk and Gourley (1983) was conducted to evaluate the low- to moderate-temperature geothermal potential of an area proposed for a possible Missile Experimental (MX) operations base in the Escalante Valley region of Utah (fig. 1). Thermo Hot Springs is included in the study area and has recorded temperatures ranging from 42^o to 78^oC. A temperature of 60^oC was measured in a very deep (11,998 feet) geothermal test well. The highest water-well temperatures (27^o and 28^oC) were found in a second area northwest of Zane. Trilinear plots of common ions, as well as Li and B

concentrations, indicate waters in the valley are also similar to those waters sampled at Thermo Hot Springs.

Chemical geothermometers (both Na-K-Ca with Mg correction and quartz conductive) indicate that the expected maximum reservoir temperatures at both Thermo Hot Springs and the area northwest of Zane are less than 130°C . Chemical analysis also indicates Thermo Hot Springs waters have cooled conductively whereas the Zane area water has cooled by mixing with near-surface aquifers.

Temperature-depth measurements were taken in 22 "holes of opportunity" in the valley. The highest calculated gradient ($140^{\circ}\text{C}/\text{km}$) was located less than 1.25 miles from the highest temperature water well (28°C). However, the temperature-depth profile used to calculate this gradient only extended to a depth of 187 feet and the maximum bottom-hole temperature recorded was 23°C .

Cache Valley

The Cache Valley study by de Vries (1982) indicates three areas have potential for low temperature applications. These areas are: (1) North Logan, with temperatures ranging from 16° to 25°C ; (2) Benson, with water temperatures ranging from 13° to 23°C ; and (3) Trenton, with water temperatures ranging from 23° to 50°C . Geothermal reservoir temperatures calculated using Na-K-Ca and silica geothermometers range from 50° to 100°C . Silica mixing models applied increases this range of temperatures to 200°C . Temperatures of this magnitude, however, are considered unlikely.

North-Central Box Elder County

The north-central Box Elder County study (Davis and Kolesar, 1984) indicates two areas have definite potential for low-temperature geothermal resource development. One area is located east of Snowville and has recorded temperatures ranging from 17⁰ to 25⁰C. The second area is located in northeastern Hansel Valley. Temperatures in this area range from 17⁰ to 30⁰C. Common ion analyses indicate these elevated temperature waters have high concentrations of Na and Cl. Chemical geothermometers indicate reservoir temperatures as great as 161⁰C can be expected. However, temperatures ranging between 75⁰ and 110⁰C seem more realistic. Gradients calculated from temperature-depth measurements logged in these two areas range from 86⁰ to 267⁰C/km (1 km = 3259 feet). All remaining gradients ranged from isothermal to 65⁰C/km.

Wasatch Front

Box Elder County--The Malad and Bear River valleys in Box Elder County have four geothermal areas which are manifested at the surface as thermal springs. These areas are: (1) Udy (Belmont) Hot Springs; (2) Crystal (Madsen) Hot Springs; (3) Utah Hot Springs; and (4) Stinking and Little Mountain Hot Springs. Investigations were conducted at Udy, Crystal, and Utah Hot Springs by Murphy and Gwynn (1979c). Maximum reported temperatures at these three sites are 54⁰, 57⁰, and 62⁰C, respectively.

The valley-wide study by Klauk and Budding (1984) has identified three additional areas as having low-temperature geothermal potential: Little Mountain, an area west and southwest of Plymouth, and an area west and south of the Cutler Dam.

The Little Mountain area is identified by geochemical techniques. Common ion concentrations indicate water is either Na-Ca Cl or Na Cl in character and, therefore, similar to chemical analyses of known thermal areas. Trace element analyses show that concentrations of Sr, Li, and B are comparable with thermal springs in the study area and are generally much higher than non-thermal samples. The ratio of Ca/HCO_3 for water in this area is similar to ratios for thermal samples. Chemical geothermometry indicates similarities between non-thermal samples and Little Mountain and Stinking thermal springs samples, all within this area.

The Plymouth and Cutler areas are identified by temperature-depth measurements. No anomalous chemical concentrations are found in the well samples analyzed. However, both areas have temperature-depth profiles with high calculated gradients. In addition, bottom-hole temperatures are greater than 20°C.

Weber and Davis Counties--Weber and Davis Counties have two thermal areas which are manifested at the surface by warm springs. Ogden Hot Springs, located at the mouth of Ogden Canyon in Weber County, has a temperature of 56°C. Hooper Hot Springs is located 10 miles southwest of Ogden on the east shore of the Great Salt Lake in Davis County. A temperature of 57°C has been measured at this spring. Glenn and others (1980) state that the thermal waters have mixed with cooler shallow ground waters and that the temperatures of these hot spring waters, prior to mixing, are estimated to be between 70°C and 150°C.

Little Mountain geothermal area is not manifested at the surface by a major thermal spring. This geothermal area is located approximately 15 miles west of Ogden, Utah, and consists of numerous shallow flowing wells and springs. Water temperatures measured at these wells and springs range from 14° to 20°C (Murphy and Gwynn, 1979c). Murphy and Gwynn (1979c) conclude that the distribution of flowing warm water wells may indicate an east-west striking fault and that an area of warm water may also exist at the southern end of Little Mountain.

The geothermal reconnaissance study by Klauk and Prawl (1984) conducted for these two counties identified 12 wells with water temperatures 20°C or greater. However, only one of these wells exhibited chemical characteristics indicative of warmer temperature at depth. This well, in addition to three other non-thermal wells (14° to 16°C), have delineated a possible low-temperature thermal area northwest of Ogden. Chemical geothermometer results indicate temperatures to be expected at depth range from 60° to 90°C . Other chemical characteristics indicative of low-temperature geothermal potential include common ion concentrations high in Na and Cl, high concentrations of trace elements such as Li, Ba, and Sr, as well as Ca/HCO_3 and Cl/B ratios greater than background.

Salt Lake County--The Jordan Valley in Salt Lake County has two geothermal systems with warm springs. One of these, the Warm Springs fault geothermal system, was investigated by Murphy and Gwynn (1979b). The system is located in northern Salt Lake County, immediately west of the Salt Lake salient, in an area approximately 3 miles long and three-fourths of a mile wide. Included within this strip are Beck Hot Springs, Wasatch Warm Springs,

Hobo Warm Springs, and Clark Warm Springs. Also included are two shallow wells from which warm water is pumped by the Monroc Corporation. The discharge temperatures in this system range from 27°C (Clark Warm Springs) to 55°C (Beck Hot Springs).

The other geothermal system (Crystal Hot Springs) was reported on by Murphy and Gwynn (1979a), the Utah Energy Office (1981), and Morrison-Knudson Company, Inc. (1982). Crystal Hot Springs is located in southern Salt Lake County near the town of Draper (north of the Traverse Mountains) and between two range-front faults. Fractured Paleozoic quartzite (at depth) leaks warm water into the springs through overlying, unconsolidated material. Temperatures as great as 84°C have been measured at spring orifices. Furthermore, a geothermal production well for the Utah State prison, drilled into the fractured Paleozoic rock, encountered temperatures from 85°C to 90°C.

In July 1978, the Utah Energy Office submitted a successful proposal to the Department of Energy (DOE) in response to a Program Opportunity Notice (PON) for Direct Utilization of Geothermal Energy Resources. It proposed to develop the Crystal Hot Springs geothermal resource adjacent to the Utah State Prison for a variety of direct applications at suitable sites within the prison complex. A geothermal well, heat exchange system, and injection disposal well were proposed to form the initial demonstration of providing geothermal water for space heating and domestic water heating for the minimum security facility at the prison. The project was programmed into three phases, which consisted of (1) Phase I - resource assessment; (2) Phase II -

resource development; and (3) Phase III - construction and inspection of demonstration.

The Utah Geological and Mineral Survey was involved with Terra Tek, Inc. in the resource assessment phase of this project (Utah Energy Office, 1981). Presently, Utah Roses, Inc. is using part of this resource to heat a large greenhouse operation immediately adjacent to the prison. An initial assessment recommendation was to perform a long-term flow test of the prison production well in order to verify predicted long-term drawdown characteristics, to assess system recharge effects, and to determine the effect of the Utah Roses production well on the prison well. This extended flow test was conducted during the months of June and July 1982 by Morrison-Knudson Company of Boise, Idaho. Results of the test indicate the geothermal resource is larger than originally anticipated and plans are underway to expand the heating project at the prison.

Geothermal reconnaissance techniques utilized in the valley-wide study by Klauk and Darling (1984) included: (1) a temperature survey; (2) chemical analysis of wells and springs; (3) temperature-depth measurements; and (4) a gravity survey and modeling.

The gravity survey, consisting of 800 gravity stations, was conducted to complement two previous surveys at the Warm Springs fault and Crystal Hot Springs areas and work by previous investigators. A complete Bouguer gravity map was completed by Adihidjaja and others (1981). Further site specific gravity modeling for the Warm Springs fault geothermal area and initial

modeling for the entire valley were also completed (Meiji Resource Consultants, 1983).

Areas identified as having potential low-temperature geothermal resources at depth as a result of the valley-wide study 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 20°C 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° to 100°C . Reservoir temperatures for non-thermal water are generally less than 50°C .

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

Utah County--An extensive gravity survey of Utah County was conducted, adding 536 new stations to 563 stations from previous surveys. This survey

was undertaken to provide the structural framework needed to help define geothermal targets, by delineating faults, structural trends, intrusions, thickness of valley fill, and areas of increased host rock density as the result of thermal metamorphism. Results of the modeling of this data by Davis and Cook (1982) indicate the association of (1) Saratoga Hot Springs, Lincoln Point Warm Springs, Crater Hot Springs, and Warm Springs at Bird Island with the Utah Lake fault zone; (2) Goshen Warm Springs with the Long Ridge fault; and (3) other warm springs with other fault zones. These studies substantiate the fact that most of the springs in Utah Valley are fault controlled.

A temperature survey and chemical analysis of wells and springs by Klauk and Davis (1984) have identified five areas in Utah County warranting further investigation for low-temperature geothermal resources. One area in northern Utah Valley coincides with the Utah Lake fault zone and includes Saratoga Hot Springs. Water temperatures within this area range from 21° to 43°C . Common ion analyses as well as B and Li concentrations indicate all the waters sampled in this area are part of a large geothermal system or systems. Two other areas in southern Utah Valley also coincide with the Utah Lake fault zone. Common ion analyses, trace element concentrations, and Cl/HCO_3 ratios distinguish these areas from all other waters in this valley. Temperatures for these areas range from 21° to 32°C . All three of these thermal areas are considered to be the result of deep circulation of meteoric water being warmed and subsequently migrating upward within the Utah Lake fault zone.

Based on new data, the geothermal area at Castilla Hot Springs has been expanded to include a spring located 2 mi to the east up Spanish Fork Canyon

near the Thistle earthflow. A temperature of 50°C was recorded for this spring and chemistry is similar to Castilla.

Goshen Valley is the fifth geothermal area identified. Temperatures ranging from 20° to 27°C have been recorded for some wells and springs in this area. Chemical analyses do not indicate the location of low-temperature reservoirs at depth.

OTHER GEOTHERMAL CONTRIBUTIONS

Since July 1, 1977, the UGMS has made other contributions to the advancement of low-temperature geothermal resources in Utah. The UGMS supplied low-temperature spring and well data to Section B (sample data/chemical analyses) of the U.S. Geological Survey computerized geothermal resources file known as GEOTHERM. Papers were presented at the Glenwood Springs (Klauk and others, 1981) and Salt Lake City (Klauk, Foreman, and Gourley, 1982) technical conferences. These papers discussed research that was being conducted in the Jordan Valley and the Escalante Valley, respectively. A paper was also presented at a Geothermal Resources Council meeting by Murphy (1981) discussing the geologic and hydrologic setting of Crystal Hot Springs. Furthermore, an article was published detailing the UGMS's low-temperature geothermal assessment program (Klauk, 1982). Additionally, data was supplied for U.S. Geological Survey Circulars 790 (Muffler, 1978) and 892 (Reed, 1982).

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