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# SURVEY NOTES

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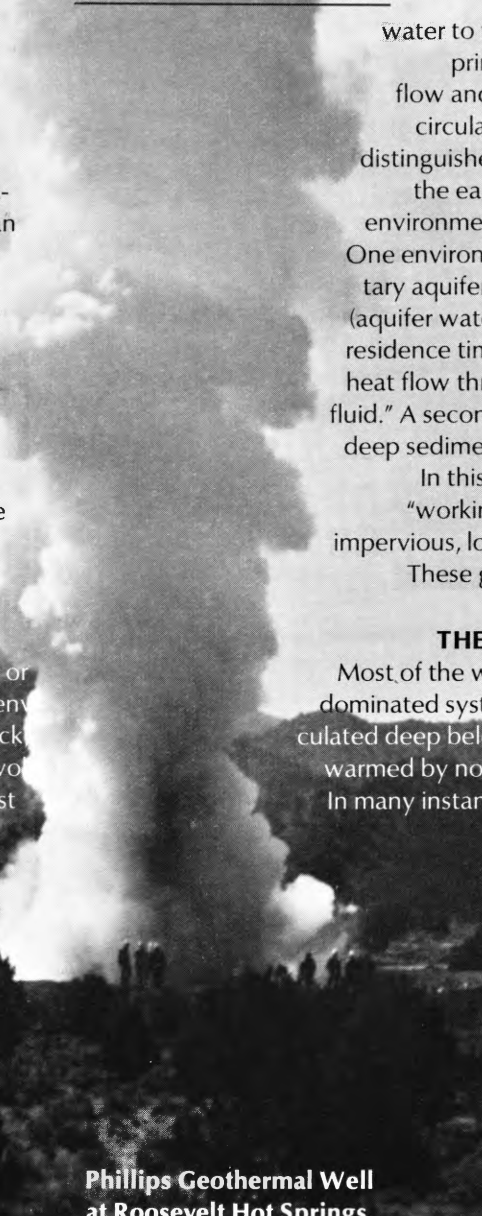
# GEOTHERMAL ENERGY
## Another of Utah's Abundant Resources

By ROBERT H. KLAUK

### INTRODUCTION

Geothermal energy in concentrations that are of economic importance is commonly associated with regions of recent volcanic activity and current earthquakes. Both conditions exist in western Utah. Geothermal energy "systems" can be classified on the basis of geological, hydrological, and heat transfer characteristics with the term "geothermal resource" being applied to systems in which the heat of the earth is concentrated to the extent that it can be extracted and put to beneficial use. Sources of heat for these systems involve volcanic activity, cooling igneous intrusion or heat generated by the radioactive decay of anomalous concentrations of $U^{238}$, $U^{235}$, $Th^{232}$, $K^{40}$, as well as the normal geothermal gradient.

Geothermal systems can be convective or conductive, depending on their geologic environments and heat transfer regimes (Ryback 1981). Convective geothermal systems involve the circulation of fluids which transfer most of the heat. Generally, two types of environments are conducive to convective systems. One environment involves young, shallow, magmatic intrusions with circulation of fluids through hot, highly permeable materials surrounding the intrusion. A second environment involves deep circulation of meteoric water in regions with moderate to high conductive heat flow. These systems require fault and/or fracture zones with permeabilities great enough to allow water to flow. The temperatures attained depend primarily on the magnitude of regional heat flow and the depth to which the meteoric water circulates. Conductive geothermal systems are distinguished by heat transferred from depth within the earth by thermal conduction. Two types of environments are conducive to this type of system. One environment involves deep, extensive sedimentary aquifers with high porosity. The "working fluid" (aquifer water) increases in temperature as a result of residence time within the aquifer and the conductive heat flow through the aquifer rocks and the "working fluid." A second environment which is a special case of deep sedimentary aquifers is geopressured reservoirs. In this system, according to Ryback (1981), the "working fluid" is under artesian pressure due to impervious, low conductivity shales above and below. These geopressured zones represent heat traps.



Phillips Geothermal Well at Roosevelt Hot Springs.

### THERMAL WATERS IN UTAH

Most of the warm water in Utah is part of convection-dominated systems; that is, meteoric water that has circulated deep below the surface of the earth and has been warmed by normal or slightly elevated subsurface heat. In many instances, this water recirculates to or near the

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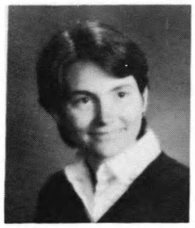

# FROM THE DIRECTOR'S DESK

## LEGISLATURE UPDATE

The 1983 General Session of the Utah state legislature has adjourned and the lesiglators have gone home. Two of their actions will significantly impact the UGMS.

**House Bill 297.** Alarik Myrin (R, Duchesne) sponsored this piece of legislation on behalf of the UGMS and the UGMS Board. The bill's innocuous title "Geological and Mineral Survey Amendments," the ease with which it unanimously passed both houses, and the lack of any news coverage on it disguised the importance of this piece of legislation. The act makes it possible for the UGMS to maintain, as confidential, certain types of information it receives from a variety of sources.

Presently, the UGMS cannot guarantee to maintain, as confidential, information given voluntarily by private industry. This information includes drilling data collected by industry in areas where the UGMS is also performing studies. The UGMS uses this information to corroborate its geologists' conclusions, and includes it in generalizations concerning the mineral resources (their continuity, value, chemistry, etc.). However, donors are reluctant to share specific site, mine and exploration information without the guarantee of its confidentiality.

The federal government has not been willing to share much of the geologic information they collect on public lands with the UGMS. Government representatives have consistently refused to share this information, in spite of the assurance of state/federal partnership and the need of the state to have this information in making leasing decisions. Lawyers for the federal government have advised the state that the UGMS statute has not guaranteed confidentiality and, hence, that the data should not be shared.

The UGMS Board has the authority to implement the act and promulgate criteria under which the UGMS may maintain confidentiality. The new language specifically states that information will be maintained at the level of confidentiality assigned to it by the donor. This act will not change the UGMS policy of disseminating, as public information, all geologic findings and interpretation of UGMS studies.

It may be optimistic to think that the federal government will share its drilling information on public lands, or that it will become a common practice for industry to share its information with the UGMS, but at least the UGMS will be in a better position to acquire geologic information at virtually no cost to the taxpayer. This information can greatly enhance the UGMS's inventories of Utah's resources and our understanding of the state's geologic hazards.

**Geologic Mapping Project.** The legislature's appropriations committee has authorized UGMS to embark upon a new program to map the geology of ten 7.5-minute quadrangles per year. This new program will require four additional geologists on the UGMS staff as well as a draftsman. UGMS geologists will map five of the ten quadrangles and non-UGMS staff will be contracted for the remaining five. It is anticipated that most of the outside contracting work will be done as cooperatives with the USGS. There will be additional information forthcoming on this project in future issues of *Survey Notes*.

In conclusion, the 1983 General Session invested heavily in the UGMS and we, at the UGMS, intend to show that their investment in basic data collection is a wise one. The UGMS will be able to accept confidential information as early as May, and the geologic mapping project will begin on July 1, 1983.■

Genevieve Atwood

## NEW PUBLICATIONS

**From UGMS:**

- Map 53-B, **Surface-water resources of the northern Wasatch Front, Utah,** by Don Price and L. J. Jensen, scale 1:100,000, two sheets, 24" x 36", multi-color (sheet 1 contains map; sheet 2 contains hydrographs, table and explanatory text); $4.00/set over-the-counter.
- Map 54-B. **Surface-water resources of the central Wasatch Front, Utah,** by Don Price and L. J. Jensen, scale 1:100,000, two sheets, 24" x 36", multi-color (sheet 1 contains map; sheet 2 contains hydrographs, table and explanatory text); $4.00/set over-the-counter.
- Map 55-B. **Surface-water resources of the southern Wasatch Front, Utah,** by Don Price and L. J. Jensen, scale 1:100,000, two sheets, 24"x36", multi-color (sheet 1 contains map; sheet 2 contains hydrographs, table and explanatory text); $4.00/set over-the-counter.
- Map 54-A, **Geologic map of the central Wasatch Front, Utah,** compiled by Fitzhugh Davis, May 1983, scale 1:100,000, two sheets, 25" x 36", full color (sheet 1 contains map; sheet 2 contains explanation, map index and explanatory text), printed on durable Texoprint stock; $5.00/set over-the-counter.
- Map 55-A, **Geologic map of the southern Wasatch Front, Utah,** compiled by Fitzhugh Davis, April 1983, scale 1:100,000, 2 sheets, 25" x 36", full color (sheet 1 contains map; sheet 2 contains explanation, map index and explanatory text), printed on durable Texoprint stock; $5.00/set over-the- counter.
- Map 68, **Energy resources map of Utah,** compiled by the UGMS Geologic Staff and Illustrations Section, May 1983, scale 1:500,000, 39" x 54½", full color; $6.00 over-the-counter (includes tube).
- **Geologic excursions in the Overthrust Belt and metamorphic core complexes of the Intermountain Region,** Geological Society of America Guidebook - Part I, edited Klaus D. Gurgel, UGMS Special Studies 59, May 1983, 160 p., numerous figs. and tables; $10.00 over-the-counter.

- **Geologic excursions in stratigraphy and tectonics from southeastern Idaho to the southern Inyo Mountains, California, via Canyonlands and Arches National Parks, Utah,** Geological Society of America Guidebook - Part II, edited by Klaus D. Gurgel, UGMS Special Studies 60, May 1983, 92 p., numerous figs. and tables.; $10.00 over-the-counter.
- **Geologic excursions in volcanology: eastern Snake River Plain (Idaho) and southwestern Utah,** Geological Society of America Guidebook - Part III, edited by Klaus D. Gurgel, UGMS Special Studies 61, May 1983, 55 p., numerous figs. and tables; $10.00 over-the-counter.
- **Geologic excursions in neotectonics and engineering geology in Utah,** Geological Society of America Guidebook - Part IV, edited by Klaus D. Gurgel, UGMS Special Studies 62, May 1983, 109 p., numerous figs. and tables; $10.00 over-the-counter.

**From UGA:**

- **Programs and abstracts for the UGA 1982 symposium on the Overthrust Belt of Utah,** edited by T. L. Britt, UGA Publication 11, 1982, 19 p.; $2.00 over-the-counter.

**Orders must be pre-paid.** Postage rates: Orders less than $10.00, add $1.50; $10.00 - $24.99, add $3.00; $25.00 - $100.00, add $5.00; more than $100.00, add $10.00; add $1.50 for tube for rolled map (maximum of four map sheets per tube).

## BOOK REVIEWS

***Handbook of Geothermal Energy,*** edited by L. M. Edwards et al., 1983, 588 pages, figures, tables, glossary, index, cloth; $69.95 plus $1.50 for postage from Gulf Publishing Co., P.O. Box 2608, Dept. 16, Houston, TX 77001

The *Handbook of Geothermal Energy* provides an excellent overview of the geothermal energy field. The book provides information about exploration, drilling, completion, reservoir engineering, production and economics. Chapters by ten outstanding geothermal scientists summarize world-wide geothermal development and also provide valuable and complete information on U.S. exploration and production.

*R. H. Klauk*

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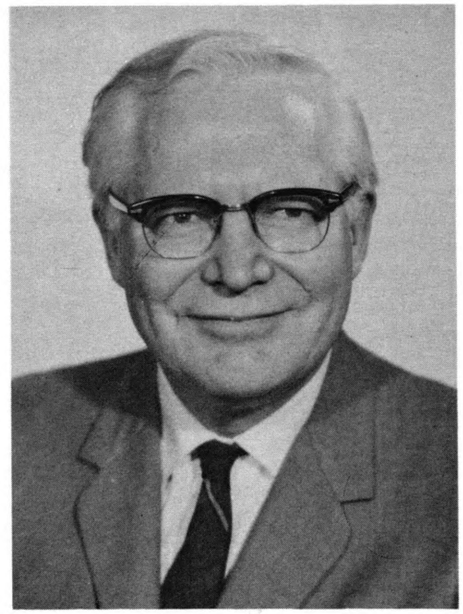
# LOOKING BACKWARD

**By Wm. LEE STOKES**



Wm. Lee Stokes

### GEOLOGY WITH AND WITHOUT THRUST FAULTS

The northern termination of the Arapien Basin in central Utah coincides with the south end of the Wasatch Range. The transition zone was studied by A. J. Eardley in the early 1930s. Here, on the southern side of Mt. Nebo, he found clear evidence of a great displacement which he called the Nebo thrust. Hanging wall, foot wall, and thrust plane are well exposed. In the late 1930s, A. A. Baker found and mapped the northern segment of the fault trace and the structure became the Charleston-Nebo thrust. Another exposure of the trace is exposed just north of the Strawberry Reservoir; this segment is now being referred to as the Strawberry thrust. Clearly, a better name than Nebo-Strawberry-Charleston thrust is needed. The concept of thrust faulting came gradually to dominate geologic thinking about the Wasatch, but the influence of previous interpretations had to be overcome. The 40th Parallel Survey geologists, working in the 1870s, mapped their entire 1200-mile long traverse without finding or needing thrust faults. I calculate they crossed at least 18 significant thrust faults in their traverse from the Front Range to the Sierras.

What are some of the consequences of this blissful ignorance? How, for instance, did pioneer geologists map the sliced-up front of the Wasatch Range near Ogden? Here, the exposed section begins with a clean quartzite now called Brigham. Upon this is a carbonate fine-clastic section with Cambrian fossils followed by a thinner unfossiliferous quartzite. We now know that the upper quartzite is in a thrust slice detached from the thicker Brigham below. But the original interpretation, based on simple superposition, was that it is an independent formation. It was named, and entered the literature as the Ogden Quartzite. Taking this section as a standard, geologists of the 40th Parallel trecked westward and found what they took to be Ogden Quartzite in many ranges. What they mapped as the Ogden is now known as the Swan Peak or Eureka Quartzite of Ordovician age. There is no Ordovician in the Wasatch Front south of Ogden. Elliot Blackwelder discovered this and gave a revised and correct interpretation of the stratigraphy and the structure in 1910.

Failure to recognize thrust faults created difficulities, even impossible situations, with thickness figures, measured sections, and paleogeographic maps of the west. Consider the geology of the Frisco district, Beaver County, mapped by B. S. Butler and described in U.S. Geological Survey Professional Paper 80. The impressive mass of quartzite consituting the northern crest of the range rests on Ordovician limestone and is a remnant of a great thrust plate of Precambrian Prospect Mountain Quartzite. But Butler, believing in strict stratigraphic succession, mapped it as Silurian and named it the Morehouse Quartzite. I recall seeing a paleogeographic map of the Silurian of the

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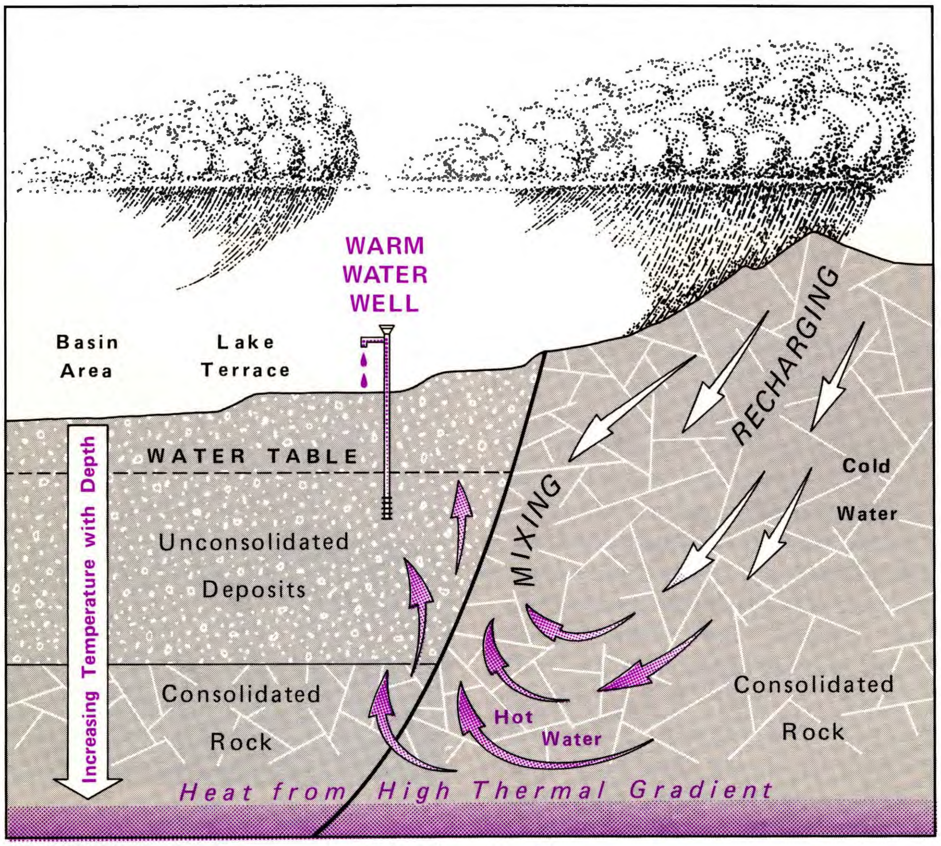


Figure 1. Diagram depicting a general model of the origin of low to moderate temperature geothermal water in Utah.

(Continued from Page 1)

surface through permeable conduits, such as fault zones. Figure 1 depicts this model. In some areas, such as Roosevelt Hot Springs, Cove Fort-Sulphurdale, and possibly Crater (Abram) Hot Springs, the convective heating may result from a "still-hot" intrusive body. In such cases, meteoric water does not have to travel to relatively deep depths to become heated.

The Geothermal Resources of Utah map (Murphy, 1980) identifies 327 thermal wells and springs in Utah with temperatures greater than 50°F. 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. KGRAs are defined either by geologic criteria or competitive interest. Utah has nine such areas (Figure 2). Also designated are areas of significant lateral extent, favorable for discovery and development of water less than 194°F. The following is a brief discussion about geothermal areas in Utah that have, or possibly have, commercial power generation potential.

**Roosevelt KGRA**

Roosevelt Hot Springs KGRA is located in Beaver County, Utah on the western flank of the Mineral Mountains (Figure 2). The geothermal system at Roosevelt Hot Springs is a structurally controlled hot water system; four major faults have been described in this area by Nielson and others (1978). Surface manifestations of this system include zones of hydrothermal alteration, opaline and chalcedonic sinter deposits, and thermal springs that flowed as recently as 1957 (Murphy, 1980). At depth, this reservoir consists of faulted Tertiary intrusive and metamorphic rocks (Nielson and others, 1978). Temperatures as high as 509°F have been recorded.

Phillips Petroleum has developed four wells at Roosevelt Hot Springs to supply a generating plant for Utah Power and Light (UP&L). UP&L is presently investigating whether to develop the geothermal power resource by conventional methods, a new method presently being tested, or a combination of both. The facility, when it does go into operation (presently scheduled for the spring of 1984), will be the first commercial geothermal electrical generating plant outside of California.

**Cove Fort - Sulphurdale KGRA**

Cove Fort - Sulphurdale KGRA is located near the junction of the Pavant Range and the Tushar Mountains in parts of Beaver and Millard Counties (Figure 1). The geothermal system at Cove Fort - Sulphurdale KGRA is structurally controlled by normal faults (Moore and Samberg, 1979).

Surface manifestations of this system consist of numerous hydrogen sulphide seeps, native sulphur deposits, and altered alluvium and bedrock, with the reservoir consisting of fractured limestones, dolomites, and intrusive igneous rocks (Murphy, 1980). Reservoir temperatures of 345°F have been recorded, with the heat source possibly being related to recent basaltic volcanism (Murphy, 1980). Cove Fort-Sulphurdale appears, at this time, to have the second greatest potential for commercial electrical power generation in Utah.

**Whirlwind Valley Area Geothermal Prospect**

Phillips Petroleum Company has conducted gradient hole drilling in an area approximately 14 miles wide and 20 miles long nearly centered on Whirlwind Valley in western Utah. Initial exploration indicate this area has potential as a possible commercial power generation resource, and further exploration is being conducted.

## USES FOR LOW TEMPERATURE THERMAL WATER

Electrical power generation excluded (temperatures greater than 392°F), thermal water uses can be divided into three general categories: domestic; agricultural; industrial; (Goode, 1978). It should be noted that specific uses within each of these categories depend on the suitable chemical composition of the water. Some common uses and the minimum temperatures needed (in degrees Fahrenheit) are shown in Table 1:

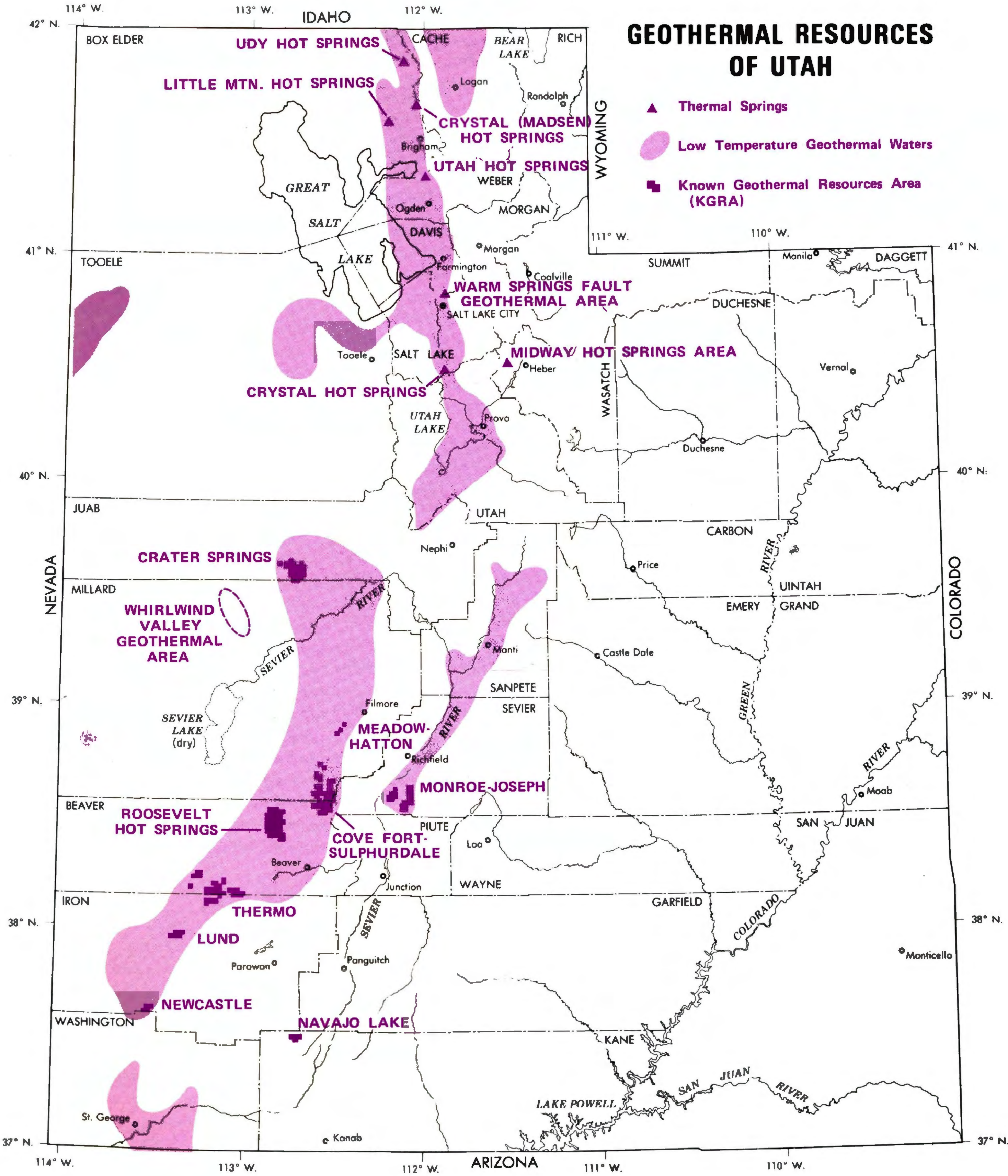
GEOTHERMAL RESOURCES
OF UTAH
Thermal Springs
Low Temperature Geothermal Waters
Known Geothermal Resources Area (KGRA)
UDY HOT SPRINGS
LITTLE MTN. HOT SPRINGS
CRYSTAL (MADSEN) HOT SPRINGS
UTAH HOT SPRINGS
WARM SPRINGS FAULT GEOTHERMAL AREA
MIDWAY HOT SPRINGS AREA
CRYSTAL HOT SPRINGS
CRATER SPRINGS
WHIRLWIND VALLEY GEOTHERMAL AREA
MEADOW-HATTON
MONROE-JOSEPH
ROOSEVELT HOT SPRINGS
COVE FORT-SULPHURDALE
THERMO
LUND
NEWCASTLE
NAVAJO LAKE
IDAHO
WYOMING
NEVADA
COLORADO
ARIZONA
BOX ELDER
CACHE
RICH
WEBER
MORGAN
DAVIS
TOOELE
SALT LAKE
SUMMIT
DAGGETT
DUCHESNE
UINTAH
WASATCH
UTAH
JUAB
CARBON
MILLARD
EMERY
GRAND
SANPETE
SEVIER
BEAVER
PIUTE
WAYNE
IRON
GARFIELD
SAN JUAN
WASHINGTON
KANE
GREAT SALT LAKE
UTAH LAKE
BEAR LAKE
SEVIER LAKE (dry)
LAKE POWELL
SEVIER RIVER
GREEN RIVER
COLORADO
SAN JUAN RIVER
Logan
Randolph
Brigham
Ogden
Morgan
Farmington
Coalville
SALT LAKE CITY
Tooele
Heber
Provo
Manila
Vernal
Duchesne
Nephi
Price
Manti
Castle Dale
Filmore
Richfield
Moab
Loa
Beaver
Junction
Parowan
Panguitch
Monticello
St. George
Kanab
114° W.
113° W.
112° W.
111° W.
110° W.
42° N.
41° N.
40° N.
39° N.
38° N.
37° N.

Figure 2.

## UTAH GEOLOGICAL AND MINERAL SURVEY LOW TEMPERATURE GEOTHERMAL RESEARCH

The Utah Geological and Mineral Survey (UGMS) has been, and is now, conducting 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 (DOE/GRE) contract DE-AS07-77ET 28393 (originally EG-77-S-07-1679) since July 1, 1977. In addition to the aforementioned map of Geothermal Resources of Utah (Murphy, 1980), a number of other publications have been completed. "Thermal Waters of Utah" by Goode (1978) depicts 16 areas in western and central Utah that yield slightly warm (60° to 67°F), warm (67.1° to 94°F), or hot (94.1°F and above) water. Also included are tables that disclose records of approximately 1500 wells and springs with temperatures greater than 60°F. These records include location, ownership, temperature, yield, depth (of wells), geologic unit, and chemical analysis.

The UGMS has also conducted investigations at Udy (Belmont) Hot Springs, Crystal (Madsen) Hot Springs, Utah Hot Springs, Little Mountain-south geothermal area, Warm Springs fault geothermal area, Crystal Hot Springs and the Midway geothermal system (Figure 2). These areas were studied because of their proximity to metropolitan areas, with people and industry as potential users. These investigations provided more 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 studied, 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 is transported 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. Depth of descent, rate of ascent, and degree of mixing with non-thermal water are the main factors influencing the temperature of fluids observed. The source of warmed water for the Midway geothermal area is not fully understood at this time (Kohler, 1979).

**Table 1. Minimum temperatures and some common uses in geothermal energy.**

| Domestic (°F) | Agricultural (°F) | Industrial (°F) |
|---|---|---|
| Heating swimming pools- 86° | Fish farming- 68° | Space heating- 59°-77° (with pumps) |
| Therapeutic bathing- 104° | Soil Warming- 86° | All-year mining- 86° |
| Home hot-water- 194° | Greenhouse- 122° | Deicing- 86° |
| Public hot-water supplies at campgrounds, resorts, etc.- 203° | Protein extraction from plants- 122° | Space heating- 140°-194° (optimum) |
| | Mushroom growing- 122° | Refrigeration- 158° |
| | Animal husbandry- 140° | Drying cement- 230° |
| | Drying produce- 212° | Air conditioning- 230° ($H_2O$+Li+Br system) |
| | | Fresh water by distillation- 230° |
| | | Sugar refining- 230° |
| | | Evaporation of saline solutions- 230° |
| | | Food canning- 284° |
| | | Alumina- 302° |

The UGMS has been conducting surveys in Cache Valley and Escalante Valley as well as in all valleys along the Wasatch Front since 1980. The purpose of these studies is 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) 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.

### Cache Valley

The Cache Valley study is available, free of charge (until the present stock is depleted), at the UGMS, as Report of Investigation No. 170 (deVries, 1982). Results of the investigation indicate three areas have potential for low temperature applications. These areas are: (1) North Logan, with temperatures ranging from 60° to 77°F; (2) Benson, with water temperatures ranging from 56° to 73°F; and (3) Trenton, with water temperatures ranging from 73° to 122°F. Applying mixing models increases this value to as much as 392°F, but temperatures of this magnitude are not considered likely.

### Escalante Valley

The study 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 will be published in July 1983 by the UGMS as Special Studies 63 (Klauk and Gourley, 1983). Thermo Hot Springs is included in the study area and has recorded temperatures ranging from 107° to 172°F. A temperature of 140°F was measured in a very deep (11,998 feet) geothermal test well. The highest water-well temperatures (81° and 82°F) were found in a second area northwest of Zane. Trilinear plots of common ions, as well as Lithium (Li) and Boron (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 northwest of Zane are less than 266°F. 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" the valley. The highest calculated gradient (7.67°F/100 feet) was located less than 1.25 miles from the highest temperature water well (82°F). 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 73°F.

**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 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 129°, 135°, and 143°F, respectively.

Preliminary results from the present study indicate several potential areas for thermal waters. Water temperatures measured, range from 51°F in a well approximately 2 miles southeast of Riverside, to 111°F at Stinking Hot Springs. Several wells and springs in the Penrose - Little Mountain area are slightly warm (62° to 71°F) and are chemically similar to thermal waters at other locations along the Wasatch Front. Temperature-depth profiles measured west of the Cutler Dam, indicate gradients much greater than the normal background for this area although maximum bottom hole temperatures recorded were only 70°F. A temperature of 73°F is reported for Cutler Warm Springs by Goode (1978) in this area but which was not found during the field investigation. Also, a 165°F temperature was reported for a well located in the Chesapeak Gun Club area, south of Little Mountain. This well no longer exists. The final report of this study is scheduled to be available this summer.

**Weber and Davis Counties**

Weber and Davis Counties, have two known 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 132°F. Hooper Hot Springs is located about 10 miles southwest of Ogden on the east shore of the Great Salt Lake in Davis County. A temperature of 134°F has been measured at this spring. Glen 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 158° and 302°F.

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 58° to 68°F (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.

During the months of August and September 1982, 55 water temperatures and chemistry samples were collected from wells and springs in Weber and Davis Counties. Water temperatures, excluding Ogden and Hooper Hot Springs, ranged from 53° to 75°F. With seven of the recorded temperatures being 68°F or greater. Water chemistries have not been analyzed as of this date and no "holes of opportunity" were located which were adequate for logging. The report for this area is scheduled to be completed in late summer.

**Salt Lake County**

Salt Lake County has two geothermal systems classified as low temperature 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 80°F (Clark Warm Springs) to 131°F (Beck Hot Springs).

The other geothermal system (Crystal Hot Springs) was reported on by Murphy and Gwynn (1979a), the Utah Energy Office (December 1981), and Morrison-Kundsen Company, Inc. (September 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 of between 131° and 140°F have been measured at the springs. In contrast, a geothermal production well for the Utah State prison, drilled into the fractured Paleozoic rock, encountered temperatures from 185° to 194°F.

Currently the remainder of Salt Lake County is under investigation for additional geothermal resources that are not manifested at the surface but could be concealed by hundreds to thousands of feet of unconsolidated valley sediments. The investigation has consisted of measuring water temperatures and collecting samples for chemical analyses from more than 200 wells and springs within the valley. Also temperature-depth profiles were logged in 30 "holes of opportunity." At this stage of the investigation, these indicate that low-temperature geothermal resource potential areas include: (1) the northcentral valley area; (2) the north Oquirrh area; (3) the central valley area; and (4) the Sandy City - Draper area. Gradients calculated for temperature-depth measurements southwest of Herriman are higher than the 2°F/100 feet, generally considered normal for the Basin and Range physiographic province, of which the Salt Lake Valley is a part, and could be indicative of a convective geothermal system in the area.

Concurrent with the above investigation, a gravity survey consisting of 800 gravity stations was conducted in the Salt Lake Valley. This survey was designed to complement two site specific surveys at the Warm Springs fault and Crystal Hot Springs areas and previous work by other investigators. A complete Bouguer gravity map has been completed and the data are currently being modeled to correlate structural interpretations with the indicated warm areas. A report of this investigation is scheduled to be published in late spring or early summer.

**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. The results of the survey indicate the association of (1) Saratoga Hot Springs, Lincoln Point Warm Srings, 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.

Approximately 70 wells and springs were sampled for chemical analysis and their temperatures were recorded. In addition, temperature-depth logs were taken at 16 "holes of opportunity." All of these data are presently being analyzed and, hopefully, will characterize the geothermal systems in Utah County as to areal extent and possible reservoir temperatures.

The structural report is available from UGMS as Report of Investigation no. 179 (Davis and Cook, 1983); it may be obtained free of charge while supplies last. Temperature-depth data and chemistry data are scheduled to be available this summer.

## Utah State Prison Space Heating with Geothermal Heat

In July 1978, the Utah Energy Office submitted a successful proposal to the Department of Energy (DOE) with regard 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; (3) Phase III - construction and inspection of demonstration.

The Utah Geological and Mineral Survey was involved with Tera 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. ■

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# A CONTROVERSIAL DAM AND RESERVOIR: JORDANELLE

**By BRUCE N. KALISER**

The last article in the "Sights on Public Facility Sites" series (Survey Notes, vol. 16, no. 3) concerned itself with dams and reservoirs in general; this article focuses on a project currently in the midst of planning. The Jordanelle Dam and Reservoir is proposed by the U.S. Bureau of Reclamation as an integral part of the Bonneville Unit of the Central Utah Project. The 320,000 acre-foot impoundment is to provide municipal and industrial water to Salt Lake County and northern Utah County. Hydroelectric power, flood control, supplementary irrigation and recreation are supplemental functions of the facility.

Location of the earth structure is proposed on the Provo River about 6 miles north of Heber City, Utah, and about 40 miles southeast of Salt Lake City. The dam is planned as a 295-foot high embankment in the *appraisal design* prepared in 1979. Included in this design are an outlet works with low-level and multilevel intakes, an auxiliary outlet works, a glory hole spillway, and a 10,400-Kw powerplant.

Because of the controversy generated over the Jordanelle site during the last four years, and because of the geologic complexity of the damsite, a three-member consulting panel was convened in Autumn 1982. This damsite consulting panel consisted of an engineering geologist, a seismologist, and an earth embankment dam specialist engineer, and its charge was to address the integrity of the damsite itself. Prior to the formation of the panel, the Utah Geological and Mineral Survey was called upon by the State Engineer and the Governor to evaluate information acquired on the damsite and also on the reservoir site. The UGMS functions in an advisory capacity to these two entities.

Over the course of the exploration phase for this project, comments relevant to the geologic aspects have been made by a consortium of mining interests in the Park City mining district, local citizens of the Heber Valley and environmentalist organizations. The mining consortium volunteered to submit considerable data relevant to the project vicinity and made a presentation to the Governor in early 1981. This material was submitted to the UGMS for evaluation and culminated in a report (Report of Investigation no. 170) which addressed five major areas of concern relevant to both the dam and reservoir sites. Because these concerns are illustrative of those frequently requiring attention for dam and reservoir sites in Utah, they are briefly discussed below.

Geotechnical suitability of the damsite should not be thought of as an all-or-nothing proposition. Every proposed site has some geotechnical constraints. At the Jordanelle site there has been reason to scrutinize the rock quality on the right abutment and the location and characteristics of faulted rock at the damsite. The depth of weathering of rock inside and outside of mineral alteration zones becomes a significant factor at Jordanelle. Landslides are identified in the vicinity of both abutments and their stability, with or without seismic perturbation, is an obvious concern. Surface mapping of the abutments revealed considerable variation of rock dips and strikes. A thermal spring area has been reported in the damsite vicinity. Subsurface exploration has identified a narrow 100-foot deep section of valley fill across the dam axis an abrupt drop in bedrock which is normally at about a 30 foot depth. A near vertical contact with over 300 feet of relief between andesite porphyry and pyroclastics on the right abutment await resolution. In the reservoir basin, shallow slope failures southeast of Keetley Junction have lead to concerns of subaqueous alluvial slope stability.

The seismotectonic regime and related geologic hazards are questions that are most frequently picked up by the media. Faults in both the dam abutment (right) and axis require definition and analysis. The seismic regime of the Wasatch hinterland sub province has not heretofore undergone rigorous treatment and it is now recognized that there is a lack of information on the stress regime in the region as well as in the dam vicinity.

The hydrogeologic regime relative to the Park City mining district's existing and future underground workings is of concern to the mining consortium. Ten mine openings would be inundated by reservoir waters. Evidence suggests that northeast striking faults extend across the reservoir vicinity which could more-or-less act as subsurface "conduits." Still, another factor is the possibility of erosion of tighter early Quaternary valley fill in the reservoir basin and later infilling with higher permeability late Quaternary alluvium which would allow vertical migration of reservoir waters into the deeper subsurface rock aquifers.

**Sights on Public Facility Sites**
*Tenth article in a continuing series*

The economic geology of the project area is far from precisely understood. On the east side of the reservoir basin lies the Elk Horn District in which exploration holes have penetrated to less than 1000 feet. Fissures, veins, and faults controlling economic mineralization may extend on strike northeastward from the Park City District across the reservoir basin. Most recent mine drifting has been eastward towards the reservoir.

The environmental geochemistry of the mineralized areas that will be inundated in the reservoir vicinity poses questions of water quality of the reservoir basin. This problem has not been reported upon.

The UGMS and other concerned entities encouraged the Bureau of Reclamation to contract with independent experts to resolve these and other geotechnical questions. The three-man damsite consulting panel presented its final report to the Bureau and the State in Denver on February 1, 1983. It con-

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## UGMS Bulletin Series Now Available on Microfiche

All of the UGMS bulletins are now available on "fiche," including those long out of print. Among bulletins still in demand but for some time unavailable except in libraries are:

Bibliography of Utah Geology to December 31, 1950, Bulletin 40 ($3.50).
Geology of Salt Lake County, 1964, Bulletin 69 ($2.50).
Geology of Washington County, 1960, Bulletin 70 ($2.50).
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Geology of Deep Creek Mountains, 1966, Bulletin 77 ($2.50).
Mineralization of the Gold Hill mining district, 1970, Bulletin 83 ($1.50).
Mineral Deposits of the Deep Creek Mountains, 1973, Bulletin 99 ($2.50).
Mineral Resources of Piute County, 1973, Bulletin 102 ($3.50).
Allosaurus Fragilis: a revised Osteology, 1976, Bulletin 109 ($3.50).

All other bulletins are listed in the latest List of Available Publications (February 15, 1983). Maps on fiche appear in black and white in page-size segments.

The price shown above includes postage. The fiche are available from:

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Telephone (801)581-6832

## BOOK REVIEWS (Cont'd)

***Wellsitting Rocky Mountain Wildcats, revised and enlarged edition, Oil Finding Versus Hole Making,*** by Graham S. Campbell, 1982, 77 p.; $19.50 from Hart Publications, Inc., Book Department, P. O. Box 1917, Denver, CO 80201.

This is a revised edition of Graham Campbell's 1978 *Wellsitter's Guide for Rocky Mountain Wildcats,* and takes advantage of the experience of the several dozen $10 to $20 million Rocky Mountain wildcats drilled since then. "Wellsite geology," according to the author, "is the scientific examination and monitoring of subsurface sediments and drilling events, in a manner most likely to result in profitable exploitation of hydrocarbons." Since the petroleum industry commonly hires inexperienced geologists to wellsit, the book is intended, in part, to increase their efficiency and effectiveness, but also has information for those with many years experience. Subjects covered include what well logs are, how to make and interpret them, and how to work with other professionals and with drillers.

*M. R. Smith*

(Continued from Page 3)

United States that attempts to isopach 7000 feet of Silurian in southwestern Utah where actually none exists. Butler mapped no thrusts in the Frisco district, yet in 1919 he was writing about thrust faults in the Wasatch. By then thrust faults were accepted, but not everywhere recognized.

### COMMENTS AND REFERENCES

Geologic results of the pioneer surveys of the west (King, Hayden, and Powell) were published mainly in the 1870s and 1880s. These impressive reports contain no references or descriptions of thrust faulting. Numerous dislocations are shown in cross-sections but are invariably depicted as steeply dipping normal or vertical. The "fault theory" of the origin of the basin ranges was a much debated topic. Later, in the opening decades of the twentieth century, chiefly as a result of more detailed mapping, thrust faults could no longer be denied. Boutwell (Journal of Geology, vol. 15, 1907) discovered thrust faults in the Park City district; Gale and Richards (U.S. Geological Survey Bulletin 430) found extensive thrusts in southeastern Idaho. Blackwelder (Geological Society of America, vol. 21, 1910) was the first to recognize the extent of thrusting in the northern Wasatch. He named the Willard thrust and postulated its possible connection with the Bannock thrust in Idaho. Hintze (NYAS Annual, vol. 13, 1925) found thrusts in the central Wasatch Mountains but Schneider (Journal of Geology, vol. 33, 1923) in a general review of the range scarcely mentions them. Even Gilbert makes no reference to the reverse faults in his classic study of basin-range structure (U.S. Geological Survey Professional Paper 153, 1928). Writers of the *Ore Deposits of Utah* (U.S. Geological Survey Professional Paper 111, 1920) devote one short paragraph to "reverse and overthrust faults" and mention none by name. Eardley's doctoral dissertation describing the Nebo thrust was published in 1933 in the Proceedings by the Michigan Academy of Sciences. During his subsequent career he mapped many thrusts from Nevada to Montana.

In 1938 Baker began to unravel the details of Wasatch Range geology and emphasized the importance of thrusting near Provo (10th Annual Intermountain Association of Petroleum Geologists Guidebook). In the same publication Bissell connected the exposed traces to outline the Wasatch Mountain Allochthon. The mirror image Cache Valley Allochthon of the northern Wasatch is now firmly established. The surface traces of the great thrust planes which had been detected by routine mapping hinted at immense dislocations beneath the entire Basin and Range Province. Only now, a full century later than the pioneer surveys, with the application of deep seismic soundings, are these being traced. Apparently, little, if any, of the Basin and Range has not been translated eastward. What lies below the thrust planes is now the exciting frontier. ■

Editor's Note: In 1982, the Utah Geological Association sponsored a symposium and field conference on the Overthrust Belt of Utah. The guidebook for the symposium (UGA Publication 10 available through the UGMS) was dedicated to Dr. Wm. Lee Stokes who presented the keynote symposium address. In the address, entitled "Who's Fault Is This," Dr. Stokes reviewed some of the early geologic studies in Utah and the people who made them. Future issues of *Survey Notes* will contain excerpts from his address.

# ANNUAL INDEX

## *SURVEY NOTES, VOLUME 16, 1982*

## NEW UGMS STAFF

**Ray Kerns** joined the UGMS staff in January as chief of the Petroleum Section. He has a diversified background including teaching, research, mineral exploration, petroleum exploration, and two years with the State Geological Survey of Oklahoma.

Ray received a B.S. degree in geology from Waynesburg College, Pennsylvania; he earned his M.A. degree in geology from Southern Illinois University, and received a Ph.D. in geology from the University of Oklahoma.

Previous professional activities have included petroleum and mineral exploration in Utah, Wyoming, Idaho, Montana, New Mexico, Colorado, Washington, Oregon, and Oklahoma. Ray also taught petrology, clay mineralogy, x-ray mineralogy, and geochemistry at Utah State University from 1967-74.

The petroleum section at the UGMS is responsible for compiling information on the petroleum industry and geology of the state of Utah, organizing this information into reports, and disseminating these reports to he public. The survey has established a tradition of response to questions from the public, in general, as well as industry in particular. As chief of the petroleum section, Ray intends to carry on this tradition and invites inquiries from all persons interested in Utah petroleum information. ■

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cluded that a safe dam could be built at the proposed Jordanelle site. These conclusions were based on knowledge available at present and the panel recommended several additional specific studies. The panel also concluded that a design fault displacement of 3 meters (over 9 feet) might be requisite for faults intercepting the axis of the structure.

To evaluate the potential reservoir effects on the local hydrogeologic regime, the Bureau contracted with another private entity. In January 1982, a copy of their preliminary report was furnished to the state and the UGMS. Additional aquifer testing, however, will be required this summer to resolve the larger questions.

It is clear that the Jordanelle Project is one in which geoscience and geotechnical elements are so complex and numerous that an easy grasp of all of them is difficult. Only during late stages of site work will answers to many of the above addressed questions be forthcoming. ■

**UTAH GEOLOGICAL AND MINERAL SURVEY**
***Survey Notes***

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