Review of Selected Geothermal Areas in Southwestern Utah

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ABSTRACT

The Sevier thermal area extends across portions of five counties in southwestern Utah and contains most of the state's identified high- and moderate-temperature geothermal systems. A few of these identified systems have been significantly explored and developed in the past while others have not. Several of the areas that remain undeveloped possess potential for future power generation, agribusiness, or industrial processing and are reviewed here to highlight either new or previously obscure resource information. Areas reviewed here include (1) the Drum and Little Drum Mountains near the Juab-Millard County line, (2) the nearby Crater Springs KGRA associated with Abraham Hot Springs and the Fumarole Butte Quaternary eruptive center, (3) the Meadow-Hatton geothermal area with its associated large travertine mound in the southern part of the Black Rock Desert, (4) the Neels railroad siding well in the western part of the Black Rock Desert, (5) the Thermo Hot Springs geothermal area near the Beaver-Iron County line, and (6) the Beryl-Wood's Ranch area of the southwestern Escalante Desert.

Introduction

Mabey and Budding (1987) proposed the name "Sevier thermal area" for a region of southwestern Utah where all of the state's known moderate- and high-temperature (>90°C [>194°F]) hydrothermal systems occur. The Sevier thermal area (STA) covers a portion of the eastern Basin and Range Physiographic Province, and part of the Basin and Range-Colorado Plateau (B&R-CP) transition zone (Figure 1). The Cenozoic geology of this region, which encompasses all of the Sevier, Black Rock, and Escalante Deserts of southwestern Utah, includes (1) abundant late Cenozoic normal faults, (2) Tertiary plutonic and volcanic rocks and Quaternary basalt and rhyolite, (3) high regional heat flow, (4) a complex structural history, and (5) zones of active seismicity (Smith and Sbar, 1974).

The STA is centered around the Roosevelt Hot Springs and Cove Fort-Sulphurdale Known Geothermal Resource Areas (KGRAs) where geothermal power development in Utah began

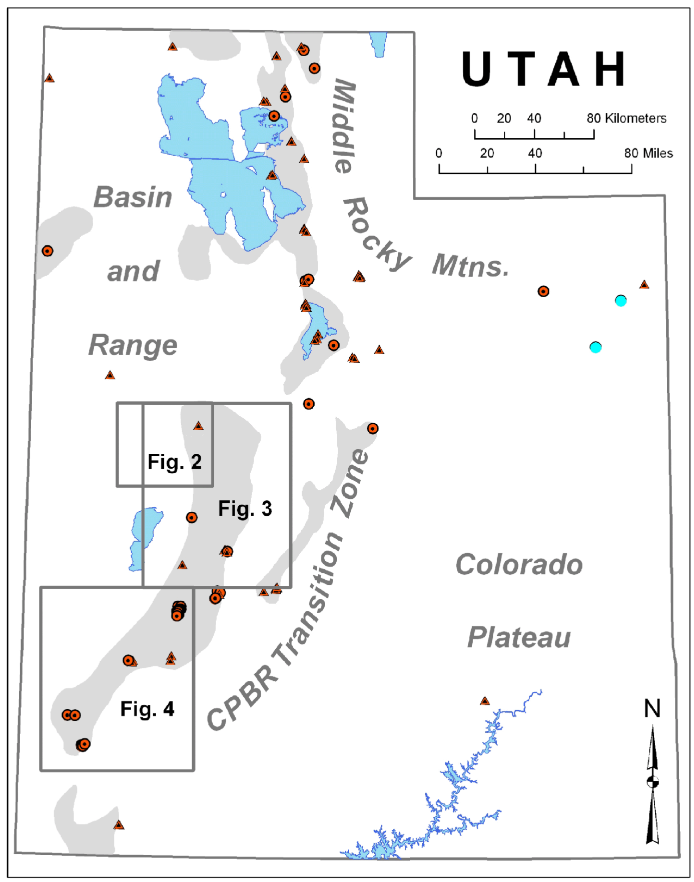

Figure 1. Geothermal areas and physiographic regions in Utah. Symbols denote locations of major thermal wells (circles) and springs (triangles). Shaded regions denote areas favorable for the discovery of low-temperature geothermal water. The outlines of figures 2, 3, and 4 are also shown.

more than 20 years ago and continues today. Other geothermal developments in the region include a hot spring resort at the Monroe-Red Hill area and commercial greenhouses at Newcastle. Known geothermal areas that have remained essentially undeveloped include the Abraham (Crater Springs) Hot Springs area, the Meadow-Hatton area, and the Thermo Hot Springs area. Other areas with development potential that have been explored in the past, but lack identified resources, are the Drum Mountains-Whirlwind Valley area near the Millard-Juab County line and the Beryl area in western Iron County. Please note that the well-known geothermal areas at Roosevelt Hot Springs, Cove Fort-Sulphurdale, Monroe-Joseph, and Newcastle are not included in this review. These areas have undergone geothermal exploration and development and are adequately addressed elsewhere (see Blackett and Shubat, 1992; Forrest, 1994; Huttrer, 1994; Mabey and Budding, 1987; Moore and Nielson, 1994; Ross and Moore, 1985; and Ross and others, 1982;).

Sevier and Black Rock Deserts

Drum Mountains-Whirlwind Valley

The Drum Mountains geothermal prospect is located roughly 64 km (40 mi) northwest of the town of Delta, Utah, near the head of the Whirlwind Valley (Figure 2) and includes parts of the Drum and Little Drum Mountains. The Crater Springs geothermal area (described in more detail below) lies about 24 km (15 mi) to the east. It is not clear if the prospect was originally explored for minerals development, but it is evident that exploration interests eventually collected temperature-depth data from shallow boreholes during the 1970s and 1980s. The Little Drum Mountains consist of Eocene-Oligocene intermediate composition volcanic rocks associated with a deeply eroded volcano complex. To the west lie the Swasey Mountains and the House Range consisting of Cambrian carbonate, quartzite, and shale. The Drum Mountains, to the east, also consist mainly of Cambrian carbonate and quartzite, in addition to Precambrian quartzite.

Rowley (1998) described broad east-west transverse zones and related Cenozoic igneous belts in the Great Basin that include numerous geologic structures, igneous centers, mineralized districts, and hot springs that appear related in space and time. The Drum Mountains area lies within the Ely-Tintic igneous belt, and near the Payson and Sand Pass transverse zones. Later overprinting of Basin and Range faulting produced the north-south oriented Drum Mountains fault zone (DMFZ, see Figures 2 and 3).

Sass and others (1999) presented summaries of exploratory drill-hole data for the Drum Mountain area, acquired by the U.S. Geological Survey, from companies (Amax and Phillips) that explored the region during the 1970s and early 1980s. The Geothermal Laboratory at Southern Methodist University made these data available through the Internet (Blackwell and others, 1999). Boreholes in this area vary in depth generally from 96 to 153 m (315 to 502 ft). One borehole was completed to a depth of 372 m (1220 ft). The highest bottom-hole temperature was 70°C (158°F) at a depth of 150 m (492 ft) measured in a borehole near the east edge of the Whirlwind Valley along the west side of the Little Drum Mountains (Blackett, 2004). Beyond these data, no identified moderate-high temperature geothermal system has been publicly reported. The presence of young volcanic rocks, young faults, and geothermal springs nearby, however, suggests that the area may contain geothermal resources.

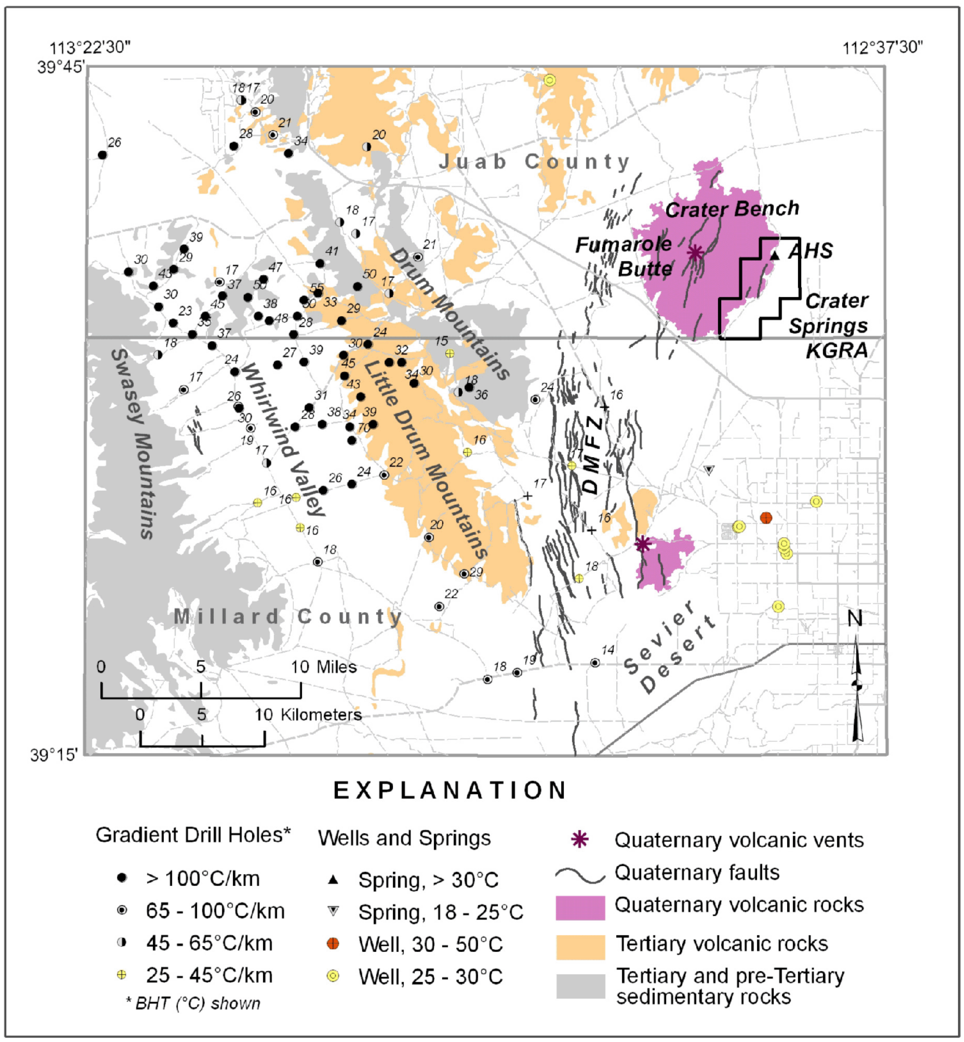

Figure 2. Drum Mountains-Whirlwind Valley geothermal prospect and Crater Springs geothermal area in Juab and Millard Counties, Utah. Locations of thermal gradient boreholes (with bottom-hole temperatures [BHTs] indicated) are shown, along with thermal wells and springs. General geology is also shown. AHS: Abraham Hot Springs. DMFZ: Drum Mountains fault zone. KGRA: known geothermal resource area.

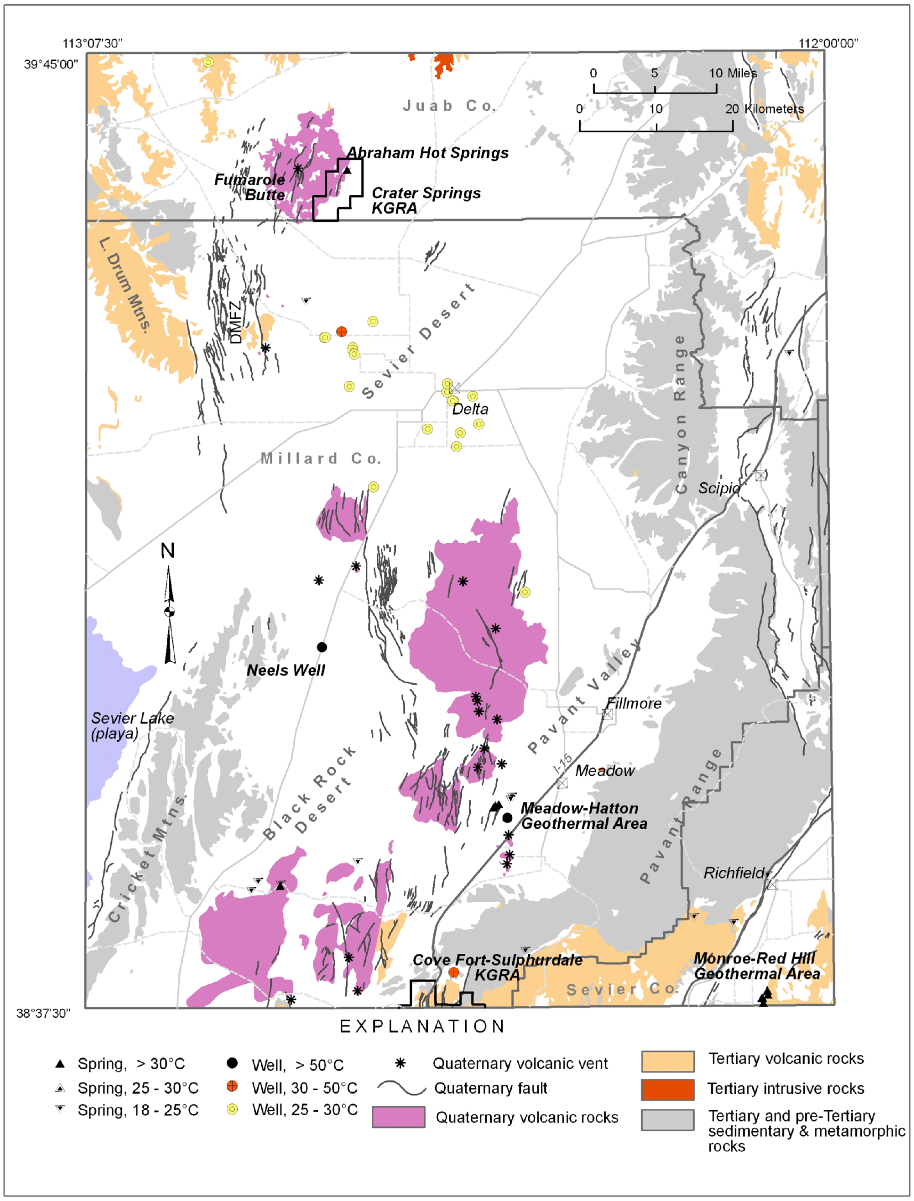

Figure 3. Geothermal areas of the Sevier and Black Rock Deserts of west-central Utah showing locations of thermal wells and springs, and general geology.

Crater Springs Geothermal Area

The Crater Springs geothermal area surrounds a Quaternary eruptive center known as Fumarole Butte in the northern Sevier Desert of Juab County (Figure 2). Early Pleistocene basalt flows (0.9 Ma) erupted from the vent area and formed a broad volcanic apron known as Crater Bench. The DMFZ, a north-northeast-trending zone of high-angle normal faults, offsets basalt flows along the west-central side of Crater Bench at Fumarole Butte. Warm vapor rises from several fissures in the vicinity of Fumarole Butte. Abraham Hot Springs (AHS, see Figure 2), also referred to in literature as "Crater Springs" or "Baker Hot Springs," issues 8 km (5 mi) to the east of Fumarole Butte along the east margin of the Crater Bench basalt flows. Mabey and Budding (1987) postulated that the vapor venting from Fumarole Butte and the thermal waters at AHS are part of the same geothermal system. They also described a gravity high trending north-northwest with the axis passing through AHS, suggesting a possible buried horst block. Rush (1983) suggested the anomaly might be due to higher-density volcanic rocks at depth or hydrothermal mineralization.

Temperatures at AHS range up to 87°C (189°F). Rush (1983) estimated total flow rates from about 40 spring orifices at between 5400 and 8400 L/min (1400 and 2200 gpm), making it one of the most active thermal spring areas in Utah. The geologic structure controlling the system is unknown, and the reservoir temperature is uncertain. Analyses of cold springs that also issue at the site showed that this water is very similar in composition to that of the hot springs, suggesting that the cold springs are merely cooled hot water. The thermal water is sodium calcium-chloride type with TDS ranging from 3590 to 4060 mg/L. Rush (1983) used geothermometry and a silica-enthalpy mixing model of Truesdell and Fournier (1977) to determine that the hot spring water may be 50 percent mixed with non-thermal water, and the temperature of the hot water component could be 140°C (284°F).

Ross and others (1993) performed self-potential (SP) studies at AHS to identify electrical expressions that may relate to fluid flow. Although AHS is expressed as a weak dipolar SP anomaly, a coherent negative anomaly was mapped west of the spring mound, suggesting upward fluid flow beneath Quaternary basalts of Crater Bench.

Meadow-Hatton Area

The Meadow-Hatton geothermal area (Figure 3) consists of a large travertine mound, marshland, and thermal springs located about 16 km (10 mi) southwest of the town of Fillmore on the east side of the Black Rock Desert in Millard County. The Black Rock Desert contains some of the state's youngest volcanic rocks — possibly less than 1000 years old at the Ice Springs basalt flows located a few miles north of the Meadow-Hatton area. Hatton Hot Spring issues from the south end of a large, northeast-trending travertine mound at a temperature of 63°C (145°F). Meadow Hot Springs, comprised of several thermal springs in a northeast alignment and located in a marshy area about 2 km (1.3 mi) northwest of the Hatton travertine mound, issue at temperatures up to 41°C (106°F). Flow rates from the springs are low and vary from 0 to 240 L/min (63 gpm). The spring waters are probably coupled to the regional ground-water flow system of the Pavant Valley and Black Rock Desert (Mabey and Budding, 1987).

Ross and others (1993) described analyses of fluid samples from the Meadow Hot Springs area in conjunction with the results of SP surveys that revealed three sharp, coherent SP lows beneath the southern part of the travertine mound. The largest minimum (-120 mV) occurs 300 m (1000 ft) northeast of Hatton Hot Spring. More recent chemical data show very different values for potassium, silica, and fluoride concentrations compared to earlier data, suggesting temporal variations in spring chemistry. Standard geothermometers range between 205°C (401°F) (Na-K-Ca) and 86°C (187°F) (Na-K-Ca-Mg), with most likely equilibration temperatures around 108°C (226°F) (quartz conductive).

Neels Area

An area northeast of the Cricket Mountains in the northern part of the Black Rock Desert may also be of interest for geothermal exploration. Lee (1908) described events during drilling of a 609 m (2000 ft) water supply well in 1906 near a rail siding called Neels along the then "San Pedro, Los Angeles, and Salt Lake Railroad." During drilling, hot water was encountered at several horizons, and steam apparently vented continually from the well. Reportedly, some oil was encountered, and a pocket of gas was penetrated at a depth of 549 m (1802 ft). The well was eventually abandoned because of drilling difficulties and poor water quality.

An intriguing bit of information was a water analysis on a sample taken from a depth of 426 m (1398 ft) (Lee, 1908). The sample had a TDS content of 3345 parts per million and reported "siliceous matter" (presumably SiO_2) content of 370 parts per million. Silica geothermometers applied to the latter value yield equilibrium temperatures of over 200°C (392°F), suggesting the possibility of a high-temperature reservoir somewhere in the subsurface. Two other water samples taken at horizons both above and below the 426-m (1400-ft) depth yielded more normal values for silica.

In 1980, Cominco American, Inc. completed a deep test well ("2 Beaver River") to a depth of 4021 m (13,193 ft) near the old Neels siding. The well reportedly penetrated an unconformity at 610 m (2000 ft) and Precambrian rocks at 756 m (2480 ft). The well also reportedly penetrated a thrust fault at 2557 m (8390 ft), continued in lower Paleozoic rocks to total depth, and probably bottomed in the Cambrian Tintic Quartzite. Geophysical logs indicate that a bottom hole temperature of 153°C (308°F) was measured five hours after circulation of the drilling mud was stopped. The "2 Beaver River" well was reportedly later plugged back to 180 m (600 ft) and converted to a water supply well (Utah Division of Oil, Gas and Mining well files).

Escalante Desert

Thermo Hot Springs Area

The Thermo Hot Springs geothermal area is located within the northeast part of the Escalante Desert in southern Beaver County (Figure 4). Thermal water discharges from two large spring mounds, consisting primarily of cemented windblown quartz sand and silt, situated near the axial drainage of the Escalante Desert valley. The Shauntie Hills, located to the northwest, and the Black Mountains, located to the southeast, consist largely of volcanic mudflow deposits, mudflow breccias, and lava flows of dacitic and rhyodacitic composition. Rocks in the Black Mountains and the Shauntie Hills probably erupted from separate, although possibly time-equivalent (Miocene, 29 to 19 Ma) stratovolcanos. Rowley (1978) mapped an exposure of rhyolite 3.2 km (2 mi) to the east of the hot spring mounds, for which he obtained a K-Ar age of 10.3 Ma.

Northeast-oriented normal faults that displace Quaternary valley-fill units and form a broad zone of faulting are mapped along the hot spring mounds and elsewhere in the vicinity. Faults mapped within the volcanic units of the low hills southeast of the thermal area, and within the Black Mountains, exhibit a dominant northwest orientation. The orientation of these two sets of structures and the position of the hot springs led Rowley and Lipman (1975) to suggest that a structural intersection localized the geothermal system. Based upon the regional gravity data of Sawyer and Cook (1977) and Cook and others (1981), Mabey and Budding (1987) postulated that a subsurface fault with several hundred feet of displacement (down to the west) passes through the hot springs area.

Mariner and others (1978) reported a temperature of 89.5°C (193.1°F), and discharge rates between 30 and 120 L/min (8 and 32 gpm) at Thermo Hot Springs. Blackett and Ross (1992) reported a much-reduced flow. Klauk and Gourley (1983) reported spring temperatures ranging from 42 to 78°C (108 to 172°F), and the results of water analyses on four spring samples. Klauk and Gourley (1983) indicated that the Thermo water is sodium-calcium chloride-sulfate-bicarbonate in character and enriched in Na, K, and SO_4. They also reported quartz-conductive geothermometer temperatures ranging from 128 to 131°C (262 to 268°F).

Republic Geothermal, Inc. released temperature gradient, geophysical, and geochemical data. The unpublished data package includes information from temperature-gradient boreholes (not shown on Figure 4) and water analyses, as well as production test and temperature data from a deep (2221 m [7288 ft]) exploratory well (TE 57-29 on Figure 4). The distribution of anomalous temperature gradients indicates warmer shallow temperatures in the vicinity of the hot springs. Although most of the thermal gradient holes are shallow and relatively widely spaced, the temperature data indicate that anomalous temperatures may extend eastward several thousand feet from the spring mounds.

Ross and others (1991) performed an SP survey near Thermo Hot Springs to determine the SP expression of the geothermal system. The SP survey covered an area of approximately 10.4 km^2 (4.0 mi^2) and showed no outstanding anomalies across the two spring mounds. A broad, complex SP low, however, occurs in the southeast part of the area near the Minersville road, approximately 1.6 km (1 mi) southeast of the southern mound. The anomaly occurs over alluvium, perhaps 15 m (50 ft) above the level of the valley floor. No deep drilling data or geophysical data are available in the immediate area to give any insight into the probable source of the SP anomaly. The anomaly occurs on the up-thrown side of a mapped, northeast-oriented fault, and the shape of the SP anomaly somewhat mimics the topography of an overlying alluvial fan, suggesting some contribution from fluids within or beneath this fan. Northwest-oriented drainage patterns

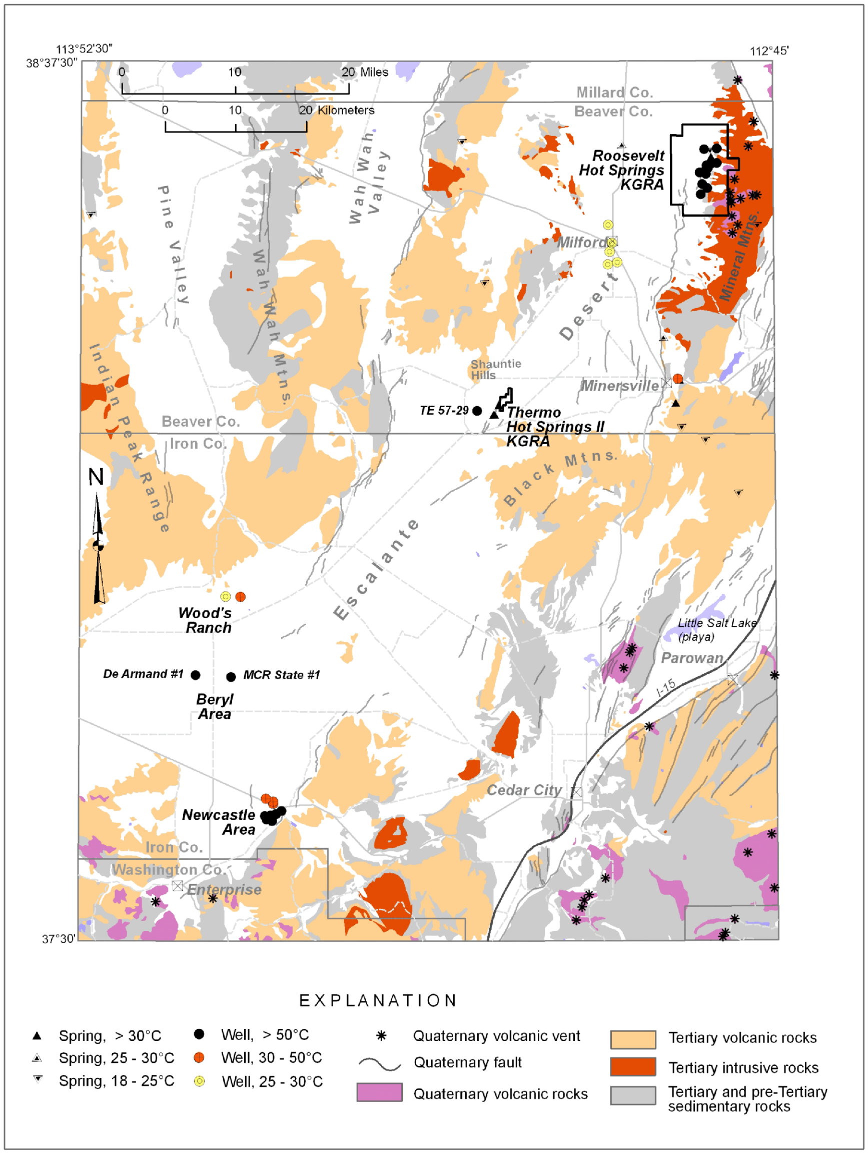

Figure 4. Geothermal areas of the Escalante Desert of southwestern Utah showing locations of thermal wells and springs, and general geology.

and similarly oriented faults mapped in bedrock to the south and southeast suggest the source of the geothermal system (?) could occur at a buried fault intersection.

Beryl-Wood's Ranch Area

The Beryl-Wood's Ranch area is located within the southern Escalante Valley of Iron County, extending south of the Wah Wah and Indian Peak Ranges to the center of the Escalante Valley (Figure 4). Goode (1978) reported a temperature of 149°C (300°F) from a depth of 2134 m (7000 ft) measured within a 3748 m- (12,295 ft-) deep well that he termed "De Armand #1." Goode also reported that, upon testing, the well flowed at a rate of 3785 L/min (1000 gpm) and that the water contained less than 4000 mg/L dissolved solids. No flowing temperature was given.

According to records obtained from Utah Division of Water Rights, three companies—McCulloch Oil Corporation (MCR Geothermal Corp.), Geothermal Kinetics, Inc., and Utah Power & Light Company—formed a partnership to drill and complete a well referred to as "MCO-GKI-UPL-DeArman #1." The well was located in the SW¼SE¼SW¼ section 18, T. 34 S., R. 16 W., and was drilled during the spring of 1976. Documents filed with Water Rights during December 1981 and correspondence dated November 12, 1985, suggest that the well was drilled to a depth of at least 2361 m (7745 ft) and that it did not comply with state-regulated abandonment procedures at that time.

Klauk and Gourley (1983) made no mention of the above-referenced "DeArmand" well, but reported a temperature of 60°C (140°F) measured at a depth of 2461 m (8072 ft) within an unnamed geothermal test well located in the NE¼NE¼NW¼ section 22, T. 34 S., R. 16 W., Salt Lake Base Line and Meridian. This location corresponds to a well reportedly drilled in 1976 by MCR Geothermal Corp., and referred to as "State #1" (letter from Utah Division of Water Rights to Insurance Company of North America, dated November 12, 1985).

Wood's Ranch is located just south of the Wah Wah Mountains and Indian Peak Range in the northwest part of the Escalante Valley in Iron County, roughly 16 km (10 mi) NNW of the DeArmand #1 well (Figure 4). One of two wells, a 61-m- (200-ft-) deep water well drilled for irrigation on the ranch produces 36.5°C (97.7°F) water. No hot springs are present. An SP survey performed at Wood's Ranch (Ross and others, 1991) revealed a broad, negative SP anomaly interpreted as thermal upflow. Beyond the SP survey and one water analysis, the property remains unexplored. Chemical geothermometers suggest reservoir temperatures in the range of 100°C to 115°C (212°F to 239°F). The warm water produced from the well may be a mixture of thermal water and non-thermal ground water from the Escalante Valley aquifer.

Summary

The Sevier thermal area of southwestern Utah, because of its geologic framework and thermal characteristics, is known to contain most of the state's higher quality geothermal systems. With respect to power generation, the known geothermal systems in the region are either undeveloped or under-developed, mostly due to high development costs and risk associated with exploration, and lack of production incentives in the past. For geothermal direct-use projects, most of the systems are remote and pose transportation or access challenges. The six prospective geothermal sites reviewed here probably reflect only a portion of the undeveloped geothermal endowment in the region. Additional exploration, a considerable but necessary up-front investment, will be required to assess the economic viability of these systems. With new utilization technology entering the marketplace and new renewable energy incentives, the market dynamics may be changing in favor of expanded geothermal development in southwestern Utah.

References

Blackett, R.E., 2004. "Geothermal gradient data for Utah, *in* Blackett, R.E., and Wakefield, Sharon, compilers, Geothermal resources of Utah – 2004." Utah Geological Survey Open-File Report 431, CD-ROM.

Blackett, R.E., and H.P. Ross, 1992. "Recent exploration and development of geothermal energy resources in the Escalante Desert region, southwestern Utah, *in* Harty, K.M., editor, 1992, Engineering and environmental geology of southwestern Utah." Utah Geological Association Publication 21, p. 261-279.

Blackett, R.E., and M.A.Shubat, 1992. "A case study of the Newcastle geothermal system, Iron County, Utah." Utah Geological Survey Special Study 81, 30 p.

Blackwell, D.D., M.A. Richards, K.W. Wisian, and J.L.Steele, 1999. "System specific geothermal gradient/heat flow database for the western United States." Geothermal Resources Council Transactions, v. 23, p. 461-466.

Cook, K.L., J.I. Adhidjaja, and S.C. Gabbert, 1981. "Complete Bouguer gravity anomaly and generalized geology map of Richfield lx2 degree quadrangle, Utah." Utah Geological and Mineral Survey Map 59, scale 1:250,000.

Forrest, R.J., 1994. "Geothermal development at Roosevelt Hot Springs geothermal area, Beaver County, Utah 1972 – 1993, *in* Blackett, R.E., and Moore, J.N., editors, 1994, Cenozoic geology and geothermal systems of southwestern Utah." Utah Geological Association Publication 23, p. 37-44.

Goode, H.D., 1978. "Thermal waters of Utah." Utah Geological and Mineral Survey Report of Investigation 129, 183 p.

Huttrer, G.W., 1994. "Geothermal exploration at Cove Fort – Sulphurdale, Utah 1972 – 1992, *in* Blackett, R.E., and Moore, J.N., editors, Cenozoic geology and geothermal systems of southwestern Utah." Utah Geological Association Publication 23, p. 61-80.

Klauk, R.H., and C. Gourley, 1983. "Geothermal assessment of a portion of the Escalante Valley, Utah." Utah Geological and Mineral Survey Special Study 63, 57 p.

Lee, W.T., 1908. "Water resources of Beaver Valley, Utah." U.S. Geological Survey Water-Supply Paper 217, 57 p.

Mabey, D.R., and K.E. Budding, 1987. "High-temperature geothermal resources of Utah." Utah Geological and Mineral Survey Bulletin 123, 64 p.

Mariner, R.H., C.A. Brook, J.R. Swanson, and D.R. Mabey, 1978. "Selected data for hydrothermal convection systems in the United States with estimated temperatures greater than or equal to 90°C." U.S. Geological Survey Open-File Report 78-858, 493 p.

Moore, J.N., and D.L. Nielson, 1994. "An overview of the geology and geochemistry of the Roosevelt hot springs geothermal system, Utah, *in* Blackett, R.E., and Moore, J.N., editors, Cenozoic geology and geothermal systems of southwestern Utah." Utah Geological Association Publication 23, p. 25-36.

Ross, H.P., R.E. Blackett, and M.A. Shubat, 1991. "Exploring for concealed hydrothermal resources using the self-potential method, Escalante Desert, Utah." Geothermal Resources Council Transactions, v. 15, p. 279-287.

Ross, H.P., R.E. Blackett, M.A. Shubat, and R.W. Gloyn, 1993. "Self-potential and fluid chemistry studies of the Meadow-Hatton and Abraham Hot Springs, Utah." Geothermal Resources Council Transactions, v. 17, p. 167-174.

Ross, H.P., and J.N. Moore, 1985. "Geophysical investigations of the Cove Fort-Sulphurdale geothermal system, Utah." Geophysics, v. 50, no. 11, p. 1732-1745.

Ross, H.P., D.L. Nielson, and J.N. Moore, 1982. "Roosevelt hot springs geothermal system, Utah - case study." American Association of Petroleum Geologists Bulletin, v. 66, no. 7, p. 879-902.

Rowley, P.D., 1978. "Geologic map of the Thermo 15-minute quadrangle, Beaver and Iron Counties, Utah." U.S. Geological Survey Map GQ-1493, scale 1:62,500.

---, 1998. "Cenozoic transverse zones and igneous belts in the Great Basin, western United States – their tectonic and economic implications, *in* Faulds, J.E., and Stewart, J.H., editors, Accommodation zones and transfer zones: the regional segmentation of the Basin and Range Province." Geological Society of America Special Paper 323, p. 195-228.

Rowley, P.D., and P.W. Lipman, 1975. "Geological setting of the Thermo KGRA (known geothermal resource area), Beaver County, Utah (abs.)." Geological Society of America Abstracts with Programs, v. 7, no. 7, p. 1254.

Rush, E.F., 1983. "Reconnaissance of the hydrothermal resources of Utah." U.S. Geological Survey Professional Paper 1044-H, 44 p.

Sass, J.H., S.S. Priest, A.J. Blanton, P.C. Sackett, S.L. Welch, and M.A. Walters, 1999. "Geothermal industry temperature profiles from the Great Basin." U.S. Geological Survey Open-File Report 99-425, on-line version 1.0. [http://wrgis.wr.usgs.gov/open-file/of99-425/webmaps/home.html, July 2003].

Sawyer, R.F., and K.L. Cook, 1977." Gravity and ground magnetic surveys of the Thermo Hot Springs KGRA region Beaver County, Utah." University of Utah, Department of Geology and Geophysics Technical Report, v. 77-6, 42 p.

Smith, R.B., and M.L. Sbar, 1974." Contemporary tectonics and seismicity of the western states with an emphasis on the Intermountain seismic belt." Geological Society of America Bulletin, v.85, p. 1205-1218.

Truesdell, A.H., and R.O. Fournier, 1977. "Procedure for estimating the temperature of a hot-water component in a mixed water by using a plot of dissolved silica versus enthalpy." U.S. Geological Survey, Journal of Research, v. 5, p. 49-52.