Geothermal Utah

Geology, Resources and Development in the Beehive State

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Utah comprises parts of three major physiographic provinces (Fenneman, 1931), each with characteristic landforms and geology (Fig. 1). These include the Basin and Range Province, the Middle Rocky Mountains Province, and the Colorado Plateau Province. An overlapping of two of these provinces essentially forms a fourth distinctive physiographic region. The Basin and Range-Colorado Plateau Transition Zone extends through central and southwestern Utah, and contains physiographic and geologic features similar to both the Basin and Range and Colorado Plateau Provinces. The physiographic regions of Utah are also shown in Figure 2.

The Middle Rocky Mountains Province in northeastern Utah consists of mountainous terrain, stream valleys, and alluvial basins. It includes the north-south trending Wasatch Range, comprising mainly pre-Cenozoic sedimentary and Cenozoic silicic plutonic rocks, and the east-west trending Uinta Mountains, comprising mainly Precambrian sedimentary and metamorphic rocks.

The Colorado Plateau is a broad area of regional uplift in southeastern and south-central Utah characterized by essentially flat-lying, Mesozoic and Paleozoic sedimentary rocks. Scattered Tertiary and Quaternary volcanic rocks are present on the western margin of the Colorado Plateau in south-central Utah, and some Tertiary intrusive bodies are present in southeastern Utah. Plateaus, buttes, mesas, and deeply incised canyons exposing flat-lying or gently warped strata distinguish the Colorado Plateau of southeastern Utah. Bedrock units are spectacularly exposed, while surficial deposits are sparse.

The Basin and Range Province is noted for numerous north-south oriented, fault-tilted mountain ranges separated by intervening, broad, sediment filled basins. The mountain ranges are typically 20 to 50 km (12 to 31 mi.) apart, 45 to 80 km (28 to 50 mi.) long and are bounded on one, or sometimes two sides by high-angle, often listric, normal faults. Typical ranges are asymmetric in cross section, having a steep slope on one side and a gentle slope on the other. The steep slope reflects an erosion-modified fault scarp and the range is a tilted fault block (Hintze, 1988). Rocks within the Basin and Range vary widely in age and composition. Older rocks consist mostly of a variety of Mesozoic and Paleozoic sedimentary units and their metamorphic equivalents. Proterozoic-age rocks have limited exposures in the region. Cenozoic volcanic rocks and valley-fill units generally overlie the sedimentary and metamorphic rocks. Valley-fill deposits consist mostly of late Cenozoic lakebeds and alluvium as much as 3,000 m (10,000 ft.) thick.

Figure 1 - Physiographic provinces of Utah (Utah Geological Survey, Open File Report 311, 1994).

The Transition Zone is a broad region in central Utah containing structural and stratigraphic characteristics of both the Basin and Range Province to the west and the Colorado Plateau Province to the east. The boundaries of the Zone are the subject of some disagreement, resulting in various interpretations using different criteria (Stokes, 1988). Essentially, extensional tectonics of the Basin and

Range has been superimposed upon the adjacent coeval uplifted blocks of the Colorado Plateau and Middle Rocky Mountains. The result is that block faulting, the principal feature of the Basin and Range, extends tens of kilometers into the adjacent provinces forming a 100 km- (62 mi.-) wide zone of transitional tectonics, structure, and physiography (Hecker, 1993; Black, et al., 2003).

Late Cenozoic Tectonics in Utah

Comprising essentially the western half of Utah, the Basin and Range Province is separated from the Middle Rocky Mountains by the Wasatch Fault Zone in northern Utah, and from the Colorado Plateau by the Transition Zone in central and southern Utah (Fig. 2). Within the Basin and Range and the Transition Zone, east-west structural extension is thought to have taken place over the past 17 million years (Hintze, 1988) creating numerous north-south-oriented, fault- bounded blocks. Prior to Basin and Range extension (during mid-Cenozoic time), voluminous silicic volcanism with associated hydrothermal activity took place within several east-west trending belts (Stewart, et al., 1977). Patterns of volcanism changed during the latter stages of the Basin and Range development to less-voluminous basalt and rhyolite (bimodal assemblage), spatially controlled by north-south Basin and Range faults.

Quaternary Faults

Tectonically active regions typically have abundant active geothermal systems as fault movement fractures bedrock, thereby opening potential fluid pathways. In areas of active tectonism, meteoric water has more opportunity to circulate deep and absorb thermal energy from the surrounding rocks. Hecker (1993) presents a detailed review of the Quaternary tectonic activity in Utah and describes the potential for earthquake-related hazards in the state. Utah is in a tectonically active region where the Intermountain Seismic Belt (ISB), a north-trending zone of historical seismicity, bisects the state. The ISB coincides with the broad transitional eastern margin (including the Transition Zone) of the Basin and Range Province, extending from southern Nevada, through Utah, southeastern Idaho, western Wyoming, and into central Montana. It includes the major active faults of Utah, such as the Wasatch fault system in northern Utah, and the Hurricane and Sevier faults in southern Utah and northern Arizona (Fig. 2).

Quaternary Volcanic Rocks

Recent igneous activity may provide local, high-level, heat sources for geothermal systems. As a result, the distribution and timing of volcanic events is important for assessing the geothermal potential of a region. Hecker (1993) summarizes previous work (Best, et al., 1980; Hoover, 1974; Clark, 1977; Lipman, et al., 1978; Nash, 1986; Anderson, 1988; and Anderson and Christenson, 1989) to describe the distribution and timing of Quaternary volcanic rocks in Utah.

Clusters of young volcanic rocks (generally less than 2 Ma) extend from northwestern Arizona through southwestern and west-central Utah. These units consist of a bimodal assemblage of mainly basaltic rocks and less voluminous rhyolitic rocks. In southwestern Utah, several clusters of mostly basaltic rocks are oriented northeast-southwest, subparallel to the Basin and Range-Transition Zone margin. This occurrence of volcanic rocks consists of series of basaltic flows and vents that do not seem to coincide with mapped faults. Rather, some vents lie adjacent to major faults, such as the Hurricane and Sevier faults, localized on the footwall or hanging-wall block, but not appearing to have used the fault as a conduit for magma. Cinder cones and mounds, which generally form alignments parallel to the faults, appear to have formed along steep joints.

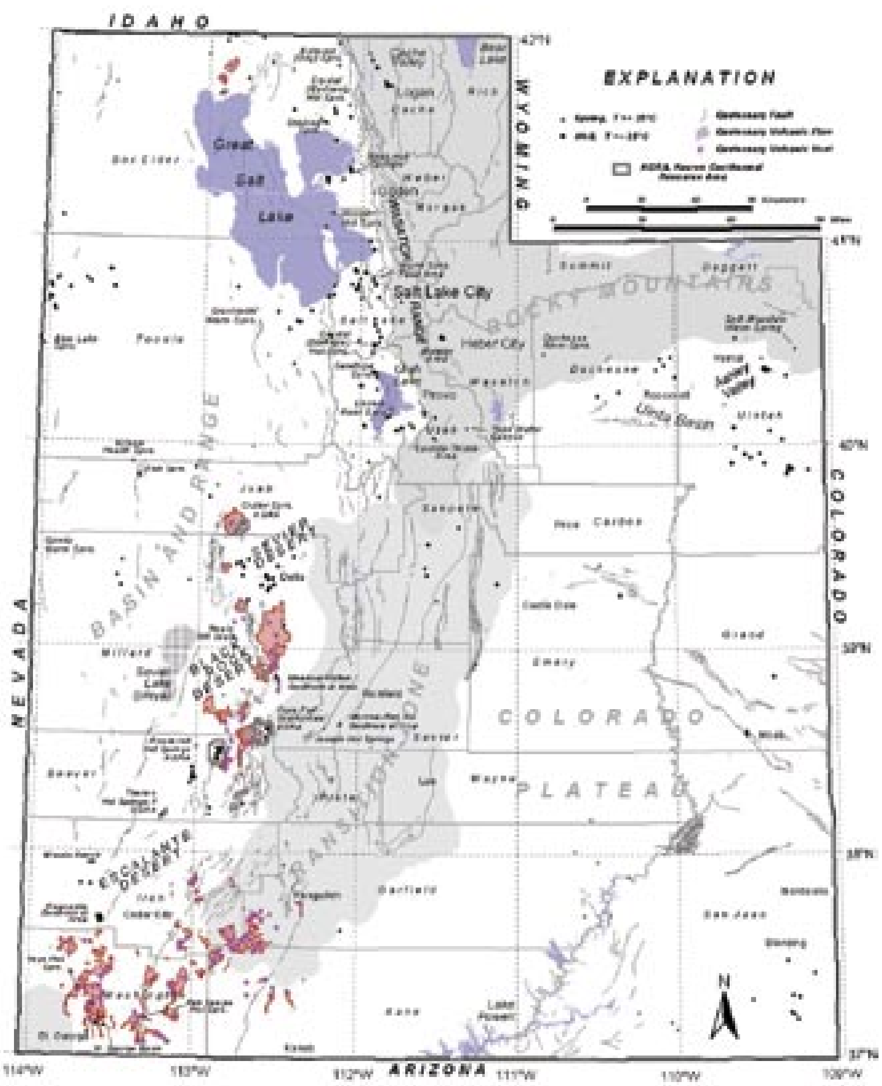

Figure 2 - Geothermal resources of Utah, including thermal wells and springs. Quaternary tectonic and volcanic features, and major physiographic regions.

In west-central Utah, another cluster of young basaltic rocks, with lesser quantities of rhyolite form a narrow belt generally aligned with the eastern margin of the Basin and Range. This volcanic assemblage formed in an intra-graben area between the Pavant and Tushar Mountains on the east, and the Mineral and Cricket Mountains to the west. The region is referred to as (from south to north) the northern part of the Escalante Desert, the Black Rock Desert, and the southern part of the Sevier Desert. Volcanism here appears to have been concurrent with east-west extension across numerous, small-scale intra-basin faults. Vents and cinder cones mostly lie along high-angle normal faults, suggesting that the faults provided the conduits for movement of magma. Basaltic eruptions began in this region about 2 Ma, and have continued intermittently.

A small volcanic field of Pleistocene age is located just north of Great Salt Lake in the southern Curlew Valley in Box Elder County. Basaltic rocks comprise the field and have been dated between about 0.7 and 1.15 Ma. Although the field is aligned generally parallel to Basin and Range faults, it does not appear to be spatially associated with any mapped Quaternary faults.

Table 1 - Geothermal power utilization in Utah.

Name	Location	Temperature °F (°C)	Installed Capacity MWe
Blundell	Roosevelt	520-600 (271-316)	26
Bonnett	Cove Fort/ Sulphurdale	315-350 (157-177)	11
TOTAL			**36**

Geothermal Investigations

The earliest implied reference to geothermal systems in Utah is by Gilbert (1890), who described Fumarole Butte and the nearby Crater (Abraham) Hot Springs. Stearns and others (1937) and Waring (1965) summarized data for about 60 known thermal occurrences. Mundorff (1970) prepared a comprehensive report on the thermal springs of Utah that included data on individual springs. Swanberg (1974) made estimates of subsurface temperatures using chemical analyses of water samples and employing geothermometry. Goode (1978) and Rush (1983) both produced summaries of geothermal occurrences in Utah.

Various workers from the University of Utah Department of Geology and Geophysics, Utah Geological Survey, Utah Energy Office, and the University of Utah Energy and Geoscience Institute have published details on geothermal systems and geothermal applications in Utah.

Budding and Bugden (1986) compiled a bibliography of this early work through the mid-1980s. Since then, several authors (Blackett, 1994; Blackett and Moore, 1994; Blackett and Ross, 1992;) have published more recent compilations and research on geothermal systems in Utah. Mabey and Budding (1987, 1994) compiled detailed geological, geochemical, and geophysical information, including previously unpublished data on seven individual systems within the Sevier Thermal Area, a tract of central and southwestern Utah containing all of the state's known high-temperature geothermal systems.

Budding and Sommer (1986) gathered field data and published a study of low-temperature geothermal resources in the St. George area of southwestern Utah. Wright and others (1990) summarized geothermal resources and developments in Utah up through the 1980s, and discussed how factors such as regional low energy costs resulted in relative low growth of geothermal energy in the state. Blackett and Ross (1992) published the results of geochemical and geophysical studies for geothermal systems within the Escalante Desert of southwestern Utah.

Geothermal Occurrences in Utah

With few exceptions, higher temperature geothermal areas in Utah occur either in the Basin and Range Province or within the Transition Zone (Fig. 2). In central and western Utah, most thermal areas are located in valleys near the margins of mountain blocks, and are probably controlled by active Basin and Range faults. Other geothermal systems occur in hydrologic discharge zones at the bottoms of valleys. A few thermal areas are situated in mountainous regions.

The most significant known occurrence of geothermal water in eastern Utah is from wells in the Ashley Valley Oil Field, which yield large volumes of nearly fresh water at temperatures between 43º C and 55º C (109º F and 131º F) as a byproduct of oil production. In 1981, the Ashley Valley field yielded 5.42 million m^3 (26.1 million barrels) of water (Goode, 1985).

Using geothermometry and other information, Rush (1983) suggested that six areas in Utah have high-temperature geothermal systems with reservoir temperatures above 150º C (302º F). He also suggested that 10 other areas could be classified as moderate-temperature geothermal systems with reservoir temperatures between 100º C and 150º C (212º F and 302º F). Known high-temperature systems include the Roosevelt Hot Springs and Cove Fort–Sulphurdale Known Geothermal Resource Areas (KGRA). Other potential moderate- to high-temperature systems are Thermo Hot Springs, Joseph Hot Springs, the Newcastle area, and the Monroe-Red Hill area.

Geothermal Power in Utah

Two separate electric power plants using geothermal energy have been installed in the southern part of the state, at Cove Fort–Sulphurdale (Bonnett) and near Roosevelt (Blundell) (Table 1). Presently, electric power is generated at the Roosevelt Hot Springs and the Cove Fort–Sulphurdale KGRAs. The Bonnett plant is presently (early 2005) shut down and probably will be replaced with a 30-to 40-megawatt (MW) power plant.

Utah Power, a PacifiCorp company that merged with Scottish Power in 1999, has operated the single-flash, Blundell geothermal power station at the Roosevelt Hot Springs geothermal area near Milford in Beaver County since 1984. Intermountain Geothermal Co., a subsidiary of California Energy Co. and the current field developer, produces geothermal brine for the Blundell plant.

Table 2 - Geothermal direct utilization in Utah.

Type of Use	Name	Location	Temperature °F	(°C)	Installed Capacity MWt	Annual Energy Use 10^9 Btu(t)	TJ
Greenhouses	Castlevalley Greenhouses	Newcastle	210	(99)	1.76	13.1	31.8
Greenhouses	Milgro Nursery	Newcastle	192	(89)	14.94	93.0	98.0
Greenhouses	Milgro No. 2	Newcastle	203	(95)	1.05	6.6	6.9
Greenhouses	Milgro No. 3	Newcastle	203	(95)	0.86	5.3	26.0
Greenhouses	Bluffdale Flower Growers	Bluffdale	190	(88)	3.29	24.6	5.2
Greenhouses	Allan Plant Co.	Ogden	136	(58)	0.66	4.9	
							15.5
Aquaculture	Crystal Springs Fisheries	Bluffdale	80	(27)	0.73	14.7	33.7
Aquaculture	Hi-Tech Fisheries	Bluffdale	189	(87)	1.60	32.0	
							0.6
Space Heating	Hi-Tech Fisheries	Bluffdale	189	(87)	0.08	0.6	16.1
Space Heating	Utah State Prison	Bluffdale	178	(81)	2.05	15.3	0.2
Space Heating	LDS Wardhouse	Newcastle	132	(56)	0.04	0.2	0.6
Space Heating	Camperworld Hot Springs	Garland	127	(53)	0.08	0.6	
							13.9
Swimming Pool	Camperworld Hot Springs	Garland	127	(53)	0.59	13.2	22.6
Swimming Pool	Crystal Hot Springs	Honeyville	140	(60)	1.03	21.4	4.8
Swimming Pool	Mountain Spa Resort	Midway	110	(43)	1.03	4.6	8.2
Swimming Pool	Mystic Hot Springs	Monroe	168	(76)	0.29	7.8	8.1
Swimming Pool	Saratoga Homeowners Assoc.	Lehi	112	(44)	0.32	7.7	7.4
Swimming Pool	Veyo Hot Springs	Veyo	85	(29)	0.29	7.0	13.9
Swimming Pool	The Homestead Resort	Midway	104	(40)	0.59	13.2	
							14.8
Scuba Diving	Bonneville SeaBase	Grantsville	76	(24)	0.59	14.0	13.9
Scuba Diving	The Homestead Crater	Midway	96	(36)	0.59	13.2	13.9
Scuba Diving	Camperworld Hot Springs	Garland	127	(53)	0.59	13.2	
			TOTALS		33.05	326.2	343.7

The Blundell geothermal reservoir lies in fractured, crystalline rock. Resource depths range generally between 640 and 1,830 m (2,100 and 6,000 ft). Resource temperatures are typically between 271º and 316º C (520º and 600º F). Wellhead separators are used to "flash" the geothermal fluid into liquid and vapor phases. The liquid phase, or geothermal brine, is channeled back to the reservoir through gravity-fed injection wells. The vapor phase, or steam fraction, is collected from the production wells and directed into the power plant at temperatures between 177º and 204º C (350º and 400º F), with steam pressure approaching 7.66 kg/cm^2 (109 psi). The plant produces 26 MW gross (23 MW net).

In 1985, Mother Earth Industries, in cooperation with Provo City, UT, installed a binary-cycle geothermal power system and a steam-turbine generator at Sulphurdale in Beaver County. In 1990, Provo City and the Utah Municipal Power Agency (UMPA) dedicated the Bonnett geothermal power plant, the third geothermal unit to go on-line at Sulphurdale. Estimated net output from the power units is about 10 MW. Because hydrogen sulfide (H_2S) gas is produced, the plant employs a sulfur abatement system designed to extract up to 1.36 metric tonnes of sulfur per day.

In 2003, Recurrent Resources acquired the Sulphurdale geothermal properties and facilities of Provo City/UMPA. Recurrent has shut down the operation and plans to reconstruct the facility, eventually building a 30- to 40-MW binary power plant. Production wells primarily tap a shallow, vapor-dominated part of the geothermal system at depths between 335 and 366 m (1,100 and 1,200 ft). A deeper well (~ 730 m [2,400 ft]), however, reportedly taps the liquid-dominated part of the system.

Geothermal Direct Use in Utah

Direct-use of geothermal energy resources is more extensive in Utah than power generation. Geothermal energy is used at 21 sites along the entire central arc of geothermal resources in the state (Fig. 2 / Table 2). Greenhouse heating is the largest use, followed by swimming pools. Direct use of geothermal energy in Utah amounts to equivalent savings of about 162,000 barrels of oil (assuming 35% efficiency from electricity), and eliminates 42,000 tons of carbon dioxide. Commercial greenhouses that use thermal water for space heating operate at Newcastle in Iron County, at Crystal Hot Springs near Bluffdale in Salt Lake County, and at Utah Hot Springs near Pleasant View in Weber County. Ten resorts use geothermal water for the heating swimming pools, small space-heating applications, and therapeutic baths. However, due to location, economics and other factors, many of Utah's former geothermal resorts and spas have closed throughout the state. Three of the newer direct-use geothermal developments consist of commercial scuba diving and aquaculture facilities near Grantsville in Tooele County, near Plymouth in Box Elder County, and at Midway in Wasatch County.

Commercial Direct-Use Facilities. Various research organizations and energy companies became interested in the Newcastle area of Iron County in the 1970s after farmers accidentally discovered a relatively shallow hydrothermal system while drilling an irrigation well. The well had encountered a hot-water aquifer with a maximum temperature of 108º C (226º F) at depths between 75 and 94 m (245 and 310 ft). Subsequent studies by the Utah Geologic Survey (UGS) suggested a model of hot water rising along a range-bounding fault and discharging into an aquifer in unconsolidated Quaternary sediments, forming a broad outflow plume. Temperatures within the outflow plume generally range between 82º and 104º C (180º and 220º F). Several commercial greenhouses, covering about 100,000 m^2 (25 acres), use the geothermal fluid from shallow production wells 152 m (~500 ft.) deep to produce high-quality flowers, vegetables, and ornamental plants year-round. Bluffdale Flower Growers (formerly Utah Roses) operates a geothermal-heated greenhouse complex at Crystal (Bluffdale) Hot Springs at the southern end of the Salt Lake Valley. The facility covers about 11,700 m^2 (2.9 acres), and produces cut roses as its primary product. Other commercial geothermal direct–use opertions include:

- Bonneville SeaBase is a scuba diving facility developed at Grantsville Warm Springs, about 66 km (40 mi.) west of Salt Lake City along Interstate 80 in Tooele County. SeaBase consists of several dive pools fed by warm springs and stocked with tropical marine fish. The facility is associated with Neptune Divers of Salt Lake City, a business devoted to scuba diving and related-product sales.

- At Belmont (Udy) Hot Springs in northeastern Box Elder County, about 50 hot springs and seeps issue along the Malad River at about 52º C (125º F). In addition to a golf course and camping facilities, the resort has therapeutic hot tubs, a swimming pool, and a scuba diving pool. The resort also operated a commercial aquaculture facility, raising lobsters and crayfish for distribution out of the local area, which is now closed.

- Hi-Tech Fisheries, Inc., located at the nearby Utah State Prison, uses heated water cascaded from the prison geothermal production well for a commercial tropical fish farm. Surface spring temperatures are about 62º C (144º F). Subsurface temperatures of 88º C (190º F) have been reported in one of two 122-m (400-ft.) production wells. The springs normally issue from valley alluvium into several ponds. When production wells are in operation, the surface springs and ponds are said to dry up.

- Crystal (Madsen) Hot Springs Resort, near Honeyville along Interstate Highway15 in Box Elder County, uses cold springs and hot springs at the same facility. The springs are situated along the northern extension of the Wasatch fault, which traverses along the western side of the Wellsville Mountains. An 11º C (52º F) cold spring helps fill a 1.1-million liter (300,000-gallon swimming pool, while 60º C (140º F) hot springs fill therapeutic hot tubs, mineral pools, and warm the swimming pool. Pool temperatures range from 29º to 44º C (85º to 112º F).

- Thermal springs in and around Midway in Wasatch County issue from several widespread, coalescing travertine mounds covering an area of several square km. Temperatures in the springs generally range from 35º to 46º C (95º to 115º F). Thermal water at Midway probably originates from deep circulation of meteoric water from recharge zones located to the north near Park City. The Mountain Spa Resort uses thermal water for heating a swimming pool and for therapeutic baths. The Homestead, a hotel and resort complex, uses thermal water in a therapeutic bath, and also offers guests scuba diving within a 35º C (95º F) thermal pool inside "the old hot pot," a large travertine mound.

- Along with overnight camping, Mystic Hot Springs offers a geothermal-heated swimming pool, therapeutic baths, and tropical fish ponds at the Monroe-Red Hill Hot Springs area, 16 km (10 mi.) south of Richfield in Sevier County. The Monroe and Red Hill Hot Springs issue at about 77º C (170º F) near the surface trace of the Sevier fault adjacent to the Sevier Plateau. The area was the focus of U.S. Department of Energy-sponsored geothermal studies in the late-1970s.

- Veyo and Pah Tempe Hot Springs resorts in southwestern Utah offer swimming and therapeutic baths. At Veyo Hot Springs Resort, southeast of Veyo in the Santa Clara River Canyon, spring flows are channeled to a swimming pool at a temperature of about 32º C (89º F). At the Pah Tempe Hot Springs Resort, springs flow at about 42º C (108º F) from a number of vents along the Virgin River near its crossing of the Hurricane Fault between the towns of Hurricane and La Verkin. Thermal water at Pah Tempe is channeled into a swimming pool and therapeutic baths. ■

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