UGMS GL01540

SUMMIT CO.

	SEC.	T.	R.	DEPTH	°F	
√1	6 SE	2N	6E	3700	98	
√2	17	2N	11E	3416	87	12.88
				10583	132	
√3	4	3N	7E	6021	116	
√4	14 SE	3N	14E	17676	234	10.80
				8793	128	
				17796	240	11.07
				17904	238	
√5	23	3N	14E	15848	188	9.15
				8852	130	
√6	24	3N	14E	15621	194	
√7	25	3N	14E	11781	182	
				13164	170	
				15342	170	
				15742	181	
√8	26 NW	3N	14E	13528	163	8.87
				15865	200	
√9	26	3N	14E	8899	122	
√10	28 SE	3N	14E	16297	183	8.59
				16395	185	8.60
				16412	183	
√11	14 SW	3N	16E	4124 (28.4 at 43)	160	
√12	28 NW	6N	8E	5366	96	

plotted

ambient 43°F on all

SUMMIT Co

TOTAL ALL WELLS: 34

" ANOMALOUS " : 3

Sec	T	R	depth (meters)	°C	°C/km	Cond
10	2N	7E	627	37.8	50	6.1
9	2N	14E	763	38.9	43	6.1
14	3N	16E	1257	71.1	52	6.1

PI Summit Co

UGMS

6	
7	
108	
109	
110	
111	
112	
113	
114	
115	
116	
117	
118	
119	
120	
121	
122	
123	50.5°C/km
124	
125	
126	
127	43.0°C/km

1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	51.7°C/km
12	

UT
Tooele
Bonn

BONNEVILLE SALT FLATS–A POSSIBLE GEOTHERMAL AREA?

by J. A. Whelan[1] *and Carol A. Petersen*[2]

INTRODUCTION

In his paper on the hydrogeology of the Bonneville Salt Flats, Utah, L. J. Turk (1973) noted indications of an abnormally high geothermal gradient in several brackish water wells, several deep brine wells, and two warm springs in the Bonneville Salt Flats area (see table 1 and figures 1 and 2). From Turk's data, Whelan noted both sets of wells are on essentially north-south lines (figure 3) and that water and brine temperatures are consistently higher to the south (figure 4).

In the Utah Geological and Mineral Survey's program of developing and publishing data on potential geothermal areas, it was considered appropriate to expand on the data furnished by Turk.

DESCRIPTIONS OF WARM WELLS AND SPRINGS

Deep Brine Wells

Thirteen deep brine wells (drilled between 1939 and 1951) near the western edge of the Bonneville Salt Flats playa range in depth from 1,070 to 2,069 feet (Turk, 1973). These wells are in a south-southeasterly line, about six miles long, as shown on figure 3. Temperature data on water from seven wells indicate that temperatures increase from north to south along the line, as shown in figure 4. Drillers' logs of those deep brine wells for which temperature data are available are given in the Appendix. For drillers' logs of the other deep brine wells, the reader is referred to Turk (1973).

Hydrologic data on the deep brine aquifer are sketchy. Turk (1973, p. 5) reports specific capacities (Q/s, where Q = discharge, and s = drawdown in feet) between 11.5 gpm/ft and 52.4 gpm/ft. The brines contain 120,000 to 130,000 ppm total dissolved solids, as shown in table 2.

Brackish Water Wells

The data given in this section are abstracted from Turk (1973, p. 2-5).

Table 1. Temperatures of water from brackish water wells, deep brine wells, and fault-line springs (Turk, 1973, tables 5 and 8a).

Source of sample	Date	Temperature °C	Temperature °F	Remarks
FW3	8-4-67	35	95	
FW5	8-4-67	31	88	
	9-8-67	31	88	
FW9-A	8-4-67	25.5	78	
FW11	8-4-67	25.5	78	
DBW1	1-22-48	41	106	
	1-23-48	42	108	
	1-24-48	42	108	
	1-25-48	42	108	
	1-26-48	42	108	
	1-27-48	42	108	
	1-28-48	43	109	
	1-29-48	43	109	
	1-30-48	43	109	
DBW3	–	56	133[1]	Depth 1,502 ft
	–	88	190[1]	Depth 1,636 ft
DBW6	7-24-67	27	80	
	8-14-67	27	80	
	9-13-67	27	80	
DBW7	6-16-67	24.5	76	
	7-24-67	25	77	
	8-14-67	24.5	76	
	9-13-67	24.5	76	
DBW8	6-16-67	28	82	
	7-24-67	28	82	
	8-14-67	28	82	
	9-13-67	28	82	
DBW10	6-16-67	25	77	Temperature fluctuation probably the result of short pumping time before sample was collected
	7-24-67	27	80	
	8-14-67	24.5	76	
	9-13-67	23	73	
DBW13	7-25-67	22	71	Same as above
	8-14-67	24	75	
	9-13-67	24.5	76	
Spring No. 1, Blue Lake	9-14-67	29	84	
Spring No. 2, Pilot Valley	7-23-67	24.5	76	

[1] Temperatures of mud bailed when drilling.

[1] Research geologist, Utah Geological and Mineral Survey, and Professor, Department of Geological and Geophysical Sciences, University of Utah, Salt Lake City, Utah 84112.
[2] Geologist, Utah Geological and Mineral Survey, Salt Lake City, Utah 84112.

Utah Geology, Vol. 1, No. 1, p. 71 to 82.

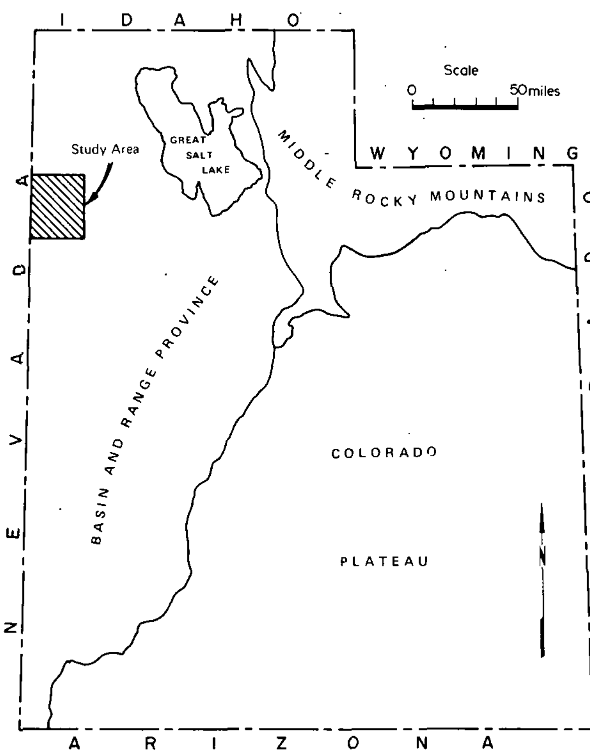


Figure 1. Map of Utah showing physiographic divisions and study area. (Turk, 1973)

Several alluvial fans along the southeast flank of the Silver Island Range are important aquifers yielding large volumes of brackish water. The fanglomerates interfinger with lacustrine sediments near the margins of the salt flats and consist of poorly sorted angular to rounded cobbles, pebbles, sand, and silt.

Twenty-seven wells, most of them less than 100 feet deep, were drilled for Bonneville, Ltd. in the 1940's and 1950's. The water is used for the daily operation of the Bonneville, Ltd. potash plant. Turk noted abnormally high temperatures on four of these wells (1973). A driller's log of one of these wells is given in the Appendix.

Turk (1973, p. 3) states that tests on two wells yielded transmissivities of 159,000 gpd/ft and 412,000 gpd/ft for the alluvial fan aquifers; storage coefficients ranged from 0.00023 to 0.00046. The brackish water wells were all flowing artesian wells when first drilled, but most of them are now being pumped. The potentiometric surface was above ground in 1960, but dropped to more than 19 feet below the surface in 1965 (Turk, 1973). The water levels in these wells have been rising since 1966 (Turk, 1973).

The brackish water contains total dissolved solids of 6,800 to 8,200 mg/l (Turk, 1973). An analysis of water from one brackish water well and water analyses from two warm fault-line springs are given in table 3. Turk (1973) indicates the sources of the water are: (1) rainfall on the fans and runoff from adjacent slopes; (2) brine from the playa; and (3) upward leakage of warm water along the border fault of the range, which is covered by the fans. Turk suggests that surface recharge is significant but not abundant, and that contribution from the playa is indicated by an increase

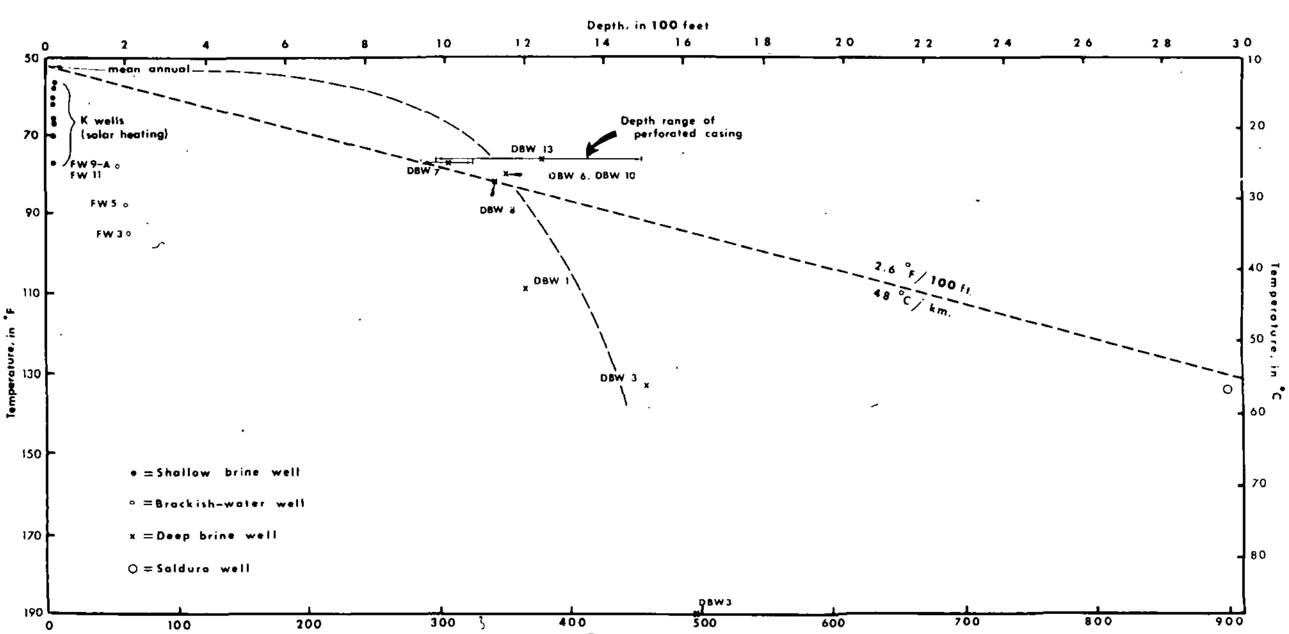


Figure 2. Depth-temperature profile, Bonneville Salt Flats. After Turk (1973, p. 29). Profile of deep brine well gradient added by Whelan and Petersen.

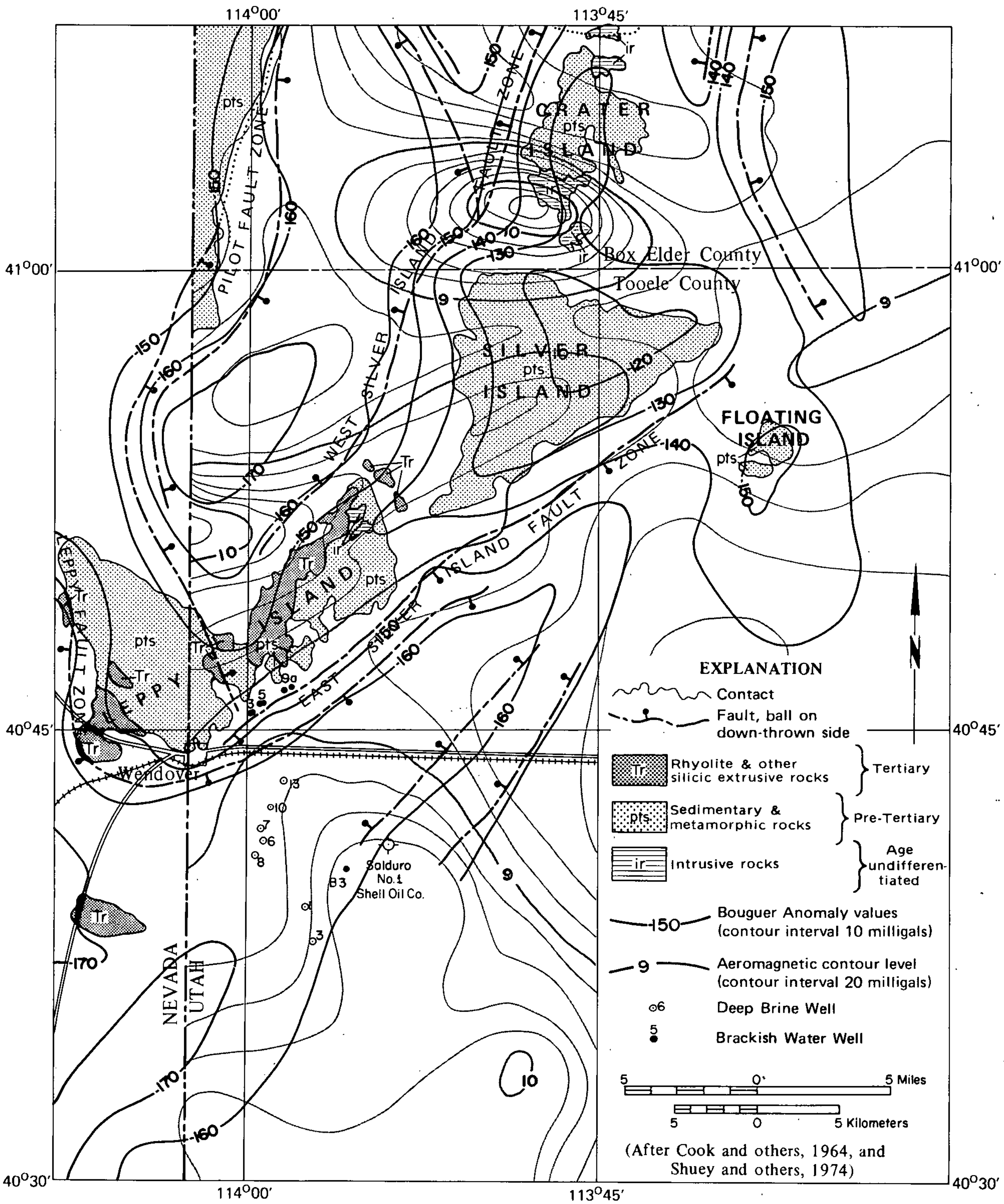


Figure 3. Bouguer gravity, aeromagnetic, and generalized geologic map of the Bonneville Salt Flats.

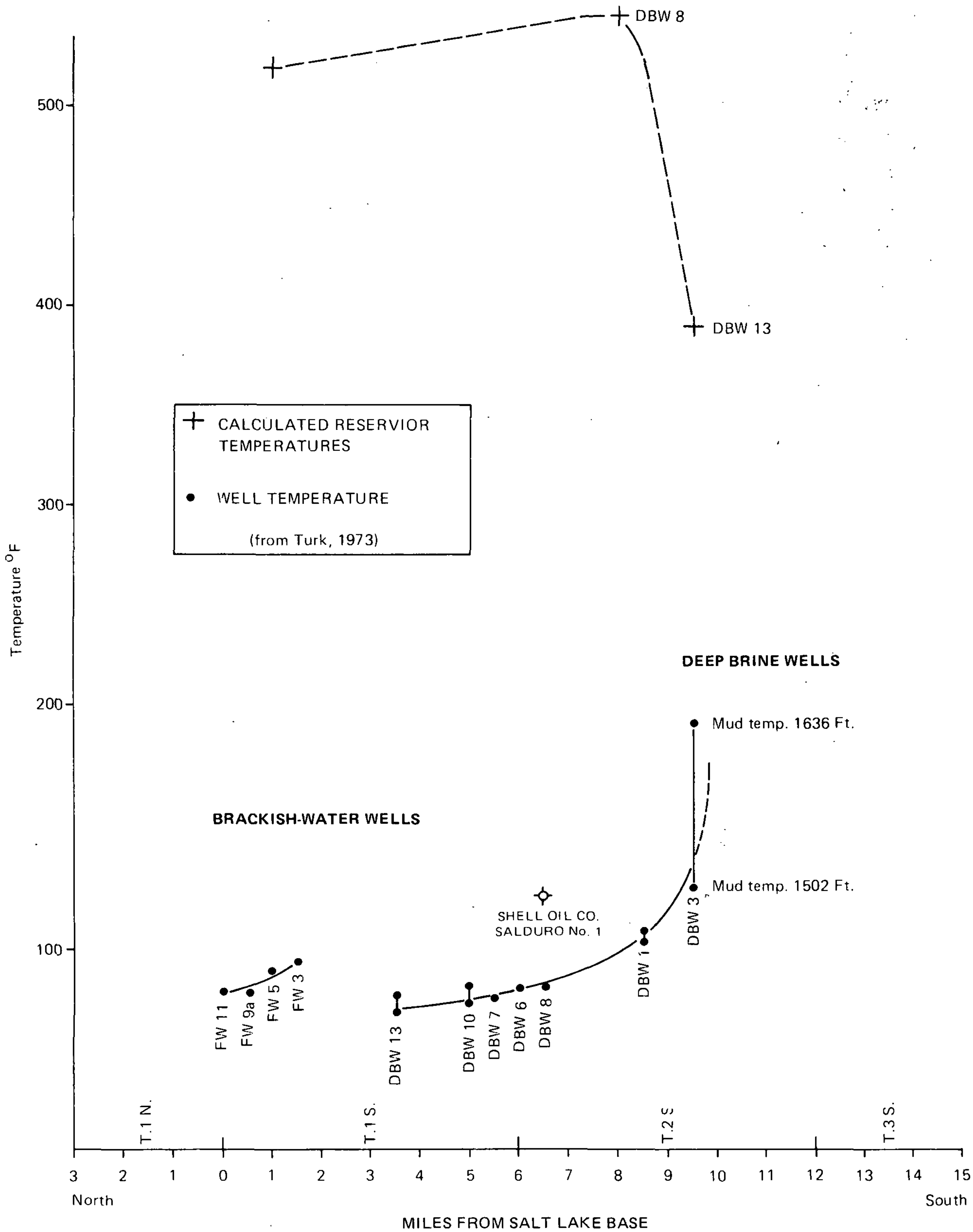


Figure 4. Calculated reservoir temperatures and observed fluid temperatures of brackish water wells and deep brine wells, compared with distance north or south of the Salt Lake Base (latitude).

Table 2. Composition of brine from deep wells (analyses by Kaiser Chemicals, San Leandro, California). (From Turk, 1973, p. 9).

Sample no.	Source	Constituents in parts per million						
		Ca	Mg	Na	Li	K	SO_4	Cl
1.14	DBW8	1,600	1,400	41,400	16	1,800	6,000	70,000
1.15	DBW13	1,500	1,400	46,000	17	2,000	6,200	72,800

in salinity of the water from the wells with time. He attributes the warm water to the same aquifer that supplies hot water to the deep brine wells.

Fault-Line Springs

Turk (1973) notes that the water issuing from fault-line springs on the southeast side of the Silver Island Range and in Pilot Valley is warm. One such spring, Pilot Valley Spring, is 76° F.; and another spring, Blue Lake Spring, is 84° F. Analytical data on the spring waters are given in table 3.

GEOLOGY

Generalized geology of the Bonneville Salt Flats and adjoining mountain ranges, together with gravity data, is shown on figure 3. The geology and gravity data were adapted from Cook *et al.* (1964). Figure 3 also shows aeromagnetic data from Shuey (1974) and well locations from Turk (1973, plate 1).

Bonneville Salt Flats

The Bonneville Salt Flats are located within a large playa in the western part of the Great Salt Lake Desert, near the Utah-Nevada border. The average elevation of the land surface is about 4,215 feet above sea level, with a relief of only 1.53 feet (Turk *et al.*, 1973). The salt crust occupies about 150 square miles and is up to five feet thick in the center (Turk *et al.*, 1973, p. 68).

Wendover Graben

Gravity data by Cook *et al.* (1964) indicate the salt flats are underlain by a structure that they designated as the Wendover Graben, which trends parallel to the front of the Silver Island Range. The graben is probably more than 35 miles long and at least 10 miles in maximum width (Cook *et al.*, 1964, p. 731). Beneath the salt crust, this graben is filled with lacustrine sediments underlain by fluvial sediments. At depths of about 1,200 feet, the deep brine wells encountered "hard rock" or "conglomerate" (Turk, 1973, p. 51-55). Turk *et al.* (1973, p. 66) indicate these hard rocks may be volcanic breccia, corresponding with the post-Early Pliocene and pre-Late Pleistocene volcanic rocks of the Silver Island Range as described by Schaeffer and Anderson (1960, p. 143).

The log of the Shell Salduro #1 well, located in the NW¼ Sec. 4, T. 2 S., R. 18 W. (Salt Lake Base and Meridian) is given as table 4. The volcanics of this well are probably equivalent to the volcanic breccia described by Turk *et al.* (1973). The fact that the hole bottomed in basic igneous rocks, interpreted as an intrusion, is of considerable interest, because similar intrusions might act as heat sources for geothermal systems.

Silver Island Range

The Silver Island Range forms the northwest border of the Bonneville Salt Flats. This range trends northeast and is about 32 miles long. The southwest end of the range is six miles west of the Utah-Nevada border, due west of Wendover. The range has a maximum relief of about 3,000 feet.

There are no outcrops of Precambrian or Mesozoic rocks in the Silver Island Range. However, every system of the Paleozoic Era is represented in the 24,000 feet of exposed sediments. The Tertiary is represented by about 4,000 feet of lacustrine and volcanic strata. Fluvial and lacustrine Quaternary deposits outcrop along the flanks of the range.

The range is intruded by five stocks of unknown age, ranging in composition from quartz monzonite to granodiorite. In the southern part of the range, a light green to black diorite-porphyry stock, about one-half

Table 3. Composition of brackish water and water from fault-line springs (analyses by Kaiser Chemicals, San Leandro, California). (From Turk, 1973, p. 5).

Sample no.	Source	Constituents in parts per million						
		Ca	Mg	Na	Li	K	SO_4	Cl
1.16	FW5	100	80	2,100	1.2	100	300	3,700
1.17	Spring 1	200	50	1,400	1.4	100	200	2,600
1.18	Spring 2	270	50	2,000	1.7	130	100	3,400

Table 4. Log of Shell Salduro #1 well (Sec. 4, T. 2 S., R. 18 W.). (From Utah Oil and Gas Conservation Division.)

Feet From	Feet To	Percent	Shows italicized
40	340	100	*Clay*, light grayish green, calcareous, very soft and gummy.
340	570	70	*Clay*, as above.
		30	*Gypsum*, transparent, fractured (or cleaved).
570	610	90	*Gypsum*, as above.
		10	*Clay*, as above.
610	630	50	*Gypsum*, as above.
		50	*Limestone*, light gray, oolitic, very fossiliferous.
630	710	80	*Gypsum*, as above.
		10	*Clay*, as above.
		10	*Limestone*, as above.
710	730	60	*Gypsum*, as above.
		30	*Limestone*, light brownish gray, very fossiliferous.
		10	*Clay*, as above.
730	790	90	*Limestone*, as above.
		10	*Gypsum*, as above.
790	890	100	*Siltstone*, gray, calcareous, argillaceous.
890	970	100	*Limestone*, *siltstone*, *gypsum*, interbedded, as above (Ls., I VFA).
970	1,320	100	*Shale*, *gypsum*, interbedded, shale: medium gray, silty, gummy.
1,320	1,350	100	*Limestone*, medium gray, I VFA, very argillaceous.
1,350	1,489	100	*Volcanic fragments*, composed of basalt, andesite, tuff, etc.
1,489	1,504		Core #1, recovered 11.0 feet.
			Conglomerate, variegated dark reddish brown and dark green, irregular splotches of dark green, poorly consolidated, massive with no apparent bedding. 50% clasts: average diameter ¼ inch, ranging up to 1 inch, composed predominantly of volcanics (andesite or basalt) with rare vitric tuff and buff I VFA, Ls. clasts angular to subrounded. 50% matrix: clay to fine sand, calcareous, soft, predominantly red, rare green, common subrounded coarse grained quartz fragments. Probable age: Tertiary
1,504	1,610	100	*Conglomerate*, composed chiefly of volcanic fragments, altered reddish brown and green, clasts composed of andesite, rare tuff.
1,610	1,740	100	*Volcanics* (andesite?), variegated, green, red, black, fine grained to aphanitic, calcite veinlets common.
1,740	1,800	100	*Limestone*, light gray, sandy, tuffaceous, contains biotite, chert, and rare pyrite.
1,800	1,840	100	*Tuff* (?), bright yellow, altered.
1,840	1,860	100	*Sandstone*, light gray, calcareous, tuffaceous, contains some chert.
1,860	1,900	100	*Volcanic breccia*, composed predominantly of light brown to black andesite, few tuffaceous clasts, fractures filled with calcite.
1,900	1,915		Core #2, recovered 11.0 feet.
			Volcanic breccia, greenish, indurated, no bedding apparent. 60% clasts: very heterogeneous in rock type, composed predominantly of different varieties of andesite, light brown to black, aphanitic to porphyritic, some vesicular, few clasts tuffaceous and in part altered to bentonite. Diameter ranges from ¼ inch to 5 inches, 1 inch average. 40% matrix: probably tuffaceous, non-calcareous, rare opaline cement. Probable age: Tertiary
1,915	2,260	100	*Volcanic breccia*, as above.
2,260	2,280	100	*Bentonite* or *tuff*, medium reddish brown, calcareous.
2,280	2,300	100	*Volcanic breccia*, as above.
2,300	2,340	100	*Bentonite* or *tuff*, light gray, calcareous.
2,340	2,560	100	*Volcanic breccia*, as above.
2,560	2,640	100	*Limestone*, white to light brown, sandy, tuffaceous, some interbedded calcareous sandstone and tuff.
2,640	2,720	100	*Andesite*, generally black and dark green, fine-grained, calcite veins.
2,720	2,740	100	*Limestone*, mottled brown.
2,740	2,820	100	*Basalt*, mottled black, brown, green, contains feldspar laths and probably some olivine.
2,820	2,830		Core #3, recovered 10.0 feet.
			Basalt or possibly *microgabbro* or *diabase* dark gray to black with some green mottling, fine to medium grained, hard, massive, generally fresh but partially altered to chlorite and serpentine. Composed of 70% mafic minerals, chiefly pyroxene with amphibole (hornblende?) and possible biotite, 30% plagioclase feldspar. Minor olivine (?). Mafics partially altered to chlorite and serpentine. Fractures predominantly 45° and 90° filled completely with chlorite and serpentine.
2,830	2,941	100	*Microgabbro*, mottled black, dark gray, brown, green, fine to medium grained, composed of pyroxene, hornblende, plagioclase feldspar, chlorite, serpentine, olivine. Partially altered.

Table 4. (continued)

Feet		Percent	Shows italicized
From	To		
2,941	2,950		Core #4, recovered 9.0 feet.
			Olivine augite diabase, black to dark gray with greenish cast, massive, in part altered to greenstone, commonly fractured–irregular (general) with one well-defined fracture surface dipping 45%, fractures commonly healed with serpentine and chlorite and pyrite, appear tight. Texturally and mineralogically–the rock appears essentially same as in core #3, but with melaphyric dike–3 to 4 inches thick at 2,947 feet.

mile in width, intrudes one of the granodiorite-monzonite stocks (Schaeffer and Anderson, 1960, p. 121). Perhaps the dioritic stock is equivalent to the basic rock encountered at the bottom of the Salduro #1 well.

Dikes of andesite, aplite, lamprophyre, rhyodacite, rhyolite porphyry, dacite, and quartz latite porphyry are found in the Silver Island Range. The dikes range from a few inches to 20-feet wide and are as long as 600 feet.

Schaeffer (Schaeffer and Anderson, 1960, p. 123-124) notes seven volcanic flows of rhyolitic or andesitic composition in the southern Silver Island Range. His "early" volcanic group consists of rhyolites and one andesite, and he gives the group a post-Permian and pre-Pliocene age. He assigns a post-Early Pliocene and pre-Late Pleistocene age to rhyolites and andesites which overlie Tertiary sediments, and he designates them as the "late volcanics". Armstrong (1970, p. 210-211) states that the tridymite rhyolites of Schaeffer's "early" volcanics are 11.6 ± 0.4 million years old.

The Silver Island Range consists of several alternating anticlines and synclines, cut by both normal and reverse faults (Schaeffer and Anderson, 1960, p. 133-139). Schaeffer and Anderson described a border fault parallel to the southeastern margin of the range. The last movement on this fault occurred after Early Pliocene and before Late Pleistocene; the displacement on this fault is 1,100 to 5,000 feet. This fault is one of the western border faults of the Wendover Graben, and it is thought that the warm water of the brackish water aquifer has risen through it.

According to Stokes (1963), the rock outcrops in the vicinity of the warm spring at Blue Lake consist of Late Tertiary rhyolite-dacite-quartz latite flows. Turk (1973, p. 4) considers the warm spring to be a fault-line spring. Alluvial fans on the eastern flank of the Silver Island Range are the site of the brackish water wells with the abnormal temperature gradients described above.

Great Salt Lake Desert

Shuey (1974, personal communication) indicates the gravity high shown on the southern part of figure 3 may represent a buried intrusion. The gravity data of Cook *et al.* (1964) are incomplete in this portion of the Great Salt Lake Desert.

TEMPERATURE OF THE RESERVOIR

Estimates of reservoir temperatures were made for those wells for which Turk (1973) supplied sufficient analytical data. The sodium-potassium-calcium method of Fournier and Truesdell (1973) was used; results are shown in table 5.

Possible reservoir temperatures of 177° to 285° C. (351° F. to 545° F.) indicate adequate heat for a hot water geothermal system. However, the extremely high salinities of the deep brine wells may affect the empirical model used, and the calculated temperatures may not be very accurate. The reservoir temperatures calculated from the brackish water well (FW5) and the warm springs are perhaps better indicators of actual reservoir temperatures.

LAND OWNERSHIP

All of the deep brine wells are on private land owned by Bonneville, Ltd. Some of the brackish water wells are on State School Section 2, T. 1 N., R. 19 W. (Salt Lake Base and Meridian).

Bonneville, Ltd. has rights to the brackish water and brines of the wells. In Utah, under the Geothermal Energy and Associated Resources Act (Section 73-1-20, Utah Code Annotated 1953), geothermal rights are considered to be water rights. Because Bonneville, Ltd. has surface rights and also brine and water appropriations, it appears the company controls the area containing the possible geothermal system.

Land in the surrounding area is federally owned, but withdrawn, as military lands of the Wendover Bombing and Gunnery Range.

Table 5. Analytical data, fluid temperatures, and calculated reservoir temperatures of wells and springs, Bonneville Salt Flats area.

Well or spring	Constituents in parts per million			Specific gravity	Temperature of sampled water	Calculated temperature of reservoir	
	Ca^{++}	Na^+	K^+		°C	°C	°F
DBW8	1,600	41,400	1,800	1.0945-1.0960	28	285	545
DBW13	1,500	46,000	2,000	1.1098-1.0995	22-24.5	199	390
FW5	100	2,100	100	1.039	31	270	518
Spring No. 1 (Blue Lake)	200	1,400	100	1.003[1]	29	181	358
Spring No. 2 (Pilot Valley)	270	2,000	130	1.004[1]	24.5	177	351

[1] Calculated from table A-1 of Levorsen (1958, p. 663).

CONCLUSIONS AND RECOMMENDATIONS

The Bonneville Salt Flats just south of Wendover, Utah, possibly contain a geothermal reservoir. All of the theoretical requirements for the system could be present. There is a buried intrusive which could be a heat source; water, in the form of brines, appears to be present; the faulting of the Wendover Graben could provide the required permeability; and buried volcanics could provide the cap rock.

Land in the area is privately owned, state-owned school sections, or federally owned but withdrawn for military purposes. Because the private land is owned by Bonneville, Ltd., and the state school sections are under lease with brine rights to the same company, the decision to test the geothermal potential or not will rest with that company.

Initial exploration should probably consist of temperature gradient holes, particularly in the center and southern parts of T. 2 S., where the highest-temperature deep brine wells and the highest calculated reservoir temperatures occur. Gradient wells along the eastern edge of the Wendover Graben and over the magnetic high 18 miles southeast of Wendover, which probably represents a buried intrusion, would also be useful.

Analyses of the deep brines, brackish water, and warm springs water should be made for their silica contents, in order to estimate the reservoir temperatures by the method of Fournier and Rowe (1966). If initial results of the gradient holes and silica analyses are favorable, more elaborate geophysical studies should be made, followed by test drilling.

Areas of geothermal potential may be present in other valleys of Utah. Indicators may be:

(1) Abnormal temperatures in water or oil wells,

(2) Aeromagnetic data indicating buried intrusions,

(3) Gravity data indicating faults bordering grabens, which may supply fracture permeability, and

(4) Young intrusive or extrusive rocks exposed in adjacent mountain ranges.

REFERENCES

Armstrong, R. L., 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, U. S. A.: Geochimica et Cosmochimica Acta, v. 34, p. 203-232.

Cook, K. L., M. D. Halverson, J. L. Stepp, and J. W. Berg, Jr., 1964, Regional gravity survey of the northern Great Salt Lake Desert, and adjacent areas in Utah, Nevada, and Idaho: Geol. Soc. Am. Bull., v. 75, p. 715-740.

Fournier, R. O. and J. J. Rowe, 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet-steam wells: Am. Jour. Sci., v. 264, p. 685-697.

Fournier, R. O. and A. H. Truesdell, 1973, An empirical Na-K-Ca geothermometer for natural waters: Geochimica et Cosmochimica Acta, v. 37, no. 5, p. 1255-1276.

Levorsen, A. I., 1958, Geology of petroleum: W. H. Freeman Co., San Francisco, California, 703 p.

Schaeffer, F. E. and W. L. Anderson, 1960, Geology of the Silver Island Mountains, Box Elder and Tooele Counties, Utah, and Elko County, Nevada: Utah Geol. Soc. Guidebook no. 15, 185 p.

Shuey, R. T., 1974, Aeromagnetic map of Utah--northwestern quadrant: Department of Geology and Geophysics, Univ. of Utah, Salt Lake City, Utah (available from Utah Geol. and Mineral Survey).

Stokes, W. L., 1962, Geologic map of Utah, northwest quarter: Utah Geol. and Mineral Survey.

Turk, L. J., 1973, Hydrology of the Bonneville Salt Flats, Utah: Utah Geol. and Mineral Survey Water-Res. Bull. 19, 81 p.

Turk, L. J., S. N. Davis, and C. P. Bingham, 1973, Hydrogeology of lacustrine sediments, Bonneville Salt Flats, Utah: Econ. Geol., v. 68, p. 65-78.

APPENDIX

Drillers' logs of deep brine wells
and brackish water wells
(From Turk, 1973).

WELL NO. DBW1

Location: SE¼NE¼ sec. 14 (on east section line), T. 2 S., R. 19 W.
Year drilled: Started 1939, completed 1943
Total depth: 1,200 ft
Casing: 1,175 ft, 8-inch

Depth (ft)	Description	Remarks
0-5	Salt, white, hard	Water in hole
5-50	Clay, light gray, soft	Water in hole to 40 ft; dry hole at 45 ft
50-80	Clay, dark gray, soft	Little water from 55 ft to 70 ft
80-100	Clay, light gray, soft	Dry hole
100-120	Clay, dark gray, soft	Little water 85 ft to 105 ft
120-180	Clay, light gray, soft	Dry hole except little water at 140 ft
180-205	Clay, dark gray, soft	
205-270	Clay, light gray, soft	
270-340	Gypsum and little clay, medium hard	Lots of water at 290 ft; water level 100 ft
340-345	Gypsum and light gray, hard	
345-395	Gypsum and little clay, medium hard	
395-410	Straight gypsum, medium hard	Lots of water at 405 ft
410-415	Clay and showing of gypsum	Water level 30 ft after standing 15 hrs
415-460	Gypsum and some clay, medium hard	
460-525	Gypsum and some clay, medium hard	Water level 268 ft after standing 12 hrs
525-585	Gypsum and little clay, medium hard	Hole caving at 565
585-595	Gypsum and clay, medium hard	
595-620	Straight gypsum, medium hard	
620-660	Gypsum and clay, medium hard	
660-676	Blue clay	
676-677	Hard pan	
677-690	Blue clay	
690-695	Salt and sand	More water; water level 76 ft after 12 hrs
695-705	Blue clay	
705-710	Blue clay and gypsum	
710-760	Blue clay	
760-765	Blue clay and gypsum	
765-791	Blue clay	Trace sand at 780 ft
791-792	Blue clay and gypsum	Drills harder than clay
792-844	Blue clay	
844-852	Blue clay and gypsum	Hole began filling with water at 844 ft, apparently from gypsum
852-866	Blue clay	

WELL NO. DBW1 (continued)

Depth (ft)	Description	Remarks
866-867	Gypsum	
867-870	Blue clay	
870-875	Blue clay and gypsum	
875-885	Blue clay	
885-898	Blue clay and gypsum	
898-918	Blue clay	
918-920	Fine sand	Water
920-923	Blue clay	
923-930	Fine sand and clay	Water
930-940	Blue clay	
940-950	Fine sand with streaks of clay	
950-955	Blue clay	Water level 420 ft
955-975	White clay	
975-1,000	White clay	
1,000-1,015	White clay	
1,015-1,025	Blue clay	Water broke in
1,025-1,027	Sand, hard	Water level 215 ft
1,027-1,030	White clay	After standing three days the water level is 125 ft
1,030-1,040	Blue clay	Water level 85 ft
1,040-1,058	Blue clay	Water level 90 ft
1,058-1,062	Blue clay	Water level 105 ft
1,062-1,071	Blue clay	
1,071-1,074	Blue clay	
1,074-1,092	White clay	Water level 85 ft
1,092-1,104	White clay and gypsum	
1,104-1,106	Blue clay	
1,106-1,107	Blue clay	
1,107-1,109	Sand	
1,109-1,113	Blue clay	Water level 150 ft
1,113-1,115	Blue clay	
1,115-1,118	Sand	Water level 105 ft
1,118-1,135	White clay, sandy	Water level 85 ft
1,135-1,139	Sandy blue clay	Water level 65 ft
1,139-1,142	Hard sand, gypsum and clay	
1,142-1,145	Blue clay	
1,145-1,151	Blue clay	
1,151-1,152	Yellow clay	
1,152-1,157	Dark blue clay	Water level 80 ft
1,157-1,163	Blue sticky clay	
1,163-1,166	Hard sand	
1,166-1,168	Hard sand	
1,168-1,171	Rock	
1,171-1,177	Rock	
1,177-1,180	Rock (black sand running in from above)	
1,180-1,185	Black volcanic rock	
1,185-1,196	Black volcanic rock	
1,196-1,198	Black volcanic rock	
1,198-1,200	Black volcanic rock	Water level 25 ft (water cannot be bailed below 25 ft)

Appendix (continued)

WELL NO. DBW3

Location: NE¼SW¼ sec. 24, T. 2 S., R. 19 W.
Year drilled: 1949 (?)
Total depth: 2,068 ft
Casing: 36 ft, 20-inch; 418 ft, 16-inch

Note: This well was abandoned and later covered by a pond; no trace of the well at the surface.

Depth (ft)	Description	Remarks
0-249	Blue clay	
249-251	Gypsum	
251-280	Blue clay	
280-282	Gypsum	
282-293	Blue clay	
293-296	Gypsum	
296-400	Clay and gypsum	
400-420	Gypsum (trace gravel)	
420-450	Clay	
450-555	Clay, gypsum, gravel (hard)	
555-575	Gypsum, clay	
575-620	Clay, sticky	
620-630	Gypsum (trace gravel)	
630-646	Clay	
646-652	Gypsum	
652-675	Clay	
675-687	Blue clay	
687-690	Gypsum, clay, gravel	
690-697	Clay, sticky	
697-700	Gypsum (hard)	
700-705	Gray sandy clay	
705-719	Conglomerate	
719-785	Clay, sticky, gray	
785-788	Gypsum (hard)	
788-820	Clay, sticky, gray	
820-822	Conglomerate, hard	
822-835	Clay, gray	
835-836	Gypsum, hard	
836-879	Clay, blue and gray	
879-881	Gypsum	
881-920	Clay, dark, sticky	
920-922	Gypsum	
922-1,017	Clay, gray, sticky to hard	
1,017-1,018	Gypsum	
1,018-1,061	Clay, sticky to hard	
1,061-1,070	Conglomerate, hard	
1,070-1,075	Clay, sticky	
1,075-1,079	Sand and gypsum	
1,079-1,147	Clay, sticky	
1,147-1,148	Conglomerate, hard	
1,148-1,166	Clay, sticky, sandy	
1,166-1,170	Clay, sticky, and gravel (first iron)	
1,170-1,193	Clay, sticky to sandy	
1,193-1,195	Gravel	
1,195-1,210	Conglomerate	
1,210-1,214	Conglomerate, hard	
1,214-1,215	Clay, sticky	
1,215-1,218	Gravel, tight	
1,218-1,220	Clay and gravel	
1,220-1,277	Conglomerate	
1,277-1,281	No log	
1,281-1,289	Conglomerate	
1,289-1,291	Clay, sticky, and gravel	

WELL NO. DBW3 (continued)

Depth (ft)	Description	Remarks
1,291-1,386	Conglomerate	
1,386-1,420	Gravel and sand	
1,420-1,423	Conglomerate	
1,423-1,427	No log	
1,427-1,429	Sand and gravel	
1,429-1,432	Sand and clay, very sticky	
1,432-1,435	Conglomerate, sticky	
1,435-1,449	Conglomerate, hard	
1,449-1,452	No log	
1,452-1,479	Conglomerate, sticky	
1,479-1,514	Sand and gravel, hard; some blue clay (132.8° F at 1,502 ft)	
1,514-1,557	Conglomerate, hard	
1,557-1,558	Clay, sticky	
1,558-1,712	Hard (190.4° F at 1,634 ft)	
1,712-1,768	Conglomerate and gravel	
1,768-1,788	Conglomerate, sticky	
1,788-1,834	Conglomerate	
1,834-1,858	Conglomerate, sticky	
1,858-1,890	Conglomerate and gravel	
1,890-1,907	Conglomerate, sticky	
1,907-1,914	Conglomerate, hard	
1,914-1,965	Conglomerate, light brown	
1,965-2,006	Conglomerate, gray, sticky	
2,006-2,012	Core (no description)	
2,012-2,042	Conglomerate, gray, sticky	
2,042-2,068	Hard	

WELL NO. DBW6

Location: SE¼SW¼ sec. 34, T. 1 S., R. 19 W.
Year drilled: No record
Total depth: 1,153 ft
Casing: No record

Depth (ft)	Description	Remarks
0-265	Clay	
265-268	Gypsum	
268-315	Clay	
315-318	Gypsum	
318-455	Clay	
455-459	Gypsum	
459-487	Clay	
487-489	Gypsum	
489-492	Clay	
492-500	Gypsum	
500-634	Clay with gypsum showing	
634-645	Gypsum	
645-714	Clay	
714-716	Gypsum	
716-835	Clay	
835-875	Hard clay	
875-885	Hard clay with a small amount of gypsum and gravel showing	

Appendix–WELL NO. DBW6 (continued)

Depth (ft)	Description	Remarks
885-902	Sticky clay	
902-918	Hard clay	
918-932	Sand, gravel and clay	
932-944	Hard clay	
944-1,153	Conglomerate	

WELL NO. DBW8

Location: SE¼NW¼ sec. 34, T. 1 S., R. 19 W.
Year drilled: 1950
Total depth: 1,126 ft
Casing: No record

Depth (ft)	Description	Remarks
0-268	Clay	
268-272	Gypsum	
272-320	Clay	
320-323	Gypsum	
323-380	Clay	
380-381	Gypsum	
381-390	Clay	
390-391	Gypsum	
391-400	Clay	
400-416	Clay and gypsum	
416-460	Clay	
460-463	Gypsum	
463-475	Sticky clay	
475-485	Clay	
485-487	Gypsum	
487-496	Sticky clay	
496-507	Gypsum	Caving, hole filled up 11 ft
507-513	Clay	
513-515	Gypsum	
515-565	Clay	
565-571	Gypsum	
571-608	Clay	
608-610	Gypsum	
610-628	Clay	
628-634	Hard gypsum	
634-638	Clay	
638-645	Gypsum	
645-700	Clay	
700-704	Gypsum	
704-745	No log	
745-754	Clay	
754-757	Gypsum	
757-872	Clay	
872-894	Gypsum	
894-918	Clay	
918-930	Clay, gravel showing in sample	
930-944	Gravel	
944-1,039	Conglomerate	
1,039-1,046	Gravel	
1,046-1,060	Hard conglomerate, brown in color	
1,060-1,126	Conglomerate	

WELL NO. DBW8 (continued)

Depth (ft)	Description	Remarks
		Pumping test: 1,300 gpm produced at 1,800 rpm. Hole filled up to 1,045 ft
		Pumping test: 1,270 gpm with 85 ft drawdown
		1,000 gpm with 70 ft drawdown
		($T \approx 25{,}000$ gpd/ft)

WELL NO. DBW10

Location: NW¼NE¼ sec. 34, T. 1 S., R. 19 W.
Year drilled: 1951 (?)
Total depth: 1,152 ft (?)
Casing: No record

Depth (ft)	Description	Remarks
0-60	No log	
60-190	Clay	
190-192	Gypsum	
192-262	Clay	
262-265	Gypsum	
265-268	Clay	
268-272	Gypsum	
272-278	Clay	
278-285	Gypsum	
285-321	Clay	
321-323	Gypsum	
323-350	Clay	
350-352	Gypsum	
352-370	Clay	
370-381	Gypsum	
381-498	Clay	
498-505	Gypsum	
505-518	Clay	
518-521	Gypsum	
521-531	Sticky clay	
531-533	Hard	
533-600	Sticky clay	
600-605	Gypsum	
605-632	Sticky clay	
632-643	Gypsum	
643-677	Clay	
677-687	Sticky clay	
687-692	Gypsum	
692-831	Sticky clay	
831-836	Hard	
836-840	Sticky clay	
840-853	No log	
853-860	Hard	
860-862	Gypsum	
862-866	No log	
866-867	Hard	
867-880	Clay	
880-882	Hard	
882-904	Clay	
904-914	Sticky clay	
914-926	Hard	

Appendix–WELL NO. DBW10 (continued)

Depth (ft)	Description	Remarks
926-933	Clay	
933-965	Sticky clay	
965-1,016	Hard	
1,016-1,018	Conglomerate	
1,018-1,115	Hard	
1,115-1,121	No log	
1,121-1,129	Hard	
1,129-1,130	Sticky clay	
1,130-1,131	Hard	
1,131-1,137	Conglomerate	
1,137-1,152	Hard	

WELL NO. DBW7

Location: SW¼NW¼ sec. 3, T. 2 S., R. 19 W.
Year drilled: 1950
Total depth: 1,070 ft
Casing: 138 ft perforated casing on bottom

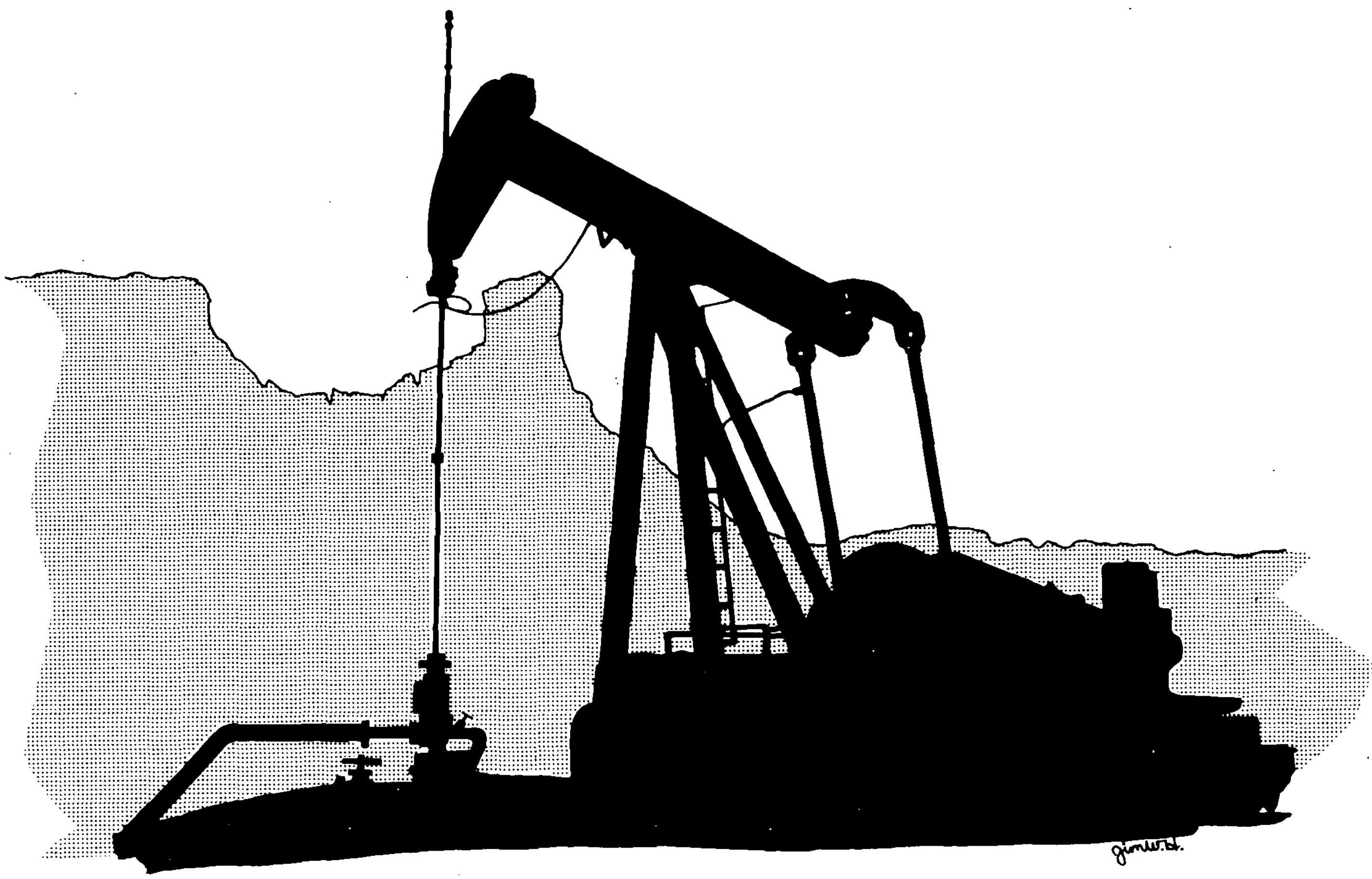
WELL NO. DBW13

Location: NW¼SW¼ sec. 23, T. 1 S., R. 19 W.
Year drilled: 1951
Total depth: 1,496 ft
Casing: 511.5 ft of 10-inch perforated casing on bottom

WELL NO. FW9-A

Location: 713.4 ft E. and 1,555.9 ft N. from SW cor. sec. 2, T. 1 S., R. 19 W. (541.7 ft NE of FW9)
Year drilled: 1947
Total depth: 193 ft

Depth (ft)	Description	Remarks
0-96	Clay	
96-101	Gravel	
101-110	Gravel and clay	
110-121	Gravel	
121-139	Clay	
139-150	Gravel	
150-152	Hard pan	
152-169	Gravel and clay	
169-190	Gravel and conglomerate	
190-193	Loose gravel	



UGMS OFR 14
1974

BONNEVILLE SALT FLATS ---
A POSSIBLE GEOTHERMAL AREA?

Preliminary version of article in UT Geol vol 1, #1, 1974

by

J. A. Whelan[1]

and

C. A. Petersen[2]

Introduction

In a paper on the hydrology of the Bonneville Salt Flats, L. J. Turk (1973) noted indications of an abnormally high geothermal gradient in several brackish-water wells, several deep brine wells, and two warm springs in the Bonneville Salt Flats area (UGMS Water-Resources Bulletin, Tables 5 & 8a). From Turk's data, Whelan noted that both sets of wells are on essentially north-south lines and that water and brine temperatures are consistently higher to the south.

---

[1] Research Geologist, Utah Geological & Mineral Survey; and Professor, Department of Geology and Geophysics, University of Utah.

[2] Geologist, Utah Geological and Mineral Survey

Note: Maps and figures to accompany this report will be published along with the text in Utah Geology, vol. 1, no. 1.

In the Utah Geological and Mineral Survey's program of developing and publishing data on potential geothermal areas, it was considered appropriate to expand on the data furnished by Turk.

Descriptions of Warm Wells and Springs

Deep Brine Wells

Thirteen deep brine wells near the western edge of the Bonneville Salt Flats playa range in depth from 1070 to 2069 feet. The wells were drilled between 1939 and 1951 (Turk, 1973). These wells are in a south-southeasterly line, about six miles long. Temperature data on seven wells indicate that temperatures rise from north to south along the line. For drillers' logs, the reader is referred to Turk (1973).

Hydrologic data on the deep brine aquifer are sketchy. Turk (1973, p. 5) reports specific capacities (Q/s, where Q=discharge, and s=drawdown in feet) between 11.5 gpm/ft and 52.4 gpm/ft. The brines contain 120,000 to 130,000 ppm total dissolved solids.

Brackish Water Wells

The data given in this section are abstracted from Turk (1973, p. 2-5).

Several alluvial fans along the southeast flank of the Silver Island Range are important aquifers which yield large volumes of brackish water. The fanglomerates consist of poorly-sorted angular to rounded cobbles, pebbles, sand and silt that interfinger with lacustrine sediments near the margins of the salt flats.

Twenty-seven wells, mostly less than 100 feet deep, were drilled for Bonneville Ltd. in the 1940's and 1950's. The water is used for the daily operation of the Bonneville Ltd. potash plant. Turk noted abnormally high temperatures on four of these wells (1973). A driller's log of one of these wells is given in Appendix A.

Turk (1973, p. 3) states that tests on two wells yielded transmissivities of 159,000 gpd/ft and 412,000 gpd/ft for the alluvial fan aquifers; with storage coefficients ranging from .00023 to .00046. The brackish-water wells were all flowing artesian wells when first drilled, but most of them are now being pumped. The potentiometric surface was above ground in 1960, but dropped to more than 19 feet below the surface in 1965 (Turk, 1973). The water levels in these wells have been rising since 1966 (Turk, 1966).

The brackish water contains total dissolved solids of 6,800 to 8,200 mg/l (Turk, 1973). An analysis of water from one brackish-water well and also analyses of waters from two warm fault-line springs are given in Turk (1973). Turk (1973) indicates that the sources of the water are: (1) rainfall on the fans and runoff from adjacent slopes; (2) brine from the playa; and (3) upward leakage of warm water along the border fault of the range, which is covered by the fans. Turk suggests that surface recharge is significant but not abundant, and that contribution from the playa is indicated by an increase of salinity of the water from the wells with time.

He attributes the warm water to the same aquifer that supplies hot water to the deep brine wells.

Fault-Line Springs

Turk (1973) notes that the water issuing from fault-line springs on the southeast side of the Silver Island Range and in Pilot Valley is warm. One such spring, Pilot Valley spring, is 76°F; and another spring, Blue Lake Spring, is 84°F. Analytical data on the spring waters are given in Turk (1973, p. 5).

Bonneville Salt Flats

The Bonneville Salt Flats are located within a large playa in the western part of the Great Salt Lake Desert, near the Utah-Nevada border. The average elevation of the land surface is about 4215 feet above sea level, with a relief of only 1.53 feet (Turk and others, 1973). The salt crust occupies about 150 square miles and is up to five feet thick in the center (Turk and others, 1973, p. 68).

Wendover Graben

Gravity data by Cook and others (1964) indicates that the salt flats are underlain by a structure that they designate as the Wendover Graben, which trends parallel to the front of the Silver Island Range. The graben is probably more than 35 miles long and at least 10 miles in maximum width (Cook and others, 1964, p. 731). Beneath the salt crust, this graben is filled with lacustrine sediments that are underlain by fluvial sediments. At depths of about 1200 feet, the deep brine wells encountered "hard rock" or "conglomerate" (Turk, 1973, p. 51-55). Turk and others (1973, p. 66) indicate that these hard rocks may be volcanic breccia, corresponding with the post-Early Pliocene and pre-late Pleistocene volcanic rocks of the Silver Island Range as described by Schaeffer and Anderson (1960, p. 143).

The log of the Shell Salduro Number One well, is located in the northwest quarter of section 4, T. 2 S., R. 18 W. (Salt Lake Base and Meridian) (well log is on record at Utah Oil & Gas Conservation Division). The volcanics of this well are probably equivalent to the volcanic breccia described by Turk and others (1973). The fact that the hole bottomed in basic igneous rocks, interpreted as an intrusion, is of considerable interest, because similar intrusions might act as a heat source for a geothermal system.

Silver Island Range

The Silver Island Range forms the northwest border of the Bonneville Salt Flats. This range trends northeast and is about 32 miles long. The southwest end of the range is six miles west of the Utah-Nevada border, due west of Wendover. The range has a maximum relief of about 3000 feet.

There are no outcrops of Precambrian or Mesozoic rocks in the Silver Island Range. However, every system of the Paleozoic era is represented in the 24,000 feet of exposed sediments. The Tertiary is represented by about 4,000 feet of lacustrine and volcanic strata. Fluvial and lacustrine Quaternary deposits outcrop along the flanks of the range.

The range is intruded by five stocks of unknown age that range in composition from quartz monzonite to granodiorite. In the southern part of the range, a light-green to black diorite-porphyry stock, which is about one-half mile in width, intrudes one of the granodiorite-monzonite stocks (Schaeffer and Anderson, 1960, p. 121). Perhaps the dioritic stock is equivalent to the basic rock encountered at the bottom of the Salduro Number One well.

Dikes of andesite, aplite, lamprophyre, rhyodacite, rhyolite porphyry, dacite and quartz latite porphyry are found in the Silver Island Range. The dikes range in width from a few inches to 20 feet, and are as long as 600 feet.

Schaeffer (Schaeffer and Anderson, 1960, p. 123-124) notes seven volcanic flows of rhyolitic or andesitic composition in the southern Silver Island Range. His "early" volcanic group consists of rhyolites and one andesite, and he gives the group a post-Permian and pre-Pliocene age. He assigns a post-early Pliocene and pre-late Pleistocene age to rhyolites and andesites which overlie Tertiary sediments, and he designates them as the "late volcanics". Armstrong (1970, p. 210-211) states that the tridymite rhyolites of Schaeffer's "early" volcanics are 11.6 ± 0.4 million years old.

Alluvial fans on the eastern flank of the Silver Island Range are the side of the brackish-water wells with abnormal temperature gradients that are described above.

The Silver Island Range consists of several alternating synclines and anticlines, cut by reverse and normal faults (Schaeffer and Anderson, 1960, p. 133-139). Schaeffer and Anderson described a border fault parallel to the southeastern margin of the range. The last movement on this fault occurred after early Pliocene and before late Pleistocene; the displacement on this fault is 1,100 to 5,000 feet. This fault is one of the western border faults of the Wendover Graben, and it is thought that the warm water of the brackish-water aquifer has risen through it.

According to Stokes (1963), the rock outcrops in the vicinity of the warm spring at Blue Lake consist of late Tertiary rhyolite-dacite-quartz latite flows. Turk (1973, p. 4) considers the warm spring to be a fault-line spring.

Great Salt Lake Desert

Shuey (1974, personal communication) indicates that a gravity high in T. 2 S., R. 18 W.; T. 3S., R. 18 W.; and T. 3 S., R. 17 W. may represent a buried intrusion. The gravity data of Cook and others (1964) are incomplete in this portion of the Great Salt Lake Desert.

Temperature of the Reservoir

Estimates of reservoir temperatures were made for those wells for which Turk (1973) supplied sufficient analytical data. The sodium-potassium-calcium method of Fournier and Truesdell (1973).

Possible reservoir temperatures of 177° to 285°C (351°F to 545°F) indicate adequate heat for a hot-water geothermal system. However, the extremely high salinities of the deep brine wells may affect the empirical model used, and the calculated temperatures may not be very accurate. The reservoir temperatures calculated from the brackish-water well (FW5) and the warm springs are perhaps better indicators of actual reservoir temperatures.

Land Ownership

All of the deep brine wells are on private land owned by Bonneville, Ltd. Some of the brackish-water wells are on State School section 2, T. 1 N., R. 19 W. (Salt Lake Base and Meridian).

Bonneville Ltd. has rights to the brackish water and brines of the wells. In Utah, under the Geothermal Energy and Associated Resources Act (Section 73-1-20, Utah Code Annotated 1953), geothermal rights are considered to be water rights. Because Bonneville Ltd. has surface rights and also brine and water appropriations, it would appear that the company controls the area containing the possible geothermal system.

Surrounding areas are federally owned but are withdrawn military lands of the Wendover Bombing and Gunnery Range.

Conclusions and Recommendations

The Bonneville Salt Flats just south of Wendover, Utah, possibly contain a geothermal reservoir. All of the theoretical requirements for the system could be present. There is a buried intrusive which could be a heat source; water, in the form of brines, appears to be present; the faulting of the Wendover Graben could provide the required permeability; and buried volcanics, the cap rock.

Land in the area is privately owned, or state-owned school sections, or federally owned but withdrawn for military purposes. Because the private land is owned by Bonneville, Ltd., Inc., and the state school sections are under lease with brine rights to the same company, the decision to test the geothermal potential or not will rest with that company.

Initial exploration should probably consist of temperature gradient holes, particularly in the center and southern parts of T. 2 S., R. 18 & 19 W., where the highest-temperature deep brine wells and the highest calculated reservoir temperatures occur. Gradient wells along the eastern edge of the Wendover Graben and over the magnetic high 18 miles southeast of Wendover, which probably represents a buried intrusion, would also be useful.

Analyses of the deep brines, brackish waters, and warm spring waters should be made for their silica contents, in order to estimate the reservoir temperatures by the method of Fournier and Rowe (1966). If initial results of the gradient holes and silica analyses are favorable, more elaborate geophysical studies should be made, followed by test drilling.

Areas of geothermal potential may be present in other valleys of Utah: Indicators may be:

(1) Abnormal temperatures in water or oil wells.

(2) Aeromagnetic data indicating buried intrusions.

(3) Gravity data indicating faults bordering grabens, which may supply fracture permeability.

(4) Young intrusive or extrusive rocks exposed in adjacent mountain ranges.

REFERENCES

Armstrong, R. L., 1970, Geochronology of Tertiary Igneous rocks, Eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, USA: Geochimica et Cosmochimica Acta, vol. 34, p. 203-232.

Cook, K. L., Halverson, M. D., Stepp, J. L., and Berg, J. W. Jr., 1964, Regional gravity survey of the northern Great Salt Lake desert, and adjacent areas in Utah, Nevada, and Idaho: Geol. Soc. Amer. Bull., vol. 75, p. 715-740.

Fournier, R. O., and Rowe, J. J., 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet-steam wells: Amer. Jour. Science, vol. 264, p. 685-697.

Fournier, R. O., and Truesdell, A. H., 1973, An empirical Na-K-Ca geothermometer for natural waters: Geochim. et Cosmochim. Acta, vol. 37, no. 5, p. 1255-1276.

Levorsen, A. I., 1958, Geology of Petroleum: W. H. Freeman, San Francisco, 703 p.

Schaeffer, F. E. and Anderson, W. L., 1960, Geology of the Silver Island Mountains, Box Elder and Tooele Counties, Utah and Elko County, Nevada: Utah Geological Society, Guidebook No. 15, 185 p.

Shuey, R. T., 1974, Aeromagnetic map of Utah: Northwestern quadrant: Department of Geology and Geophysics, Univ. of Utah (Available from Utah Geol. & Mineral Surv.).

Stokes, W. L., 1962, Geologic map of Utah, northwest quarter: Utah Geol. and Mineral Survey.

Turk, L. J., 1973, Hydrology of the Bonneville Salt Flats, Utah: Utah Geol. & Mineral Surv., Water Resources Bull. 19, 81 p.

Turk, L. J., Davis, S. N., and Bingham, C. P., 1973, Hydrogeology of lacustrine sediments, Bonneville Salt Flats, Utah: Econ. Geology, vol. 68, p. 65-78.

TOOELE CO

TOTAL ALL WELLS 2
" ANOMALOUS WELLS 1

Sec	T	R	depth	BHT	GRAD.	AMB.T
15	2S	5W	1628 m	89.4 °C	49 °C/km	10.0 °C

UGMS

TOOELE co.

	SEC.	T.	R.	DEPTH	°F
①	14	2S	5W	6601	145 ✓
②	15	2S	5W	5343	193 ✓✓✓

26.8°F/1000 at 50°

plotted

ambient 50°F on both

UGMS

1 ○ 26.2°C/km

2 ● 48.8°C/km