BRUSHWELLMAN
ENGINEERED MATERIALS

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BRUSH WELLMAN INC.

GEOTHERMAL PROPERTIES

TOPAZ MOUNTAIN DISTRICT, UTAH

Executive Summary

NOTE: The information contained herein is believed by Brush Wellman to be accurate, but Brush Wellman does not warrant the accuracy thereof.

Lands containing one or more potential geothermal resource occurrences have been identified by Brush Wellman in the vicinity of its major beryllium mining operations in West Central Utah. Brush Wellman has acquired and now holds approximately 20,364 acres of Federal geothermal leases and approximately 5,119 acres of State of Utah geothermal leases covering these lands. A small portion of these leased lands and certain other lands also are covered by certain pre-1970 unpatented mining claims owned and held by Brush Wellman in connection with its beryllium mining operations, which claims it is believed may give to Brush Wellman the rights to the geothermal resources contained therein. The general area of Brush Wellman's geothermal properties (the "properties") is shown in Figure 1. The geothermal leases are located in two adjoining areas. Figure 2 shows the location of the Federal and State geothermal leases and pre-1970 mining claims with respect to topography and other local features of the general area. The more northerly lease area is generally north of Brush Wellman's beryllium mining operations, whereas the more southerly lease area is generally south of Brush Wellman's beryllium mining operations. Table 1 contains a listing and summary of the Federal and State geothermal leases.

The Brush Wellman geothermal anomaly is characterized among other things by (1) geothermal gradients and average heat flows significantly above the regional average, (2) location of the anomaly within a favorable geologic "ring" or possible "caldera" structure, (3) the presence of active and Recent thermal springs, late Tertiary intrusive and extrusive igneous rocks, and favorable late Tertiary mineralization types associated with the ring structure, (4) favorable geochemical and geothermometric results based on water samples taken from springs and shallow drill holes near or within the area of the geothermal anomaly, and (5) the presence of numerous faults which may enhance geothermal reservoir capacity and flow rates. Other geologic, geophysical and geochemical features are of significiance in connection with the evaluation of the Brush Wellman geothermal anomaly.

Summarized below are the data and information which Brush Wellman now has concerning the geothermal properties and their characteristics and features.

1. Description of the Geothermal Properties

The area of the properties occupies much of a ten mile by eight mile area adjacent to the Spor Mountain exposed bedrock area in Juab County, Utah, and extending out into the alluvium covered valley west of Spor Mountain. The properties include, in addition to the approximately 25,483 acres of Federal or State of Utah geothermal leases, approximately 10,240 acres of pre-1970 unpatented mining claims, some of which claims occupy the same lands as some of the geothermal leases. Figure 2 depicts the extent of the properties, including both leases and unpatented mining claims.

Brush Wellman's interest in the various geothermal leases of course is subject to the royalties reserved to the United States or the State of Utah, which royalties in general will be 10% of the gross value of the geothermal energy produced and sold. The leases are all on standard (noncompetitive) forms with the standard royalties and usual lease obligations.

To the extent that Brush Wellman has rights to geothermal resources by virtue of its unpatented mining claims, there would be no royalty obligation to the United States or other third party. However, although Brush Wellman's mining claims predate passage of the Geothermal Steam Act of 1970 which created the right to lease geothermal resources from the United States, there has been no determination that Brush Wellman's claims carry with them the right to the geothermal resources.

2. Nature of the Likely Possible Geothermal Resource, and Some Economic Considerations.

Certain available information concerning present geothermal power production in the United States, particulary at the Geysers in California, and information concerning the Roosevelt Hot Springs geothermal field in Central Utah, permits some general statements about the nature of the likely possible geothermal resource here, and about certain economic factors relating to that possible resource.

Geothermal energy fields for the production of electric power, the principal use contemplated here, may be considered generally to be of two types: Those which are vapor-dominated, such as the Geysers in California, and those which are hot water-dominated, such as at Roosevelt Hot Springs in Central Utah. A vapor-dominated field is characterized by the presence of all steam ("dry steam") or predominately steam as the H_2O phase as produced from the geothermal wells. In contrast, a hot water-dominated field is characterized by the production of hot water as the dominate H_2O phase from the geothermal wells. Because a hot water-dominated field has no or little steam phase as part of the fluid reservoir, the effective heat content per pound of H_2O in a hot water field is significantly lower than that of the per pound H_2O (mostly or all steam) in a vapor-dominated field such as the Geysers.

Available information concerning the properties suggests (but does not prove) that any geothermal resource present here will be of the hot water-dominated type. However, as shown by test experience of wells in the Roosevelt Hot Springs field, hot water-dominated fields can have energy producing potentials per well equivalent to or even exceeding average wells in a dry steam field.

The productive capacity and economic value of the properties of course is limited by the capability of the properties to produce geothermal energy, a capability which has not yet been defined. However, the size of the properties is sufficiently large to be permissive of enough productive capacity to permit the installation of electric power plants of hundreds of MWe total capacity. Assuming for purposes of illustration a total of 100 production wells situated upon the properties and operated over a total of 45 years and providing the energy to operate a power generating facility of 382 MWe, and further assuming a price for geothermal energy as purchased from the producer at 1.5¢ per kilowatt hour (in present, 1980, dollars), the yearly gross revenue to the producer of geothermal energy produced from the field would be approximately $50,180,000. Over 45 years, the total gross revenue to the producer of geothermal energy in terms of constant 1980 dollars would be approximately 2.25 billion dollars. Utilizing the foregoing assumptions, the proportion of total revenues which would be expected to be gross profit to the producer would be substantial.

3. General Geologic Setting

The Brush Wellman geothermal anomaly is situated in the Basin and Range geologic province. This province is characterized by generally north/south trending mountain ranges consisting of faulted and tilted sedimentary rocks generally ranging in age from Cambrian through Tertiary, with Paleozoic rocks predominating.

Many of the ranges are intruded by Tertiary granitic igneous rocks which in places are associated with various kinds of mineral deposits. In both the ranges and basins, volcanism occurred from Tertiary through Recent times. Volcanic rocks have ranged in composition from basalts through rhyolites. The most recent dated rhyolitic eruption in the Utah portion of the Basin and Range province occurred about 0.4 million years ago. The youngest basalt in Utah, near Fillmore, is 670 years old.

Superimposed on the Basin and Range structures are certain "ring" structures, possibly related to igneous activity. These structures in general are identified on the basis of structural and physical manifestations, and the distribution of rock and mineralization types. Some scientists believe that these structures may have considerable importance when prospecting for geothermal resources. The Brush Wellman geothermal anomaly is associated with such a structure, as discussed more fully below.

4. Geologic features associated with the Brush Wellman Geothermal Anomaly.

The Brush Wellman geothermal anomaly is situated in a portion of the Basin and Range province which is locally characterized by extensive, geologically young intrusive and extrusive igneous activity, mineralization, and faulting. Figure 3 is a geologic map of the properties and adjoining areas which illustrates some of these features. The properties are situated in Fish Springs Valley just west of and in part on the bedrock flank of Spor Mountain. The properties are generally underlain in descending order by alluvium, rhyolite, tuff, latite (locally), and the Paleozoic limestones and dolomite of Spor Mountain. The rhyolite, tuff and latite, as exposed in relatively shallow drilling conducted to date, are from a volcanic episode which lasted from 10.3 to 3.4 m.y. before present. During this volcanic episode in excess of 88 square miles of rhyolitic rocks, 31 square miles on andesitic rocks, and two square miles each of dacite/latite and basalt were deposited. Thus, the geothermal anomaly may be related to a cooling magma chamber at depth.

Hydrothermal mineral deposits, representing fossil geothermal systems, are in evidence in much of the general area of the properties. The most significant and widespread mineralization in the area is the beryllium-fluorite mineralization found in and adjoining Brush Wellman's present beryllium mining operations. The Paleozoic rocks of Spor Mountain contain fluorite deposits. Uranium deposits in tuffaceous sandstone and conglomerates are located east of Spor Mountain in the vicinity of the Yellow Chief Mine.

Detailed geologic mapping conducted by Brush Wellman geologists and others has identified more than 1,000 faults in the Spor Mountain area alone. These faults belong to at least five sets, at least two of which post-date emplacement of the volcanic rocks. The faults trend easterly, northerly, northeasterly, and northwesterly, and may in the aggregate substantially enhance the potential of the area for geothermal resources by improving reservoir capacity and flow rates.

A "ring" or possible "caldera" structure has been identified in the area of the properties. This ring structure is clearly apparent on high altitude photographs and is further shown by patterns of faults, the presence of thermal springs at the margin, and other geologic features. The arcuate east side of Spor Mountain marks the approximate eastern margin of the ring structure. The properties are situated along the northeastern margin and within the ring structure.

5. Geothermal Gradient and Heat Flow Data

Geothermal gradient data have been obtained from 36 holes drilled mostly for beryllium or uranium exploration within or adjacent to the properties. Approximately 13,584 feet of drill holes were temperature logged. Average geothermal gradients for the holes logged ranged from 3.0°C/100m (1.7°F/100 feet) to 26°C/100m (14.4°F/100 feet) and averaged 11.7°C/100m (6.5°F/100 feet). These data have been contoured, and are depicted in Figure 4. As shown in this figure, both the northerly and southerly lease areas contain areas of geothermal gradients in excess of 20°C/100m (11.1°F/100 feet).

Utilizing information available for thermal conductivities of various rock types in the Spor Mountain area, combined with data concerning the lithologies found in the various drill holes, average heat flow values were calculated for portions of the area covered by the properties. The results of these calculations indicated that the area of the Brush Wellman geothermal anomaly average heat flow in heat flow units (hfu) range from 3.0 hfu to 4.6 hfu with a mean of 3.8 hfu. These are high values and are believed to be a favorable indication of the presence of a geothermal system. The continental average heat flow is 1.2 hfu, and heat flows of over 2 hfu are considered anomalously high.

6. Other Direct Geothermal Manifestions- Hot Springs, Hot Spring Deposits, and Warm Water Wells.

Northwest of the properties and at or near the northerly margin of the ring structure are Wilson Hot Springs and Fish (Warm) Springs, two small groups of springs which appear to be associated with one or several fault zones. In July, 1967, the temperature of the hottest measured spring of Wilson Hot Springs was 168°F; the estimated discharge was 100 gpm. Temperatures of two of the springs of the Fish (warm) Springs groups range from 65°F to 82°F.

Calcareous deposits of probable hot spring origin occur on the properties along the northeast margin of the ring structure. These deposits, which consist of a tabular body of tan calcareous tufa overlying alluvium, indicate the presence of Recent, presently inactive hot spring activity within the boundaries of the properties.

A number of the exploration wells mentioned above for which temperature gradient data were obtained contained warm water at depth. While some of the warm water may be just an indication of the geothermal gradient, one well in a pump test produced water at a stable temperature of 23°C (74°F) during the test, a temperature about 13°C (24°F) above the mean air temperature.

7. Water Geochemical-Geothermometric data.

In an effort to understand the geochemistry and geothermometry of the hydrologic system at depth, Brush Wellman sampled all the springs in the area, as well as all of the open wells and drill holes which contained water. Of course, the data obtained are imperfect because of the necessity of sampling at or near the present surface with the necessarily-resulting near surface dilution and contamination effects. Nevertheless, the sampling program produced interesting, if difficult to interpret data. Grossly, the waters sampled are of the sodium-calcium-chloride-sulphate-bicarbonate type, with analyses generally relatively high in sodium, chlorine, and sulphate. Such sample results are permissive of waters with a geothermal component. Total dissolved solids ranged from 2,000 mg/l to 25,000 mg/l.

In order to obtain if possible an idea of the temperatures of water at depth within the properties, equilibration temperatures of the various water samples calculated using the various chemical geothermometers published in the literature, were determined. Table 2 summarizes these determinations. As will be seen, while indicated equilibration temperatures range up to 309°C, a wide array of temperatures have been obtained. The wide scatter of indicated temperature values undoubtedly reflects, at least in part, the effects of disequilibration and contamination attendant to sampling in this environment at or near the surface. However, it is believed that the results obtained are at least permissive of the presence of a significant geothermal system at depth.

8. Seismic Activity

Several writers have suggested that often there is a close spatial relationship between micro-earthquake activity and geothermal areas, and further that detailed seismic studies may be useful in geothermal areas to delineate active fault zones which may control the movement of fluids in the geothermal system. A review of available seismic data for evidence of micro-earthquakes, while sharply limited in usefulness because of the lack of nearby seismic stations, has revealed among other things evidence of at least one low magnitude swarm of seven earthquakes with an epicenter in the vicinity of the properties. This evidence of seismic activity could be a favorable indication of geothermal activity in the area.

9. Summary

In summary, the properties are considered by Brush Wellman to be a favorable geothermal prospect because of, among other things, the presence of (1) geothermal gradients and average heat flows significantly above the regional average, (2) location of the anomaly within a favorable geologic "ring" or possible "caldera" structure, (3) the presence of active and Recent thermal springs, late Tertiary intrusive and extrusive igneous rocks, and favorable late Tertiary mineralization types associated with the ring structure, (4) favorable geochemical and geothermometric results based on water samples taken from springs and shallow drill holes near or within the area of the geothermal anomaly, and (5) the presence of numerous faults which may enhance geothermal reservoir capacity and flow rates.

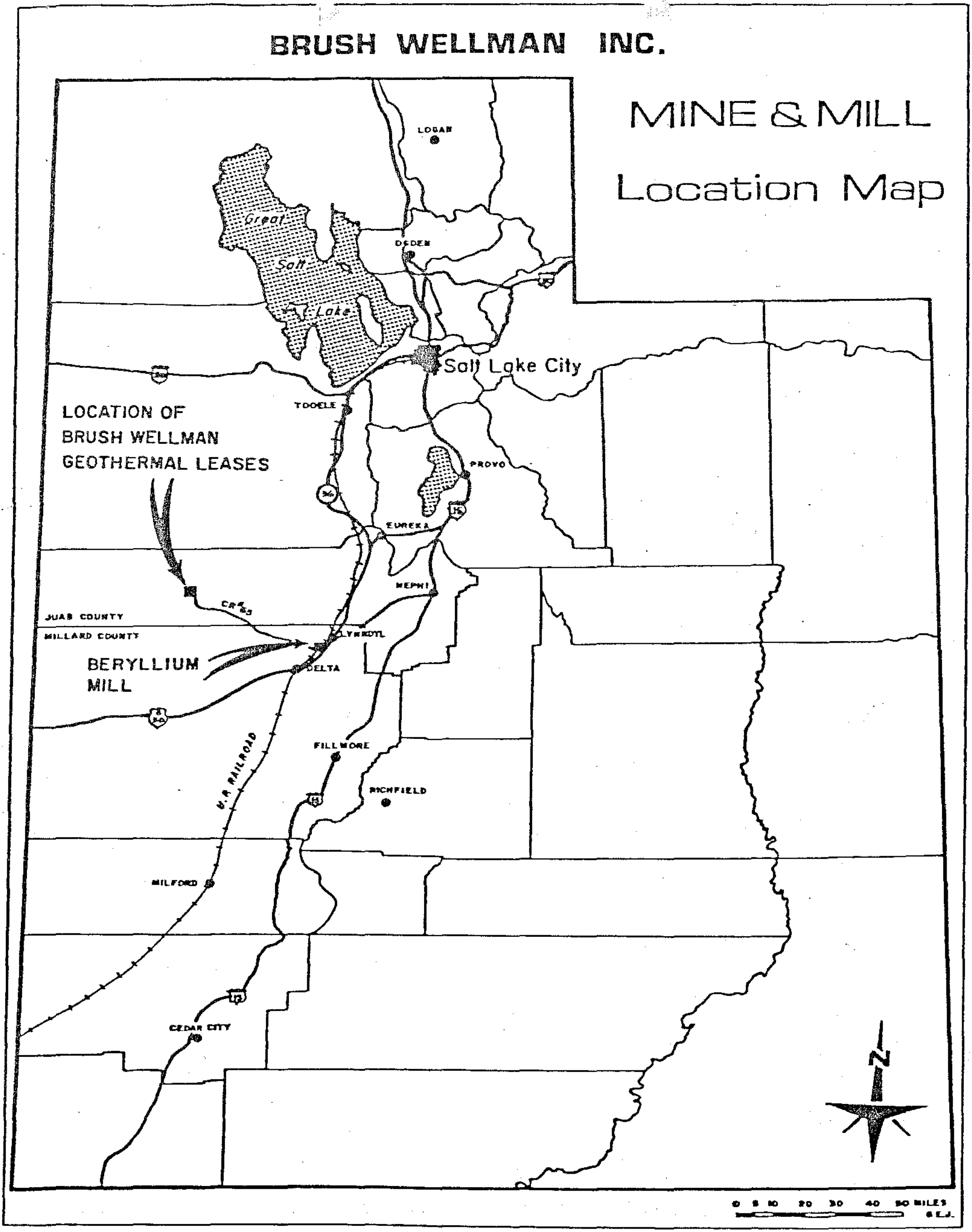

BRUSH WELLMAN INC.
MINE & MILL
Location Map
LOGAN
OGDEN
Great Salt Lake
Salt Lake City
TOOELE
LOCATION OF BRUSH WELLMAN GEOTHERMAL LEASES
PROVO
EUREKA
NEPHI
CR #
JUAB COUNTY
MILLARD COUNTY
LYNNDYL
BERYLLIUM MILL
DELTA
U.P. RAILROAD
FILLMORE
RICHFIELD
MILFORD
CEDAR CITY
N
0 5 10 20 30 40 50 MILES

FIGURE 1

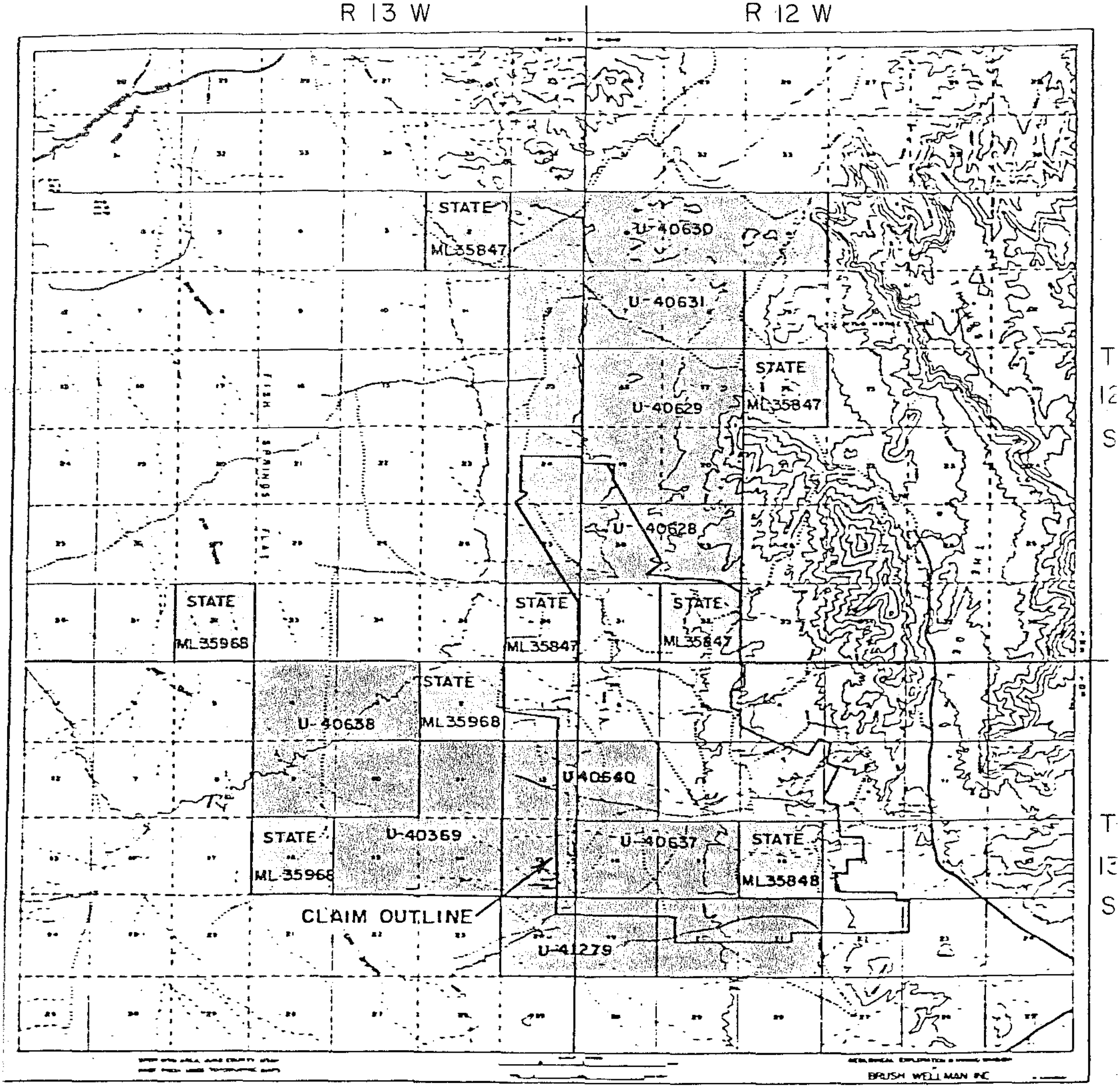


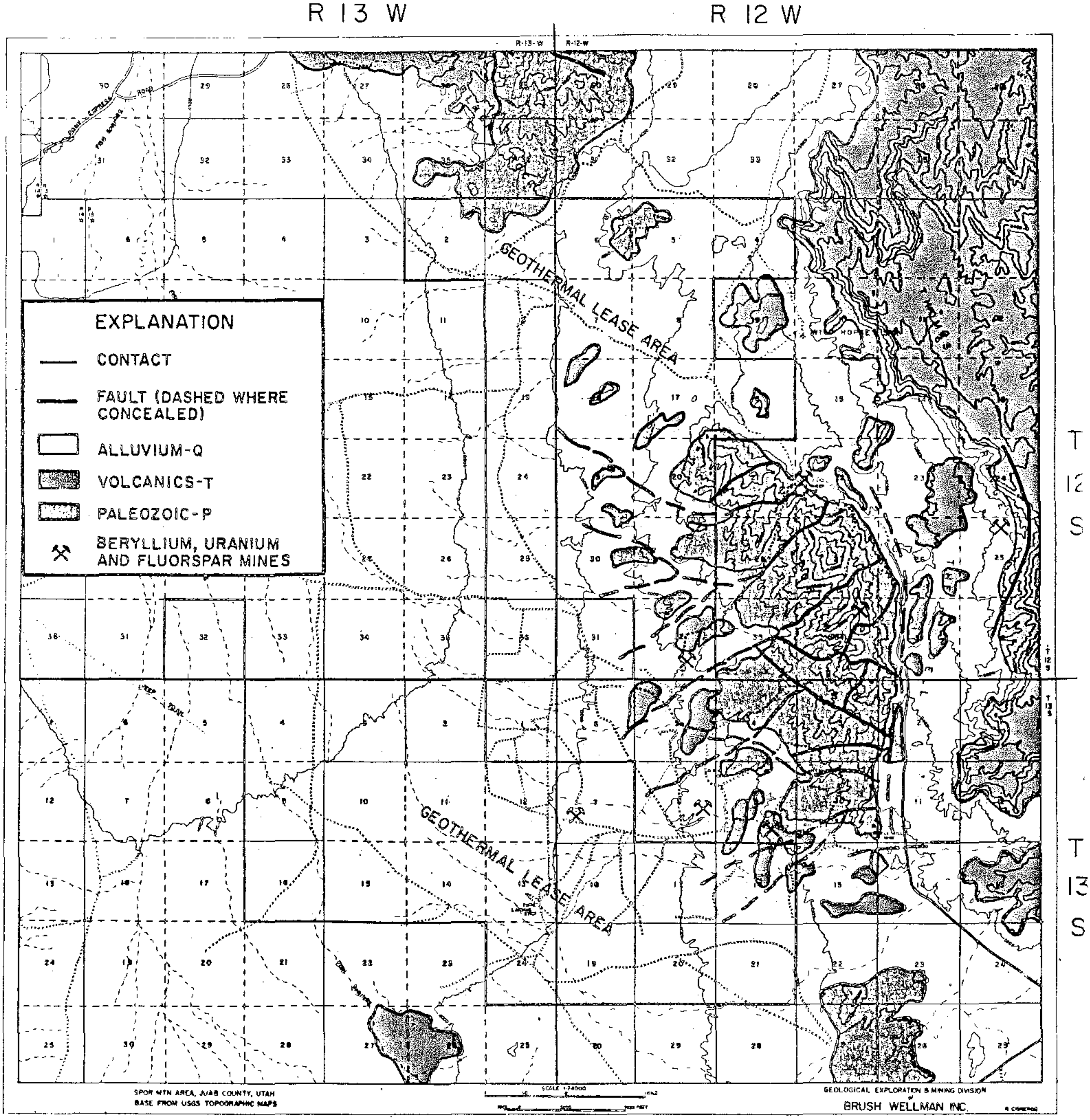
FIGURE 2

LOCATION OF BRUSH WELLMAN GEOTHERMAL
LEASES AND PRE 1970 MINING CLAIMS

TABLE 1

BRUSH WELLMAN GEOTHERMAL LEASES

LEASE NO.	STATE (S) or FEDERAL (F)	LOCATION	NOMINAL ACRES	DATE OF EXECUTION
NORTHERN GROUP				
ML-35847	S	Secs 16, 32 T12S, R12W Secs 2, 32, 36 T12S, R13W	2559.88	6/26/78
U-40628	F	Secs 29, 30 T12S, R12W Sec 24, 25 T12S, R13W	2546.00	2/1/79
U-40629	F	Sec 17,18,19,20 T12S, R12W	2529.00	2/1/79
U-40630	F	Sec 4, 5, 6 T12S, R12W Sec 1, T12S, R13W	2545.04	2/1/79
U-40631	F	Secs 7, 8 T12S, R12W Secs 12, 13 T12S, R13W	2544.00	2/1/79
SOUTHERN GROUP				
ML-35968	S	Sec 32 T12S, R13W Sec 2, 16 T13S, R13W	1919.40	7/17/78
ML-35848	S	Sec 16 T13S, R12W	640.00	6/26/78
U-40637	F	Secs 17,18,20,21 T13S, R12W	2546.72	2/1/79
U-40638	F	Sec 3, 4, 9, 10 T13S, R13W	2559.56	2/1/79
U-40639	F	Secs 11, 13, 14 T13S, R13W	1920.00	2/1/79
U-40640	F	Sec 7 T13S, R12W Sec 12, 13, T13S, R13W	1906.00	2/1/79
U-41279	F	Sec 19 T13S, R12W Sec 24 T13S, R13W	1267.20	3/1/79



GEOLOGIC MAP OF THE SPOR MOUNTAIN AREA (BASED ON STAATZ AND CARR, USGS 1964)

FIGURE 3

GEOLOGIC MAP OF THE BRUSH WELLMAN GEOTHERMAL LEASE AREA

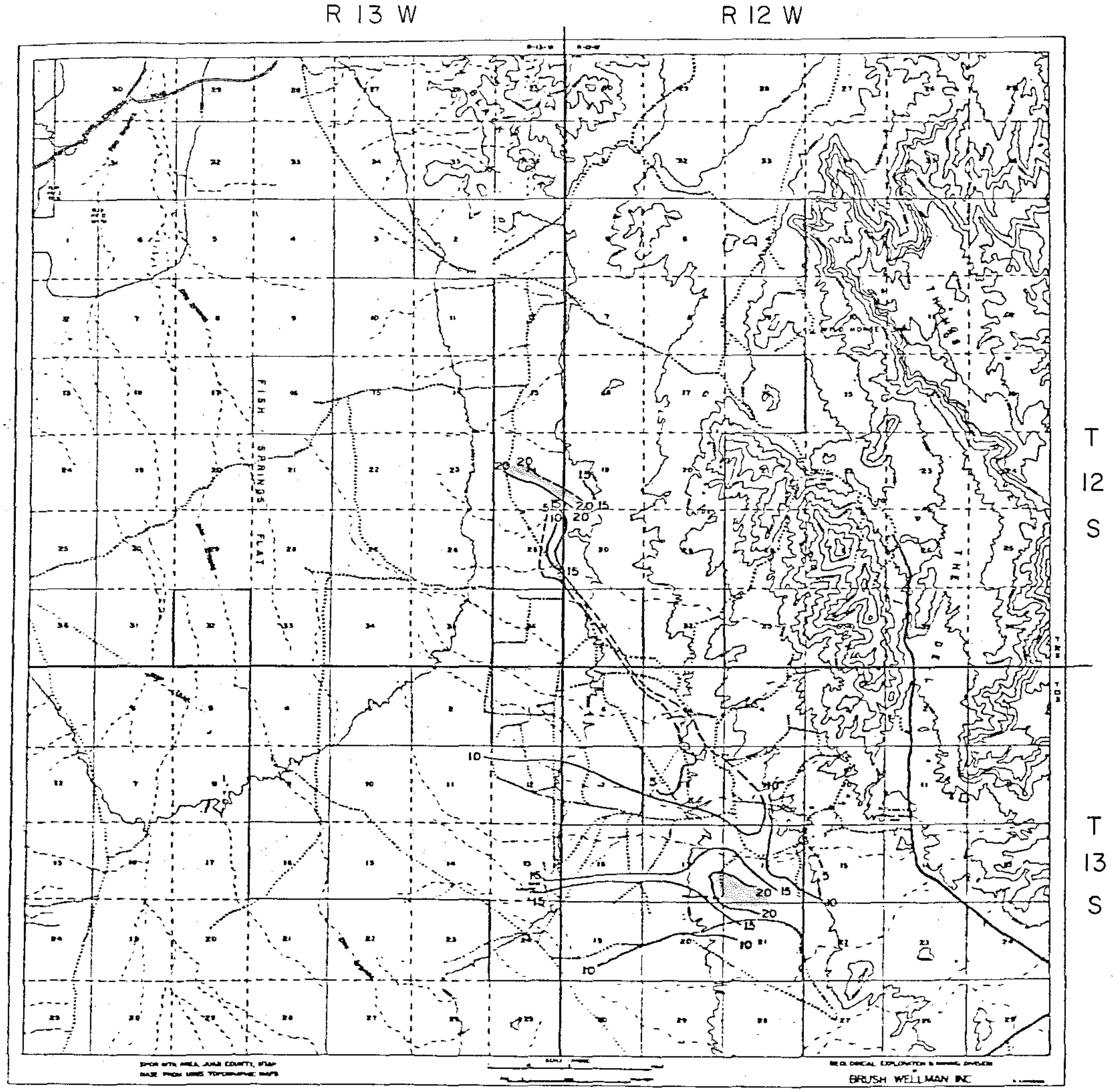


FIGURE 4

CONTOUR MAP OF GEOTHERMAL GRADIENTS
CONTOURS ARE IN °C PER 100m

TABLE 2

Chemically Determined Reservoir Temperatures Based on Water Samples
Brush Wellman Geothermal Prospecting Areas.

Sample	Max. Meas. Temp. °C	SiO_2 Qtz. Steam Flash Truesdell 1976	SiO_2 Qtz Cond Cool Truesdell 1976	SiO_2 Chalcedony Cond. Cool Truesdell 1976	Na/K Truesdell 1976	Na/K Mod Fournier 1979	Na-K-Ca** Fournier & Truesdell 1963	Na-K-Ca-MG Fournier & Potter 1979	Remarks
1 Sec. 2-2 Well	17.8	96	93	61	105	148	81		
2 Sec. 16 Drill Hole	--	119	120	90	139	177	162	121	
3 Esperanza #4 Well	16.4	105	103	72	32	83	64	---	
4 D.H. Sec. 2 Delta S.E. Corner	21.4	114	114	83	139	177	175	113	
5 Drill Hole 22-B	20.3	86	81	48	114	156	160	28	
6 Drill Hole 13-5	32.0	102	100	68	111	153	157	22	
7 Swazey Well	--	120	121	91	172	205	177	120	
8S Cane Springs, South	26.0	71	69	35	136	175	168	140	
8N Cane Springs, North	26.0	75	68	35	136	175	168	137	Silica reported as 0.5 mg/1, possibly in error.
9 Spring 5/8 Mi. N.W. of Cane Springs	--	-20	-34	-68	0	50	89	Cold	
10 Wild Horse Springs	16	81	76	42	309	308	226	93	
11 Energy Fuels Drill Hole	--	74	67	34	55	73	73	43	
12A Anaconda Well	28.1	56	48	14	203	228	195	34	
13 Brush Water Well	--	90	86	53	52	100	65	---	
E130 Drill Hole E130	28.1	99	96	64	135	174	175	26	
14 Energy Fuels Drill Hole	--	2	-10	-45	95	139	60	---	Silica reported as 1.60 mg/1, possibly in error.
Anaconda Well #2	23.3	107	106	75	107	150	186	---	
Fish Springs, Mundorff 1970	27.8	70	64	30	160	195	167	103	
Fish Springs, Conner & Mitchell 1958	27.8	73	67	33	172	204	177	36	
Wilson Springs Mundorff 1970	75.0	87	84	50	-25	25	60	60	
Great Salt Lake Desert, Shallow, Brines	--	44	35	0	135	174		---	
Great Salt Lake Desert, Deep, Brines	88.0	--	--	--	112	155	197	--	

**Best Temperature using Fournier and Truesdell's methods of selecting B.

Truesdell, A.H. (1976) Summary of Section III. Geochemical Techniques in Exploration. In proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, 1975. V. 1 pp. liii-lxxix.

Fournier, R.O. (1979) A Revised Equation for the Na?K Geothermometer. In Expanding the Geothermal Frontier, Trans. Geothermal Resources Council V. 3, pp. 221-224.

Fournier, R.O. and Truesdell, A.H. (1973). An Empirical Na-K-Ca Geothermometer for Natural Water. Geochemica and Cosmochema Acta, Vol. 37, pp. 1255-1275.

Fournier, R.O., and Potter, R.W., II (1979). Magnesium correction to the Na-K-Ca Chemical Geothermometer. Geochemica et Cosmochemica Acta, Vol. 43, pp. 1543-1550.