TEC-3

U.S. General

REPORT ON THE 1977 AND 1978 GEOTHERMAL RECONNAISSANCE PROGRAMS

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Summary

This report discusses geothermal prospects found during the 1977 and 1978 reconnaissance programs, except for the McCoy and Tuscarora prospects which were discussed in a previous report. Heatflow, geological and geochemical techniques were used in exploration. The programs produced nearly 1500 water samples and 728 heatflow determinations at a cost of approximately $120,000.

The following areas of high geothermal potential were recognized:

Nevada	Oregon	Idaho	Montana
Deeth	Glass Buttes	St. Anthony	Canyon Ferry
Dixie Valley	Wagontire		Geyser
Fence Maker			
Goldfield			
Manhattan			
Red Mountain			
Trinity Peak			

Their locations are on the following foldout map (Page iv). Detailed descriptions of heatflow, geochemical and geological regimes follow.

This report is accompanied by a map folder containing 53 1:500,000 scale maps, approximately 14 maps each for Nevada-California, Oregon, Idaho and Montana. The following were prepared for each state:

land status	chemical master	boron
master heatflow	surface temperature	ammonia
heatflow	silica subsurface temp	fluoride
thermal gradient	alkali subsurface temp	chloride

molybdenum
spring deposits

PROSPECTS FOUND IN 1978

Introduction

AMAX conducted geothermal reconnaissance programs during the summer of 1977 and 1978. This report discusses the collected data from these explorations.

Heatflow, hydrogeochemical and geological exploration techniques were used. Heatflow measurements were made on holes of varied genre, i.e., irrigation wells, windmills, mine shafts, mineral exploration holes and preexisting thermal gradient holes. Conductivity estimates were made on drill cuttings or local outcrops. Water samples from both ambient temperature and thermal sources were taken. Samples were analysed in the field for five, more or less fugitive, ions. Samples were further analysed in the AMAX Denver laboratory for twelve other ions. Samples of spring deposits were collected and analysed for their major constituents, calcium carbonate and silica. Geological assessments were made in areas of mercury, sulfur and fluorite deposition in search of evidence of recent hydrothermal activity.

The distribution of data points with respect to state and county boundaries along with approximate manpower and capital expenditures are discussed in Chapter Two. The criteria for the selection of areas discussed in this report are treated in Chapter Three. The remainder of the report is divided according to state, i.e., Nevada - California, Oregon, Idaho and Montana. Each state heading is subdivided into heatflow and geochemical anomalies.

Geothermal Reconnaissance Program

The geothermal reconnaissance program was conceived in 1977 to seek out favorable geothermal targets in which AMAX would have the commanding land position. The program began with exploration of Nevada and eastern California, resulting in the leasing of the McCoy and Tuscarora prospects in Nevada that summer. The program continued in the summer of 1978 with more detailed exploration of Nevada and initial reconnaissance of central Oregon, Idaho and western Montana.

AMAX collected nearly 1,500 water samples and made 728 heatflow measurements in these two summers. The total exploration cost, not including the cost of leasing acreage, is about $120,000. The exploration has consumed about 750 man days.

The state-county distribution of heatflow and geochemical data is on Figure 1. Clearly, little new data can be collected in Nevada except for parts of Nye, Lincoln and Clark counties. Further exploration in central Oregon, central Idaho and western Montana would be marginally productive. A few weeks should be spent in further exploration of eastern Idaho.

Many important areas still beg thorough exploration. Productive work could be done in southeastern California, southwestern Utah and much of Arizona and New Mexico. Northern California and the Cascade Range of Oregon and Washington have not been adequately explored. Future programs should concentrate in these areas.

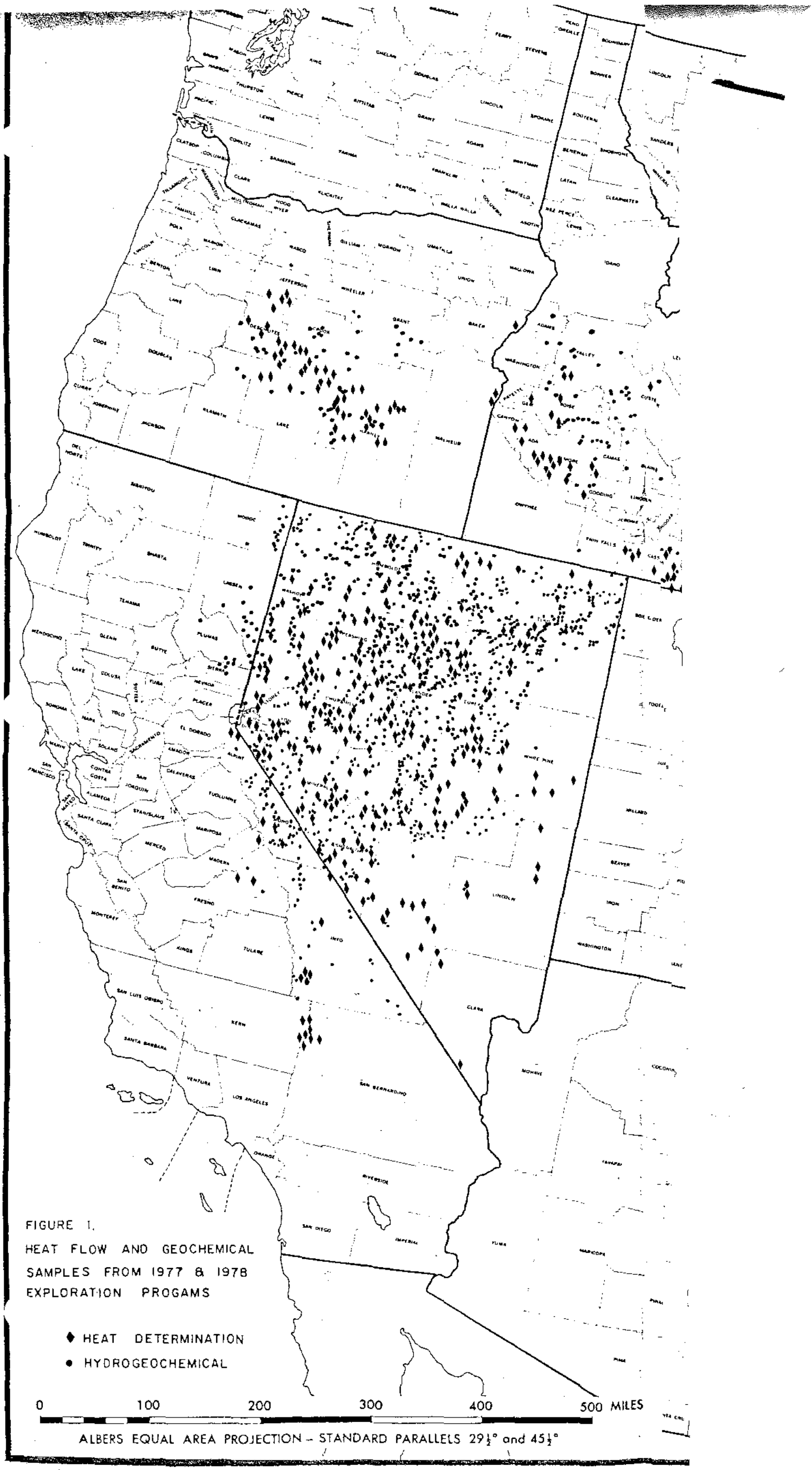

FIGURE 1.
HEAT FLOW AND GEOCHEMICAL SAMPLES FROM 1977 & 1978 EXPLORATION PROGAMS

Criteria for Selection of Heatflow and Geochemical Data

The purpose of this report is to present leaseable areas with geothermal potential. Accordingly, AMAX data is far more extensive than the size of this report indicates. Many well-known areas are not discussed for one or more of the following reasons: first, exploratory drilling produced reservoir fluids less than 170°C; second, data from an area could not be obtained and third, little or no land is available for lease. The Stillwater, Humboldt House and Steamboat Springs areas, respectively, are examples of these omissions.

Certain criteria were used to select heatflow and geochemical anomalies. The potential areas discussed under heatflow have unencumbered land positions, gradients of reasonable value and credibility and assessory geological and/or geochemical information. Potential areas based on geochemistry must first be in areas of unencumbered land and second, give reliable evidence that equilibration in excess of 170°C has occurred.

General Considerations

The Basin and Range Province is characterized by high elevation, high heatflow, thin crust, subdued magnetic anomalies and low mantle seismic velocity. The underlying mantle here may be hotter than mantle underlying other parts of the U. S. The west-northwest crustal extension, expressed as obvious north-south trending structures, is probably responsible for diapiric rise of mantle material and in turn the formation of the profound basaltic and rhyolitic volcanism. Moreover, the central Basin and Range produces more seismic events than any other part of the continental U. S. Seismic activity indicates a continuation of extensive forces and possible diapiric rise of mantle heat and molten rock. The Basin and Range may well be the most fertile geothermal area in North America.

Nevada Heatflow

AMAX made 523 heatflow measurements in Nevada and eastern California during 1977 and 1978. Unfortunately, the majority of data comes from areas which are heavily leased. A list of these areas is shown in Table 1. In these areas, the coverage varies from very complete to sparse. A complete heatflow map is included with this report.

Table 1. Popularly Leased Geothermal Areas For Which AMAX Has Heatflow Data.

Northwestern Nevada

Continental Lake	Dixie Valley
Gerlach	Allen Hot Spring
San Emido Desert	Kyle Hot Spring
Fly Ranch	Leach Hot Spring
Bradys Hot Spring	Buffalo Hot Spring
Desert Peak	Spencer Hot Spring
Soda Lake	Stillwater

Northeastern Nevada

Ruby Valley	Hot Springs Point
Beowawe Geysers	Dewey Dan Hot Springs

Southeastern Nevada and Southeastern California

Coso Hot Springs, California
Randsburg, California
Goldfield, Nevada

Seven unleased areas of high heatflow were identified in Nevada; they are called Deeth, Dixie Valley, Fence Maker, Goldfield, Manhattan, Red Mountain and Trinity Peak. Each of these areas is discussed according to heatflow, geology, geochemistry and lease position.

Deeth

Four high heatflow holes were probed north of the Deeth interchange on Interstate 80, about 32 km northeast of Elko (Figure 2).

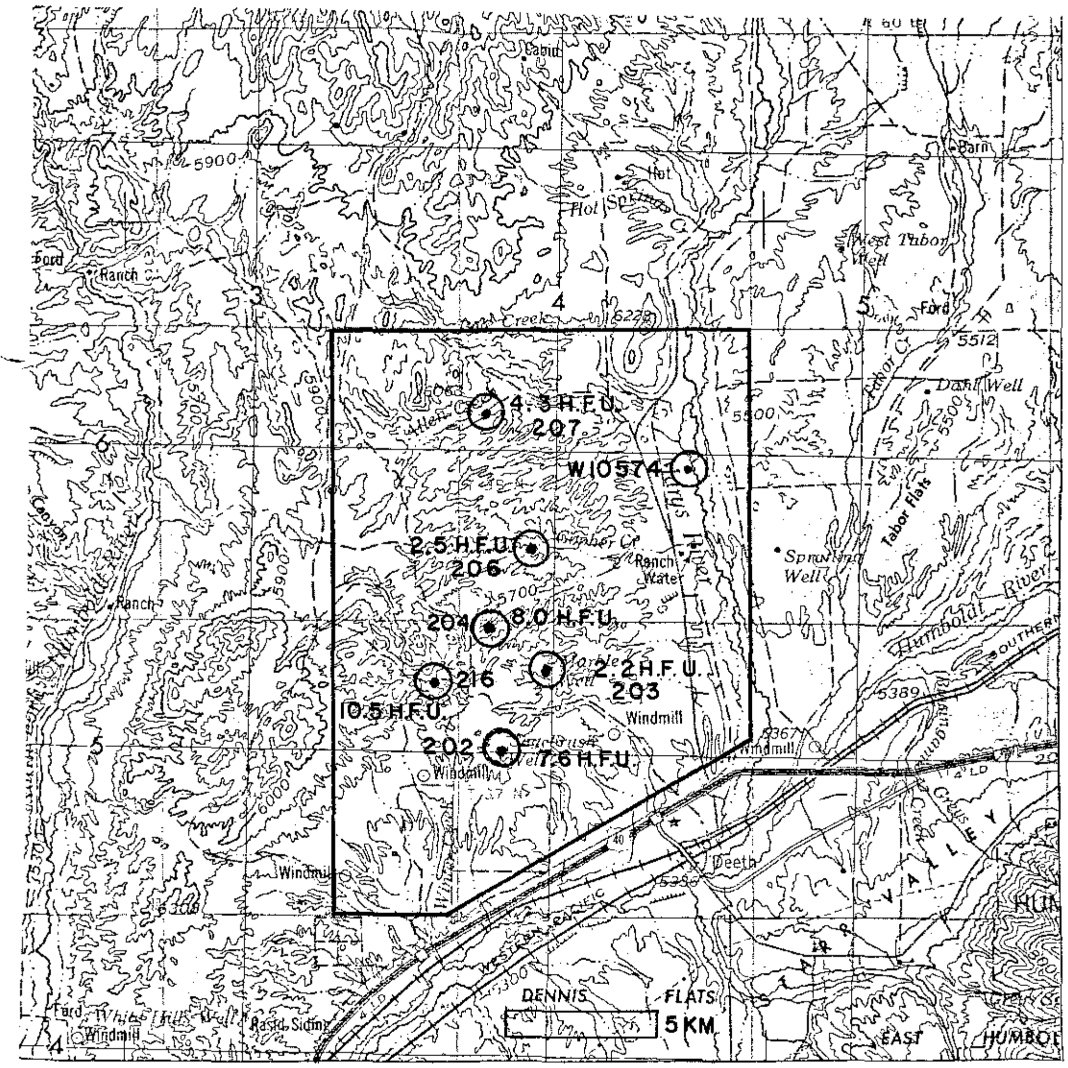

Figure 2. Deeth Prospect with Buy Line, Heatflow and Hot Spring Locations.

Table 2 is a list of specific heatflow data. The data is very credible and delineates a narrow north-south trending heatflow anomaly. Hole 204 (Plate 1) is 140 meters deep and has a gradient and bottom hole temperature of 134°/km and 45.52°, respectively.

Table 2. Deeth Heatflow Data

ΔNumber	Depth(m)	BHT°C	Q H.F.U.	ΔT°C/km
202	21	17.96	7.6	218
203	42	16.38	2.2	64
204	140	45.52	8.0	134
206	40	17.20	2.5	71
207	40	17.70	4.3	122
216	60	27.61	10.5	301

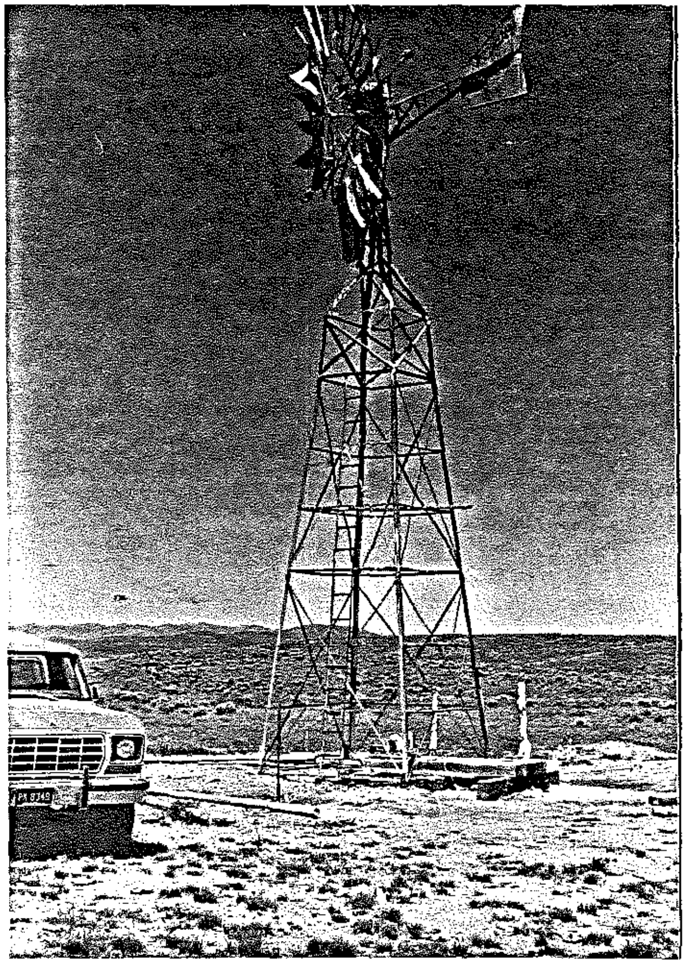

Plate 1. Deeth Hole 204 Salt Block Well

The Tertiary lacustrine Humboldt Formation dominates the local geology; however, small outcrops of Pennsylvanian Diamond Peak and Permian Gerster Formation are in sections 2 and 11 of T38N R58E. A small outcrop of highly crystalline rhyolite is exposed in sections 26 and 35 of T38N R58E. The Humboldt Formation obscures most local structure, except for the north-south trending Mary's River Fault.

The Mary's River Hot Springs are in sections 11 and 14 of T38N R59E (Figure 2 and Plate 2). The springs have deposited siliceous sinter in the

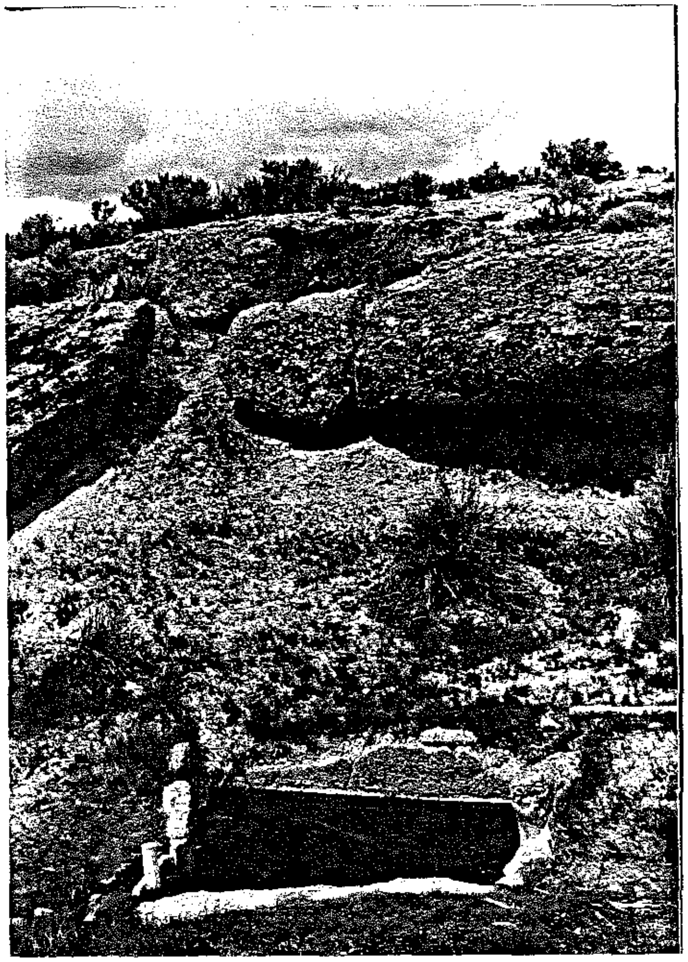

Plate 2. Mary's River Hot Spring

recent past. Major ions are distributed as follow:

$$HCO_3 > Cl > SO_4 \quad Na > K > Ca > Mg.$$

The waters are rich in fluoride and depleted in lithium, boron and ammonia (Table 3). The subsurface geothermometers should be reliable, owing to the low calcium concentration. Temperatures range from 161° to 197°C.

The prospect is located within the railroad land grant corrider so sections are alternately Federal and fee. The railroad has title to about half of the fee land while the remaining quarter is held by a diversity of individuals. Figure 2 shows a very liberal buy line which should include the majority of the north-south trending heatflow anomaly.

W-10574	
County	Elko
Temp (C)	38.
Flow (GPM)	5.
pH	8.15
Cl	29.
F	22.
SO_4	5.
HCO_3	988.
CO_3	0
SiO_2	150.
Na	500.
K	34.
Ca	3.
Mg	.4
Li	0
Cu	0
B	0
MO	15.
NH_3	.2
TDS	1741.7
$TSiO_2$	161.
TNa-K	143.
TNa-K-Ca	197.

Table 3. Analysis of Mary's River Hot Springs.

Dixie Valley

AMAX successfully filed geothermal lease applications on 7,789 acres in Churchill County as a result of the 1978 geothermal reconnaissance

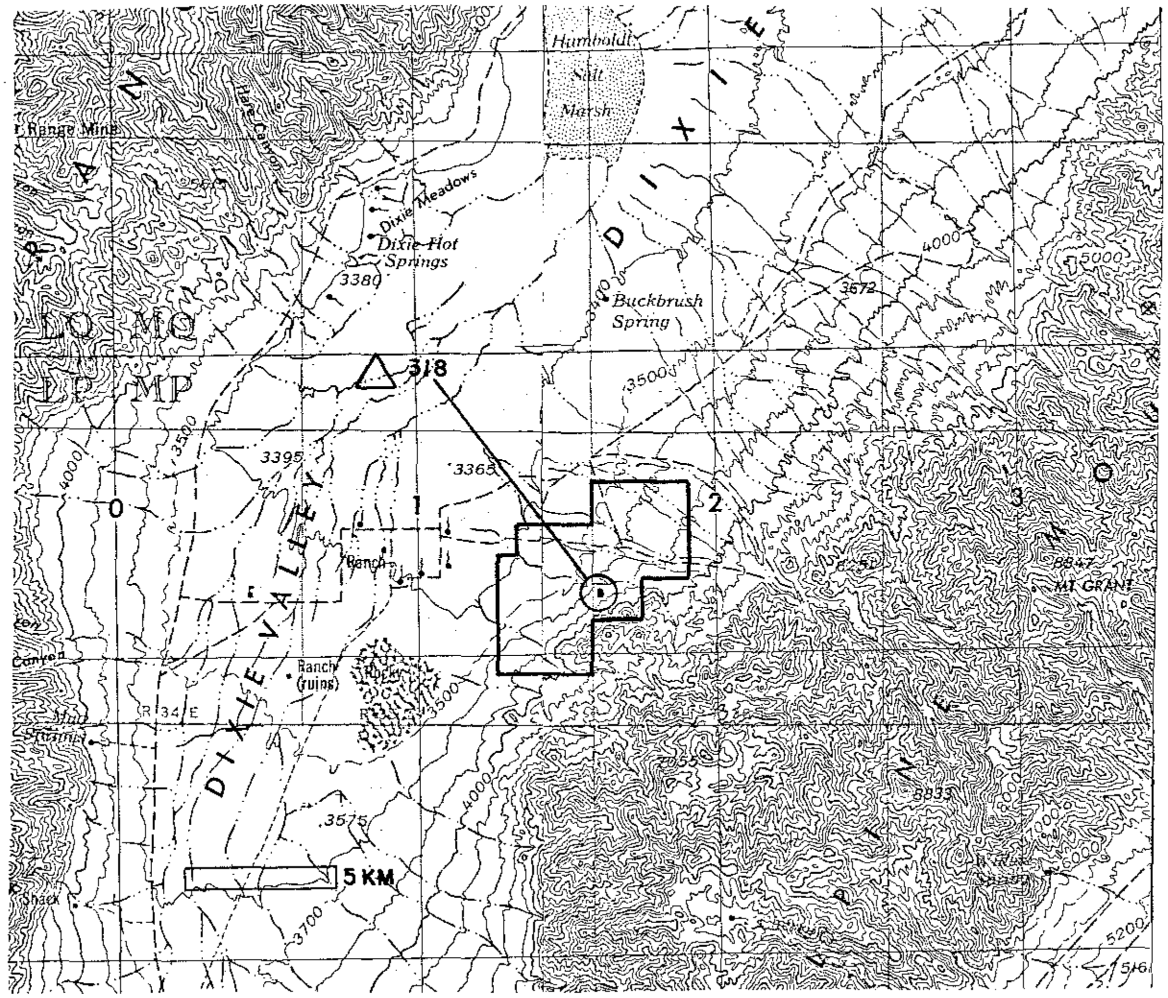

Figure 3. Dixie Valley Prospect, Land Line and Location of Hole 318

program (Figure 3). The prospect is 150km east of Reno in central Dixie Valley.

Dixie Valley is a typical Basin and Range valley. The valley is surrounded by the Clan Alpine and Stillwater Mountains which are capped with Tertiary lavas, ash flow tuffs and sediments. The valley is a complex graben formed by downward displacement on several major step faults, and has several thousand feet of alluvial fill.

A 1954 earthquake caused surface rupture along nearly 42km of the Stillwater Range near the prospect. The prospect contains a 22 meter hole with a gradient and heatflow of 557°/km and 19.5 H.F.U. respectively (Plate 3).

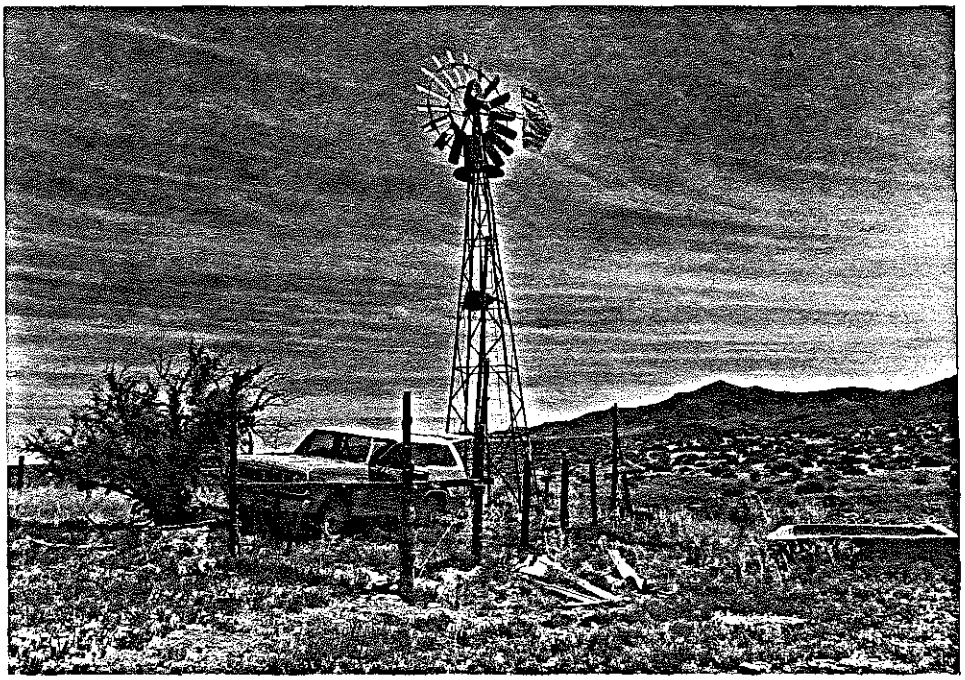

Plate 3. Grover Point Well, Number 318

Fence Maker

A single point heatflow anomaly was detected in southern Buena Vista Valley. This hole is off the west flank of the Stillwater Mountains near Fence Maker Pass (Figure 4), and exhibits the following characteristics:

ΔNumber	Depth(m)	BHT(°C)	Q H.F.U.	ΔT°C/km
372	27.5	19.98	9.1	260

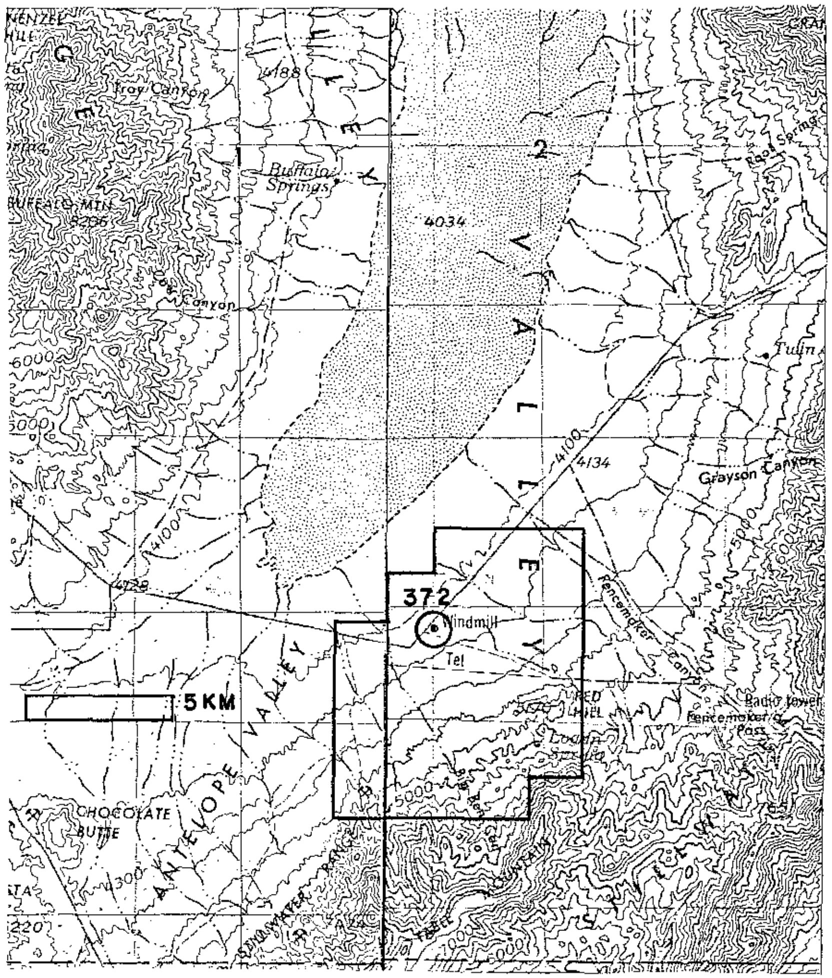

Figure 4. Fence Maker Heatflow and Buy Line

The hole's high gradient is of interest even though depth and bottom hole temperature may lessen credibility of the measurement. The hole was drilled in Recent playa material. Thickness of the underlying alluvial material may be less than 500 meters in depth. Tertiary tuffaceous sedimentary rocks crop out southeast of the hole. Further southeast, the Stillwater Mountains are formed from a Triassic argillite sequence and gabbroic intrusions capped by ash flow tuffs that range from Oligocene to Miocene in age.

The buy line in Figure 4 was conceived with great difficulty. Alternative purchase lines may be offered after further investigations are made.

Goldfield

A single point heatflow anomaly was identified in Esmeralda County, about 20km south of Tonapah (Figure 5). The data pertaining to

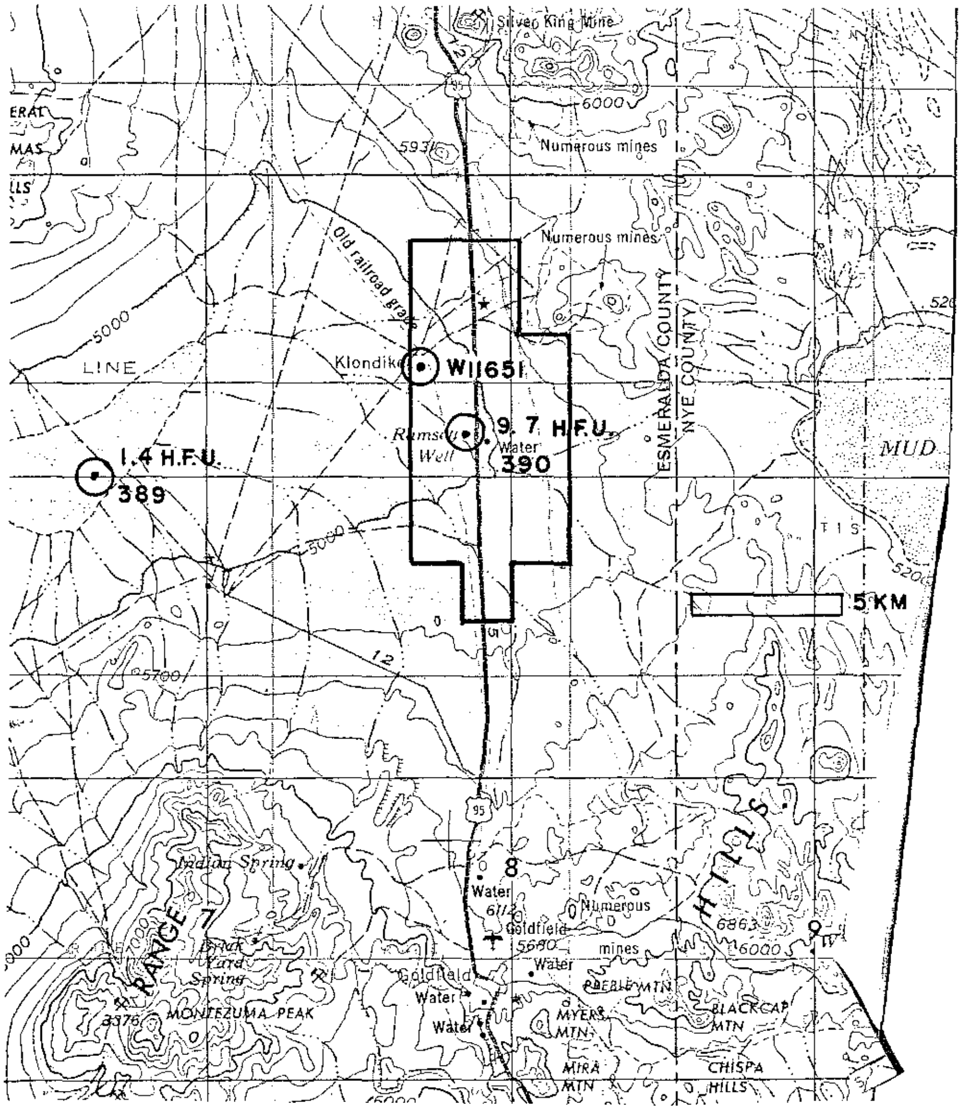

Figure 5. Goldfield Heatflow, Geochemistry and Land

390 and 389 are:

ΔNumber	Depth(m)	BHT(T°C)	Q H.F.U.	ΔT(°C/km)
390	60	24.00	9.7	278
389	55	15.36	1.4	39

A warm well (W11651) was sampled northwest of hole 390. The well produces 22°C water enriched in fluoride, boron, calcium and magnesium. The subsurface temperatures are high but lack credibility. This fluid is definitely thermal water (Table 4).

W11651	
County	Esmeralda
T°C	22
Flow	5
pH	8.1
Cl	70
F	7.4
SO_4	90
HCO_3	116
CO_3	0
SiO_2	57
Na	82
K	18
Ca	34
Mg	7
Li	.2
B	.8
NH_3	0.1
$TSiO_2$	108
TNa-K-Ca	206

Table 4. Klondyke Warm Well Analysis.

The anomaly is at the north end of the Goldfield Hills, a Tertiary volcanic center noted for epithermal gold and silver ores. The wells are drilled in a Recent playa of unknown thickness. The nearest rocks are rhyodacite flows (22m.y.), Tertiary tuffaceous sedimentary rocks, ash flow tuffs, basalts and andesites. The Goldfield Hills are a dome structure with a broadening fracture zone that controlled mineralization.

Local land position is almost entirely federal. The buy line seen on Figure 5 is based on extensions and speculated intersections of north trending structures that originate from the Montezuma Range and the Goldfield Hills.

Manhattan

Seven holes with high heatflow were logged at the southern terminus of the Carico Lake Valley (Figure 6). Specific data on each hole is listed in Table 5.

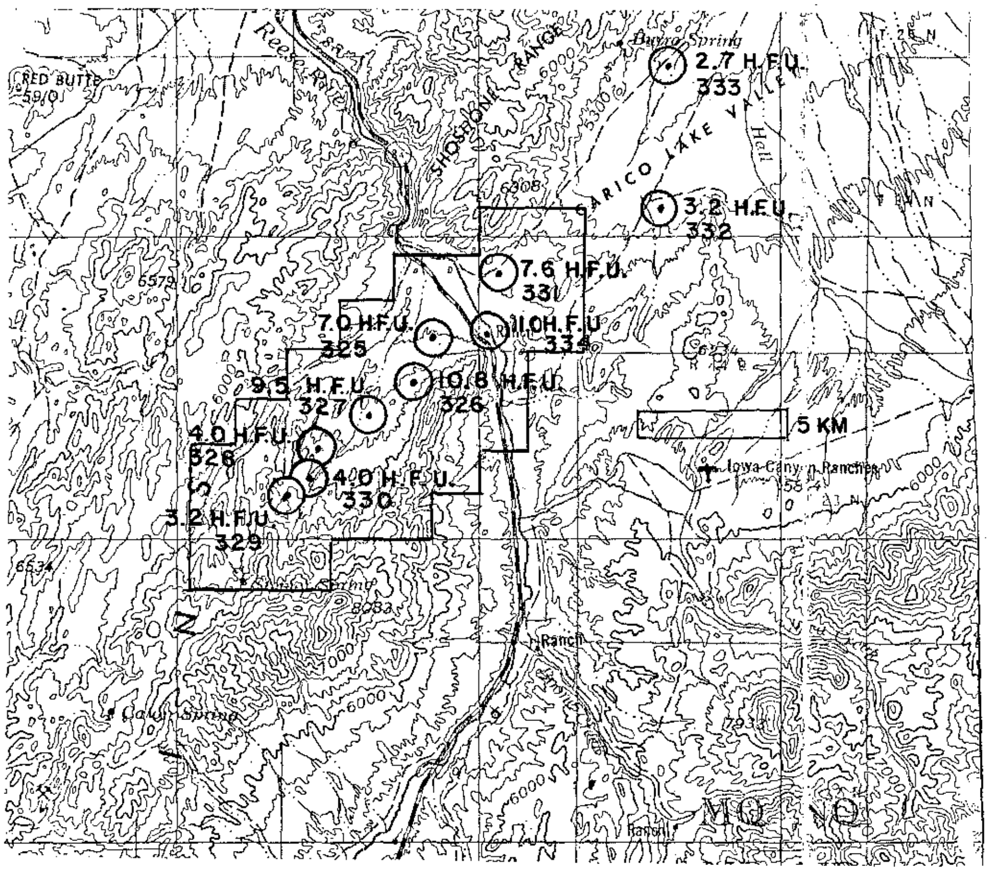

Figure 6. Manhattan Heatflow and Buy Line

Table 5. Manhattan Heatflow Data.

ΔNumber	Depth(m)	BHT(°C)	Q H.F.U.	ΔT°C/km
325	48	22.64	7.0	175
326	160	57.80	10.8	270
327	70	32.98	9.5	238
328	70	21.10	4.0	99
329	70	20.49	3.2	79
330	70	21.20	4.0	99
331	50	22.05	7.6	191
332	34	17.20	3.2	93
333	24	15.40	2.7	76
334	26	24.40	11.0	313

Credibility of the data is excellent; however, hot water was encountered in Δ326 (Plate 4) and Δ327 at depths of 65 and 100 meters, respectively.

The heatflow anomaly is clearly controlled by shallow hot water.

The local area is well covered by Recent alluvium and Tertiary lacustrine material. The Ordovician Valmy and the Permian Antler Formations are exposed locally. The Shoshone Mountains to the west are

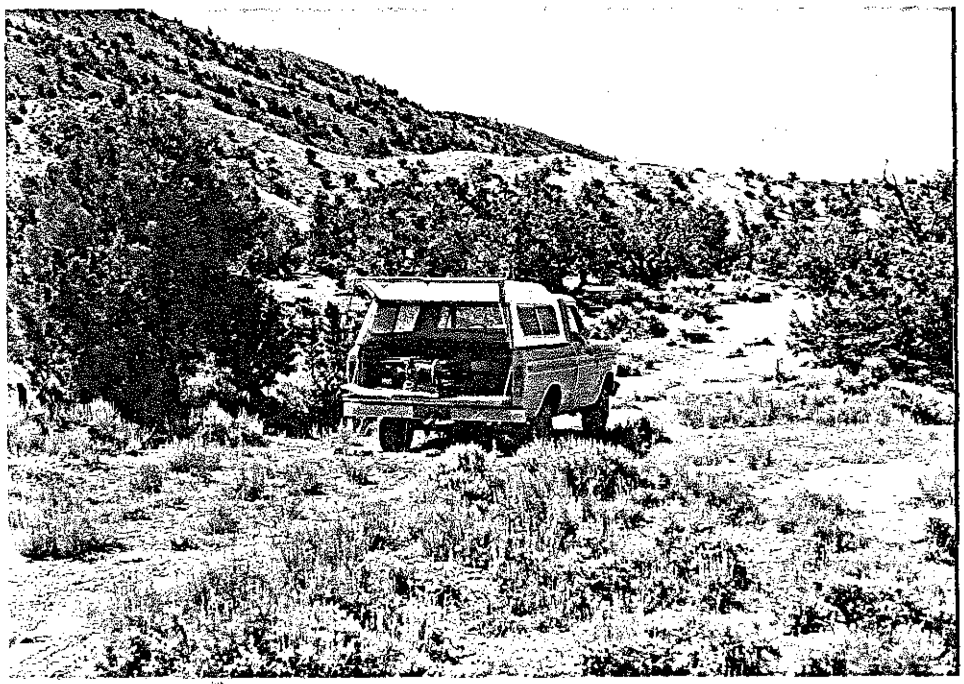

Plate 4. Manhattan Hole 326

capped by Tertiary siliceous ash flow tuffs. The Reese River Valley has suffered consistant faulting from mid-Tertiary to Recent times. Extensive northeast faulting is also present in the Shoshone Range. Fault scarps in Quaternary alluvium indicate very recent local tectonism along older stepped range front faults. Local geomorphic evidence points to a relatively recent change of course of the Reese River which may have resulted from local faulting and uplift.

The buy line seen in Figure 6 endeavors to integrate structural and heatflow data. The true heatflow anomaly may be considerably narrower than the buy line suggests.

Red Mountain

Four holes with high heatflow were logged about 24km southwest of Austin in central Nevada (Figure 7).

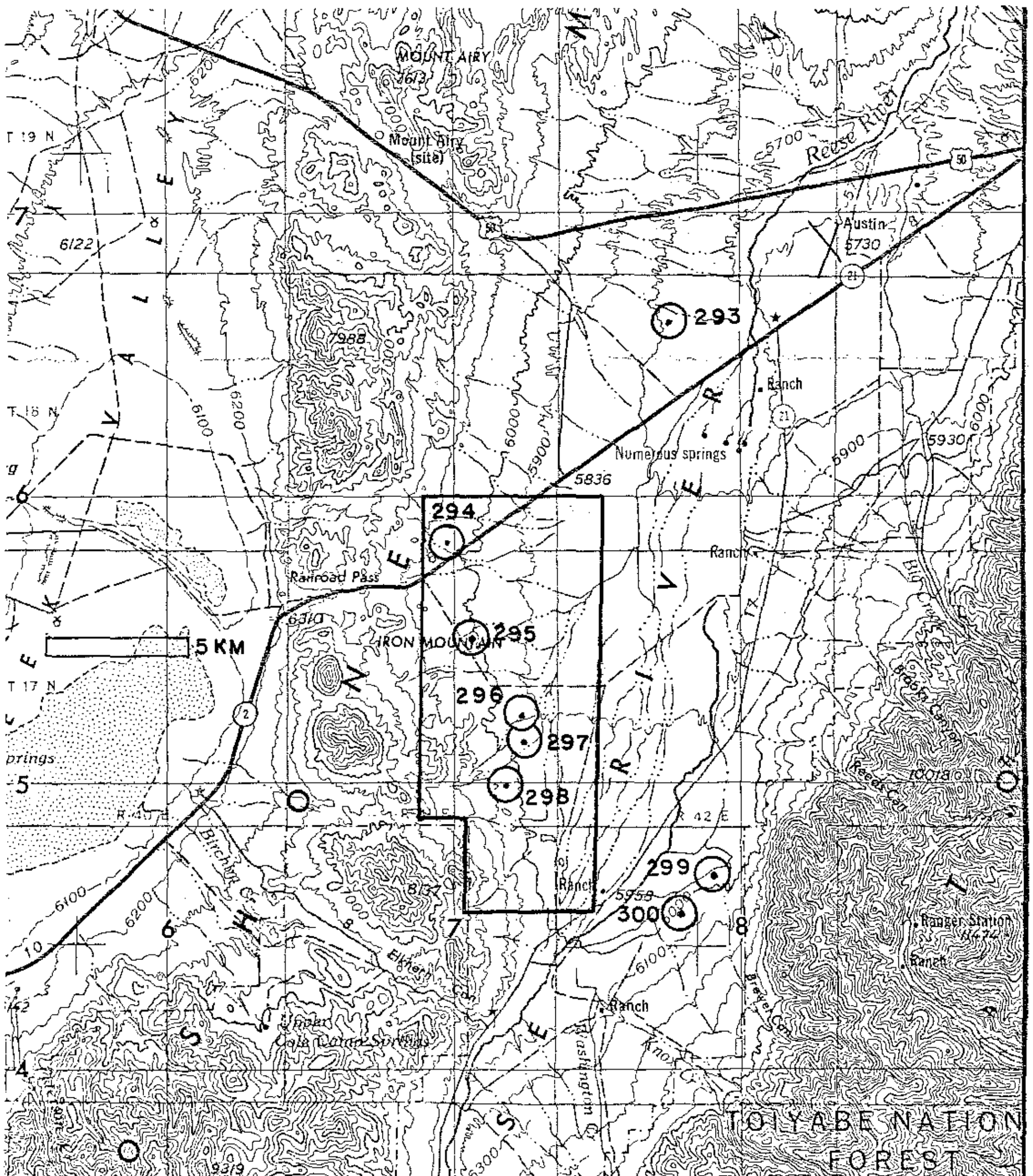

Figure 7. Red Mountain Heatflow and Buy Line

Specific data on the holes is shown in Table 6.

Table 6. Red Mountain Heatflow Data

ΔNumber	Depth(m)	BHT(°C)	Q H.F.U.	ΔT°/km
293	26	11.44	0.3	8
294	90	18.94	2.7	77
295	80	18.58	3.5	99
296	30	15.04	8.7	248
297	60	23.57	5.4	155
298	77	23.79	6.3	180
299	35	12.66	2.1	59
300	35	12.12	1.3	38

The data is reliable except for Δ293. The heatflow information delineates a narrow north-south heatflow anomaly which encircles Δ296 through Δ298 (Plate 5).

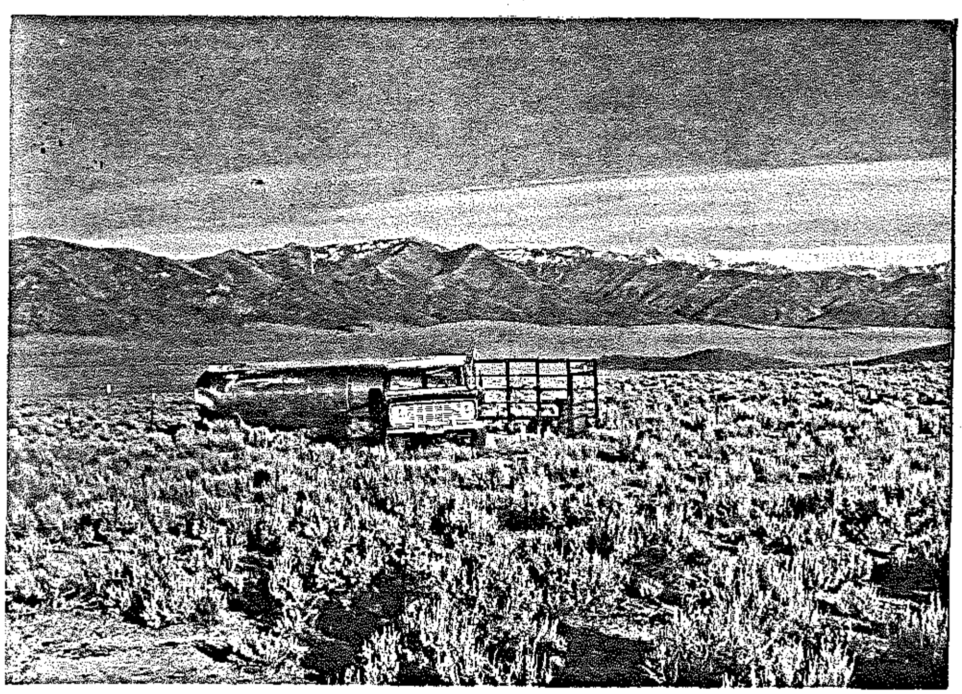

Plate 5. Red Mountain Hole 298

The prospect is on the east flank of the Shoshone Mountains. The range consists of welded and non-welded ash flow tuffs and rhyolite flows of Tertiary age. Published geology of the area is incomplete.

The cited heatflow may represent leakage along a range front fault.

Approximately one-third of the land within the buy line seen in Figure 7 is fee and the remainder is federal. The buy line is generous and probably encloses the bulk of the heatflow anomaly.

Trinity Peak

Two extraordinary heatflow measurements were made on the western flank of the Trinity Mountains in northwestern Nevada. The holes are located about 33km northwest of Lovelock (Figure 8).

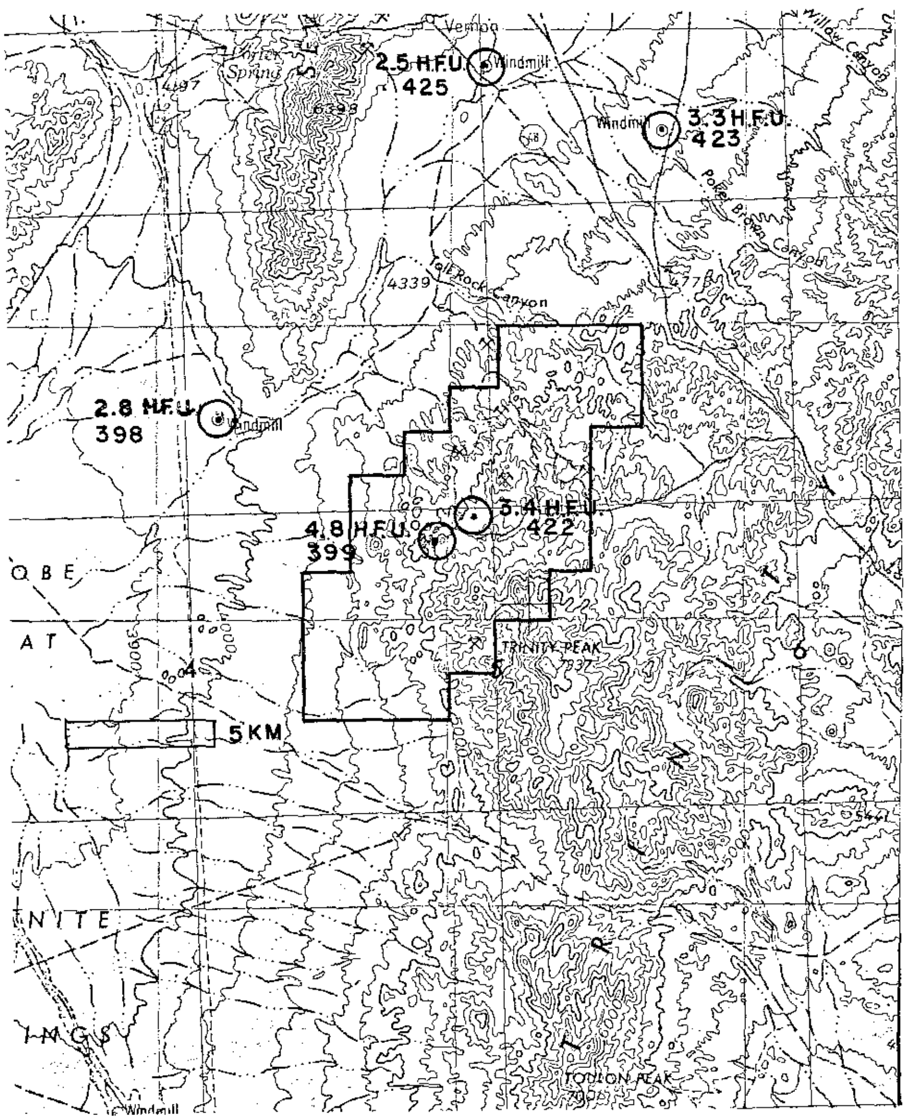

Figure 8. Trinity Peak Heatflow and Buy Line

Table 7 shows specific data pertaining to Figure 8.

Table 7. Trinity Peak Heatflow Data

ΔNumber	Depth(m)	BHT(°C)	Q H.F.U.	ΔT°C/km
398	45	17.03	2.8	81
399	32	17.34	4.8	193
422	27	20.03	3.4	172
423	27	18.84	3.3	9
425	27	18.50	2.5	70

The low heatflow relative to high gradients results from low conductivity of diatomaceous earth (Plate 6). The data retains integrity in spite of the shallow depth and relatively low bottom hole temperatures.

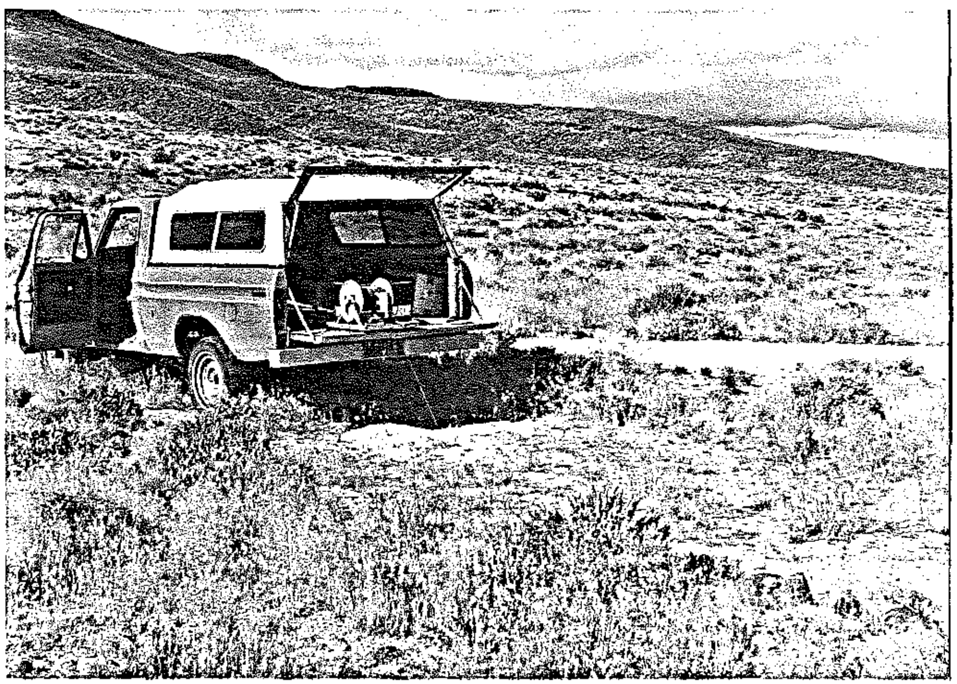

Plate 6. Trinity Peak Heatflow Hole 422. White Material is Diatomaceous Earth

The Trinity Range is a typical northeast trending block fault mountain range. The core of the range consists of Jurassic-Triassic eugeosynclinal argillitic rocks with some Cretaceous granodiorite intrusions. These are covered by as much as 760 meters of volcanic rocks. The volcanics are Miocene andesites, basalts, rhyolites and ash flow tuffs. The range is surrounded by a mantle of Tertiary lacustrine sediments. The Granite Springs Valley may contain in excess of a kilometer of alluvium. "Diatomaceous earth" that is mined locally may have resulted from the reworking of siliceous ash flow tuffs.

The local land position is almost entirely federal. A recommended purchase line based on geology and heatflow is shown in Figure 8.

Nevada Geochemistry

Four areas thought to have high geothermal potential were selected from 33 areas discussed in a previous report. These areas exhibit interesting, sound geochemistry. Geology and deep heatflow data reinforces the geochemistry. Each of the four areas is heavily leased; however, the potential merit of each area demands AMAX accrue an interest in one or all four.

Crescent Valley

Dewey Dan Hot Spring is in section 10 of T28N R49E, about 46km southeast of Carlin (Plate 7).

Plate 7. Dewey Dan Hot Spring

It issues out of a well-marked range front fault at the west margin of the Cortez Mountains. The Cortez Mountains consist of Jurassic quartz monzonite and a tuff sequence named the Pony Trail Group. Two minor mercury prospects are located within a mile of the spring. Cinnabar and realgar are clearly visible in portions of altered quartz monzonite. Spring waters deposit minor quantities of siliceous sinter.

The thermal waters have basic pH and distribution of major ions as follows:

$HCO_3 > SO_4 > Cl \quad Na > K > Ca > Mg$.

Concentrations of silica, boron and lithium are very high while calcium and magnesium are low. These waters are similar to those of Beowawe Geysers. Chemical geothermometry indicates subsurface temperatures ranging from 180°C to 218°C (Table 8).

W-10647	
County	Eureka
Temp (C)	82.
Flow (GPM)	10.
pH	8.41
Cl	82.
F	10.
SO_4	140.
HCO_3	544.
CO_3	12.
SiO_2	200.
Na	320.
K	44.
Ca	10.
Mg	1.3
Li	2.7
Cu	0
B	2.8
MO	2.
NH_3	.16
TDS	1371.
$TSiO_2$	180.
TNa-K	224.
TNa-K-Ca	218.

Table 8. Analysis of Dewey Dan Hot Spring.

Three holes of unknown origin were probed in the vicinity of the spring. Heatflows range from 4.3 to 20.5 H.F.U. (Figure 9).

Chevron has the commanding land position. The first applications were made in 1974, while others followed in 1975 and 1977. Diablo Exploration also holds acreage assigned by Chevron. The presence of Chevron complicates any ventures by AMAX in the area; nevertheless, the Dewey Dan area is an extremely interesting geothermal prospect.

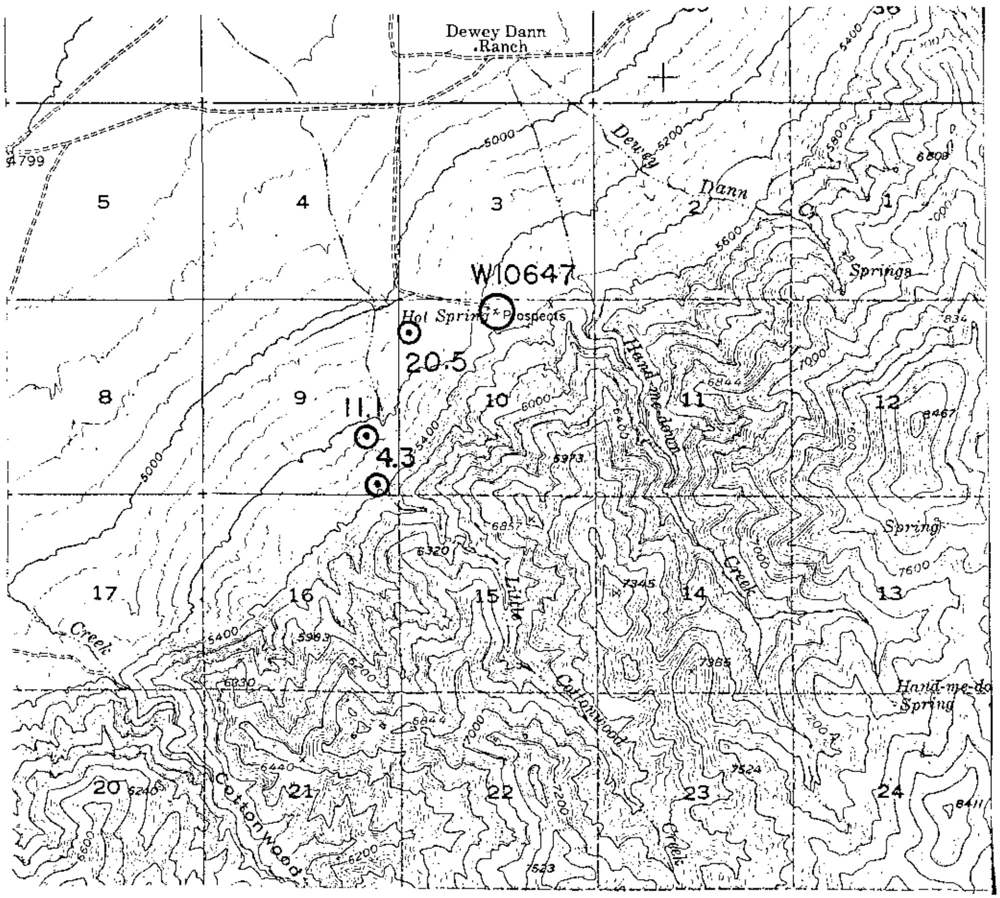

Figure 9. Dewey Dan Heatflow

Salt Wells

The Borax Works Hot Spring is 2km south of Salt Wells in section 7 of T17N R30E, (Plate 8). Water rises out of the Salt Wells

Plate 8. Borax Works Hot Spring

Basin north of the Bunejug Mountains (Figure 10). Rocks both north and south of the spring are late Miocene and early Pliocene andesite and basalt flows. The springs flow from a topographic and structural high which may be related to the north trending horst which controls the Stillwater geothermal field to the north.

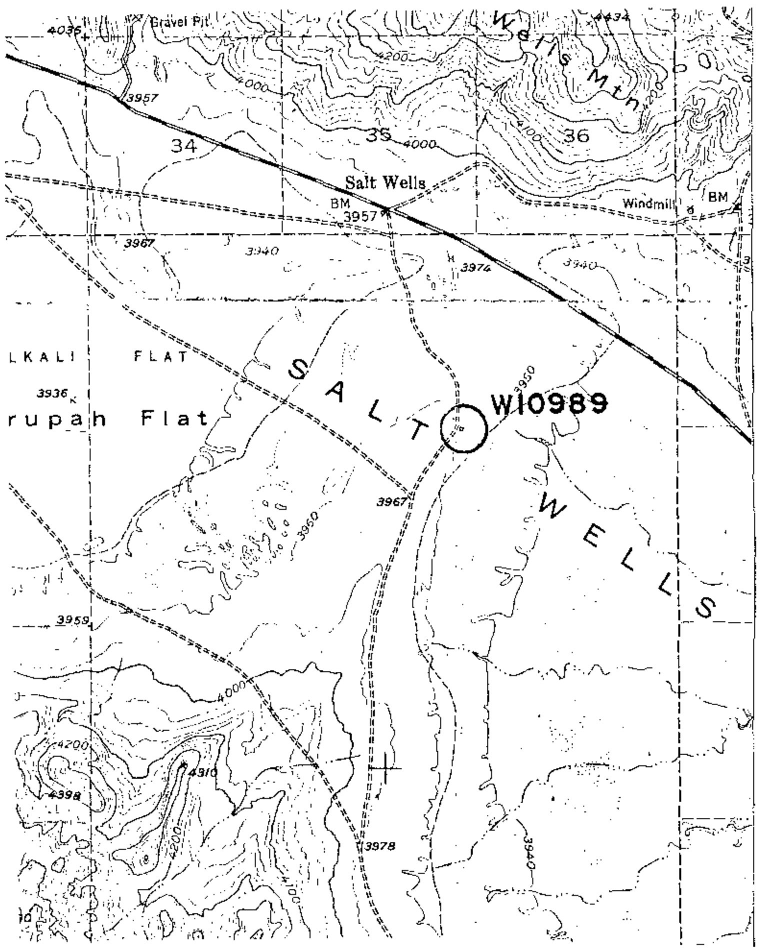

Figure 10. Location of Borax Works Hot Spring

The spring discharges sodium chloride water with the following ionic distribution:

$Cl > SO_4 > HCO_3$ $Na > K > Ca > Mg$.

Concentrations of boron, silica, lithium and ammonia are interestingly high (Table 9). Subsurface temperatures range from 186 to 195°C.

Anadarko and Occidental have the commanding land position. Their leases were applied for in January 1974. Union Oil, Hunt, Walter Leftwich and W. P. Carver also hold federal leases. The Salt Wells area is very promising. If possible, AMAX should acquire an interest in the area.

W-10989	
County	Churchill
Temp (C)	54.
Flow (GPM)	10.
pH	7.48
Cl	1200.
F	7.6
SO_4	330.
HCO_3	208.4
CO_3	0
SiO_2	220.
Na	900.
K	72.
Ca	31.
Mg	2.4
Li	2.1
Cu	0
B	5.7
MO	0
NH_3	.55
TDS	2979.7
$TSiO_2$	186.
TNa-K	159.
TNa-K-Ca	195.

Table 9. Analysis of the Borax Works Hot Spring.

Steamboat Springs

Steamboat Hot Springs are in the southeast quarter of T18N R20E, 18km south of Reno (Plate 9).

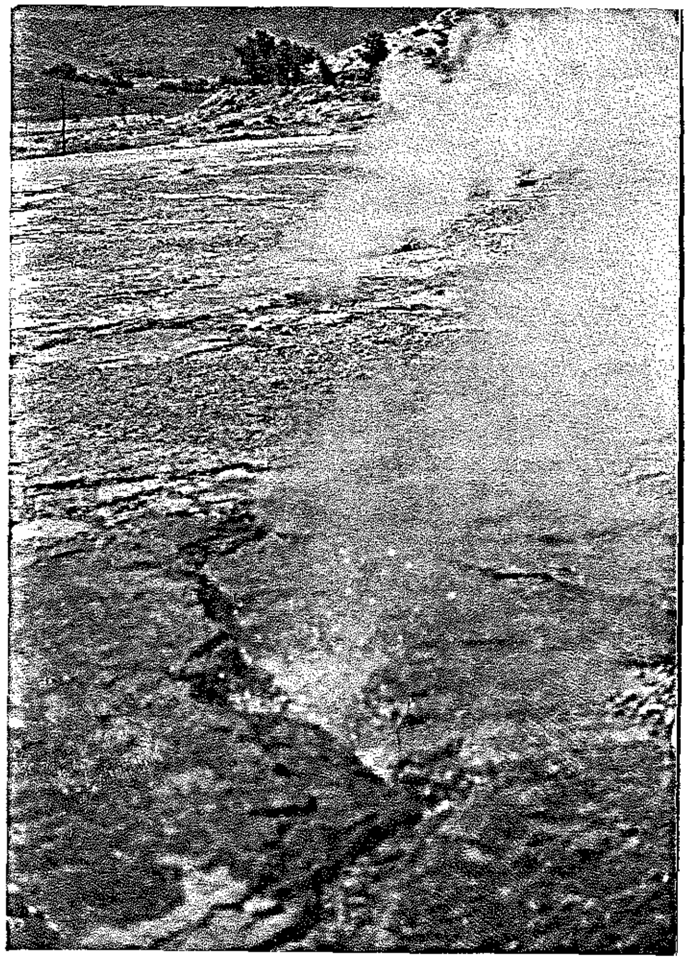

Plate 9. Steamboat Hot Springs and Sinter Deposits

Pre-Tertiary metamorphic and granitic rocks form the basement. Middle and Late Tertiary volcanic rocks are abundant in the surrounding area. Pleistocene Lousetown andesite, Steamboat Rhyolite and Pleistocene mud-volcano breccia are the most youthful rocks.

The most numerous faults in the area strike nearly north. These faults displace pre-Lake Lahontan alluvium and Mid-Pleistocene siliceous sinter. Large siliceous sinter terraces (Plate 9) are structurally controlled by a north-trending fault system. Lead, tungsten, silver and mercury mineralization are associated with certain faults.

The thermal waters have a neutral pH and contain high concentrations of boron, lithium and silica. Concentrations of calcium and magnesium are low. The major ions are distributed as follow:

$Cl > HCO_3 > SO_4$ $Na > K > Ca > Mg$.

Results from chemical geothermometry should be very reliable. Subsurface temperatures range from 190 to 210°C (Table 10).

W-11236	
County	Storey
Temp (C)	91.
Flow (GPM)	15.
pH	7.4
Cl	850.
F	2.1
SO_4	120.
HCO_3	310.
CO_3	0
SiO_2	290.
Na	650.
K	64.
Ca	12.
Mg	.5
Li	8.1
Cu	0
B	50.
MO	
NH_3	.13
TDS	2356.8
$TSiO_2$	190.
TNa-K	182.
TNa-K-Ca	210.

Table 10. Analysis of Steamboat Hot Springs.

Nevada Thermal Power Company (Magma) drilled six holes in the area between 1954 and 1961. The holes range from 159 to 588 meters. Phillips has recently completed a deep test in the southwest quarter of section 4 of T18N R20E. Shallow wells drilled in the past have been plagued by scaling and limited permeability.

The land situation is complicated. Phillips, Gulf, Hunt, Pacific Energy and William Hendrey have taken federal geothermal applications. Leasing took place from 1974 to 1975. The area is attractive and should be considered for joint ventures.

Beowawe

The Beowawe Geysers are in T31N R48E, 17km southeast of Battle Mountain (Plate 10). A blowing well drilled by Magma is visible in the background. The name Whirlwind Valley was coined by early settlers who, looking from present-day Emmigrant Pass, mistook the geysers for whirl-

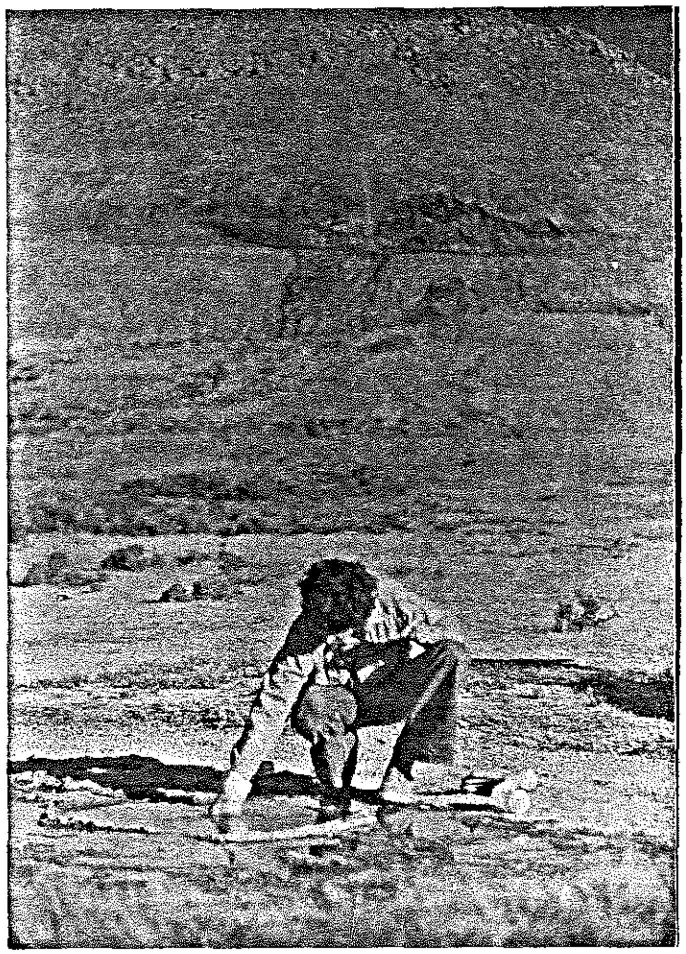

Plate 10. Beowawe Geysers

winds. Several natural springs and geysers which no longer erupt issue out at the south margin of the valley.

A profound east-west trending fault zone controls thermal activity and extensive siliceous sinter terraces which are visible from a distance of 20km. The faults separate unconsolidated valley deposits from Late Tertiary basalt and andesite flows of the Malpais Rim. The Tertiary volcanics are underlain by Silurian-Ordovician carbonates. A minor mercury deposit is located 6km east of the geysers.

Seven heatflow holes were probed in the area (Figure 11). The heatflow anomaly shows clear east-west development and structural control. Table 11 is a list of data on each hole.

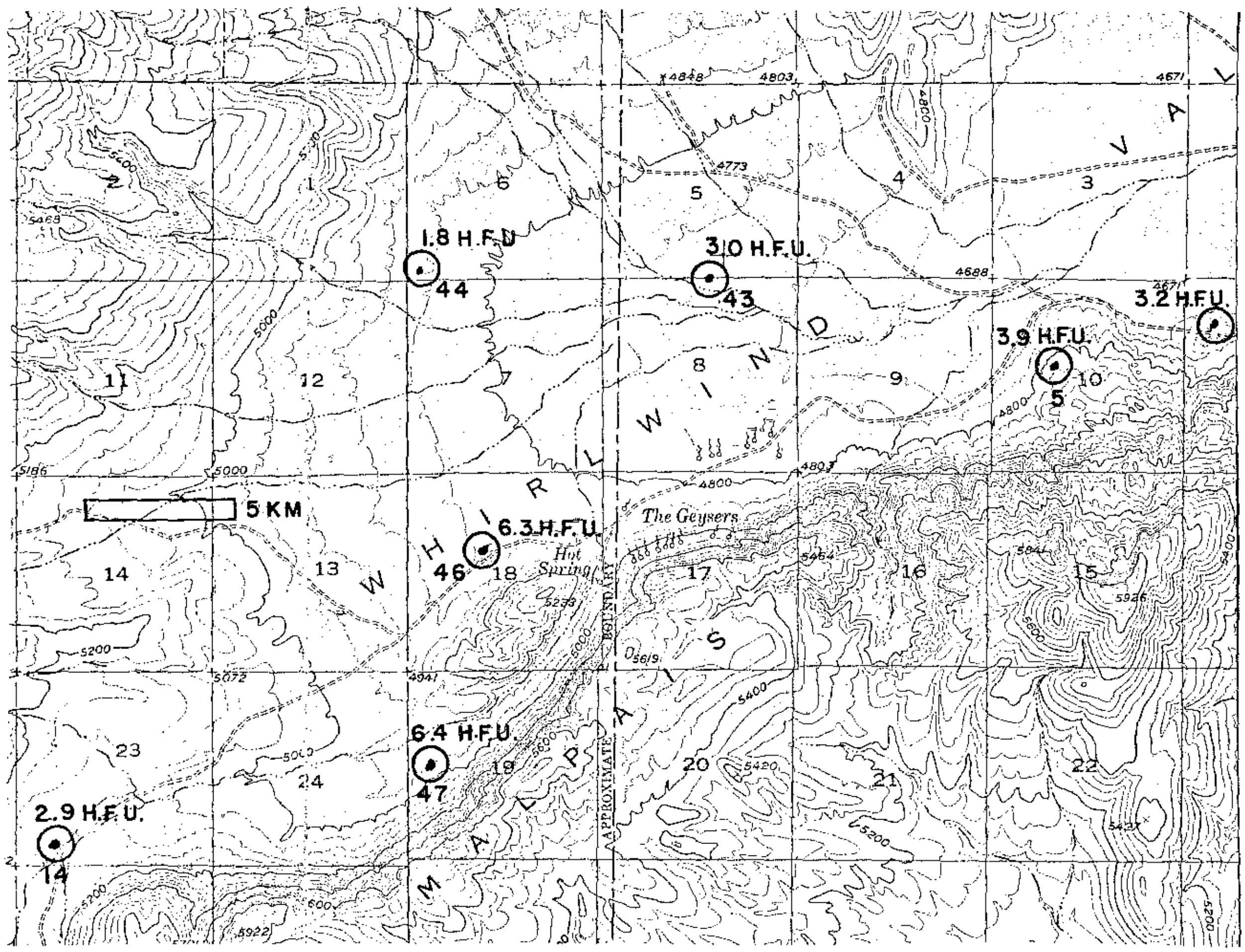

Figure 11. Beowawe Heatflow Data

Table 11. Beowawe Heatflow

ΔNumber	Depth(m)	BHT(°C)	Q H.F.U.	ΔT°C/km
4	85	18.65	2.9	73
5	25	15.10	3.9	97
43	33	12.70	3.0	100
44	34	14.80	1.8	60
46	32	18.30	6.3	180
47	33	17.83	6.4	183

The thermal waters exhibit basic pH and contain interesting concentrations of boron, lithium, ammonia and silica. The major ions occur as follow:

$HCO_3 > SO_4 > Cl$ $Na > K > Ca > Mg$.

Levels of calcium and magnesium are low. Chemical geothermometry indicates temperatures in the range of 183 to 199°C (Table 12).

Thirteen holes ranging in depth from 72 to 1661 meters were drilled from 1959 to 1975 by Magma Power, Vulcan, Thermal Power and Sierra Pacific Power. Chevron drilled two holes in excess of 1500 meters in sections 13 and 19 of T31N R47E during 1976. Temperatures of 210°C were reported.

W-10738	
County	Eureka
Temp (C)	88.
Flow (GPM)	1.
pH	9.19
Cl	54.
F	16.
SO_4	120.
HCO_3	162.2
CO_3	88.
SiO_2	260.
Na	210.
K	14.
Ca	2.
Mg	.1
Li	1.2
Cu	0
B	1.3
MO	3.
NH_3	.51
TDS	932.3
$TSiO_2$	199.
TNa-K	141.
TNa-K-Ca	183.

Table 12. Analysis of Beowawe Geyser.

Chevron has the commanding land position, acquired in 1974. Getty, G.R.I., Supron, Diablo Exploration, Delta Funds and American Thermal Resources also hold federal acreage. The bulk of leases were taken in 1974. The area has great geothermal potential and should be considered as a future venture.

Low Potential Areas

Many hot spring areas were judged unattractive after careful study. Generally, water chemistry of such springs proved unreliable and ambiguous. In some cases auxiliary data and/or deep tests conducted in the summer of 1978 abased the areas. Table 13 is a list of these areas.

Table 13. Areas of Questionable or Low Potential

Name	County	State	Estimated Subsurface Temperature °C
Hot Springs Point	Lander	NV	231
Elko Hot Hole	Elko	NV	229
Bruneau River Hot Spring	Elko	NV	225
Mound Warm Spring	Lander	NV	216
Kyle Hot Spring	Pershing	NV	209
Gridley Lake Hot Spring	Humboldt	NV	205
Company Warm Spring	Esmeralda	NV	204
Spenser Hot Spring	Lander	NV	203
Rhyolite Ridge Hot Well	Esmeralda	NV	202
Colado Hot Well	Pershing	NV	202
Manure Canyon Warm Spring	Washoe	NV	201
Golcanda Hot Spring	Humboldt	NV	196
Hazen Hot Spring	Lyon	NV	184
Great Boiling Hot Spring	Pershing	NV	192
Leach Hot Spring	Pershing	NV	191
Stoney Point Hot Spring	Lander	NV	188
Hot Springs Ranch	Humboldt	NV	187
Rose Creek Warm Spring	Humboldt	NV	186
Buffalo Valley Hot Spring	Lander	NV	185
Bonham Ranch Warm Well	Washoe	NV	173
Columbus Warm Well	Esmeralda	NV	173
Brady Hot Spring	Churchill	NV	?
San Emido Desert	Washoe	NV	?
Pinto Hot Spring	Humboldt	NV	?
Soda Lake	Churchill	NV	?
19 Hot Spring	Pershing	NV	169
Peterson Hot Spring	Modoc	CA	169
Palm Hot Spring	Inyo	CA	169
Hyder Hot Spring	Pershing	NV	167
Lee Hot Spring	Churchill	NV	166
Section 9 Hot Spring	Mono	CA	164
Hot Pot Hot Spring	Humboldt	NV	163
Alkali Hot Spring	Esmeralda	NV	163
Powley Creek Hot Spring	Modoc	CA	163
SE 36 Hot Spring	Pershing	NV	162
Needle Rocks Hot Spring	Washoe	NV	159
NW 10 Hot Spring	Washoe	NV	156
Black Rock Hot Spring	Humboldt	NV	155
Fly Ranch Geyser	Washoe	NV	150
NWNW 25 Hot Spring	Lander	NV	147
The Hot Springs	Humboldt	NV	146
Baltazor Hot Spring	Humboldt	NV	144
Rawhide Hot Spring	Mineral	NV	138
Tecopa Hot Well	Inyo	CA	137
Double Hot Spring	Mineral	NV	134
Trego Hot Well	Pershing	NV	134
Stillwater Hot Well	Churchill	NV	132
SE 32 Hot Well	Plumas	CA	132

Table 13. Continued

King Lear Hot Spring	Washoe	NV	131
Dyke Hot Spring	Humboldt	NV	130
Dixie Valley Hot Spring	Churchill	NV	129
Grovers Hot Spring	Alpine	CA	129
Leonards Hot Spring	Modoc	CA	129
Darrough Hot Spring	Nye	NV	122
Hobo Hot Spring	Lassen	CA	122
37 N 26 E Hot Spring	Humboldt	NV	116
Indian Valley Hot Spring	Plumas	CA	114
Winecup Hot Spring	Elko	NV	112
NE 2 Hot Well	Nye	NV	107
Horton Hot Spring	Modoc	CA	99
Bog Hot Spring	Humboldt	NV	98
Hicks Hot Spring	Nye	NV	98
Bruneau Hot Spring	Elko	NV	97
23 Hot Spring	Lander	NV	97
Amedee Hot Spring	Lassen	CA	97
SENE 33 Hot Well	Nye	NV	95
26 Hot Spring	Lander	NV	94
Mineral Hot Spring	Elko	NV	92
Marble Hot Well	Plumas	CA	91
Lower Ranch Hot Spring	Pershing	NV	89
NENE 4 Hot Spring	Humboldt	NV	86
Howard Hot Spring	Humboldt	NV	86
Diana's Punch Bowl	Nye	NV	84
Dick's Hot Well	Modoc	CA	83
Carson Hot Spring	Ormsby	NV	82
Brooks Hot Spring	Humboldt	NV	81
Wendel Hot Spring	Lassen	CA	81
Hobo Hot Spring	Douglas	NV	80
Peck Ranch Hot Spring	Elko	NV	79
Benton Hot Spring	Mono	CA	79
Nevada Hot Spring	Lyon	NV	79
Humboldt River Hot Spring	Elko	NV	78
Ruby Point Hot Spring	Elko	NV	77
NESE 18 Hot Spring	Nye	NV	76
Walley's Hot Spring	Douglas	NV	76
Walti Hot Spring	Eureka	NV	74
NE 2 Hot Spring	Nye	NV	73
Keough Hot Spring	Inyo	CA	72
McCoy Hot Spring	Pershing	NV	68
NWNE 22 Hot Spring	Nye	NV	66
Soldier Meadow Hot Spring	Humboldt	NV	60
Menlo Baths	Modoc	CA	60
Bruffy Ranch Hot Spring	Eureka	NV	57
Red Rock Hot Spring	Lassen	CA	54
Gambles Hole Hot Spring	Elko	NV	41
Bishop Creek Hot Spring	Elko	NV	41
State Prison Hot Spring	Ormsby	NV	41

Montana Heatflow

Twenty-one heatflow measurements were made in Montana. Only two of these measurements have both high heatflow and credibility.

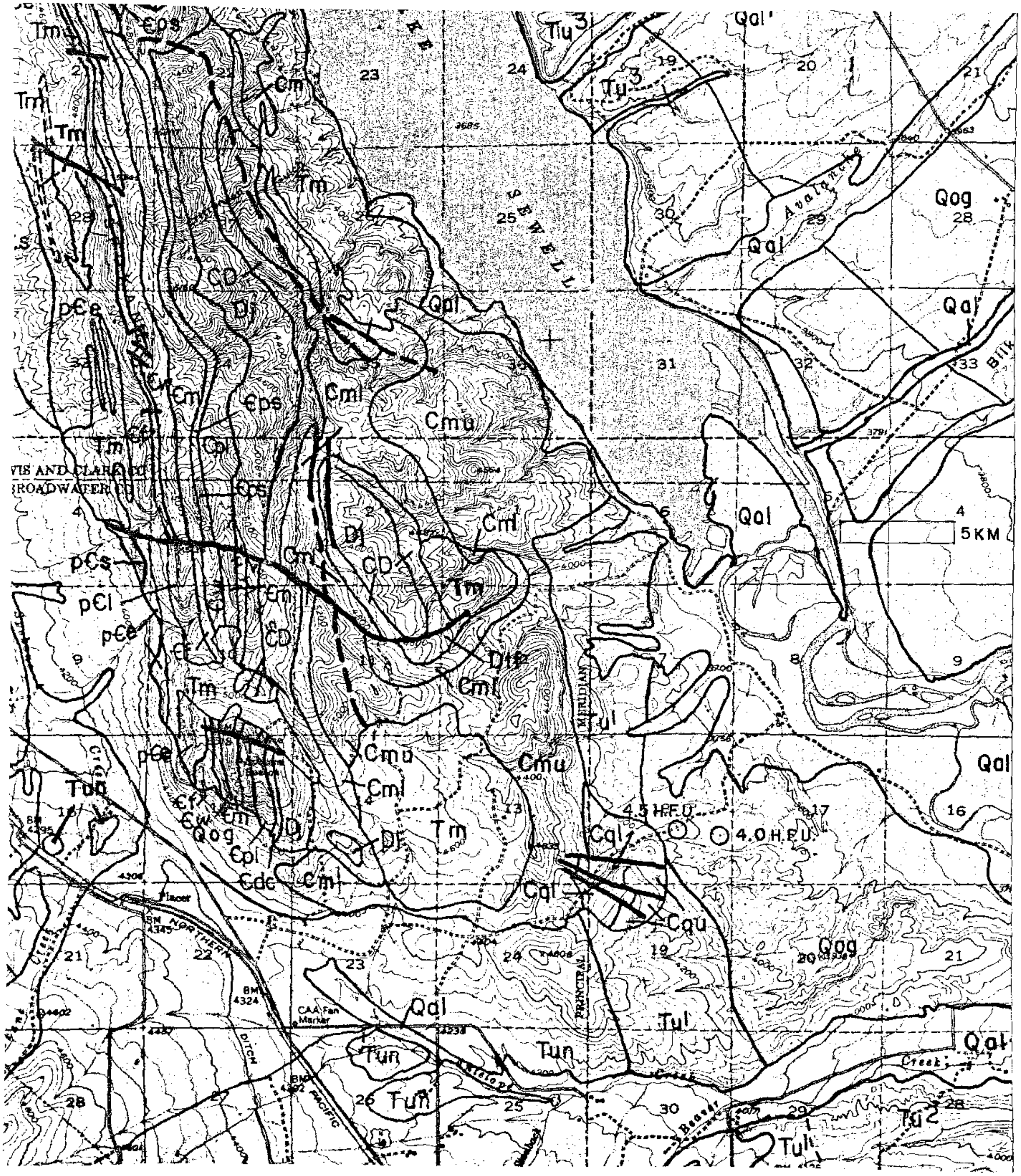

Figure 12. Canyon Ferry Heatflow and Geology

Two holes having high heatflow were found in section 18 of T2N R1E in Lewis and Clark County. The holes are about 20km southeast of Helena (Figure 12, Plate 11) on the west bank of Canyon Ferry.

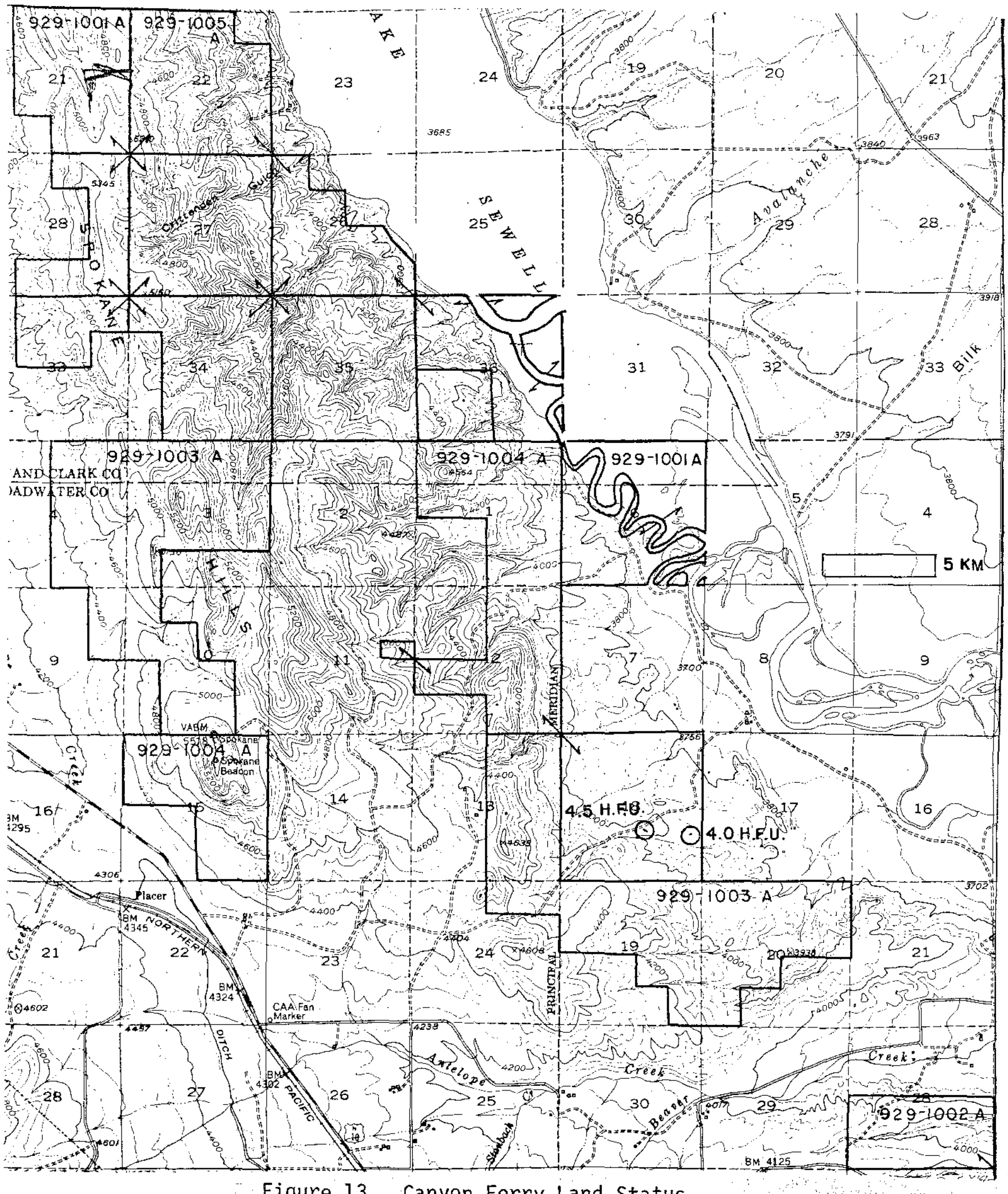

Figure 13. Canyon Ferry Land Status Controlled by AMAX

The two holes have gradients and heatflows of 193 and 233°C/k and 7.7 and 10.5 H.F.U. respectively. They are on the west flank of a giant southeast plunging synclinorium. The local lithology consists of Paleozoic sediments, Cretaceous granites and Tertiary sediments.

AMAX filed geothermal lease applications on approximately 10,192 acres during September 1979 (Figure 13).

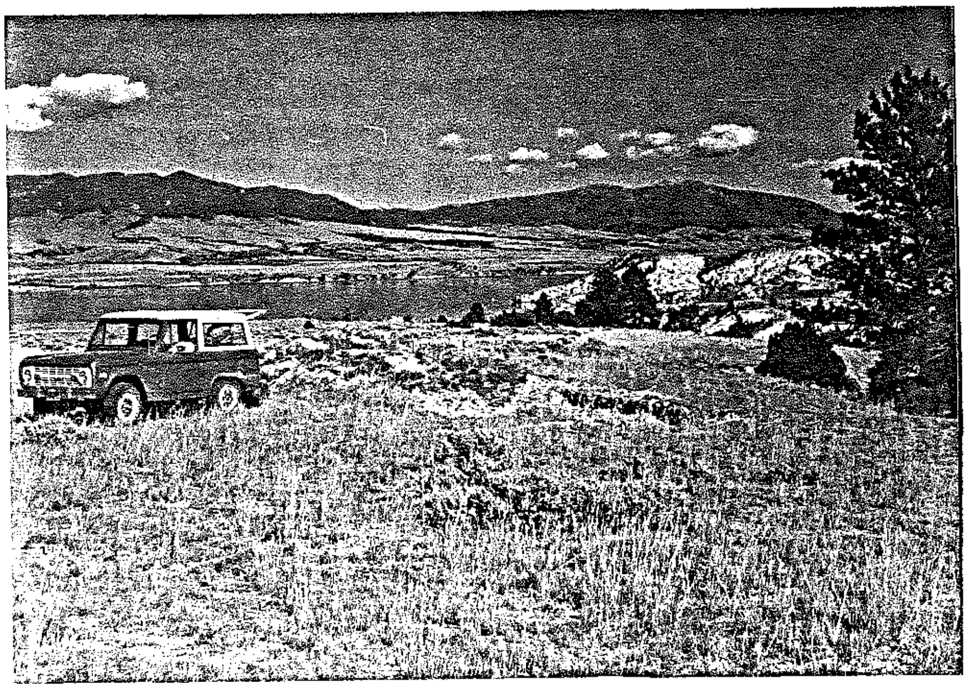

Plate 11. Hole Δ560 Next to Cuttings Pile in Center of Mound: Gradient, 233°C/km; Heatflow 10.5 H.F.U.

Montana Geochemistry

Thermal waters of Montana can be divided into two crude groupings based on either their granitic or carbonate origin. A typical carbonate thermal spring, (Table 14, Plate 12) W11866, contains little chloride, high bicarbonate, calcium, magnesium and sometimes sulfate, and has low subsurface temperatures. Travertine deposition is common (Plate 12).

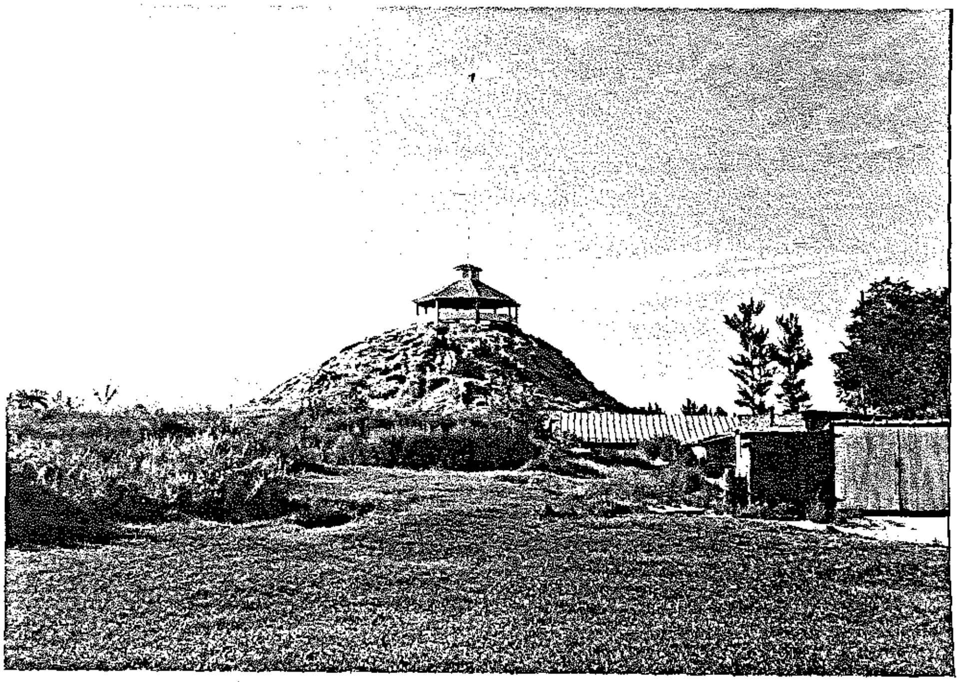

Plate 12. Warm Spring, W11866, Atop a Well-Developed Travertine Mound

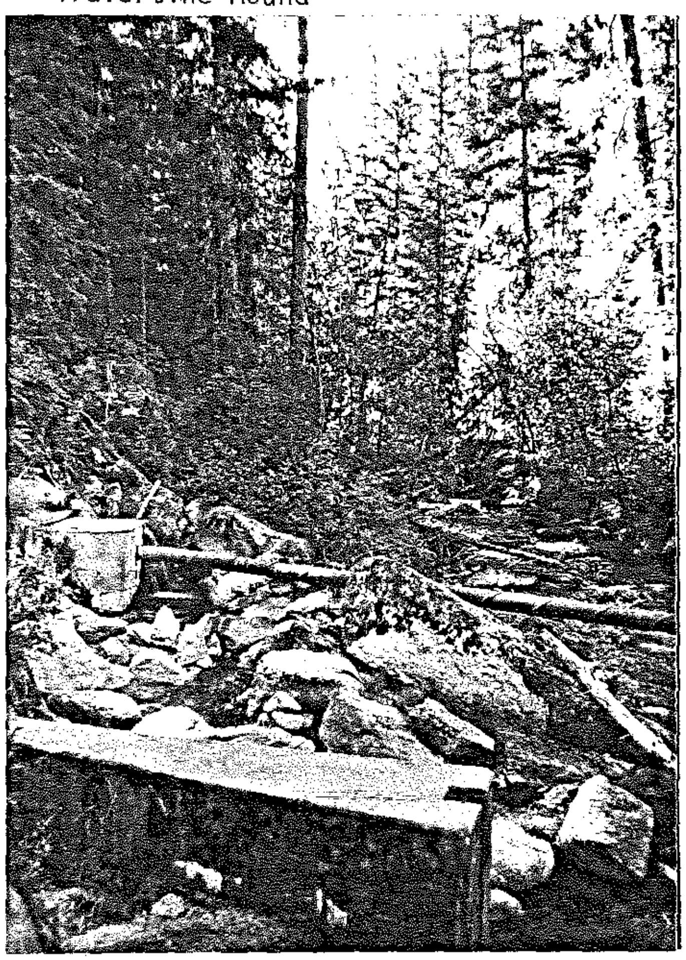

Plate 13. Lolo Hot Spring, W11876, Issues from Granitic Rocks

Table 14. Typical Montana Hot Springs Associated with Carbonate and Granitic Type Rocks.

	Warm Spring Hot Spring	Lolo Hot Springs
	W11866	W11876
T°C	77	46
Flow (gpm)	20	75
pH	6.6	9.2
Cl	6	7
F	3.9	6.8
SO_4	660	17
HCO_3	234	19
CO_3	0	58
SiO_2	58	73
Na	110	49
K	22	1.2
Ca	220	2
Mg	20	0
Li	.5	<.1
B	.2	<.2
NH_3	.1	<.1
$TSiO_2$°C	80	92
TNa/K°C	282	63
TNa-K-Ca°C	73	72

A typical hot spring in association with a granitic environment (Table 14 and Plate 13) contains minimal chloride, low to moderate subsurface temperatures and small concentrations of other major and minor ions.

None of the 87 water samples collected in Montana exhibit interesting geochemical characteristics. Table 15 is a list of the thermal springs of Montana and their best subsurface equilibrium temperature.

Table 15. Hot Springs of Montana and Their Best Subsurface Temperature Estimate.

Name	County	Subsurface Temperature °C
Jackson Hot Spring	Beaverhead	148
Elkhorn Hot Spring	Beaverhead	57
Fairmont Hot Spring	Deer Lodge	126
Warm Spring	Deer Lodge	73
Bozman Hot Spring	Gallatin	76
Alhambra Hot Spring	Jefferson	111
Boulder Hot Spring	Jefferson	104
Pipestone Hot Spring	Jefferson	89
Broadwater Hot Spring	Lewis & Clark	100
Norris Hot Spring	Madison	112
Potosi Hot Spring	Madison	55
Silver Star Hot Spring	Madison	109
New Biltmore Hot Spring	Madison	75
White Sulfur Hot Spring	Meagher	70
Chico Hot Spring	Park	64
La Duke Hot Spring	Park	77
Hunters Hot Spring	Park	76
Medicine Hot Spring	Ravilli	84
Sleeping Child Hot Spring	Ravilli	82
Camus Hot Spring	Sanders	73

Montana Spring Deposits

A prospect called Geyser having both geologic merit and recent hydrothermal alteration was identified near the crest of the Gravely Range in southwestern Montana. The area is about 60km west of Yellowstone Park in the Beaverhead National Forest (Figure 14).

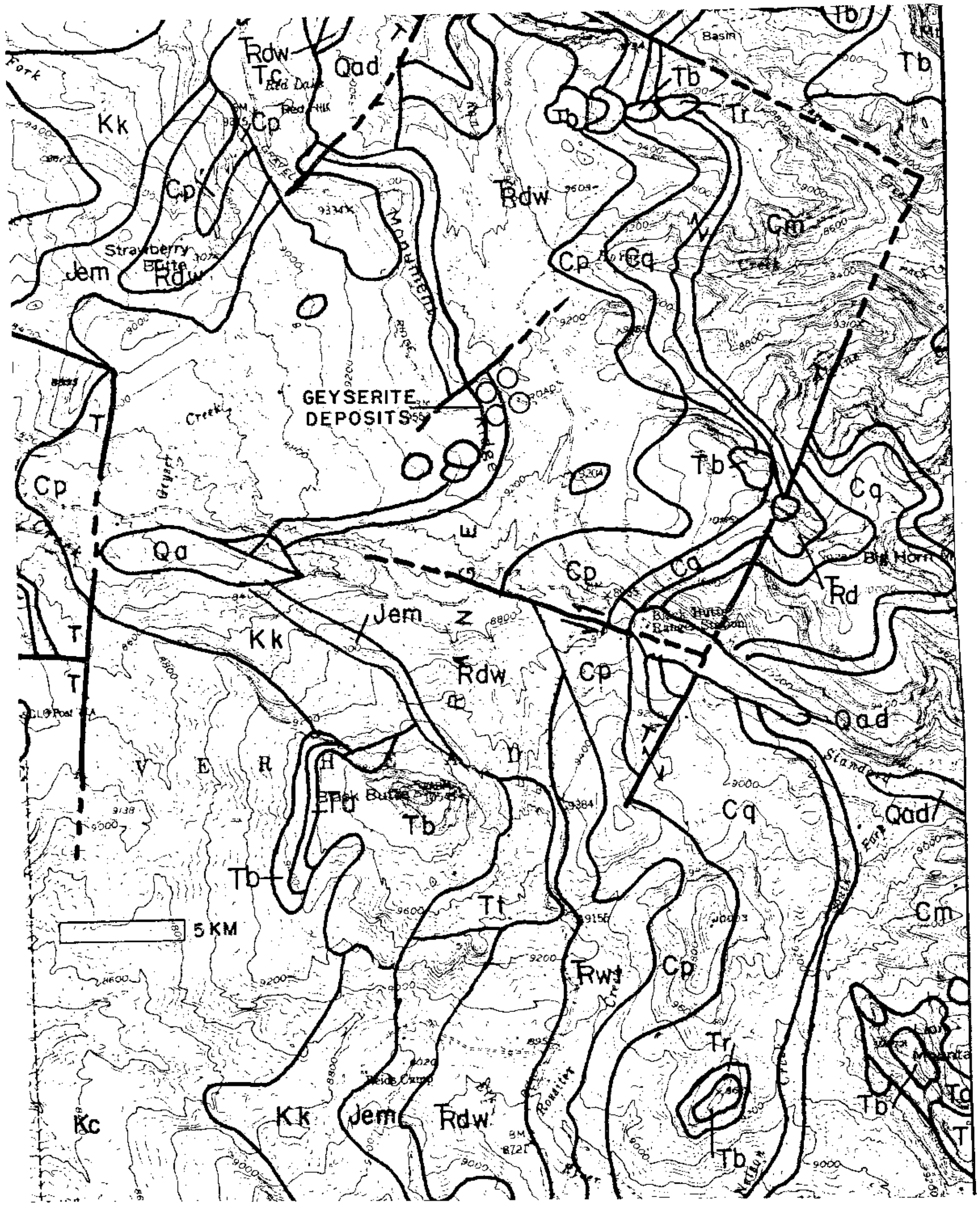

Figure 14. Geyser Geology and Spring Deposits.

The area contains an extinct geyser with several hundred square meters of associated Geyserite. A Tertiary (28 m.y.) basaltic plug called Black Butte is nearby. The area is also proximate to the 2 m.y. Upper Madison Rhyolite field. The bulk of local geology is formed from

Paleozoic through Cretaceous sediments. The area is noted for profound and recent seismic activity.

AMAX filed geothermal lease applications on approximately 5,128 acres during September 1978 (Figure 15).

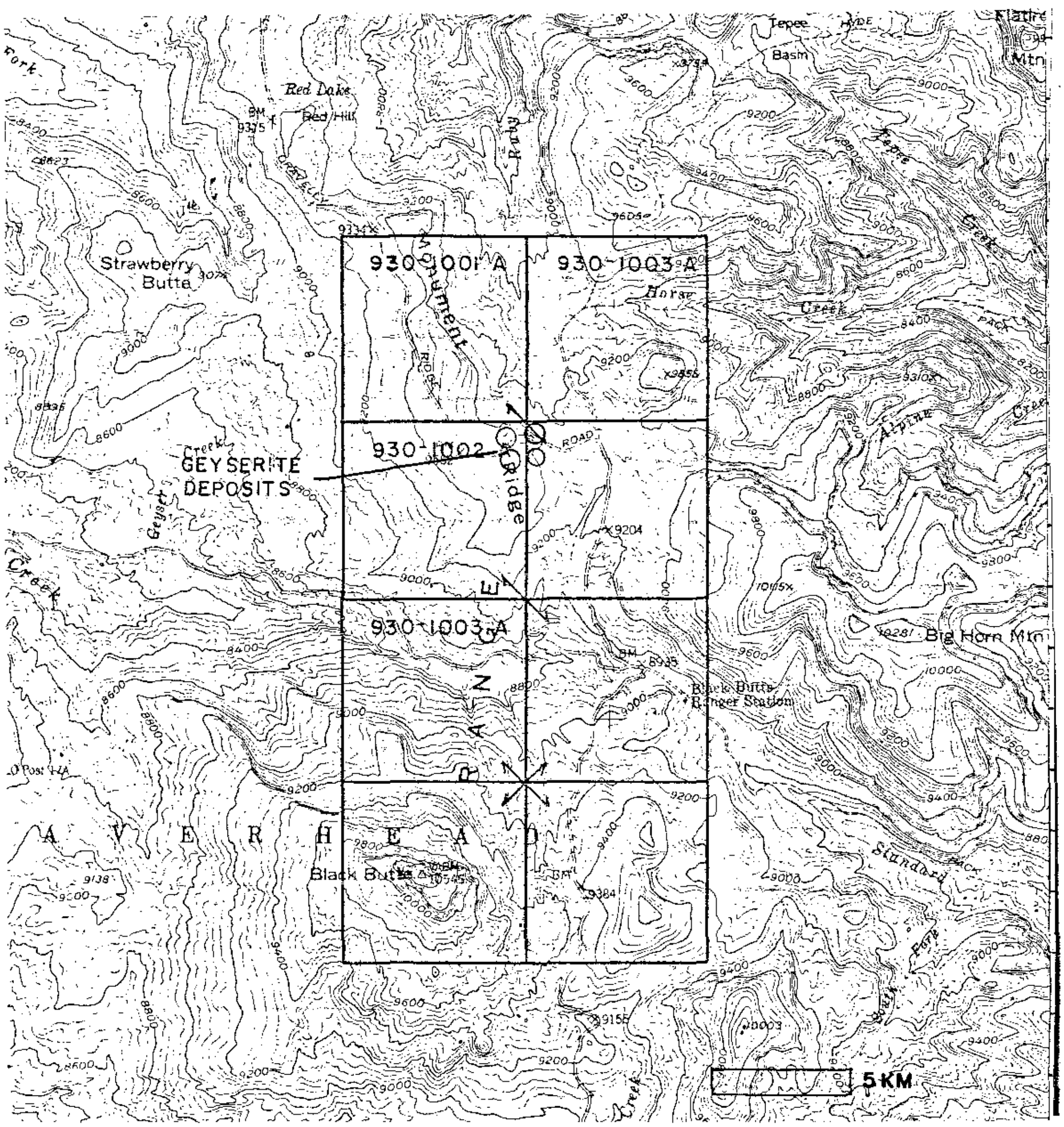

Figure 15. Geyser Land Status
Controlled by AMAX

Oregon Heatflow

Four distinct heatflow anomalies were identified from the heatflow data collected in Oregon. Two are single point anomalies of questionable reliability and will not be discussed further.

The remaining two anomalies lie on Brothers Fault Zone that extends about 300km along a N60°W trend in central Oregon (Figure 16). The zone is a series of discontinuous en echelon fractures, many of which are short

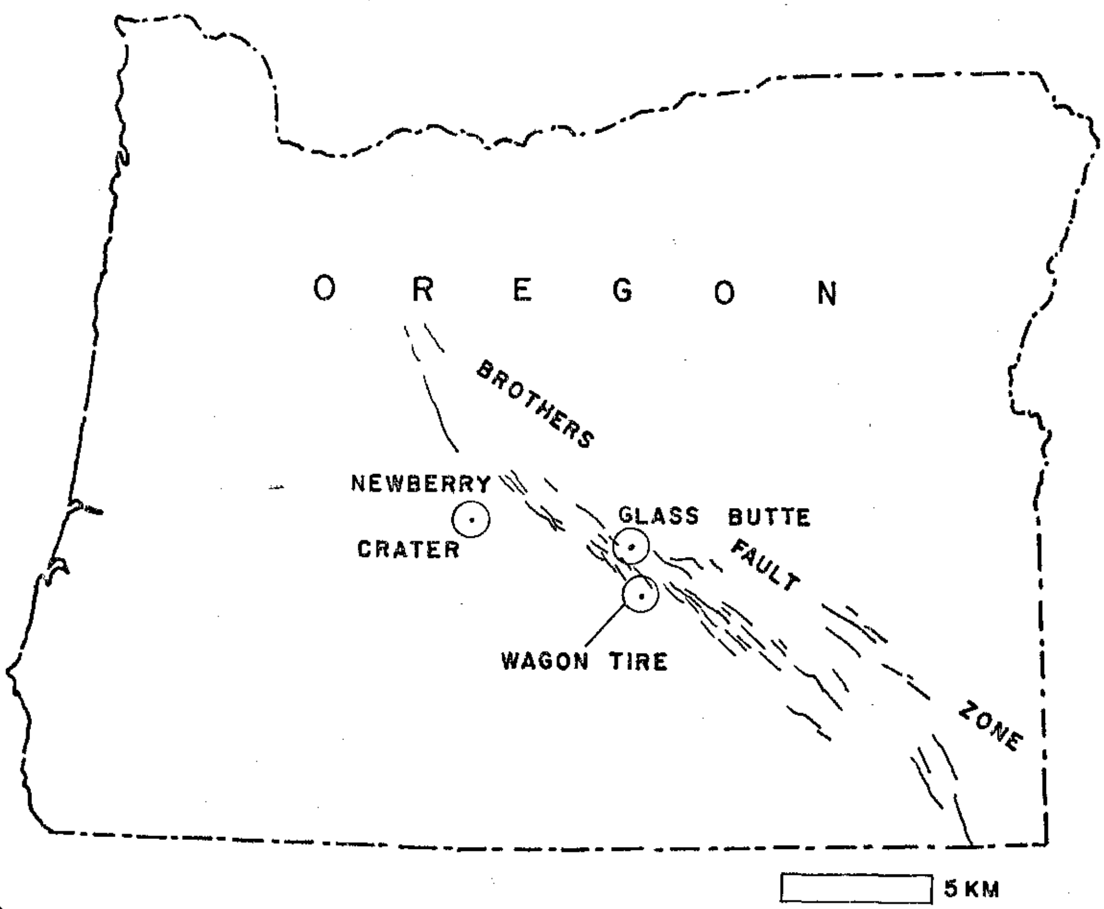

Figure 16. Location of the Glass Buttes and Wagontire Anomalies

normal faults, 10 to 20km long, with intervening minor horsts and grabens. Most of the rocks of the zone are less than 6m.y. old. The presence of volcanic vents supports the notion that the zone is a deep-seated tectonic feature. The zone forms the northern terminus of part of the Basin and Range Province. The ages of silicic vents in the zone are younger from east to west, terminating with the Holocene rhyolites of Newberry Crater. Motion along the zone may also be from east to west.

The first anomaly, Glass Buttes, is on the western segment of the Brothers Fault Zone. Glass Buttes is a complex of silicic vents and volcanic domes formed about 4.9m.y. ago. Extensive hydrothermal alteration has produced an opalite zone which contains disseminated mercury mineralization. One well contains 48°C water at 220 meters, a gradient of 125°C/km. No water sample could be obtained.

The heatflow anomaly is based on five holes, four of which were relogged and verified. The fifth hole is on the west-most tip of Glass Buttes on section 13 of T23S R21E (Figure 17). The hole has a gradient and heatflow of 198°C/km and 6.9 H.F.U., respectively.

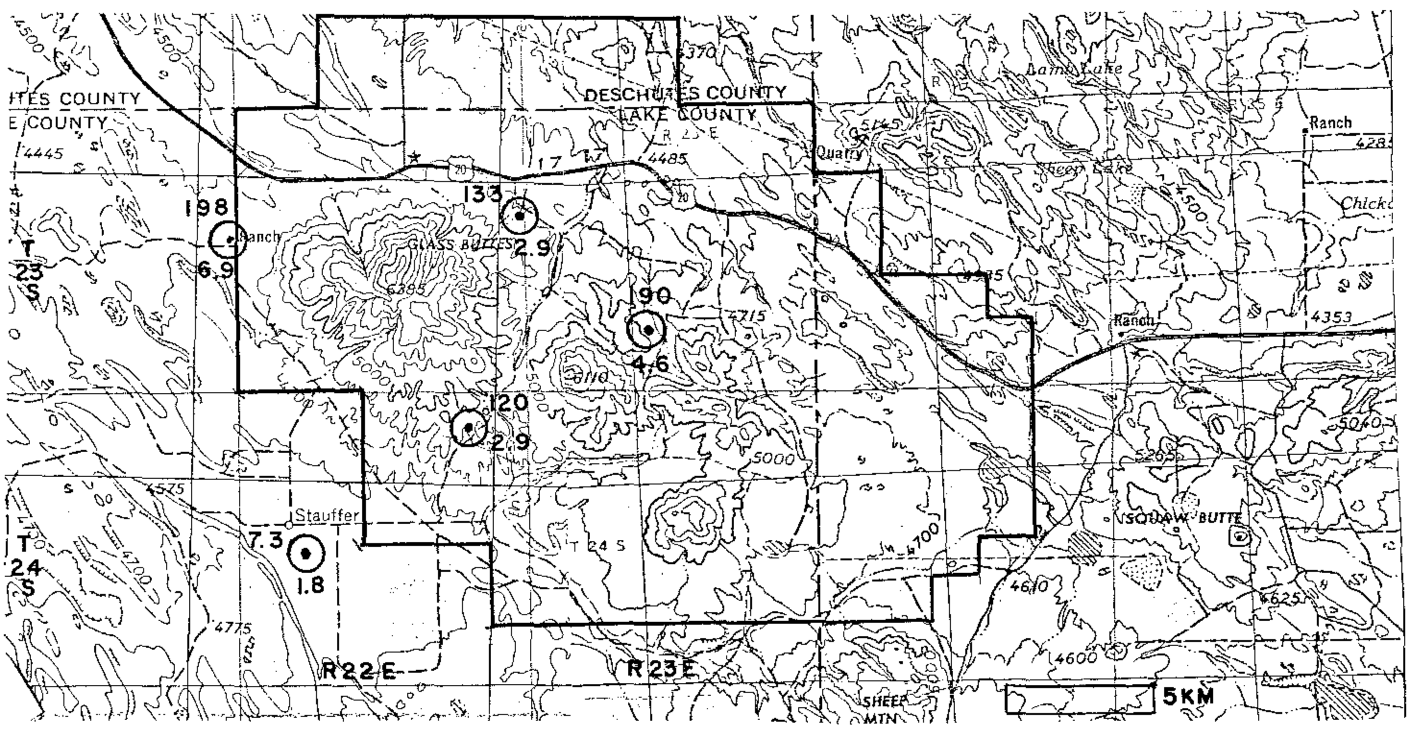

Figure 17. Heatflow and Federal Lease Position, Glass Buttes

The hot well and vicinity to the west are not leased. I recommend leasing sections 1,12,13,24,2,11,14,3 and 10 of T23S R21E. These sections are on strike with regional and local structures which probably control local heatflow manifestations.

The second heatflow anomaly identified is northeast of Wagontire in central Oregon (Figure 18). Five holes with above average heatflow define a northwest trending heatflow anomaly. Heatflow values range from 2 to 8.3 H.F.U. while gradients range from 40 to 150°C/km. Hole depths range from 33 to 60 meters. No water samples were collected from the area.

The area is covered with volcanic rocks of predominantly mafic and intermediate composition: Pliocene ash flow tuffs, Pliocene basalts and andesites and Pleistocene basalts are also present.

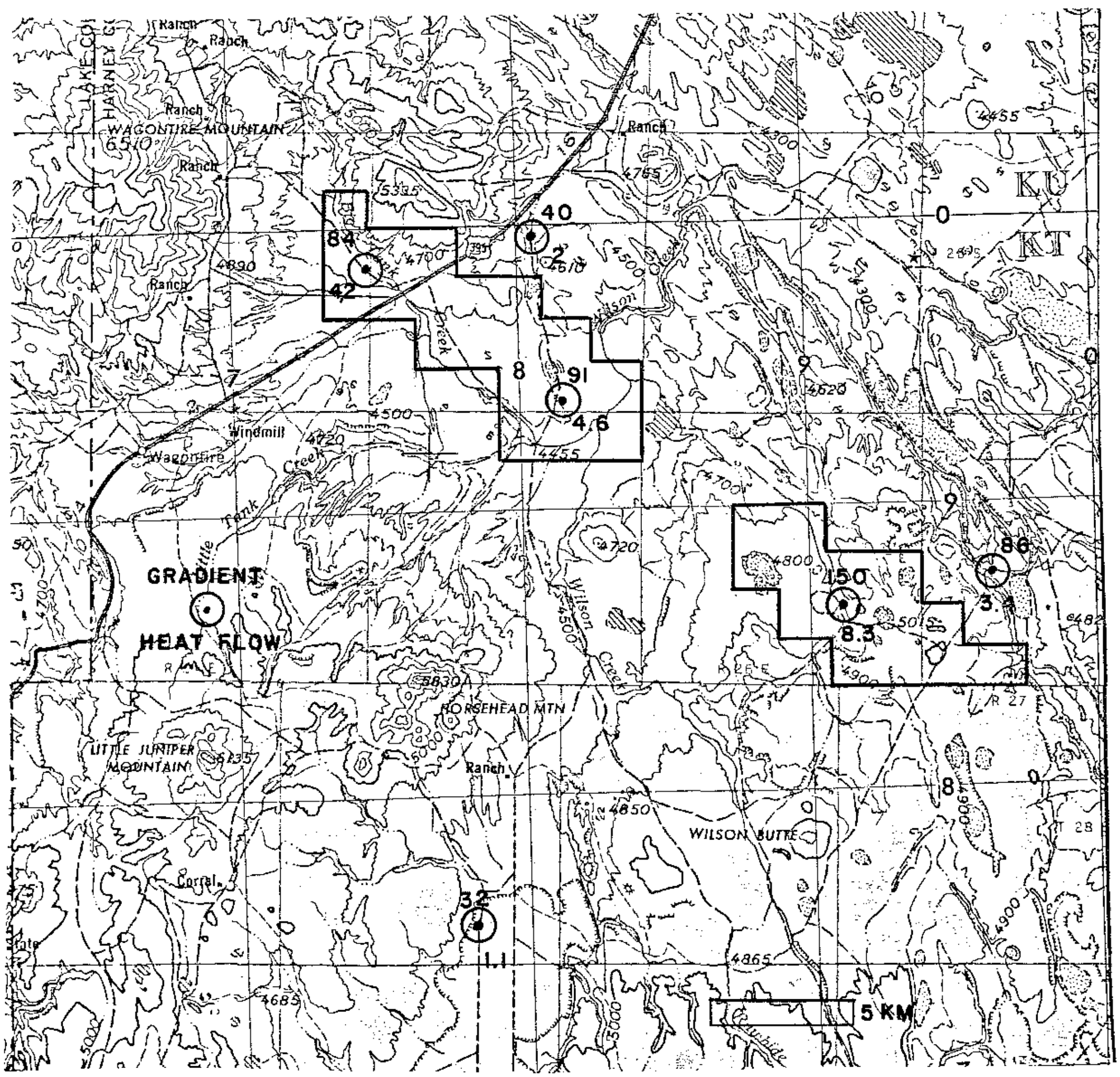

Figure 18. Wagontire Heatflow

I recommend that AMAX lease the following areas (Figure 18):

Township	Range	Sections
Township 27 South,	Range 26 East	Sections 15,16,21,22,23,24,25,26,27,35,36
27	27	31,31,32
27	25	4,5,6
26	25	17,18,19,20,21,22,26,27,28,29,34,35,36
26	24	12,13,24

Oregon Geochemistry

None of the thirty-nine thermal springs and wells collected from central Oregon-exhibit interesting hydrogeochemistry. Paulina Lake and East Lake Hot Springs are included. These thermal springs issue out of the summit of Newberry Crater, a Holocene silicic volcanic center at the west terminus of the Brothers Fault Zone. Water from both springs equilibrated below 100°C based on chemical geothermometers.

A master geochemical map and six contour maps are included in the map file which accompanies this report.

Idaho Heatflow

Five holes with high heatflow were identified in eastern Idaho (Figure 19).

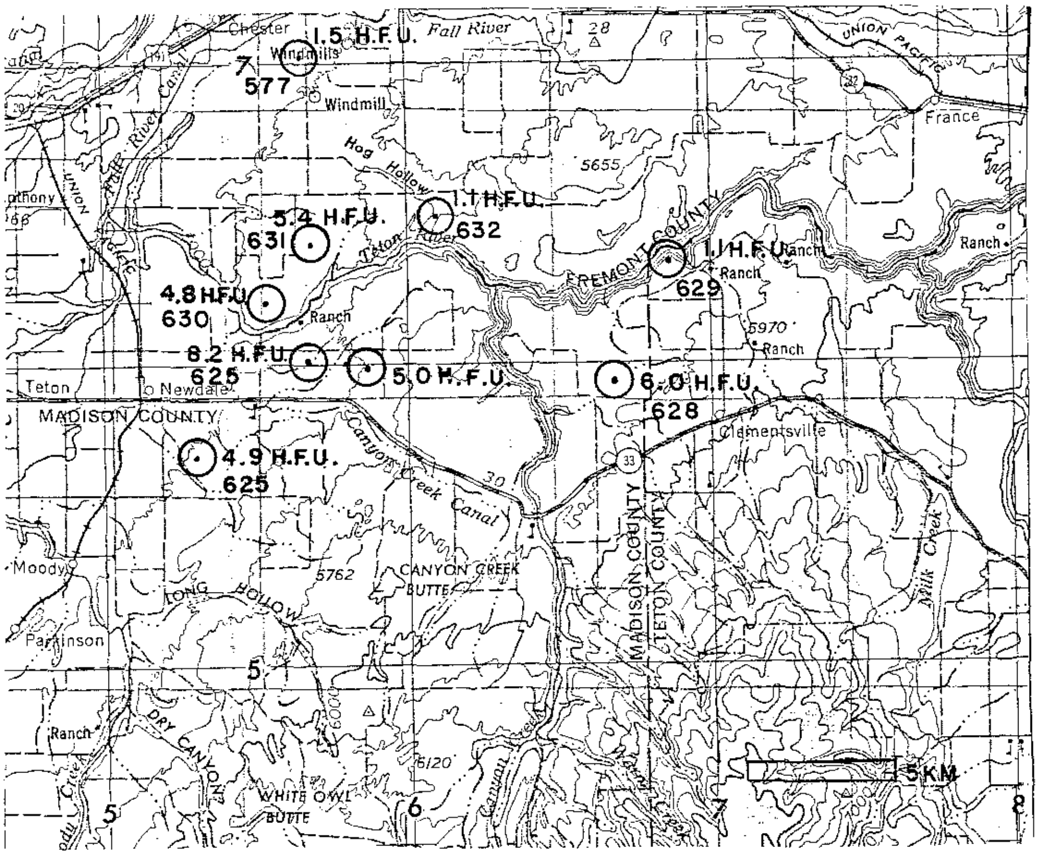

Figure 19. St. Anthony Heatflow

The data was published by the Idaho Department of Water Resources (Table 16). The area is approximately 13km southeast of St. Anthony.

Table 16. St. Anthony Heatflow Data.

ΔNumber	Depth	Q H.F.U.	ΔT°C/km
577	31	1.5	67
625	100	4.9	118
626	140	8.2	168
627	130	5.0	112
628	115	6.0	24
629	115	1.1	24
630	108	4.8	98
631	100	5.4	110
632	80	1.1	23

The Snake River Graben has produced extensive basaltic to rhyolitic volcanism from Pliocene through Recent time. Locally, basalt flows cover several hundred feet of mid-Pliocene rhyolite flows and tuffs. Loess covers some of the area to a maximum depth of 10 meters.

The Island Park Caldera is 16km north of the area. The caldera also erupted bimodal Pliocene-through-Recent lavas. The Snake River Range bounds the anomaly to the south. The range consists of Paleozoic-through-Mesozoic carbonates and some Tertiary volcanics. The north terminus of the Snake River Range is covered by 60 meters of the mid-Pliocene Kirkham Hollow welded tuff. This unit probably underlies the most recent basalt flows that cap the complex structure of the Snake River Plain.

Idaho Geochemistry

None of the water samples collected in Idaho exhibit favorable geochemical characteristics. The greatest number of hot springs is associated with intrusive rocks of Mesozoic and Tertiary age, i.e., the Idaho and Owyhee Batholiths and various granitic stocks along the Middle Fork of the Salmon River and in the Sawtooth Mountains. The majority of thermal springs are clearly associated with profound fault systems. Several thermal springs in southern and southeastern Idaho are closely associated with Mesozoic carbonates and Tertiary Snake River basalts; there, structural control is less evident.

Vulcan Hot Spring is about 66km east of Cascade in western Idaho. It is one of the most interesting thermal features in Idaho (Plate 14). The water is rich in fluoride and depleted in other ions, especially chloride (Table 17). The water is remarkably similar to other "granitic waters" of Idaho, i.e., from the Grandview, Challis and Camas Prairie areas.

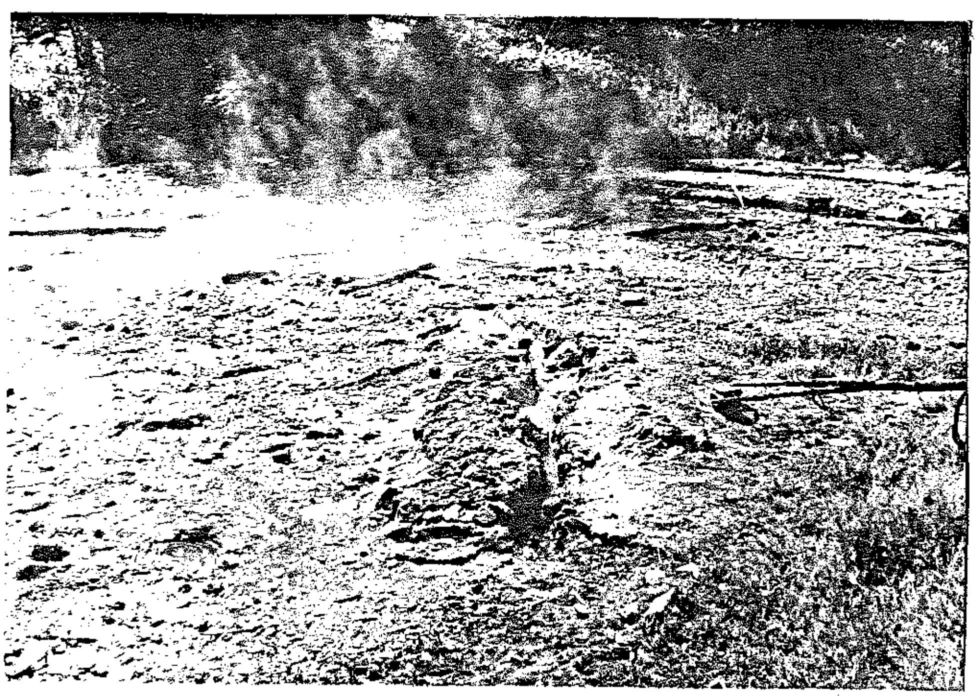

Plate 14. Vulcan Hot Spring, 87°C

Table 17. Analysis of Vulcan Hot Spring and Soda Warm Spring.

	Vulcan Hot Spring W11893	Soda Warm Spring W10446
T°C	87	29
Flow gpm	500	200
pH	8.5	6.5
Cl	17	5.4
F	24	1.7
SO_4	43	850
HCO_3	120	2100
CO_3	0	0
SiO_2	120	127
Na	94	12
K	3	23
Ca	1.8	1100
Mg	0.1	170
Li	<0.1	0.1
B	<0.2	0.3
NH_3	<0.1	<0.1
TDS	423	4290
$TSiO_2$°C	150	44
TNa-K-Ca°C	135	25

Soda Warm Spring is about 70km east of Pocatello in southeastern Idaho. The water contains large concentrations of bicarbonate, calcium, magnesium and sulfate (Table 17). The water is similar to "soda waters" associated with low grade metamorphism.

Both springs offer little more than academic interest for AMAX. Neither exhibits the characteristics of past high temperature equilibrium. Table 18 is a list of less interesting hot springs and their respective subsurface temperatures.

Table 18. Hot Springs of Idaho and Their Best Subsurface Temperature Estimate.

Name	Subsurface Temperature °C
White Licks Hot Spring	145
Zims Resort Hot Spring	85
Knigbaum Hot Spring	95
Starkey Hot Spring	70
Lava Hot Spring	60
Downata Hot Spring	60
Bear Lake Hot Spring	85
Guyer Hot Spring	90
Clarendon Hot Spring	85
Hailey Hot Spring	85
Condie Hot Spring	90
Bonneville Hot Spring	140
Kirkham Hot Spring	80
Wardnop Hot Spring	122
Worswick Hot Spring	95
Elk Creek Hot Spring	80
Barrons Hot Spring	90
Soda Warm Spring	44
Oakley Warm Spring	90
Warm Spring	25
Lidy Hot Spring	65
Sunbeam Hot Spring	130
Sullivan Hot Spring	100
Barney Hot Spring	60
Stanley Hot Spring	45
State Creek Hot Spring	90
Neimeyer Hot Spring	125
Dutch Franks Hot Spring	70
Paradise Hot Spring	75
Latty Hot Spring	135
Maple Grove Hot Spring	105
Wayland Hot Spring	125
Ashston Warm Spring	90
Big Spring	65
Roystone Hot Spring	150
White Arrow Hot Spring	115
Weir Creek Hot Spring	100
Terry Johnson Hot Spring	100
Red River Hot Spring	80
Riggins Hot Spring	95
Burgoff Hot Spring	55
Heise Hot Spring	80
Big Hot Spring	175

Table 18. Hot Springs of Idaho and Their Best Subsurface Temperature Estimate Continued

Name	Subsurface Temperature °C
Salmon Hot Spring	80
Starkey Hot Spring	135
Green Canyon Hot Spring	70
Pleasantview Hot Spring	65
Woodruff Hot Spring	80
Indian Bathtub Hot Spring	120
Murphy Hot Spring	125
Indian Hot Spring	120
Miracle Hot Spring	85
Magic Hot Spring	70
Hot Creek Spring	60
Molly's Hot Spring	85
Boiling Hot Spring	90