TEC-5

A HYDROGEOCHEMICAL STUDY
of the
FILLMORE-MILFORD-NEW CASTLE AREA, UTAH

by

Frank Dellechaie

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AMAX EXPLORATION, INC.
4704 Harlan Street
Denver, CO 80212

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SUMMARY

An extensive hydrogeochemical survey was conducted in southwest Utah during the summer of 1976.

The region contains two distinct types of groundwater. The sodium-chloride variety is intersected in valley wells which are shallower than approximately 60 meters. The chloride groundwater is a Lake Bonneville remnant and resembles the Roosevelt reservoir fluid. Calcium and magnesium-bicarbonate waters issue out of upland springs and are intersected in wells deeper than approximately 60 meters.

The following table summarizes the crucial elements for all the thermal features discussed in this report. The following thermal manifestations exhibit high geothermal potential; Hatton Hot Spring, Red Hill Hot Spring, Lava Ridge Warm Well, and Thermo Hot Spring. Geochemistry indicates temperatures in excess of 180°C at depth. Carbonate scaling, in each case, can be avoided by casing off Paleozoic sections and producing from underlying granitic reservoirs. Production wells in these areas may be substantially deeper than the current production depth at the Roosevelt reservoir.

It would be in AMAX's best interest to acquire a substantial land position on the north-trending structure between the Black Rock Volcano and White Mountain in Millard County. AMAX should retain the present land position in the vicinity of Thermo Hot Spring.

	Roosevelt H.S. USGS 9-11-57	Salt Warm Spring W10125	Crater Hot Spring W10164	Hatton Hot Spring W10261	Joseph Hot Spring W10157	Red Hill Hot Spring W10155	Twin Peak Warm Spring W10248	Lava Ridge Warm Well W10305	Thermo Hot Spring W10121	New Castle Hot Well W10254	Dotson's Warm Spring W10120	Sulfurdale Warm Well W10397	Government Warm Well W10268	Milford City Warm Well W10285	Greenville Warm Artesian W. W10184	Wah Wah Warm Spring W10184	Section 21 Warm Well W10292
Suface Temp. °C	51	25	83	66	65	77	30	21	83	95.6	32	37.9	23	27.5	22	20	24.5
Flow gpm	1	1	250	100	2	40	25	15	200	1000	30	--	5	500	20	5000	100
Well or Spring Deposits	SiO_2	SiO_2 (Gel)	$CaCo_3$	$CaCo_3$ ~1.6 sq. km	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	None	None	None	None	None	$CaCO_3$	$CaCO_3$	None
Mineral Saturation	SiO_2	SiO_2	$CaCo_3$	$CaCo_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	$CaCO_3$	Sulfates	Silicates	Silicates	Carbonates	Carbonates	Carbonates
Reservoir Rock Type	Granite	Granite	Carbonates Basic Volcanics	Carbonates	Carbonates	Carbonates	?	?	Carbonates Volcanics	?	Carbonates	?	Volcanics	?	?	?	?
Possibility of Scaling	Low	Low	High	High	High	High	High	?	High	Low	High	?	Low	Low	High	High	High
Water Type	Na-Cl	Na-Cl	Na-Cl	Na-Cl	Na-Cl	$Na-SO_4$	Na-Cl	$Na-HCO_3$	$Na-SO_4$	$Na-SO_4$	$Na-SO_4$	$Ca-SO_4$	$Na-HCO_3$	$Na-HCO_3$	$Ca-HCO_3$	$Ca-HCO_3$	$Na-HCO_3$
Groundwater Dilution	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	No	?	No	No	No	No	No
Cold Water Fraction		30% CWF	40% CWF	50% CWF		60% CWF		> 60%CWF	60%			--					
Maximum Subsurface Temperature °C	280	240	155	210	140	170	100	(180)	200	155	80	?	60	80	50	(25)	70
Pleistocene and **Holocene** Volcanics	0.6 m.y.	0.6 m.y.	None	0.45 m.y.	None	None	None	None	None	None	None	None	None	None	None	None	None
Coincidence of Heatflow Anomaly	Coincident	Coincident	No Data	(Not Coincident)	No Data	No Data	Coincident	Coincident	Coincident	Coincident	Not Coincident	Coincident	Not Coincident	No Data	Not Coincident	No Data	Not Coincident
Reservoir Fluid Volume	Large	Large	Moderate	Moderate	Moderate	Moderate	Moderate	?	Moderate to Small	Small	Small	?	Small	Small	Small	Small	Small
Cause of Manifestation	Magmatic Heat Source	Magmatic Heat Source	Fault Localized Hydrothermal System	Magmatic Heat Source	Fault Localized Hydrothermal System	Magmatic Heat Source (?)	Low Temperature Hydrothermal System	?	Fault Localized Hydrothermal System	Fault Localized Hydrothermal System	Low Temperature Fault Localized drothermal System	?	Low Temperature Fault Localized Hydrothermal System	Low Temperature Fault Localized Hydrothermal System	Low Temperature Fault Localized Hydrothermal System	Low Temperature Fault Localized Hydrothermal System	Low Temperature Fault Localized Hydrothermal System
Overall Geothermal Potential based on Scale of 10	10	10	4	7	4	6	4	6	7	4	3	?	1	1	1	1	1

INTRODUCTION

Two hundred fifty-six water samples were collected from the Fillmore-Milford-New Castle area of Utah (Figure 1) during the summer of 1976. This report will discuss 24 thermal features of the region. Sample locations are shown on 1 to 62,500 and 1 to 250,000 scale maps at the end of this report.

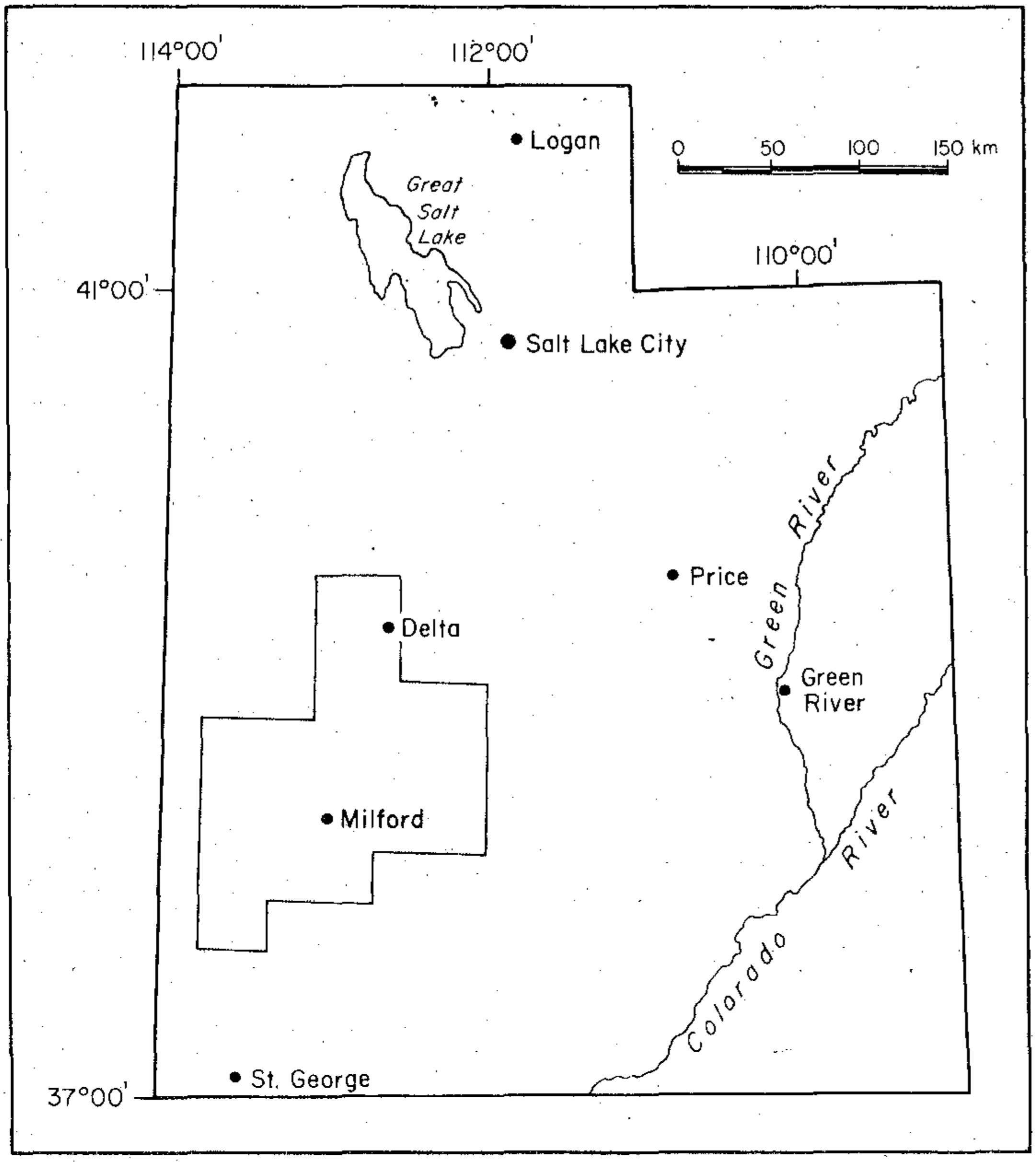

Figure 1. Location map for the Fillmore-Milford-New Castle geothermal area.

NON-THERMAL CHEMISTRY

Regional non-thermal waters consist predominately of the calcium-bicarbonate and sodium-chloride types. The calcium-bicarbonate waters issue from upland springs and from wells which produce water from below approximately 60 meters. Bicarbonate waters (Table 1, W10181) generally contain less than 500 mg/l of dissolved solids. These waters are young geologically and are chemically very similar over the entire region. Local variations are dependent on geology, i.e., Tertiary granites contain more fluoride than Precambrian granites.

Regional sodium-chloride waters contain an average of 4000 mg/l of dissolved solids and are produced from wells in the Lake Bonneville sediments (Table 2, W10167). Chloride waters are in part connate water from ancient Lake Bonneville and also contain some percent meteoric and groundwaters. Black Rock Cold Well (Table 2, W10167), 35 km north of Milford, Utah, is approximately one-hundredth as concentrated as present day Salt Lake. Well 1.15 (Table 2) at the Bonneville Salt Flats is approximately one-half as concentrated as Salt Lake. Perry (1976) shows a direct correlation between decreasing dissolved solids in pore waters of the Lake Bonneville sediments and increasing distance from Salt Lake. Lake Bonneville increased in chemical concentration as the lateral area decreased. A chemical record of this change is preserved in the sediments. These sodium-chloride pore waters are relatively immobile and older than the deeper calcium-bicarbonate waters.

Table 1. Chemical analyses of regional bicarbonate waters. Units are mg/l unless otherwise noted.

NA = not analysed, * = does not represent true subsurface conditions, i.e., $\frac{\sqrt{Ca}}{Na}$ > or → 1

	Milford City Warm Well W10285	Section 21 Warm Well W10292	Government Warm Well W10268	Greenville Warm Artesian Well W10184	Lava Ridge Warm Well W10305	Wah Wah Warm Spring W10184	Section 31 Warm Well W10303	Four Mile Knoll Cold Spring W10181
T°C	27.5	24.5	23	22	21	20	19	13.2
Flow gpm	500	100	5	20	15	5000	900	25
pH	7.2	8.30	8.68	8.22	7.78	7.43	7.40	8.00
F	1.3	0.8	1.3	0.2	1.4	0	1.8	0.6
Cl	19	59	32	35	210	35	120	37
SO_4	34	61	36	13	100	13	140	85
HCO_3	190	184	80	110	278	262	260	246
CO_3	0	0	6	0	0	0	0	0
SiO_2	48	30	44	11	76	1	19	14
Na	94	120	67	21	190	21	93	18
K	4.7	4.1	1.9	1.4	23	1.4	14	2.6
Ca	15	20	7	83	55	83	110	95
Mg	5	12	1	29	33	29	31	38
Li	0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	0.2	< 0.1
B	0.4	0.6	0.2	< 0.2	0.7	< 0.2	0.7	< 0.2
NH_3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
TDS	412	492	276	304	967	456	790	536
$TSiO_2$ °C	70	79	66	42	122	42	62	51
TNa/K °C	115*	85	73	141*	207*	141*	237*	231*
TNa-K-Ca °C	80	72	63	5	184	10	72	16
Cl/HCO_3	0.1	.3	0.4	.3	1	0.1	1	.2
Cl/SO_4	1	1	1	3	2	3	1	.4
Cl/B	48	98	160	350	300	350	171	370
Cl/Li	190	1180	640	700	1050	700	600	740
Cl/F	15	74	25	175	150	175	67	62

Table 2. Chemical analyses of regional chloride waters. Units are mg/l unless otherwise noted.

NA = not analysed, * = does not represent true subsurface conditions, i.e., $\frac{\sqrt{Ca}}{Na} >$ or → 1

	Thermal Power Sec. 2 Well	Phillips Well 54-3	Phillips Well 3-1	Roosevelt Hot Spring U.S.G.S. 9-11-57	GKI Deep Test W10430	Crater Hot Spring W10164	Hatton Hot Spring W10261	Joseph Hot Spring W10157	Meadow Warm Spg. W10306	Twin Peaks Warm Spg. W10248
T°C	260	260	205+	51	96	83	66	65	34	30
Flow gpm	---	---	---	---	400	250	100	2	2	25
pH	6.00	6.5	6.3	7.9	7.92	7.3	6.48	7.8	7.38	7.62
F	5.4	5	5	7.5	4.4	4.1	4.0	4.6	4.6	5.2
Cl	3600	4800	4090	4240	760	1450	1800	1700	1800	2100
SO_4	58	200	59	73	490	756	1000	1370	1000	400
HCO_3	186	200	180	156	220	160	366	396	364	188
CO_3	0	0	0	0	0	0	0	0	0	0
SiO_2	730	775	560	313	100	59	47	76	57	56
Na	2100	2400	2437	2500	690	816	1200	1490	1100	1490
K	410	565	448	488	80	48	160	47	140	14
Ca	8	9	8	22	140	345	490	248	530	170
Mg	0.2	19	0.01	0	18	68	90	46	93	48
Li	24	18	20	0.3	2.0	0.6	3.0	1.9	3.3	0.9
B	25	45	25	38	1.8	0.8	5.4	3.7	5.5	0.6
NH_3	---	--	---	---	1.5	---	0.8	---	<0.1	<0.1
TDS	6966	6442	7067	7800	2508	3630	5166	7530	5997	4473
$TSiO_2$ °C	270	295	263	213	137	110	99	122	108	107
TNa/K °C	278	312	267	277	201	129	220	80	214	12*
TNa-K-Ca °C	283	296	279	284	197	156	204	139	198	93
Cl/HCO_3	19	24	23	27	3	9	5	4	5	11
Cl/SO_4	62	24	69	58	2	2	2	1	2	5
Cl/B	144	107	164	112	422	2400	333	894	327	3500
Cl/Li	150	266	204	14133	380	2400	600	460	545	2333
Cl/F	666	960	818	565	173	354	450	370	391	404

Table 2. Continued

	Salt Warm Spg. W10125	Pearson Warm Well W10286	Yellow Jacket Warm Spring W10287	Dead Crow Warm Spring W10410	Black Rock Cold Well W10167	Great Salt Lake Brine	Well 1.15 Bonneville Salt Flats
T°C	25	16.5	16	25*	10	11	24
Flow gpm	1	10	2	0	50	---	---
pH	5.90	7.80	7.40	9.10	7.66	7.8	(7.0)
F	3.8	0.9	0.7	0.7	1.2	5.8	---
Cl	3100	860	1500	830	1800	149,000	72,800
SO_4	150	<10	<10	<10	240	24,800	6,200
HCO_3	224	246	346	206	156	473	---
CO_3	0	0	0	37	0	0	---
SiO_2	180	32	20	24	32	5.1	---
Na	1800	400	600	460	1000	86,100	46,000
K	260	13	29	10	43	6,700	2,000
Ca	130	100	150	47	200	342	1,500
Mg	20	84	130	77	10	11,300	1,400
Li	19	3.3	4.1	3.0	1.8	58	17
B	25	5.3	5.4	5.2	2	46	---
NH_3	0.18	<0.1	2.6	<0.1	0.5	---	---
TDS	5912	1745	2788	1700	3487	286,000	---
$TSiO_2$ °C	173	82	63	70	51	19	---
TNa/K °C	231	82	112	56	102	152*	458*
TNa-K-Ca °C	231	87	148	97	148	174*	341*
Cl/HCO_3	14	4	4	4	12	315	---
Cl/SO_4	21	172	300	166	8	6	12
Cl/B	124	162	278	160	900	3,200	---
Cl/Li	163	261	366	277	1000	2,600	4,280
Cl/F	816	956	2143	1186	1500	26,000	---

It is important to distinguish between the Lake Bonneville connate waters and geothermal leakage for exploration purposes. Shallow sodium-chloride waters are grossly similar to thermal sodium-chloride waters, however, differences are evident in the Cl/F, Cl/Li, Cl/B and Cl/SO_4 ratios (Table 3). Future oxygen and hydrogen isotope analysis should also indicate differences.

Table 3. A comparison of ionic rations for thermal and non-thermal waters.

	THERMAL WATERS					NON-THERMAL WATERS		
	Thermal Power Sec. 2 Well	Phillips Well 54-3	Phillips Well 3-1	Roosevelt Hot Spring	Salt Warm Spg. W10125	Black Rock Cold Well W10167	Great Salt Lake Brine	Well 1.15 Bonneville Salt Flats
Cl/HCO_3	19	24	23	27	14	12	315	---
Cl/SO_4	62	24	69	58	21	8	6	12
Cl/B	144	107	164	112	124	900	3200	---
Cl/Li	150	266	204	14133	163	1000	2600	4280
Cl/F	666	960	818	565	816	1500	26000	---

THERMAL CHEMISTRY

The southwest area of Utah contains a great diversity of thermal waters. The sodium-chloride, sodium and calcium-sulfate and calcium and magnesium-bicarbonate types were sampled. The sodium-chloride waters predominate over all other types in this geographic region.

REGIONAL CHLORIDE WATERS

Roosevelt Area

The Roosevelt geothermal area was an obvious target before the discovery of shallow steam. The Roosevelt area is a classic example of a high enthalpy geothermal area by virtue of the young silicic rocks both intrusive and extrusive, the generous quantities of siliceous sinter and the interesting thermal waters.

An analysis of the last Roosevelt Hot Spring demonstrates the precision with which geochemistry can be used in geothermal exploration. An analysis of a 56°C one gallon per minute flow sampled in 1957 is shown in Table 2 and Figure 2. The Roosevelt spring water is remarkably similar to the sodium-chloride water from production wells with the exception of lithium. Alkali subsurface temperatures are four to seven percent higher than average subsurface temperatures measured in production wells (Table 2).

Salt Warm Spring (Plate 1) issues out at 25°C, one kilometer north of Negro Mag Wash. No surface temperature variations have been witnessed in eight measurements over a two year period. The tepid spring water contains less dissolved solids than the reservoir water, yet, ion rations (Table 2) and the general chemical composition are very similar to the reservoir water (Figure 3). This thermal spring water is unlike any other natural thermal efficient in the region (Figure 4, 5, 6, and 7). Silica subsurface temperatures (170°C) are substantially lower than the alkali subsurface temperatures (231°C) which are in turn lower than the proven reservoir temperatures.

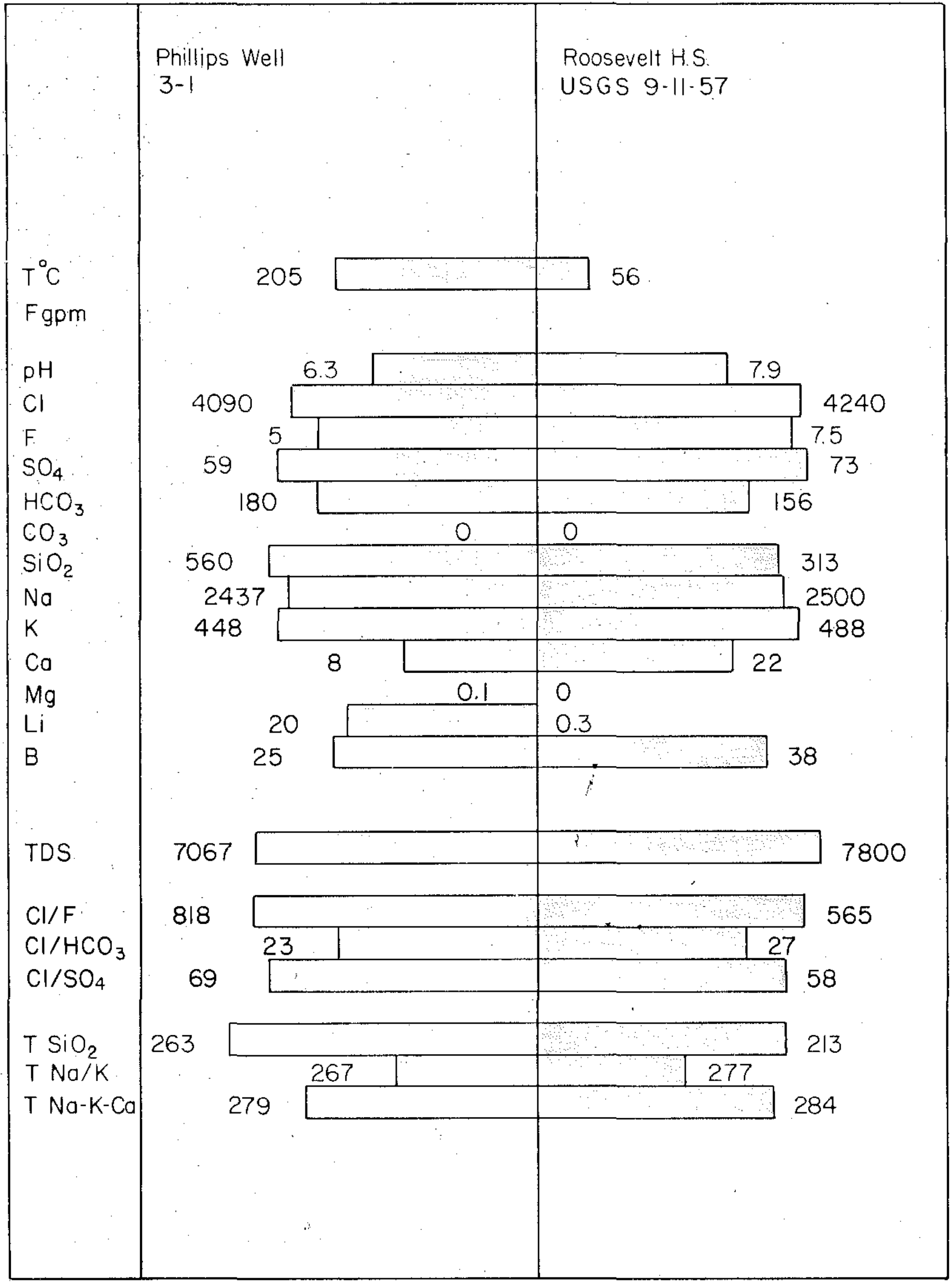

Figure 2. A graphic comparison of Phillips Well 3-1 and a 1957 sample of Roosevelt Hot Spring. Bars are based on a logarithmic scale.

Table 4. Principle anions and cations for regional thermal and non-thermal waters.

Name	T°C	Anions	Cations
		Chloride Waters	
Thermal Power Section 2	260	$Cl > HCO_3 > SO_4$	Na > K > Ca > Mg
Phillips Well 54-3	260	$Cl > HCO_3 = SO_4$	Na > K > Mg > Ca
Phillips Well 3-1	205+	$Cl > HCO_3 > SO_4$	Na > K > Ca > Mg
Roosevelt Hot Spring	51	$Cl > HCO_3 > SO_4$	Na > K > Ca > Mg
GKI Deep Test	96	$Cl > SO_4 > HCO_3$	Na > Ca > K > Mg
Crater Hot Spring	83	$Cl > SO_4 > HCO_3$	Na > Ca > Mg > K
Hatton Hot Spring	66	$Cl > SO_4 > HCO_3$	Na > Ca > K > Mg
Joseph Hot Spring	65	$Cl > SO_4 > HCO_3$	Na > Ca > K > Mg
Meadow Warm Spring	34	$Cl > SO_4 > HCO_3$	Na > Ca > K > Mg
Twin Peaks Warm Spring	30	$Cl > SO_4 > HCO_3$	Na > Ca > Mg > K
Salt Warm Spring	25	$Cl > HCO_3 > SO_4$	Na > K > Ca > Mg
Pearson Warm Well	16.5	$Cl > HCO_3 > SO_4$	Na > Ca > Mg > K
Yellow Jacket Warm Spring	16	$Cl > HCO_3 > SO_4$	Na > Ca > Mg > K
Black Rock Cold Well	10	$Cl > SO_4 > HCO_3$	Na > Ca > K > Mg
Great Salt Lake Brine	11	$Cl > SO_4 > HCO_3$	Na > Mg > K > Ca
Well 1.15 Bonneville Salt Flats	24	$Cl > SO_4 > HCO_3$	Na > Ca > Mg > K
		Sulfate Waters	
New Castle Hot Well	96	$SO_4 > HCO_3 \simeq Cl$	Na > Ca > K > Mg
Thermo Hot Spring	83	$SO_4 > HCO_3 > Cl$	Na > Ca > K > Mg
Red Hill Hot Spring	75	$SO_4 > Cl > HCO_3$	Na > Ca > K > Mg
Sulfurdale Warm Well	38	$SO_4 > Cl > HCO_3$	Ca > Mg > Na > K
Dotson's Warm Spring	32	$SO_4 > HCO_3 > Cl$	Na > Ca > Mg > K
SESW 16 Warm Well	20	$SO_4 > HCO_3 > Cl$	Ca > Na > Mg > K
Sulfurdale Bubbling Pool	5	$SO_4 > Cl > HCO_3$	Ca > Na > Mg = K
		Bicarbonate Waters	
Milford City Warm Well	27.5	$HCO_3 > SO_4 > Cl$	Na > Ca > Mg > K
Section 21 Warm Well	24.5	$HCO_3 > SO_4 > Cl$	Na > Ca > Mg > K
Government Warm Well	23	$HCO_3 > SO_4 > Cl$	Na > Ca > K > Mg
Greenville Warm Artesian Well	22	$HCO_3 > Cl > SO_4$	Ca > Mg > Na > K
Lava Ridge Warm Well	21	$HCO_3 > Cl > SO_4$	Na > Ca > Mg > K
Wah Wah Warm Spring	20	$HCO_3 > Cl > SO_4$	Ca > Mg > Na > K
Section 31 Warm Well	19	$HCO_3 > SO_4 > Cl$	Ca > Na > Mg > K
Four Mile Knoll Cold Spring	13.2	$HCO_3 > SO_4 > Cl$	Ca > Mg > Na > K

Plate 1. Salt Warm Spring, W10125, 25°C. This spring is indirect leakage from the Roosevelt reservoir.

Discrepancies between silica and alkali geothermometers generally imply disequilibrium and dilution. Various dilutions of the Roosevelt geothermal fluid (Phillips Well 54-3) were made with local groundwater (Table 5).

Table 5. Dilutions of Roosevelt Reservoir fluid with average groundwater.

	Phillips Well 54-3	DILUTION				
	X1	X0.83	X0.67	X0.56	X0.33	X0.20
Na	2400	1992	1608	1344	792	480
K	565	469	379	316	186	113
Ca	9	43	47	52	60	75
SiO_2	775	643	519	434	256	155

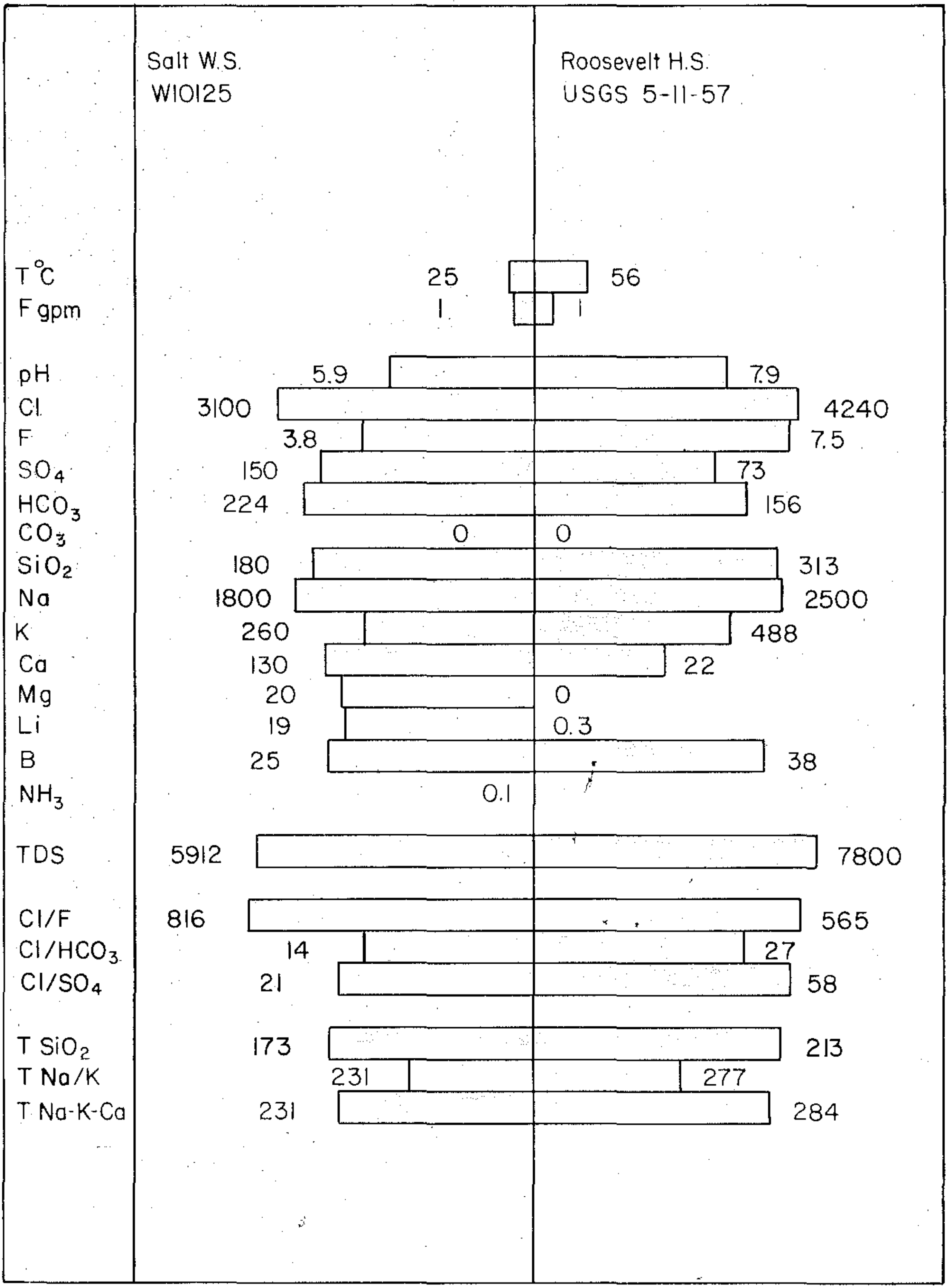

Figure 3. A graphic comparison of Salt Warm Spring (W10125) and Roosevelt Hot Spring. Bars are based on a logarithmic scale.

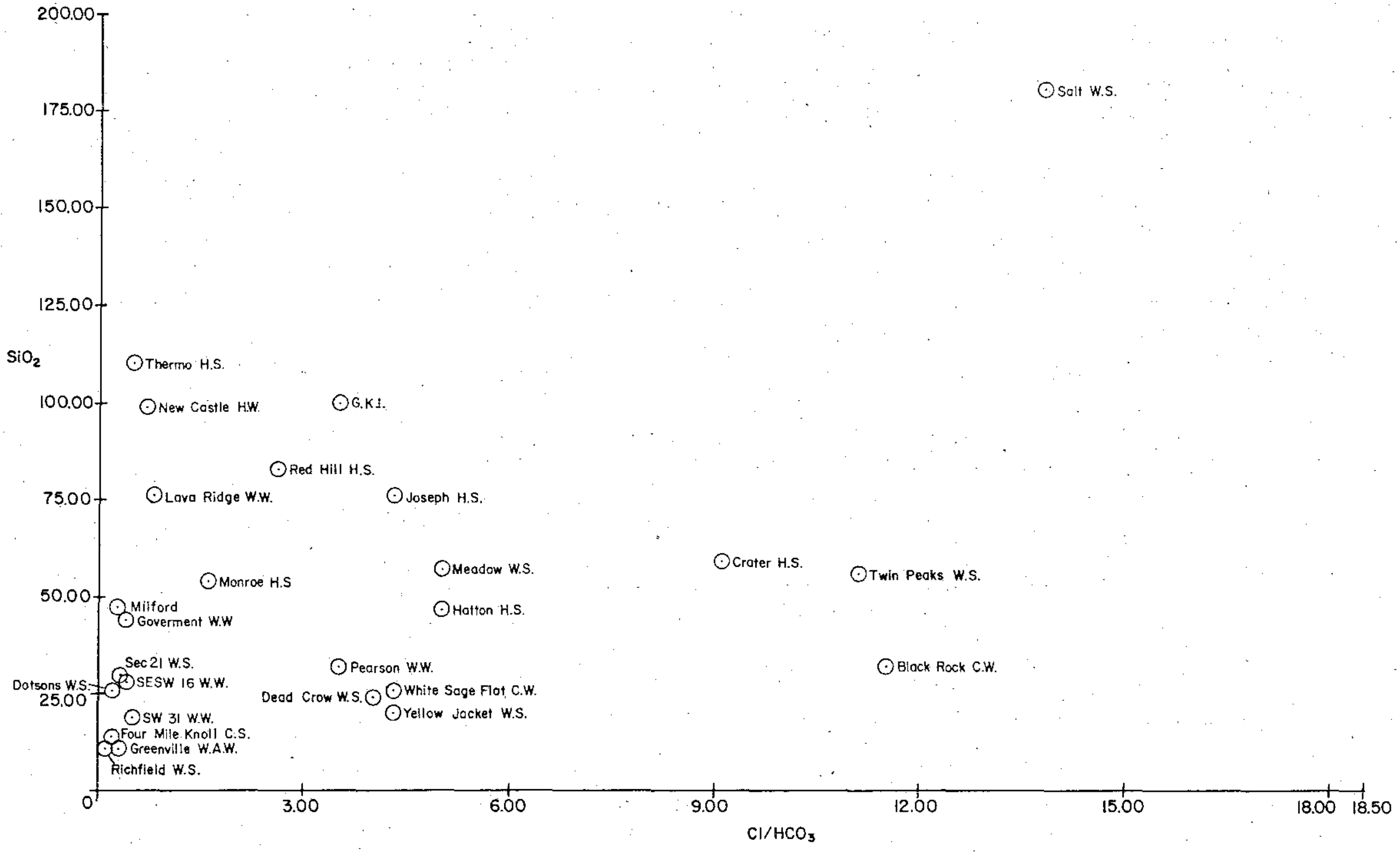

Figure 4. SiO$_2$ versus Cl/HCO$_3$

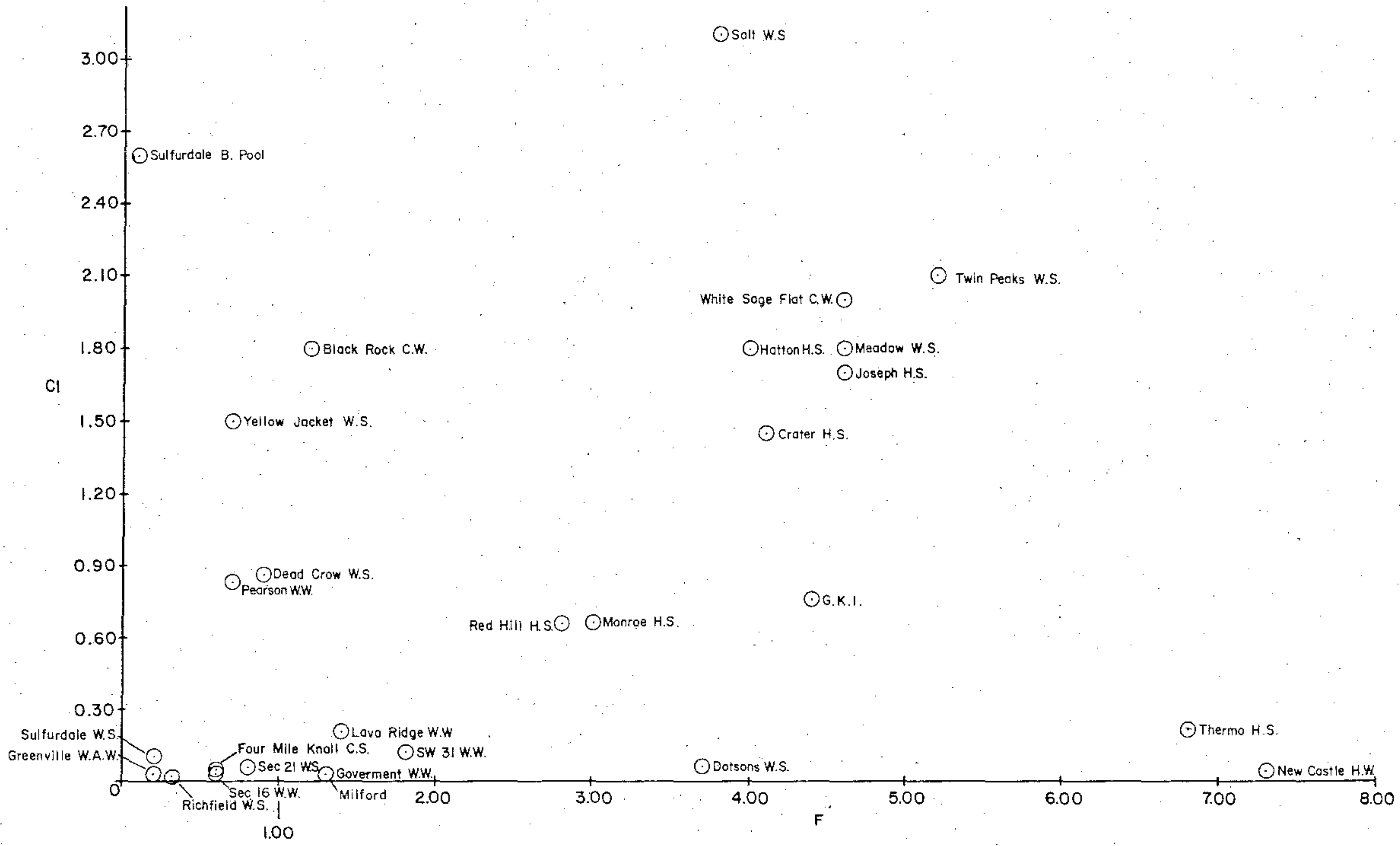

Figure 5. Cl versus F

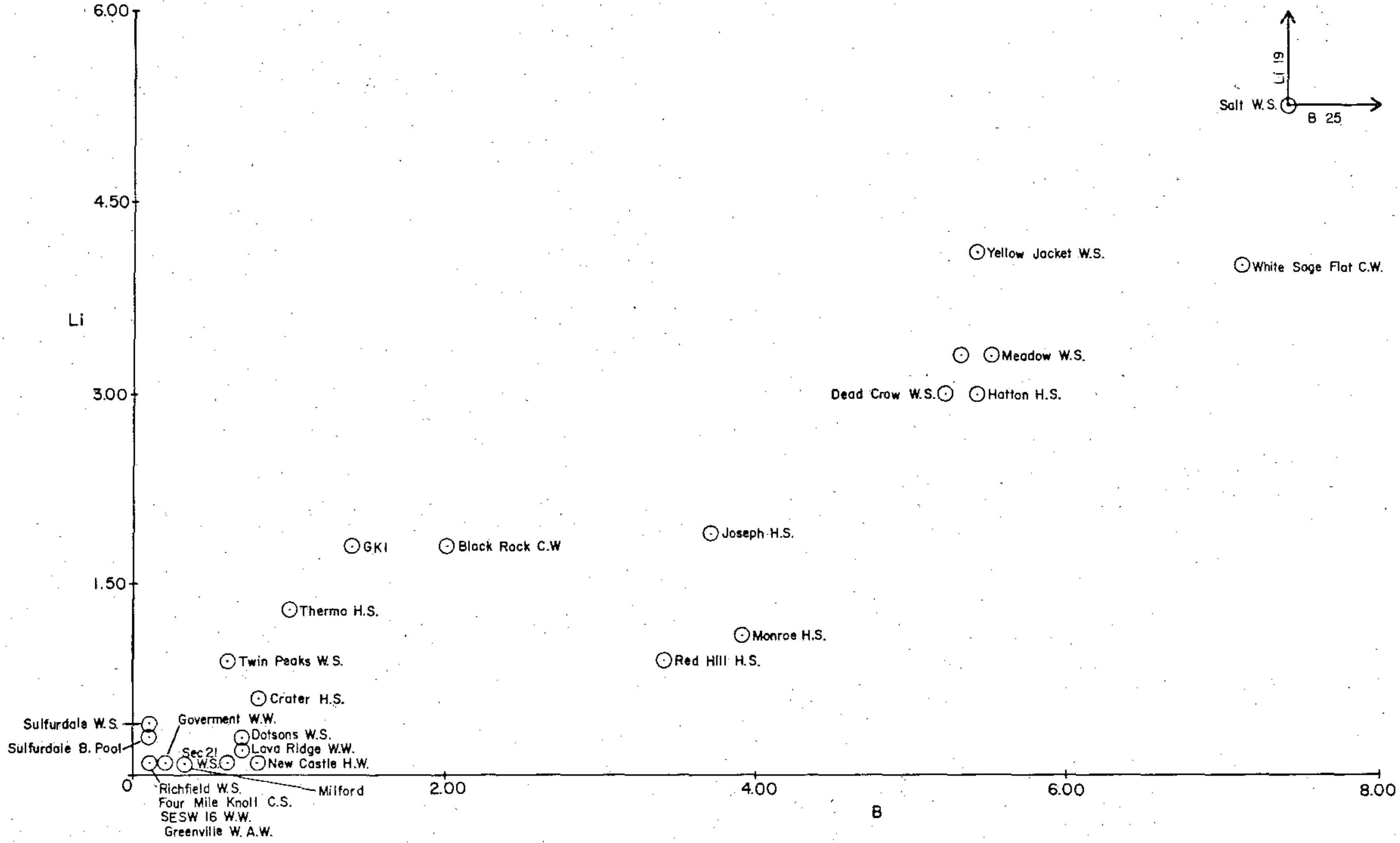

Figure 6. Li versus B

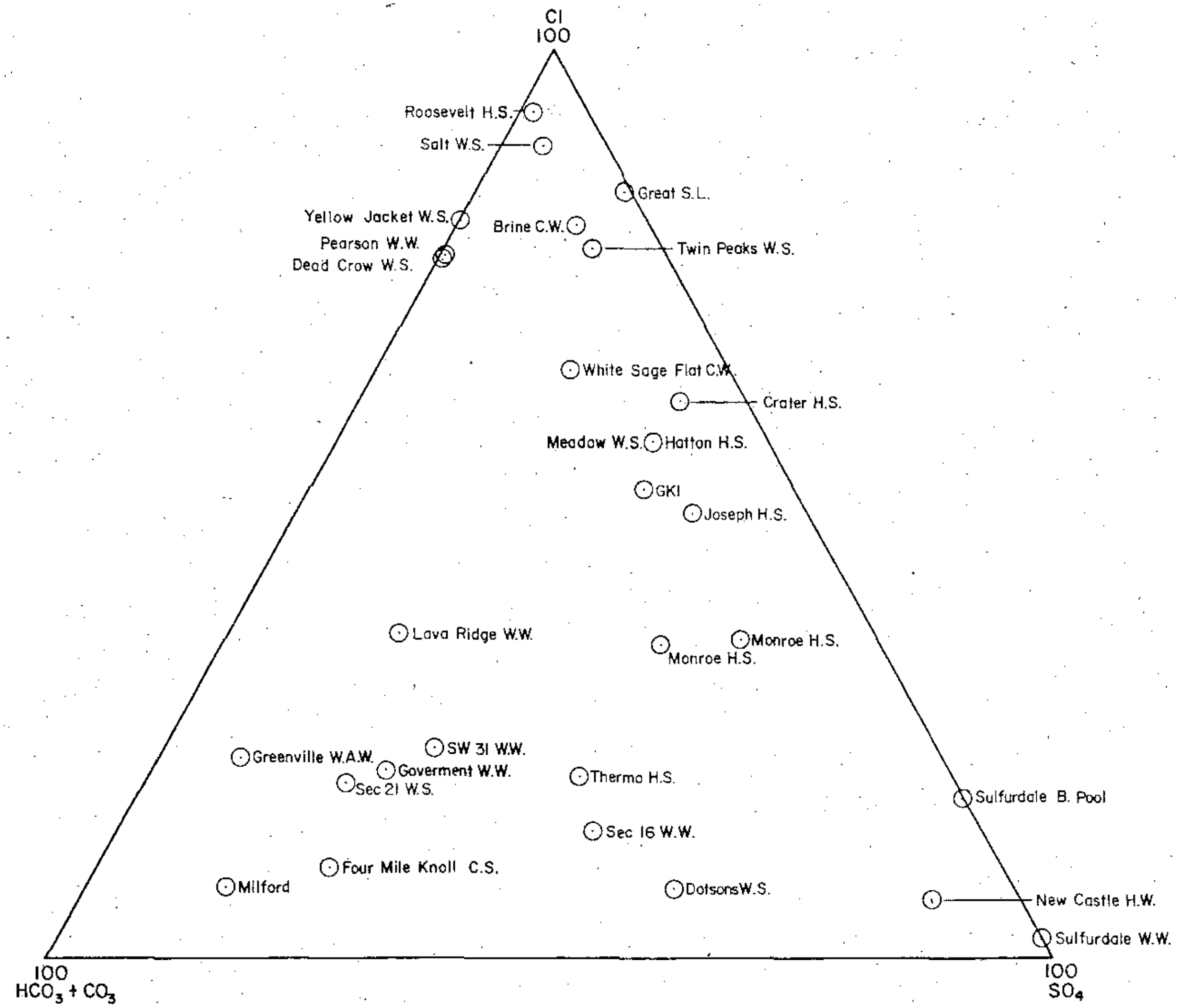

Figure 7. Three point diagram

Figure 8 is a plot of the resulting subsurface temperatures versus the dilutions seen in Table 5. The diagram indicates that the reservoir

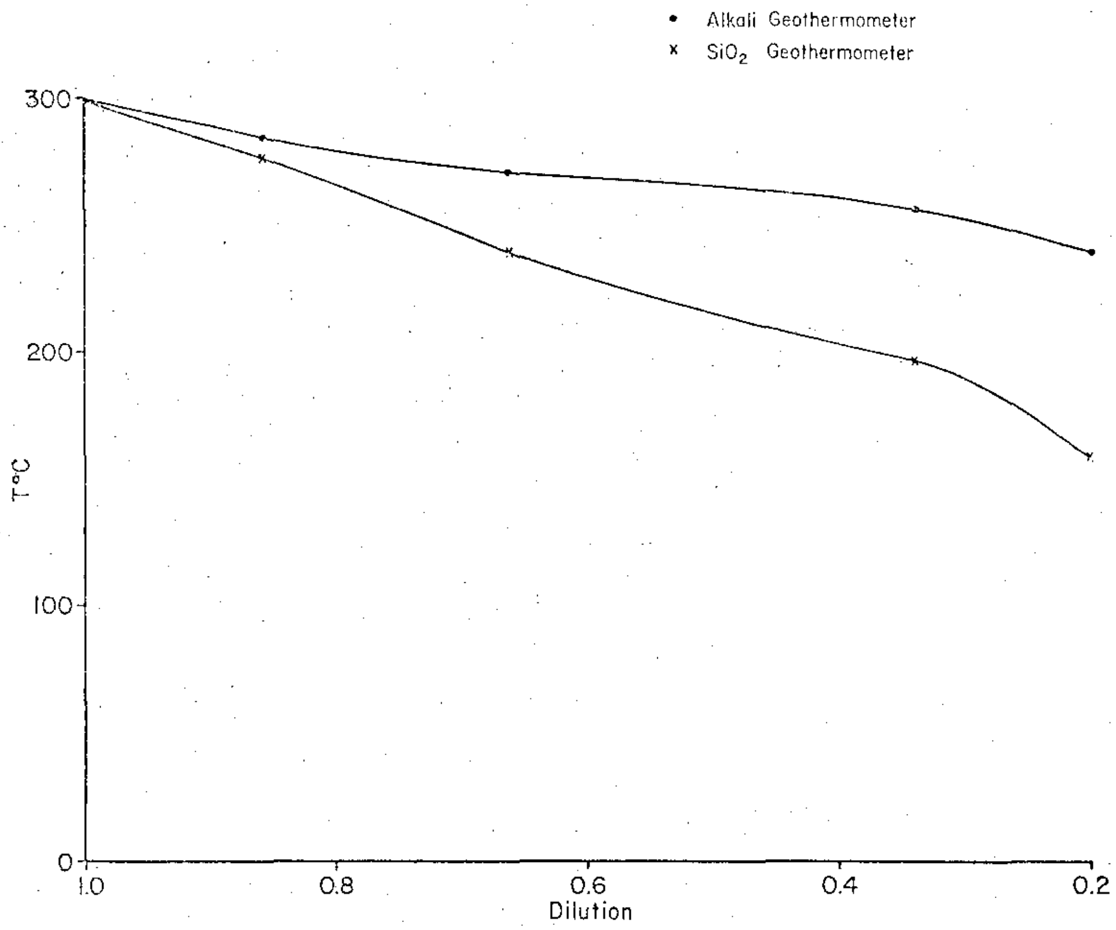

Figure 8. Reservoir fluid dilution versus subsurface temperatures.

fluid has internal equilibrium, i.e., the equilibrium temperatures are the same. Second, as dilution proceeds the discrepancy between silica and alkali temperatures increases. Lastly, the alkali temperatures are hardly affected by dilution while the silica geothermometer's temperature decreases as a direct function of dilution. The discrepancy in the equilibrium temperatures for Salt Spring (Table 2) probably results from dilution. A chloride-enthalpy mixing model indicates a 70 percent hot water fraction and a subsurface temperature of 245°C.

Thermodynamic mineral equilibria compilations can be useful in predicting scale formation. They are useful despite the lack of consideration for kinetic constraints. When thermodynamics predicts that a mineral will not appear, it cannot precipitate. When thermodynamic predictions indicate that a mineral will precipitate then it may appear as scale or it may remain completely suspended in the fluid because of nonadherence. Precipitation kinetics govern the rates at which minerals precipitate from solution. A saturated mineral or mineral assemblage may not come out of solution if the kinetics of the precipitation reactions are very slow.

The Roosevelt reservoir fluid (Table 6) as indicated by Phillips Wells 54-3 and 3-1 is saturated with the hydrated sodium silicates kenyaite, magadite and for 3-1, quartz. Mineral equilibria computations at 150°C indicate saturation with more silica minerals; kenyaite, magadite, quartz, chalcedony, and cristobalite. Silica minerals become even more saturated below 150°C. The quantity of metalliferous siliceous sinter of the Roosevelt area is profound and is the result of cooling reservoir water to temperatures of boiling or below. Accordingly, the after-flash liquid may present scaling problems if the temperature is allowed to drop below 125°C. Scaling will vary from well to well depending on the individual water chemistry. A thorough analysis of potential scaling at various pH, eH and temperature conditions will proceed at a latter date using the Helgeson-Herrick geochemical code (Miller, 1977).

Analysis by the U.S.G.S. indicates that the fluids from all the Phillips production wells contain no H^3 or C^{14}. A water age in excess of 30,000 years is indicated.

Table 6. Gibbs Free Energies in Kcal/mole for regional chloride waters. Positive values imply saturation, 0 values imply equilibrium, and negative values imply undersaturation.

	Phillips Well Phillips Petro. 3-1	Phillips Well Phillips Petro. 54-3	Roosevelt Hot Spring	GKI Deep test W10430	Crater Hot Spring W10164	Hatton Hot Spring W10261	Joseph Hot Spring W10157
T°C	205+	260	51	96	83	66	65
Carbonates				Huntite 4.8 Dolomite 4.0 Calcite 2.3 Aragonite 2.2	Dolomite 2.4 Huntite 1.9 Calcite 1.3 Aragonite 1.2	Dolomite 0.6 Calcite 0.4 Aragonite 0.3	Huntite 4.4 Dolomite 3.7 Calcite 2.0 Aragonite 1.9
Silicates	Kenyaite 17.5 Magadite 11.7 Quartz 0.5	Kenyaite 19.7 Magadite 13.3	Kenyaite 12.5 Magadite 9.4 Crysotil 6.3 Diopside 4.9 Chalcedony 1.3 Cristobalite 1.0 Clinenst 0.4 Cristobb 0.3	Tremolite 34.0 Talc 17.8 Crysotil 9.2 Diopside 6.6 Magadite 1.6 Sepiolite 1.4 Clinenst 1.1 Magnesite 1.0 Kenyaite 0.6 Quartz 0.5 Chalcedony 0.1	Tremolite 19.5 Talc 11.9 Crysotil 3.6 Diopside 2.3 Quartz 0.4 Magnesite 0.4	Talc 2.2 Quartz 0.5 Chalcedony 0.1	Tremolite 23.5 Talc 13.9 Crysotil 4.8 Diopside 3.3 Magnesite 1.0 Quartz 0.8 Magadite 0.7 Chalcedony 0.4 Cristobalite 0.1

Table 6. continued

Meadow Warm Spring W10306	Twin Peaks Warm Spring W10248	Salt Warm Spring W10125	Pearson Warm Well W10286	Yellow Jacket Warm Spring W10287	Black Rock Cold Well W10167	Great Salt Lake Brine	White Sage Flat Cold Well
34	30	25	16.5	16	10	11	15.5
Dolomite 2.0 Calcite 1.1 Aragonite 1.1 Huntite 0.8	Dolomite 0.8 Calcite 0.4 Aragonite 0.4		Calcite 0.4 Huntite 0.4 Aragonite 0.4	Calcite 0.2 Aragonite 0.2	Calcite 0.1 Aragonite 0.1	Huntite 6.3 Dolomite 3.3 Calcite 0.4 Aragonite 0.4	Calcite 0.004
Tremolite 7.8 Talc 7.4 Quartz 1.2 Chalcedony 0.6 Cristobalite 0.4 gnesite 0.02	Termolite 8.3 Talc 7.9 Quartz 1.2 Chalcedony 0.7 Cristobalite 0.4	Kenyaite 2.9 Quartz 2.0 Magadite 2.0 Chalcedony 1.4 Cristobalite 1.2 Silicaam 0.7 Cristobb 0.4 Silicgel 0.3	Talc 7.6 Tremolite 6.5 Quartz 1.1 Chalcedony 0.5 Cristobalite 0.2 Magnesite 0.1	Talc 3.9 Quartz 0.9 Chalcedony 0.2	Talc 1.7 Quartz 1.2 Chalcedony 0.6 Cristobalite 0.3	Talc 11.2 Tremolite 11.0 Crysotil 1.6 Quartz 1.2 Mirabilite 0.7 Chalcedony 0.6 Cristobalite 0.3 Gypsum 0.1	Quartz 1.0 Chalcedony 0.4 Cristobalite 0.2

Three sodium-chloride water discharges occur 11 km west of Salt Warm Spring. The waters issue out near the east bank of the Beaver River. Pearson Warm Well (W10286), Dead Crow Warm Spring (W10410) and Yellow Jacket Warm Spring (W10287, Table 2, Plate 2) produce water which is similar to the Roosevelt reservoir fluid with regard to boron, lithium, and ammonia. Mixing models indicate that these waters contain in excess of 70 percent groundwater. Chemistry indicates last equilibration at approximately 150°C for W10287. One thermal gradient well in the vicinity exhibits normal gradients. These waters may represent leakage from the Roosevelt Dome fault which has flowed down the topographic gradient to the Beaver River. Further study with hydrogen and oxygen isotopes should be conducted.

Plate 2. Yellow Jacket Warm Spring, W10287, 16°C

CRATER HOT SPRING

Crater or Abraham Hot Spring is in Juab County about 28 km northwest of Delta. The spring issues from a 120 square meter manganous mound of travertine. The mound is on the east flank of a Quaternary basalt flow which has been faulted north-south post eruption. The spring produces 83°C water at 250 gallons per minute.

The water is the sodium-chloride variety (Table 2 and 4, W10164) and contains significant concentrations of calcium, magnesium and relatively minor amounts of lithium and boron. The waters are mixed with approximately 40 percent groundwater and have also suffered significant conductive cooling.

Plate 3. Crater (Abraham) Hot Spring, W10164, 83°C. The water issues out of a recently faulted Pleistocene basalt flow and deposits copious quantities of manganous travertine.

The maximum subsurface temperature is approximately 160°C. The waters are well saturated with carbonates (Table 6) and are likely a result of deep circiulation in a major fault zone which presently is devoid of magmatism.

Hatton Hot Spring

Hatton Hot Spring and Meadow Warm Spring issue out eight km southwest of the town of Meadow in Millard County (Plate 4). They emerge from the same fault system that the 0.45 m.y. White Mountain Rhyolite, the historic Ice Spring Basalt flow and the Pleistocene Black Rock volcano arose. Hatton Hot Spring has deposited almost 1.6 square kilometers of metalliferous travertine.

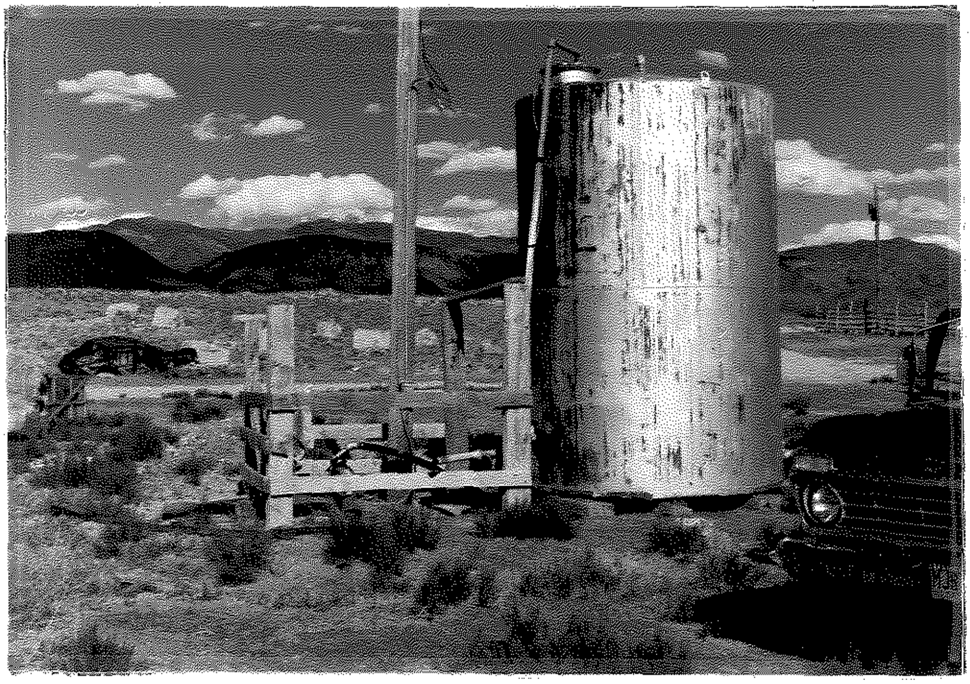

Plate 4. Hatton Hot Well, WI0261, 66°C. The spring issues out of a major fault outlined by recent basaltic and rhyolitic eruptive centers. The original hot springs have deposited a 1.6 kilometer ridge of hard tan travertine.

Both springs produce sodium-chloride water with approximately 5000 mg/l of dissolved solids. They are chemically almost identical (Figures 4 through 8). The waters are rich in lithium, boron, and ammonia. The thermal waters have lost temperature both by conductive cooling enroute to the surface and by mixing. Mixing models indicate a 48 percent cold water fraction and an original temperature of approximately 185°C. The alkali geothermometer indicates subsurface temperatures of approximately 200°C.

The Hatton and Meadow Springs are both saturated with carbonates (Table 6). The Spring waters are probably heated in a carbonate reservoir, however, a substantial granitic reservoir may underly the Paleozoic carbonates.

The Hatton area is very attractive. The area boasts the youngest rhyolite and basalt flow in Utah, vast amounts of metal bearing travertine and interesting thermal waters. Heat flow may be masked by a cold shallow artesian underflow which has been used for irrigation since the early 1900's.

Monroe Area

Three hot springs issue out of the central Sevier Valley in Sevier County. Red Hill Hot Spring (Plate 5, W10155), Monroe Hot Spring, and Joseph Hot Spring (Plate 6, W10157) deposit large amounts of travertine and issue out of major faults. Red Hill Hot Spring has the highest flow of 40 gallons per minute while Joseph Hot Spring produces two gallons per minute.

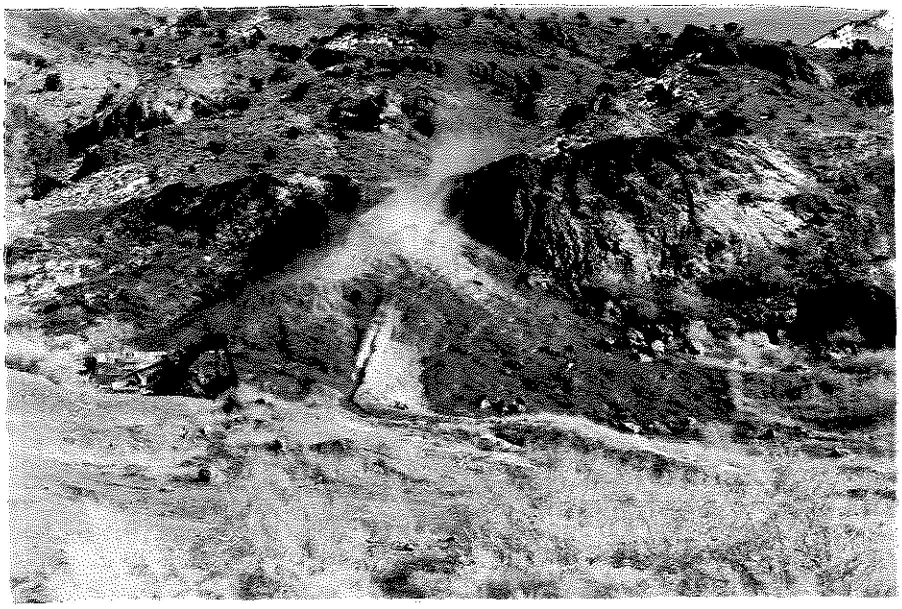

Plate 5. Red Hill Hot Spring, W10155, 75°C, issues from a concealed range front fault and deposits a manganous travertine.

Plate 6. Joseph Hot Spring, W10157, 65°C, issues from the Dry Wash Fault. The water deposits ferruginous travertine.

Joseph Hot Spring produces sodium-chloride water with 7530 mg/l of dissolved solids. The water contains high concentrations of boron, lithium, calcium and magnesium (Table 2) and is saturated with carbonates (Table 6). Geothermometers indicate a subsurface temperature of 140°C. The water chemistry does not indicate mixing.

Red Hill Hot Spring (Table 4 and 7) produces sodium-sulfate water. The water may contain over a 60 percent cold water fraction of the shallow sodium-sulfate water. The original water may be the sodium-chloride variety similar to Joseph Hot Spring. The deep reservoir temperature may be in the vicinity of 180°C. Hydrogen and oxygen isotope studies are necessary to confirm groundwater dilution.

Twin Peaks Area

A 30°C warm spring (Plate 7) issues out of the northwest flank of North Twin Peak, a Tertiary rhyolitic volcanic center. Similar water was encountered at 70 meters, 1.2 km west of the spring while drilling a thermal gradient hole.

Plate 7. Twin Peaks Warm Spring, W10248, 30°C, issues from the flank of a Tertiary rhyolitic eruptive center.

The spring produces sodium-chloride waters which have equilibrated at about 100°C (Table 2 and 4, W10248). There is no evidence of mixing with groundwaters. Thermodynamics indicates saturation with carbonates (Table 6). The waters are not geothermally interesting in spite of their sodium-chloride nature.

A 21°C warm well issues out six km southeast of North Twin Peak. The well was drilled in alluvium on the west flank of a Pleistocene basalt flow called Lava Ridge (Plate 8). The well is 35 meters deep, exhibits a 139°C/km gradient and produces 21°C water.

The well produces dilute sodium-bicarbonate water which contain 23 mg/l of potassium (Table 1 and 4, W10305). The water is saturated with carbonates and deposits minor calcite in the storage tank (Table 9). The water is strongly mixed and has been cooled significantly by conduction. The maximum subsurface temperature may exceed 180°C.

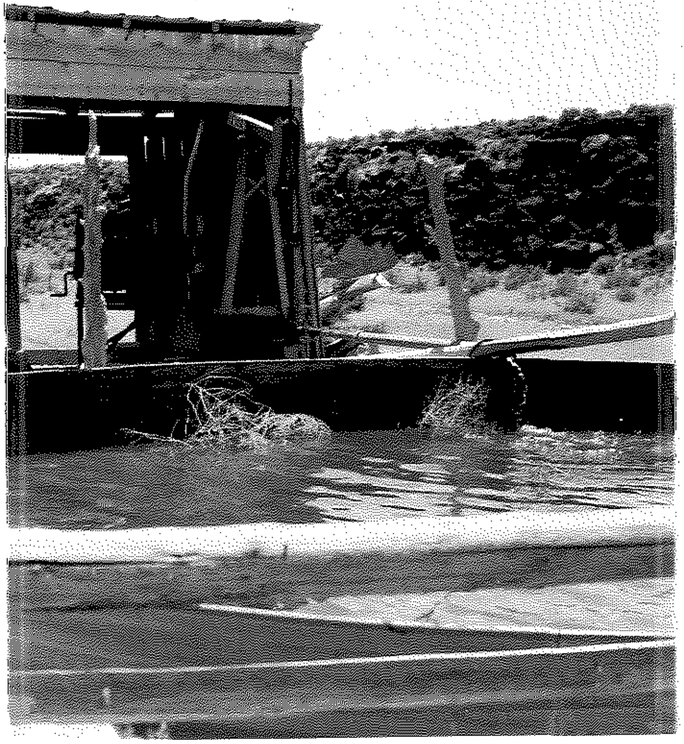

Plate 8. Lava Ridge Warm Well, W10305, 21°C

REGIONAL SULFATE WATERS

Thermo

At least 15 hot springs issue out of two parallel north-trending en echelon ridges located about 25 km west of Minersville in Beaver County. The ridges mark a north-trending fault system in the Escalante Valley. The ridges consist mostly of sand held together by moisture, vegetation and a travertine containing 22 percent silica. The maximum surface temperature is 83°C. The combined spring flow is about 200 gallons per minute (Plate 9).

Plate 9. Thermo Hot Spring, W10121, 83°C, issues out of north-trending mounds consisting of moist wind-blown sand and a gray travertine.

The Thermo Hot Springs produce rather dilute (1699 mg/l) sodium-sulfate water (Table 4 and 7). The waters are enriched in fluoride, lithium, boron and ammonia. They are similar to the New Castle Hot Wells (Table 7, W10254) with regard to the SiO_2 versus Cl/HCO_3 ratio and Cl versus Fl (Figures 4 and 5, respectively). The waters are saturated with a suite of igneous and metamorphic minerals and carbonates (Table 8). Severe carbonate scaling will occur if the deep reservoir fluids contain the high calcium concentrations of the hot springs.

The Thermo waters are mixed with approximately 60 percent calcium-rich groundwaters. The chloride-enthalpy and silica-enthalpy mixing models predict subsurface temperatures of 202°C and 206°C, respectively. This is in good agreement with the alkali geothermometer (198°C). The bulk of the calcium in the spring water comes from the cold water fraction as a result of mixing.

Sulfate waters (Table 4) are generally younger than chloride waters. Sulfate waters are associated with quick recharge circulation systems. The older chloride waters of the Roosevelt, Yellow Stone, New Zealand and Japanese geothermal areas issue from enormous slow recharge hydrothermal systems. Heat flow data for the Thermo area is in agreement with the chemical interpretation and would indicate a small convecting liquid-dominated system.

The indicated 200°C subsurface temperatures are adequate for electric production. Calcium carbonate scaling should not be substantial if the reservoir fluid contains less than 25 mg/l of calcium.

New Castle

A 152 meter well south of Newcastle in Iron County (Plate 10, W10254) produces boiling water at the rate of 1000 gallons per minute. Temperatures of 107°C at 100 meters and 105°C at 150 meters have been measured.

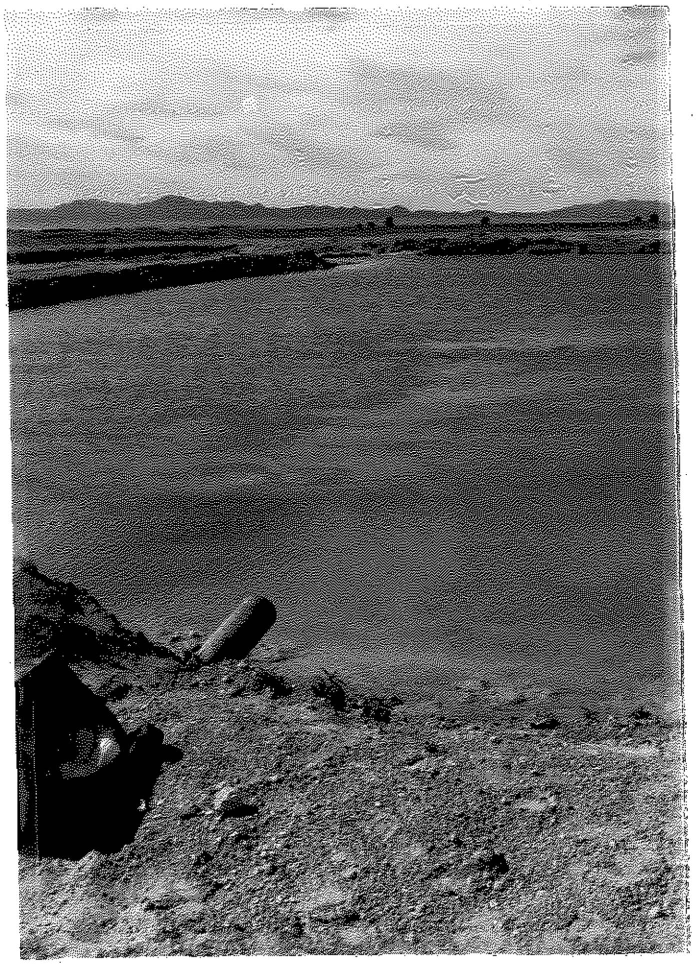

Plate 10. New Castle Hot Well, W10254, 95.6°C (flashing). Water emerges from concealed underwater pipe.

The well produces sodium-sulfate water (Tables 4 and 7) that is similar to Thermo Hot Spring with regard to SiO_2 versus Cl/HCO_3 and the Cl/F ratio (Figures 4 and 5, respectively). The water has equilibrated at approximately 155°C. The chemistry does not evidence mixing.

The New Castle water may ascend up the west range front fault of the Dixie Mountains at the edge of the Enterprise Valley and disperse in alluvium for about 1.6 square kilometers. Gradient measurements made by several companies active in the area substantiate this.

Dotson's Warm Spring

Dotson's or Radium Warm Spring issues out of the south bank of the Beaver River about 1.5 km east of Minersville (Plate 11). Waters flow from Paleozoic limestone at 32°C. The total flow is about 30 gallons per minute.

Plate 11. Dotson's Warm Spring, W10120, 32°C. The spring issues from a fault in Paleozoic limestones

Springs produce dilute (1232 mg/l) sodium-sulfate water (Tables 4 and 7). They are not particularly enriched in any ion and are similar to the majority of the warm thermal waters of the area (Figures 4 through 7). Waters were last in equilibrium about 80°C and have cooled subsequently by conduction. Chemistry does not indicate dilution. The waters are in equilibrium with carbonates (Table 8). The Minersville thermal waters probably represent a small low temperature hydrothermal system located in the east-west fault zone that separates the southern Mineral Mountains from the Black Mountains.

Dog Valley Area

Two 270 meter holes were drilled in 1958 by T. Paxton. Drillers' logs indicate hot (83°C) white bad-tasting water that stock would not drink. The descriptions indicate that these were acid-sulfate waters.

A sampling device was sent down each of these wells. Full penetration was not achieved due to caving and, as a result, no water was retrieved.

REGIONAL BICARBONATE WATERS

Government Warm Well

Government Warm Well (Plate 3), 11 km east of Thermo Hot Springs, produces 23°C sodium-bicarbonate water (Tables 1 and 4). The water does not deposit sinter and is similar to the many other warm dilute thermal waters of the region (Figures 4 through 7). The water has equilibrated at about 60°C and is not mixed. The thermal effluent of Government Warm Well probably results from circulation in a fault in the Tertiary Needles Range Formation visible near the well.

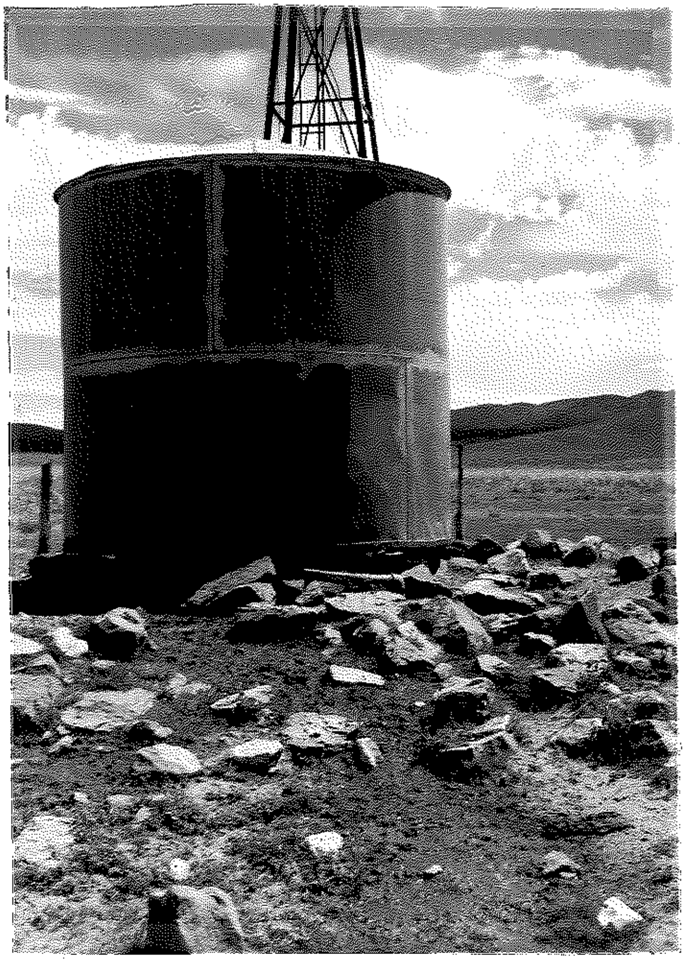

Plate 13. Government Warm Well, W10268, 23°C, produces warm water from a fault in the Tertiary Needles Range Formation.

Milford Warm Wells

Seven wells in and around the city of Milford (Plate 14) produce large volumes of 25°C to 27.5°C water. The city of Milford uses four of these wells for the municipal water supply. The wells are no deeper than 130 meters.

Plate 14. Milford City Warm Well, W10285, 27.5°C. Well is 124 meters deep and supplies municipal water.

The wells produce dilute (412 mg/l) sodium-bicarbonate water (Tables 1 and 4, W10285) that contains minor concentrations of fluoride (1.4 mg/l) and boron (0.4 mg/l). The waters are chemically similar to regional thermal and non-thermal waters (Figures 4 through 7). Geothermometers indicate last equilibration at approximately 80°C. Dilution by groundwater is not evident.

The Milford waters may arise from a circulating hydrothermal system associated with the northeast extension of the Pass Fault.

Greenville Warm Artesian Wells

Three artesian wells produce 22°C water, 1 km south of Greenville (Plate 15). Total flow is approximately 45 gallons per minute.

Plate 15. Greenville Warm Artesian Well, W10185, 22°C.

The wells produce very dilute (309 mg/l) calcium-bicarbonate water (Tables 1 and 4, W10184). The general water chemistry implies a very low temperature regime. The waters probably equilibrated below 50°C. Waters are saturated with carbonates (Table 9) and deposit minor amounts of travertine on piping.

Table 9. Gibbs Free Energies in Kcal/mole for regional bicarbonate waters. Positive values imply saturation, 0 values imply equilibrium, and negative values imply undersaturation.

	Section 21 Warm Well W10292		Government Warm Well W10268		Greenville Warm Artesian Well W10184		Lava Ridge Warm Well W10305		SW 31 Warm Well W10303		Four Mile Knoll Cold Spring W10181	
T°C	24.5		23		22		21		19		13.2	
Carbonates	Dolomite	1.0			Dolomite	1.4	Dolomite	0.9	Dolomite	0.1	Calcite	0.7
	Calcite	0.3			Calcite	0.7	Calcite	0.3	Calcite	0.1	Aragonite	0.7
	Aragonite	0.3			Aragonite	0.6	Aragonite	0.2	Aragonite	0.1	Huntite	0.2
					Huntite	0.1						
Silicates	Tremolite	11.5	Tremolite	11.6	Tremolite	9.0	Tremolite	8.7	Talc	2.0	Talc	6.0
	Talc	9.5	Talc	9.0	Talc	8.0	Talc	8.6	Quartz	0.8	Tremolite	3.5
	Quartz	0.9	Quartz	1.1	Quartz	0.4	Quartz	1.5	Chalcedony	0.2	Quartz	0.7
	Crysotil	0.5	Chalcedony	0.5			Chalcedony	0.9			Chalcedony	0.1
	Chalcedony	0.3	Cristobalite	0.3			Cristobalite	0.7				
	Cristobalite	0.1					Silicaam	0.2				

Wah Wah Warm Spring

Wah Wah Warm Spring (Plate 16) produces at least 5,000 gallons per minute of 20°C water. The spring issues out of the east flank of the Wah Wah Mountains in the vicinity of a range front fault. The water has deposited 1.4 square kilometers of travertine.

Plate 16. Wah Wah Warm Spring, W10184, 20°C. The water issues from a range fault and has deposited a 0.7 x 0.6 km travertine mount.

The spring produces dilute calcium-bicarbonate water (Table 1 and 4, W10184) that reach a subsurface temperature which is slightly higher than the surface outlet temperature. The water is similar to regional non-thermal waters as seen in Figures 4 through 7.

Section 21 Warm Well

T. Paxton owns a warm well, 8 km northwest of Dog Valley (W10292, Plate 17) in section 21, T24S, R7W. The well is 152 meters deep and produces 24.5°C water.

The well produces dilute sodium-bicarbonate water (Table 1 and 4) which is similar in composition to regional thermal and non-thermal waters (Figures 4 through 7). Dilution is not evidenced. Chemistry indicates last equilibration at approximately 75°C.

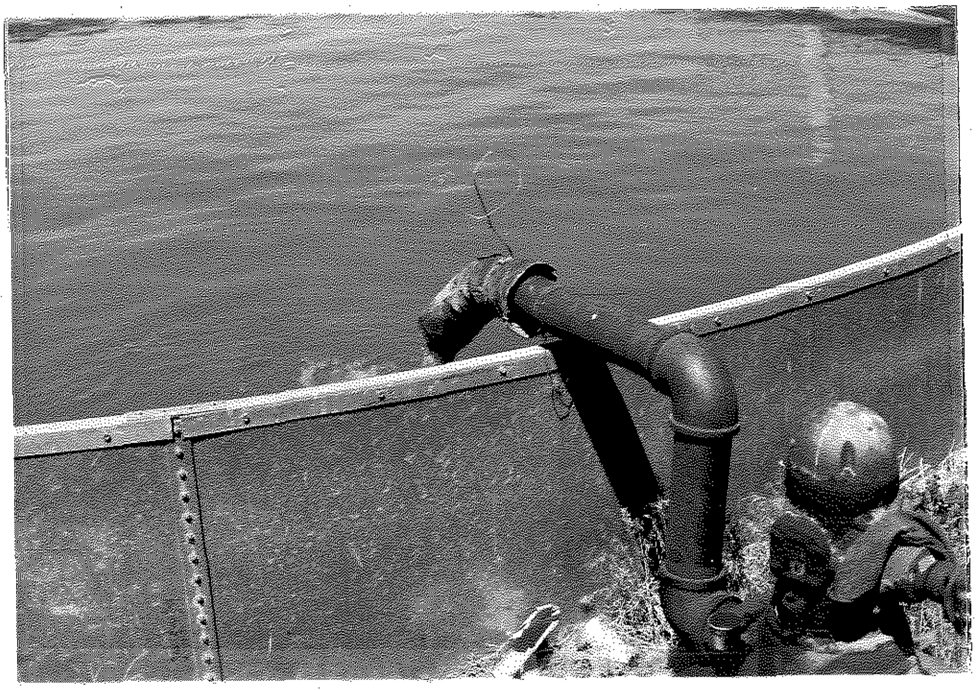

Plate 17. Section 21 Warm Well, W10292, 24.5°C.

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PORTION OF ESCALANTE
& BLACK ROCK DESERTS
UTAH
HYDROGEOCHEMICAL SAMPLE SITES

SOURCE: USGS - DELTA, RICHFIELD 1962, CEDAR CITY 1961 DATE


Surface water temperature in °C
AMAX EXPLORATION, INC.
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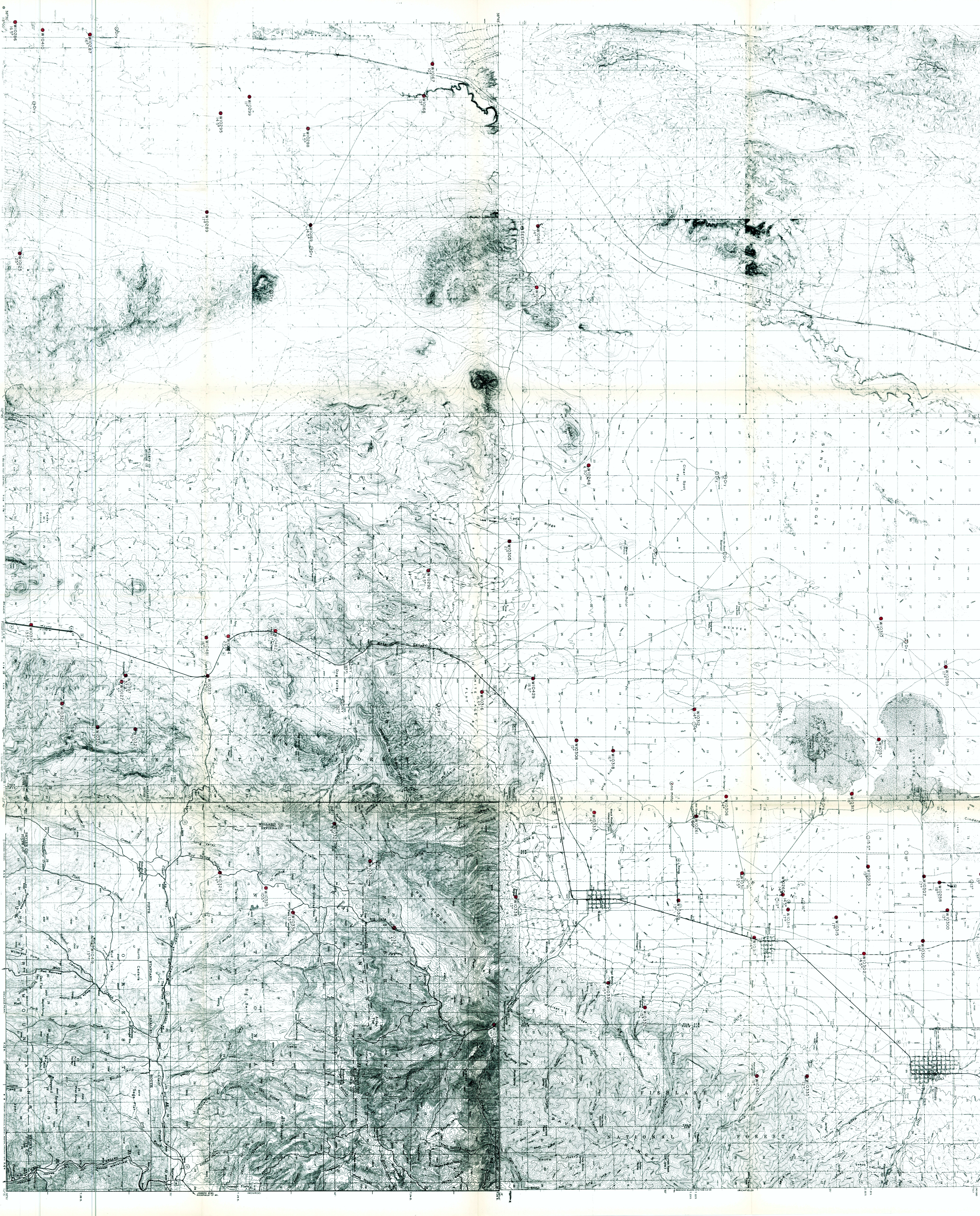
SCALE 1:62500
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
ESCALANTE DESERT
Milford
Minersville
Slag seep
PAROWAN



Surface water temperature in °C

AMAX EXPLORATION, INC.
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BEST (No.) – UTAH