Chapter 5. HYDROLOGY AND HYDROGEOCHEMISTRY

By: Burkhard W. Bohm, Roger L. Jacobson, Michael E. Campana,
and Neil L. Ingraham

5.0 HYDROLOGY AND HYDROGEOCHEMISTRY

5.1 Introduction

5.1.1 Purpose and Scope

The purpose of this portion of the study is to provide hydrologic and hydrogeochemical input to the construction of the Dixie Valley geothermal model. Since some of the most important aspects of hydrothermal reservoir assessment are the fluid characteristics and flow parameters, the hydrology and hydrogeochemistry of a particular reservoir must be considered in the formulation of any hydrothermal reservoir model, even a conceptual or qualitative one. Our primary efforts were devoted to extensive isotopic and hydrochemical sampling and interpretation of these data as direct and indirect indicators of the nature of the reservoir. Most of the work focused on the area of greatest interest to Southland Royalty Company, the northern half of Dixie Valley (between Dixie Meadows and Sou Hot Springs). The study also involved sampling outside this particular region.

The major tasks of the hydrologic-hydrogeochemical study are as follows:

(1) Review the available hydrologic and hydrogeochemical data.

(2) Obtain water samples from selected wells, hot springs and cold springs.

(3) Analyze water samples for major, minor and selected trace chemical constituents and environmental isotopes.

(4) Collect temperature and other data from selected wells and springs.

(5) Estimate recharge rates and source areas and groundwater flow rates.

(6) Estimate reservoir geometry.

(7) Provide estimates of reservoir water chemistry and, using geothermometry, reservoir temperatures.

(8) Provide hydrologic and hydrogeochemical input to the formulation of a conceptual model of the Dixie Valley hydrothermal system.

The interpretation of the environmental isotope data was intended to supplement the hydrogeochemical data and provide additional hydrologic information, particularly with respect to recharge to the reservoir. However, the complete suite of isotope data has not yet been received. The interpretations and conclusions presented herein have been made without the benefit of any isotope data, and are based almost solely upon the hydrogeochemistry. This is not an ideal approach, but was dictated by circumstance. Therefore, this chapter is incomplete since it is devoted primarily to the hydrogeochemistry of the study area with little discussion of the hydrology. An addendum to this chapter will be written as soon as the isotope data have been received, interpreted and integrated with the rest of the information.

5.1.2 Methods and Analytical Techniques

Approximately 100 samples of the thermal and non-thermal waters were collected. The collection generally involved filtration through a 0.45 µm filter for a gross sample and an acidified sample. Nitric acid was added to lower the pH to approximately 2. Samples were collected for silica using a 1:10 field dilution of the thermal waters with distilled water. Isotope samples were collected by completely filling a 125 ml glass bottle and sealing the bottle with Parafilm and electrical tape.

Field measurements were made of temperature, electrical conductivity (EC), pH and dissolved oxygen (DO). Laboratory determinations were made for Ca, Mg, Na, K, HCO_3, Cl, SO_4, NO_3, SiO_2, F, B, Li, As, Cs, Al, Hg, Fe, Mn, Sr and Ba in the Water Resources Center Laboratories.

^3H analyses (both enriched and unenriched) were performed in Water Resources Center Laboratories. ^{18}O and ^2H samples were sent to the Laboratory of Isotope Geochemistry at the University of Arizona for analysis.

5.1.3 Previous Work

Very little previous work on the hydrology and hydrogeochemistry of Dixie Valley exists. A paper by Zones (1957) describes some of the hydrologic effects of the 1954 Dixie Valley earthquake. A reconnaissance study by Cohen and Everett (1963) gives an overview of the groundwater hydrology of Dixie and Fairview Valleys. This report also includes a brief description of the groundwater chemistry of the Dixie-Fairview area. A total of 13 water chemistry samples were collected in an area of 2360 square miles, a very low sampling density. The data presented in this report were insufficient to draw any substantive conclusions concerning the groundwater system in Dixie Valley. Additional work of a limited nature in the valley was conducted by Keplinger and Associates (1977 and 1978) and by GeothermEx, Inc. (1976).

5.2 Analytical Results

5.2.1 Chemical Characteristics of Dixie Valley Waters

Table 5-1 shows the chemical analyses of all the samples collected during the study. Variations in gross chemical properties of Dixie Valley groundwater and surface water are evident on a trilinear diagram (Figure 5-1). Percentages of equivalents were plotted for major anions and cations (Cl, SO_4, HCO_3 and CO_3, Ca, Mg and Na + K). The three hot spring systems of the valley plot as separate groups. Dixie Hot Springs (D) show significant variation, but generally they are sulfate-chloride-potassium-sodium waters. Hyder Hot Springs (H) show little variation, and are bicarbonate-potassium-sodium type waters. Sou Hot Springs (S) is an intermediate type, having roughly similar equivalent percentages of the major ions. The hot springs of McCoy Ranch (M), Lower Ranch and southern Jersey Valley seem to be related to Hyder Hot Springs. Buckbrush Seeps (B) also seem to be closely related to Hyder, perhaps due to structural relationships. However, Buckbrush Seeps might be affected by evaporation. Surface runoff from the Stillwater Range, irrigation wells from the northern part of the valley and waters from the eastern ranges (Clan Alpine and Augusta Mountains) show wide variations. There is, however, a rough grouping of the water quality samples according to their areal distribution in the valley. For example, the samples from the deep wells (DF 45-14 and DF 66-21) and well SR2-A seem to be related to Dixie Hot Springs. It should be noted that samples from DF 45-14 and DF 66-21 may not be representative of the geothermal reservoir fluids because of contamination from drilling fluids and additives and/or shallow groundwater.

Table 5-1. Chemical Analyses of Dixie Valley Waters.

The letter or number in the first column identifies the group sample according to the following code:

A - Artesian wells in the vicinity of Dixie Settlement.
B - Buckbrush Seeps.
C - Carson Sink (western slopes of the Stillwater Range).
D - Dixie Hot Springs.
E - Spring or stream from the eastern mountain ranges (Clan Alpine and Augusta Mountains).
H - Hyder Hot Springs.
I - Irrigation wells in the northern part of Dixie Valley.
L - Wells in the vicinity of Dixie Settlement.
M - Intermediate temperature springs around McCoy Ranch.
S - Sou Hot Springs.
W - Spring or stream from the Stillwater Range.
1 - DF 45-14 (probably contaminated).
2 - DF 66-21 (probably contaminated).
3 - DF 45-14.
4 - DF 66-21 (probably contaminated).

Table 5-1. Chemical Analyses of Dixie Valley Waters.

		DATE	TEMP	PH	CA	MG	NA	K	CL	SO4	HCO3	SIO2	CO3	TDS
W	LL097	90878	15.00	8.00	105.600	43.300	133.000	.320	168.000	297.000	247.000	28.500	-0	1022.810
W	LL109	92878	16.00	6.90	270.400	31.300	211.000	4.000	203.000	682.000	308.000	33.400	-0	1743.190
W	DV21	32079	13.00	7.40	46.500	26.600	464.000	3.850	605.000	207.000	194.000	26.000	-0	1575.667
W	DV22	32079	11.00	8.50	56.000	32.000	116.500	3.000	12.600	92.400	302.000	19.800	-0	636.145
W	DV031	51579	17.00	8.35	82.500	33.500	108.000	2.600	126.000	218.000	225.000	20.000	-0	815.990
W	DV032	51579	26.00	8.77	54.500	52.500	176.000	10.700	258.000	178.000	251.000	31.800	-0	1012.820
W	DV045	51579	14.00	7.69	68.000	35.000	100.000	2.800	115.000	97.000	306.000	14.500	-0	738.600
W	DV046	51579	15.75	8.35	44.500	21.500	70.000	1.600	68.000	41.000	278.000	18.500	-0	543.390
W	DV047	51579	18.00	8.50	42.000	24.000	80.000	1.700	83.000	52.000	267.000	18.000	-0	567.700
W	DV048	51579	13.50	7.78	54.500	30.500	78.000	1.900	83.000	66.000	319.000	16.500	-0	649.400
W	DV049	51579	15.75	8.21	48.000	37.000	123.000	3.000	126.000	112.000	306.000	20.200	-0	775.200
W	DV050	51579	16.00	8.45	39.500	26.000	94.000	1.800	96.000	65.000	262.000	18.500	-0	603.110
W	DV051	51579	17.00	8.17	41.500	32.500	114.000	2.600	118.000	88.500	289.500	20.000	-0	706.940
W	DV052	51579	17.00	8.54	53.000	24.000	165.000	3.000	194.000	161.000	205.000	23.000	-0	828.490
W	DV053	62579	18.00	7.20	175.000	78.000	118.000	2.600	150.000	518.000	360.000	17.500	-0	1421.474
W	DV055	62579	15.00	7.86	66.000	34.500	120.000	3.800	140.000	105.000	346.000	19.500	-0	835.180
W	DV56	62579	15.00	7.66	65.000	37.800	117.000	3.500	130.000	114.000	379.000	20.000	-0	866.680
W	DV057	62579	15.00	8.45	44.000	40.000	138.000	3.300	149.000	122.000	316.000	20.000	-0	832.670
W	DV058	62579	15.00	8.60	41.500	27.800	105.000	2.100	109.000	86.000	279.000	18.000	-0	668.720
W	DV059	62579	28.00	8.70	38.000	31.300	123.000	2.600	127.000	104.000	215.000	19.500	20.000	681.090
W	DV067	62579	16.00	7.33	262.000	33.300	215.000	3.500	218.000	710.000	299.000	26.300	-0	1768.430
W	DV078	72379	22.00	7.40	95.700	16.900	187.000	2.700	227.000	171.000	327.000	26.000	-0	1056.785
W	DV092	091279	43.	8.48	32.000	65.000	197.000	7.500	255.000	168.000	282.000	32.500	17.100	1058.295
W	DV102	62579	14.00	7.71	104.000	36.000	138.000	1.600	226.000	126.000	348.000	46.500	-0	1026.430
W	DV103	62579	14.00	7.79	62.500	26.500	82.500	2.100	125.000	83.000	234.000	32.500	-0	648.320
W	DV104	62579	13.00	8.13	74.000	31.000	112.000	2.400	155.000	94.000	310.000	35.000	-0	813.710
W	DV105	62579	28.00	8.57	39.500	22.000	102.000	4.900	144.000	84.000	135.000	37.500	12.300	581.460
W	DV106	62579	26.80	8.32	42.000	26.500	118.000	3.300	148.000	88.000	207.000	35.000	3.900	672.000
W	DV107	62579	15.50	7.55	65.000	36.500	130.000	3.000	171.000	117.000	294.000	32.000	-0	848.860
W	DV108	62579	16.50	7.62	70.500	39.800	140.000	3.200	185.000	125.000	320.000	32.500	-0	916.400
W	DV109	62579	22.50	8.35	65.000	46.500	182.000	9.200	245.000	180.000	267.000	30.800	6.700	1032.820
W	DV110	62579	15.50	7.87	60.000	34.500	68.000	2.900	126.000	122.000	173.000	17.500	-0	604.430
W	DV111	62579	14.00	7.79	100.000	41.300	97.500	3.100	162.000	184.000	278.000	21.300	-0	888.570
C	CS01	72379	15.00	7.93	60.200	33.200	108.000	3.010	161.000	120.000	218.000	21.000	-0	724.410
C	CS02	72379	16.00	7.60	59.900	34.900	110.000	2.540	145.000	118.000	266.000	16.000	-0	752.340
C	CS04	72379	16.00	7.58	97.600	35.100	48.000	3.560	188.000	115.000	134.000	43.000	-0	664.460
C	CS06	72379	21.00	7.63	483.000	36.500	108.000	2.440	136.000	1134.000	278.000	32.000	-0	2218.485
C	CS07	72379	22.00	7.93	267.000	32.300	266.000	6.550	375.000	15.100	199.000	29.000	-0	1197.317
C	CS08	72379	24.00	8.73	135.000	31.800	266.000	1.880	318.000	342.000	318.000	29.000	-0	1445.505
B	DV041	51579	28.00	9.59	13.700	2.100	1150.000	16.900	360.000	450.000	1194.000	42.000	433.000	3661.700
B	DV042	51579	15.00	9.87	1.000	.600	352.000	3.200	120.000	112.000	321.000	61.000	132.000	1102.800
E	LL102	92878	10.00	7.60	14.200	2.300	18.000	1.000	10.500	12.000	69.700	25.600	-0	154.010
E	DV03	32079	11.00	7.70	37.500	4.500	154.000	8.600	134.000	98.800	194.000	35.000	-0	667.000
E	DV10	32079	15.00	7.33	165.000	66.000	55.500	2.200	64.000	472.000	277.000	15.300	-0	1121.805
E	DV12	32079	11.00	7.27	54.500	14.000	37.000	1.400	26.000	64.000	214.000	23.500	-0	435.755
E	DV060	62579	9.00	7.85	14.500	2.720	21.000	1.500	14.500	17.200	68.900	27.500	-0	168.180
E	DV061	62579	10.00	8.33	42.300	7.600	43.500	1.200	28.000	73.600	145.000	22.500	-0	363.990
E	DV062	62579	23.00	7.92	34.000	7.100	41.600	1.700	25.000	59.000	135.000	26.300	-0	330.000
E	DV063	62579	18.00	7.40	19.000	6.700	25.000	2.900	21.000	21.200	101.000	35.500	-0	232.905
E	DV091	091279	32.	8.58	3.700	.060	105.000	1.000	41.000	70.000	126.800	35.000	9.800	395.960
L	LL103	92878	19.00	7.70	20.900	2.070	62.800	3.900	25.800	78.800	99.000	64.000	-0	358.780
L	LL104	92878	16.00	7.90	28.300	2.200	56.000	4.300	25.000	78.000	111.000	64.800	-0	370.840

Table 5-1. Chemical Analyses of Dixie Valley Waters. (cont'd.)

		DATE	TEMP	PH	CA	MG	NA	K	CL	SO4	HCO3	SIO2	CO3	TDS
M	DV05	32079	39.00	7.10	39.000	13.700	144.000	12.000	27.000	65.600	454.000	39.000	-0	799.385
M	DV06	32079	29.00	6.95	68.000	19.100	164.000	12.300	28.000	124.000	554.000	44.000	-0	1019.315
M	DV11	32079	43.00	6.90	95.000	37.500	213.000	10.300	275.000	209.000	310.000	36.800	.100	1191.515
M	DV115	62579	50.00	7.31	94.000	36.500	218.000	10.000	286.000	216.000	312.000	32.500	-0	1206.370
M	DV116	62579	40.00	6.89	67.000	18.500	240.000	23.800	39.000	88.000	803.000	26.300	-0	1312.200
1	DV069	070979	68.5	9.5	20.500	.050	685.000	65.000	815.000	512.000	32.400	6.500	18.700	2163.205
1	DV70	070979	75.5	8.9	12.500	.010	605.000	53.000	740.000	352.000	5.100	31.000	52.200	1870.145
1	DV72	070979	76.5	9.1	22.500	.010	618.000	65.000	700.000	352.000	6.100	300.000	117.000	2201.726
2	DV080	81479	114.0	8.00	35.750	3.550	1288.000	31.000	1208.000	130.000	1410.000	-0	-0	4118.590
2	DV081	81479	51.00	-0	42.500	4.300	1238.000	27.000	-0	-0	-0	210.000	-0	1523.070
2	DV082	81479	86.00	7.90	27.000	3.900	1275.000	30.000	1150.000	127.500	1391.000	232.000	-0	4248.290
3	DV090	091279	94.	6.8	24.100	.015	410.000	40.000	493.000	215.000	130.500	325.000	-0	1657.545
4	DV093	091379	83.	8.	24.000	4.030	1730.000	44.000	1720.000	396.000	1283.000	189.000	-0	5410.600
4	DV094	091379	95.	8.5	23.600	9.900	2010.000	37.000	2315.000	280.000	1197.000	160.000	-0	6041.300
T	DV15	042679	71.	7.63	156.000	30.000	400.000	30.000	535.000	448.000	200.000	98.000	-0	1905.930
T	DV16		71.	7.42	145.000	28.800	398.000	18.000	550.000	445.000	203.000	100.000	-0	1898.660
T	DV030	51579	64.50	6.89	145.000	26.000	405.000	18.600	575.000	410.000	211.000	105.000	-0	1909.045

Table 5-1. Chemical Analyses of Dixie Valley Waters. (cont'd.)

		F	B	AL	FE	MN	LI	SR	NO3	AS	HG	CS
L	LL105	-0	-0	-0	-0	-0	-0	-0	1.200	-0	-0	-0
L	LL107	8.600	-0	-0	-0	-0	-0	-0	.310	-0	-0	-0
L	LL108	.750	-0	-0	-0	-0	-0	-0	4.380	-0	-0	-0
L	LL110	-0	-0	-0	-0	-0	-0	-0	2.260	-0	-0	-0
L	LL111	-0	-0	-0	-0	-0	-0	-0	.090	-0	-0	-0
A	LL106	-0	-0	-0	-0	-0	-0	-0	.220	-0	-0	-0
A	DV13	6.000	.310	.100	.010	.015	.050	.110	-0	-0	-0	-0
A	DV043	6.400	.320	.100	.010	.005	.052	.130	-0	-0	-0	-0
A	DV065	6.500	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
A	DV066	5.800	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
I	DV034	.490	1.000	.100	.020	.017	.260	1.730	-0	.010	-0	-0
I	DV037	.700	1.100	.100	.040	.021	.420	2.800	-0	.010	.006	.050
I	DV038	1.000	1.300	.100	.010	.008	.357	1.870	-0	-0	-0	-0
I	DV039	1.300	1.000	.100	.010	.005	.259	1.280	-0	-0	-0	-0
I	DV040	.800	.900	.100	.010	.016	.350	2.400	-0	.010	-0	.050
I	DV100	1.150	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
I	DV101	.900	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
I	DV113	.740	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
I	DV114	.450	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
P	DV20	.330	-0	-0	-0	-0	-0	-0	-0	-0	-0	.050
D	LL098	-0	-0	-0	-0	-0	-0	-0	1.150	-0	-0	-0
D	LL099	8.400	-0	-0	-0	-0	-0	-0	.090	-0	-0	-0
D	LL100	-0	-0	-0	-0	-0	-0	-0	.090	-0	-0	-0
D	LL101	-0	-0	-0	-0	-0	-0	-0	.400	-0	-0	-0
D	DV23	12.600	.860	.100	.030	.015	.380	.020	-0	.010	.000	.100
D	DV24	7.700	.900	.100	.010	.012	.550	4.350	-0	.010	.000	.170
D	DV054	13.000	.980	.100	.010	.005	.382	.020	0	.010	.000	-0
D	DH16	5.300	1.600	.100	.010	.005	.315	.380	0	.010	.000	-0
D	DH15	12.500	1.000	.100	.010	.005	.425	.030	0	.010	.000	-0
D	DH09	9.700	1.700	.100	.010	.008	.580	.950	0	.010	.000	-0
D	DH06	11.200	1.800	.100	.010	.005	.470	.050	0	.010	.000	-0
D	DH08	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
D	DH10	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
H	DV04	7.600	4.000	.100	.020	.022	1.600	1.200	-0	.030	.000	.280
H	DV033	7.500	4.200	.100	.040	.007	1.680	1.260	-0	.030	.000	.260
H	HHS01	8.100	4.900	.100	.020	.028	1.590	1.070	0	.020	.005	-0
H	HHS03	8.200	6.100	.100	.070	.033	1.610	1.150	0	.010	.003	-0
H	HHS05	8.100	5.000	.100	.010	.040	1.590	1.090	0	.010	.004	-0
H	HHS06	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
H	HHS12	8.200	4.900	.100	.010	.026	1.560	1.100	0	.010	.000	-0
H	HHS09	8.200	5.100	.100	.010	.021	1.630	1.060	0	.020	.000	-0
S	DV01	5.100	1.360	.100	.010	.054	.650	10.800	-0	.010	.000	.120
S	DV02	5.000	1.370	.100	.050	.045	.650	11.100	-0	-0	-0	-0
S	DV035	5.100	1.200	.100	.040	.009	.710	6.200	-0	.010	.000	.110
S	DV036	4.900	1.300	.100	.410	.006	.680	10.500	-0	-0	-0	-0
S	DV075	5.300	2.000	.100	.380	.063	.670	11.400	0	.010	.000	-0
S	DV076	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
S	DV077	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
S	DV112	4.900	-0	-0	-0	-0	-0	-0	0	-0	-0	-0

Table 5-1. Chemical Analyses of Dixie Valley Waters (cont'd)

		DATE	TEMP	PH	CA	MG	NA	K	CL	SO4	HCO3	SIO2	CO3	TDS
L	LL105	92878	20.00	8.20	13.100	.300	65.000	2.900	19.500	60.000	106.000	73.900	-0	341.900
L	LL107	92878	17.00	8.40	7.000	.200	67.000	1.900	17.500	50.200	80.500	70.800	7.100	311.110
L	LL108	92878	16.00	7.60	37.800	3.720	43.000	4.300	29.500	55.000	124.000	62.400	-0	364.850
L	LL110	92878	24.00	7.20	18.300	2.060	69.000	3.200	26.000	88.000	93.000	58.900	-0	360.720
L	LL111	92878	14.00	7.20	45.800	7.300	38.800	1.300	32.800	38.700	180.000	28.600	-0	373.390
A	LL106	92878	19.00	8.10	22.500	1.130	65.700	4.800	23.500	80.000	111.000	74.300	-0	383.150
A	DV13	32079	19.00	8.30	18.800	.950	68.000	4.500	23.000	72.800	98.000	74.500	-0	367.145
A	DV043	51579	18.30	8.26	18.000	.900	67.000	3.900	27.000	72.400	103.000	69.000	-0	368.217
A	DV065	62579	20.00	8.35	17.500	.900	68.000	4.100	23.000	72.000	101.000	70.000	-0	363.000
A	DV066	62579	20.00	8.18	19.000	1.150	65.000	3.700	23.500	69.000	104.000	62.500	-0	353.650
I	DV034	51579	19.50	7.44	182.000	60.500	206.000	8.850	515.000	194.000	265.000	52.000	-0	1486.967
I	DV037	51579	16.00	7.13	359.000	112.000	252.000	16.100	905.000	366.000	321.000	47.000	-0	2383.281
I	DV038	51579	18.50	7.25	147.500	44.500	191.000	13.800	330.000	234.000	361.000	63.000	-0	1389.445
I	DV039	51579	22.50	7.83	64.000	25.500	159.000	19.300	125.000	134.000	399.000	77.000	-0	1006.754
I	DV040	51579	15.50	7.50	305.000	99.000	195.000	14.900	715.000	332.000	297.000	49.500	-0	2011.976
I	DV100	62579	19.00	7.55	55.000	24.800	158.000	16.000	166.000	138.000	291.000	65.000	-0	914.950
I	DV101	62579	20.00	7.60	57.000	22.000	108.000	14.000	122.000	128.000	242.000	70.800	-0	764.700
I	DV113	62579	24.50	7.52	95.000	34.000	120.000	17.900	196.000	166.000	255.000	85.000	-0	969.640
I	DV114	62579	22.50	7.52	112.000	41.300	128.000	14.600	262.000	161.000	262.000	80.000	-0	1061.350
P	DV20	32079	21.00	7.60	50.000	19.700	102.000	6.800	134.000	78.800	200.000	40.800	-0	632.430
D	LL098	92878	53.50	7.80	77.200	.800	446.000	10.500	675.000	164.000	64.900	74.000	-0	1513.550
D	LL099	92878	73.50	8.70	3.900	.200	180.000	5.600	125.000	116.000	54.600	122.000	28.300	644.090
D	LL100	92878	70.00	8.40	7.600	.200	195.000	5.200	156.000	129.000	87.400	117.000	9.470	706.960
D	LL101	92878	25.00	7.40	51.800	2.900	232.000	2.600	250.000	160.000	163.000	52.700	-0	915.400
D	DV23	32079	73.00	8.65	4.300	.200	181.000	6.000	133.000	108.000	56.000	123.000	28.000	653.505
D	DV24	32079	55.00	7.80	67.500	.800	430.000	10.200	650.000	161.000	62.000	75.000	-0	1470.122
D	DV054	62579	73.00	8.77	4.000	.200	175.000	5.500	130.000	112.000	46.500	118.800	31.100	637.597
D	DH16	72379	26.00	7.65	55.000	2.950	228.000	2.270	250.000	150.000	166.000	44.000	-0	905.930
D	DH15	72379	52.00	8.25	9.600	.050	210.000	4.330	208.000	102.000	76.600	112.000	7.200	743.850
D	DH09	72379	73.00	7.80	31.000	.210	311.000	8.720	362.000	220.000	75.100	85.000	-0	1106.078
D	DH06	72379	73.00	8.20	11.500	.120	216.000	5.420	160.000	202.000	76.600	109.000	9.600	803.875
D	DH08	72379	57.00	-0	-0	-0	-0	-0	-0	-0	-0	102.000	-0	102.000
D	DH10	72379	76.00	-0	-0	-0	-0	-0	-0	-0	-0	66.000	-0	66.000
H	DV04	32079	63.00	6.61	46.500	10.300	362.000	22.000	49.000	122.000	936.000	68.500	-0	1630.842
H	DV033	51579	65.50	6.45	49.000	10.800	342.000	21.200	47.000	116.000	919.000	67.000	-0	1586.787
H	HHS01	72379	75.00	7.30	44.000	10.100	324.000	20.600	50.000	108.000	880.000	66.000	-0	1518.508
H	HHS03	72379	67.00	6.50	47.000	10.000	335.000	21.300	47.000	112.000	911.000	69.000	-0	1569.563
H	HHS05	72379	72.00	7.22	43.000	10.000	334.000	20.200	47.500	111.000	869.000	69.000	-0	1519.630
H	HHS06	72379	39.00	-0	-0	-0	-0	-0	-0	-0	-0	83.000	-0	83.000
H	HHS12	72379	63.00	6.90	47.000	9.900	322.000	20.400	50.000	110.000	884.000	66.000	-0	1525.196
H	HHS09	72379	58.00	7.50	38.000	10.200	334.000	21.000	47.000	113.000	897.000	67.000	-0	1543.321
S	DV01	32079	55.00	7.30	110.000	20.400	160.000	28.000	77.000	370.000	303.000	66.800	-0	1153.274
S	DV02	32079	51.00	7.39	103.000	21.200	163.000	28.000	77.000	370.000	292.000	71.000	-0	1143.515
S	DV035	51579	53.50	7.80	112.000	22.000	162.000	26.200	88.000	374.000	301.000	63.800	-0	1162.359
S	DV036	51579	73.00	6.50	105.000	21.500	155.000	26.000	78.000	366.000	321.000	-0	-0	1090.396
S	DV075	72379	73.00	6.05	105.000	20.800	150.000	22.000	76.000	348.000	309.000	53.000	-0	1103.713
S	DV076	72379	55.00	-0	-0	-0	-0	-0	-0	-0	-0	58.000	-0	58.000
S	DV077	72379	30.00	-0	-0	-0	-0	-0	-0	-0	-0	54.000	-0	54.000
S	DV112	62579	73.50	6.80	105.000	20.500	162.000	28.000	78.000	352.000	313.000	60.000	-0	1123.400

Table 5-1. Chemical Analyses of Dixie Valley Waters. (cont'd.)

		F	B	AL	FE	MN	LI	SR	NO3	AS	HG	CS
W	LL097	-0	-0	-0	-0	-0	-0	-0	.090	-0	-0	-0
W	LL109	-0	-0	-0	-0	-0	-0	-0	.090	-0	-0	-0
W	DV21	.800	.810	.100	.080	.017	.050	.860	-0	-0	-0	-0
W	DV22	.370	.550	.100	.010	.015	.020	.780	-0	.010	.000	.050
W	DV031	.390	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
W	DV032	.320	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
W	DV045	.300	-0	-0	-0	-0	-0	-0	-0	-0	-0	.050
W	DV046	.290	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
W	DV047	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
W	DV048	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
W	DV049	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
W	DV050	.310	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
W	DV051	.340	-0	-0	-0	-0	-0	-0	-0	-0	-0	.050
W	DV052	.490	-0	-0	-0	-0	-0	-0	-0	-0	-0	.050
W	DV053	.460	.550	.100	.010	.005	.039	1.210	0	.010	.000	-0
W	DV055	.380	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV56	.380	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV057	.370	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV058	.320	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV059	.340	-0	-0	-0	-0	-0	.350	0	-0	-0	-0
W	DV067	1.330	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV078	.570	.950	.100	.010	.005	.090	1.760	0	.010	.000	-0
W	DV092	.300	1.100	.100	.010	.005	.030	.650	-0	.010	-0	.020
W	DV102	.330	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV103	.220	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV104	.310	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV105	.260	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV106	.300	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV107	.360	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV108	.400	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV109	.620	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV110	.530	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
W	DV111	1.370	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
C	CS01	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
C	CS02	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
C	CS04	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
C	CS06	2.500	1.000	.100	.010	.290	.045	4.600	0	.010	.000	-0
C	CS07	1.900	1.900	.100	.010	.032	.075	3.350	0	.010	.000	-0
C	CS08	.330	1.700	.100	.010	.005	.050	1.630	0	.010	.000	0
B	DV041	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
B	DV042	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
E	LL102	-0	-0	-0	-0	-0	-0	-0	.710	-0	-0	-0
E	DV03	.600	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0
E	DV10	.160	.240	.100	.020	.015	.020	4.250	-0	-0	-0	-0
E	DV12	.300	.230	.100	.010	.015	.010	.690	-0	-0	-0	-0
E	DV060	.360	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
E	DV061	.290	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
E	DV062	.300	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
F	DV063	.180	.220	.100	.010	.005	.010	.080	0	.010	.000	-0
E	DV091	.560	1.200	.100	1.610	.050	.050	.030	-0	.010	-0	.020
L	LL103	-0	-0	-0	-0	-0	-0	-0	1.510	-0	-0	-0
L	LL104	-0	-0	-0	-0	-0	-0	-0	1.240	-0	-0	-0

Table 5-1. Chemical Analyses of Dixie Valley Waters. (cont'd.)

	F	B	AL	FE	MN	LI	SR	NO3	AS	HG	CS
M DV05	3.100	.900	.100	.010	.015	.270	.690	-0	-0	-0	-0
M DV06	2.800	1.260	.100	.010	.015	.350	1.380	-0	-0	-0	-0
M DV11	1.300	.800	.100	.010	.005	.150	2.450	-0	-0	-0	-0
M DV115	1.370	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
M DV116	6.600	-0	-0	-0	-0	-0	-0	0	-0	-0	-0
1 DV069	1.550	5.200	-0	.030	.005	1.060	.160	-0	-0	-0	.130
1 DV70	8.500	9.200	-0	.100	.005	1.290	.190	-0	-0	-0	.290
1 DV72	9.500	9.600	-0	.100	.006	1.540	.320	-0	-0	-0	-0
2 DV080	-0	11.000	-0	-0	-0	1.290	-0	0	1.400	-0	.210
2 DV081	-0	-0	-0	-0	-0	1.270	-0	0	2.100	-0	.280
2 DV082	-0	10.600	-0	-0	-0	1.290	-0	0	1.800	-0	.200
3 DV090	7.600	8.500	.100	1.610	.050	1.010	1.060	-0	.590	-0	.325
4 DV093	7.900	12.700	-0	-0	-0	-0	-0	-0	.160	-0	-0
4 DV094	8.800	-0	-0	-0	-0	-0	-0	-0	.160	-0	-0
T DV15	4.390	-0	-0	-0	-0	.970	3.440	-0	-0	-0	-0
T DV16	4.400	5.500	-0	-0	-0	.960	-0	-0	-0	-0	-0
T DV030	4.400	4.700	.100	.040	.030	.975	3.200	-0	.040	.000	.140

All concentrations are in parts per million (ppm) and temperatures are in °C.

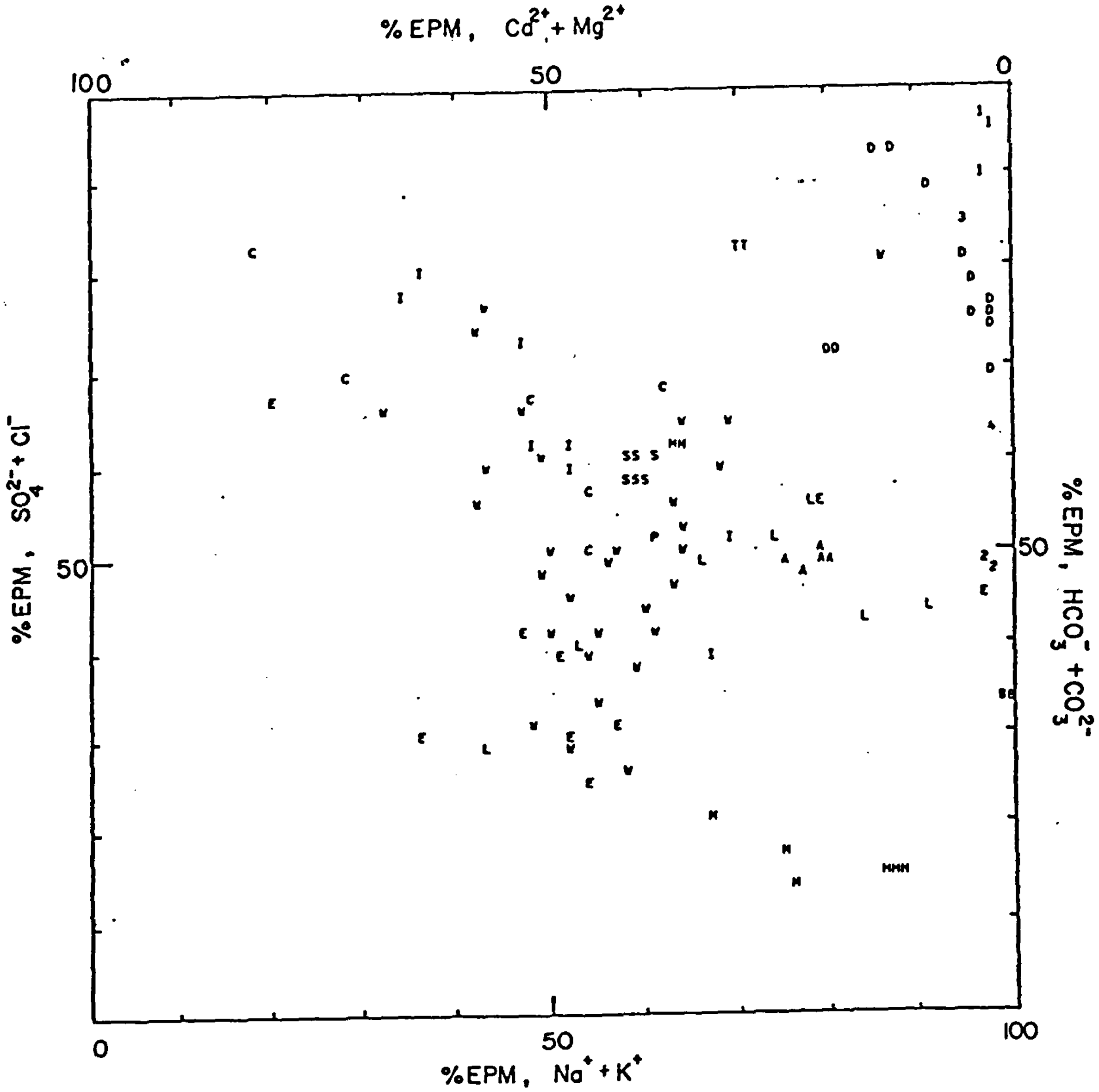

Figure 5-1. Trilinear Plot of Dixie Valley Waters. (See legend opposite Table 5-1 for letter and number code.)

All samples have comparatively low Ca and Mg levels. The hot spring systems, as well as the deep wells, seem to experience a substantial shift towards increased Na + K levels. The anions seem to indicate more clearly the differences among the three hot spring systems.

If one considers total dissolved solids (TDS), the variations in water chemistry become more apparent (Table 5-2).

Table 5-2 clearly illustrates the variations both within a given hot spring system and among the three hot spring systems. The Dixie Hot Springs system has the greatest TDS range, possessing both the lowest and highest levels. Sou and Hyder Hot Springs have very narrow TDS ranges, with Sou Hot Springs having the lower values of the two systems.

The artesian wells in the vicinity of Dixie Settlement have low values, similar to the surface water and spring water derived from the Clan Alpine Mountains. The hydrogeochemical evidence would tend to indicate that the Clan Alpine Mountains are a source of recharge for groundwater in the Dixie Settlement area. This situation is more likely than specifying the Stillwater Range waters as a source of groundwater recharge. These latter waters have high TDS levels for mountain spring water and surface runoff. These high TDS values definitely anomalous for "normal" mountain runoff will be discussed further in a later section.

5.2.2 Waters from the Clan Alpine Mountains

Most of the waters from the Clan Alpine Mountains are chemically similar to the waters from the wells at Dixie Settlement. Both groups of waters are low in TDS, but the Dixie Settlement waters exhibit relatively high temperatures for groundwater. Two Dixie Settlement samples, DV 13 and DV 66, have unusually high pH values (8.30 and 8.18) and fluoride levels (6.00 and 5.80 ppm). One anomaly in the Clan Alpine Mountains is Shoshone Spring (DV 91), which has a surprisingly low dissolved oxygen content for a mountain spring, a high pH (8.58) and temperature (32°C). The boron level in this spring, 1.2 ppm, is a significant amount.

Table 5-2. Total Dissolved Solids (TDS) Contents of Dixie Valley Waters.

Sample Location	TDS (ppm)
Dixie Hot Springs	640-3000
Sou Hot Springs	1100-1160
Hyder Hot Springs	1580-1630
McCoy and Lower Ranch Hot Springs	800-1190
Eastern Mountain Ranges (Clan Alpine and Augusta Mountains)	170-435
Stillwater Range	600-1770
Artesian Wells in Southern Dixie Valley (Dixie Settlement)	350-370
Irrigation Wells in Northern Dixie Valley	760-2380
DF 45-14	1657-2201
DF 66-21	4100-5410
SR2-A	1900

Another important aspect is that the calculated CO_2 pressures are oversaturated with respect to atmospheric CO_2 pressure in many Clan Alpine Mountain waters (Table 5-3). These elevated CO_2 pressures are caused by various dissolution reactions occurring in the subsurface, and the CO_2 pressures are indicators of the extents of these various reactions. At the present time the sources of CO_2 in geothermal systems are poorly understood.

5.2.3 Waters from the Stillwater Range

Even in the early stages of field work it was recognized that the waters from the eastern slopes of the Stillwater Range, which is considered one of the major recharge areas for the study area, are surprisingly high in TDS. One normally expects low TDS waters in a recharge area. Springs on the Carson Sink (west) side of the Stillwater Range also exhibited high TDS levels. Although some thermal springs are believed to exist in the mountains, none was found. All sampled springs have low discharges and most streams deposit travertine ($CaCO_3$). All computed CO_2 pressures are greater than atmospheric CO_2 (see Table 5-3). This tends to imply the existence of a source of CO_2 other than the atmosphere.

Samples from the eastern slopes have Cl levels as high as 260 ppm, SO_4 as high as 520 ppm, HCO_3 up to 380 ppm, SiO_2 up to 46 ppm, Mg up to 80 ppm, Na + K up to 190 ppm and Ca as high as 180 ppm. These waters apparently comprise most of the shallow groundwater north of Dixie Hot Springs. The ratios Cl/SO_4, $(Na+K)/SO_4$, Ca/SO_4 and Mg/SO_4 are relatively constant in these samples. The constancy of these ratios is apparently characteristic of volcanic rock weathering, since volcanic rocks are abundant in the Stillwater Range.

The question remains as to why the Stillwater Range waters have such high levels of TDS, a phenomenon which is usually not anticipated from waters derived from precipitation. One reason could be that these waters have a relatively long residence time in the subsurface, a hypothesis weakly supported by the few available tritium data. However, the waters from the Clan Alpine Mountains are from a similar rock environment, but have much lower TDS levels.

A second explanation might be the rapid dissolution of hydrothermal minerals, by either old or young waters. Another possibility that could also explain the high calculated CO_2 pressures (Table 5-3)

Table 5-3. Calculated log P_{CO_2} Values in Dixie Valley Waters.

Sample Locations	log P_{CO_2}
Stillwater Range	-3.4 to -1.5
Clan Alpine Mountains	-3.5 to -2.0
Artesian Wells (Dixie Settlement)	-3.5 to -3.7
Irrigation Wells	-2.5 to -1.8
Dixie Hot Springs	-4.0 to -2.6
Hyder Hot Springs	-1.4 to 0.0
Sou Hot Springs	-2.3 to 0.0
DF 45-14	-1.2
DF 66-21	-1.5
SR2-A	-2.2 to -2.0

is the ascension of thermal waters along deep reaching fault zones. These ascending thermal waters would then be slightly diluted by infiltrated precipitation, and the mixture would surface at springs.

Further work in the Stillwater Range itself will be required to verify the origin of the high TDS waters. It is possible that the isotope data will shed some light on this problem.

5.2.4 Thermal Waters in Dixie Valley

Thermal groundwaters commonly have chemical constituents that can serve as specific indicators of geothermal reservoirs. Elevated levels of F, Cl, B, SiO_2, H_2S, Na and TDS can indicate geothermal activity. SO_4 can be high if sufficient sulfide and free oxygen are available at depth. HCO_3 is commonly high in thermal waters if an appropriate source of CO_2 exists at depth. However, it should be emphasized that F, B and other trace elements are low if the reservoir rocks lack these constituents. Ca and Mg levels are usually low in thermal waters due to cation exchange with clay minerals and other similar reactions.

In the following discussion the aforementioned indicators are utilized to determine relative circulation depths of waters and reservoir temperatures.

5.2.4.1 Dixie Hot Springs

The Dixie Hot Springs system is comprised of about 35 springs and seeps. The springs show wide variations in temperature and electrical conductivity. All springs emerge from alluvium, which is about 1000 feet thick in this area. Springs and seeps discharge over an area of about four square miles.

The Dixie Hot Springs system is typical for its relatively low HCO_3 (60-90 ppm). The pH ranges between 7.4 and 8.77, which is considered rather high. Electrical conductivities change significantly between adjacent spring orifices. Temperatures are generally highest for the lowest TDS springs (Figure 5-2). Cl and Na are highest for the low temperature springs. SO_4 and Cl correlate very well, and reach their highest levels in the coldest springs. SiO_2 decreases with increasing Ca, which indicates an increasing influx of cold

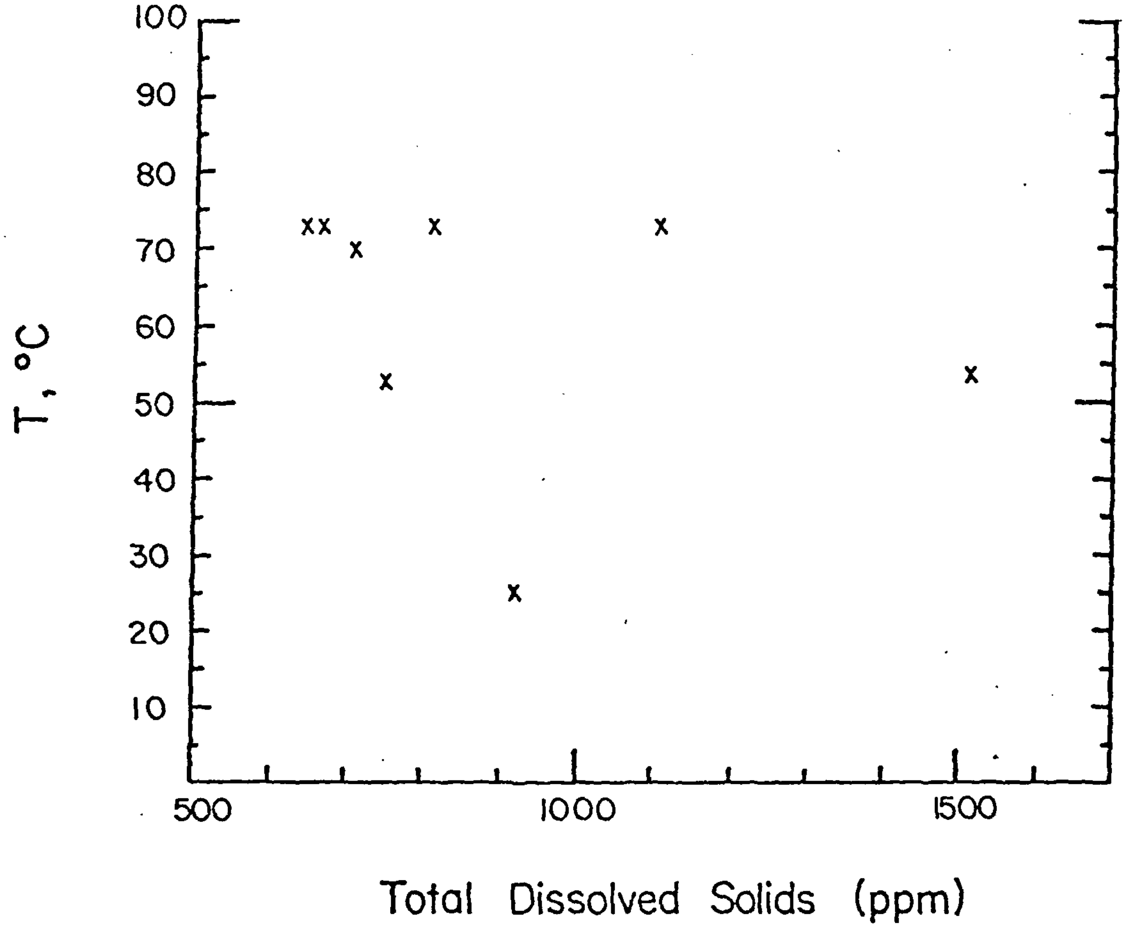

Figure 5-2. Temperature versus Total Dissolved Solids (TDS) for Dixie Hot Springs Waters.

water into the system. High Cl and Na levels indicate dissolution of shallow evaporites by cold water. F levels are the highest in the valley, whereas B, Li, As and Cs have comparatively low concentrations.

Table 5-4 shows estimated reservoir temperatures, calculated using chemical geothermometry. Conductive cooling was assumed for the silica method. Different temperatures between the two methods suggest that chemical equilibrium has not yet been attained.

The silica mixing model, based on a recharge water with 30 ppm SiO_2, yields completely different results. For DV 23 a temperature between 225 and 235^{o}C was computed. However, the mixing model is considered to be unreliable in this case, since the results are inconsistent.

In conclusion, the Dixie Hot Springs system probably shows various degrees of mixing between thermal and cold waters, which accounts for the varying temperatures and electrical conductivities. Based upon the structural analysis (Chapter 3), it is likely that the springs are fault-controlled. If fault control does exist then the colder waters with higher TDS could result from a less direct flow path that allows more cooling and more mixing within the alluvium which permits more dissolution of soluble salts. It is also possible that the low TDS waters are linked to the artesian wells of Dixie Settlement, since these are the only low TDS waters in the immediate vicinity. The increasing SO_4 with Cl (Figure 5-3) could also be attributed to cold waters from the Stillwater Range, since only there is the correlation between these ions good. Since the HCO_3 levels are low (less than 150 ppm), Dixie is probably not linked to any CO_2 source at depth. This accounts for the absence of any significant spring deposits. Low levels of most trace elements indicate that the Dixie Hot Springs system may be a relatively shallow system, whereas the high F could be due to the dissolution of ancient CaF_2 deposits. It is possible that the Dixie system is heated by a more extensive sealed geothermal reservoir at depth.

Table 5-4. Chemical Geothermometers Applied to Dixie Hot Springs Waters.

Sample No.	Quartz (°C)	Na-K-Ca (°C)	Field Temperature (°C)
DV23	149	139	73
DV54	147	137	73
DH6	142	97	73
DH15	143	95	52
DH9	128	100	73
DV24	122	88	55

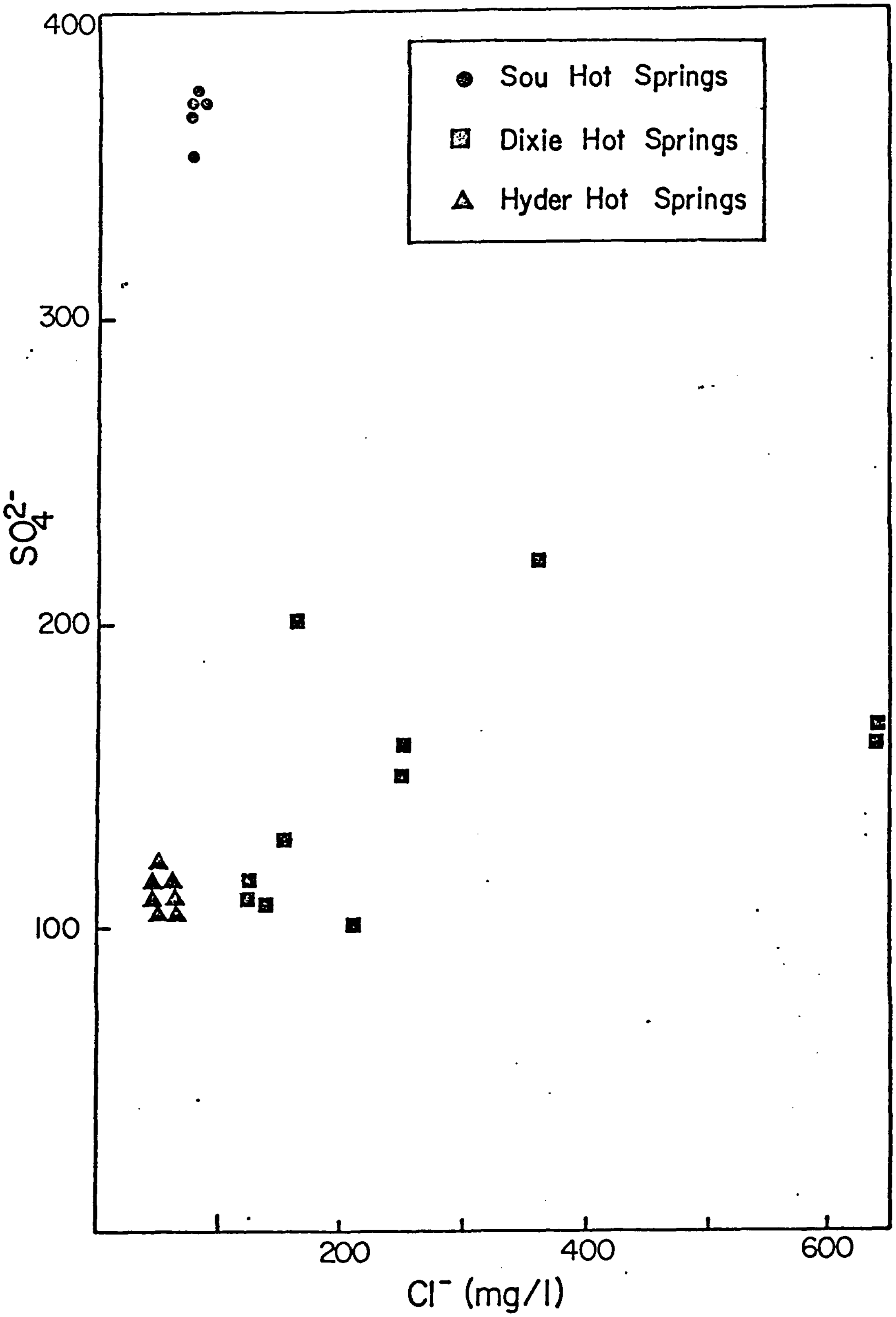

Figure 5-3. Sulfate versus Chloride for the Three Major Hot Spring Systems in Dixie Valley.

5.2.4.2 Hyder Hot Springs

The Hyder Hot Springs system emerges in the middle of the valley, where bedrock is apparently covered by a thick cover of alluvium. However, the chemical homogeneity of the springs seems to require a well-defined, fault-controlled flow system. The springs have deposited a vast amount of travertine up to 100 feet thick. Some of the springs are surrounded by delicate travertine structures.

A detailed survey of the system showed that all springs have electrical conductivities ranging from 1600 to 1850 micromhos (temperature compensated). Gross chemistry of the springs does not vary much, although temperatures differ considerably, ranging from 39°C to 75°C. Thus the system is probably relatively homogeneous, issuing from one reservoir.

Hyder waters are of the bicarbonate-sodium-potassium type. The bicarbonate levels range between 870 and 936 ppm and are the highest among all the hot springs. They are about six times as high as those from DF 45-14 but somewhat lower than those from DF 66-21. The high HCO_3 accounts for the extensive travertine deposits. The pH is as low as 6.5 in springs with high HCO_3 and as high as 7.5 in those with low HCO_3. Some evidence of degassing (probably CO_2) was found, which probably accounts for the inverse correlation of pH with HCO_3.

The SO_4 and Cl levels are among the lowest of the hot springs in the valley (108-116 ppm SO_4, and 47-50 ppm Cl). Sulfate is about as low as the first sample from DF 66-21. The relatively high bicarbonate concentrations indicate that Hyder is connected directly to a geothermal reservoir. In addition the low SO_4 indicates a relatively deep water with limited capability to oxidize sulfides (Figure 5-3). However, no evidence of H_2S was found in Hyder, and the dissolved oxygen content was as high as 2.9 ppm in some of the springs.

Since electrical conductivities and silica levels are relatively constant, the silica geothermometer, assuming conductive cooling and no mixing, was applied. Calculated temperatures range from 115°C to 127°C. The cation geothermometer yielded consistent temperatures between 159°C and 162°C. Slight calcite precipitation is possible for those springs with highest discharge temperature, but the increase in calculated temperature would be negligible in this case.

In conclusion, the Hyder Hot Springs system is of one water type and thus emerges from a well-defined flow system, with little mixing with shallow groundwater. The high HCO_3 values indicate connection to a CO_2 source at depth. However, the water chemistry is inconclusive; therefore the relationship of the spring water to the deep system is unknown.

5.2.4.3 Sou Hot Springs

Vast amounts of spring deposits are present at Sou Hot Springs. The chemistry of the hot springs do not vary considerably, and are of an intermediate type. The temperatures range between 30°C and 73°C. The pH is as low as 6.5; a pH of 6.05 was measured but it is believed to be too low due to a faulty meter. Among the three major hot spring systems, Sou has the highest Ca, Mg and SO_4 levels. Cl levels are comparatively low (less than 100 ppm) as are F and B (DV36 in Figure 5-4). Sr is the highest among all the hot springs. HCO_3 levels are lower (about 300 ppm) than they are at Hyder Hot Springs.

The silica geothermometer, assuming no mixing and conductive cooling, yields temperatures between 105°C and 118°C. The cation geothermometer yields temperatures between 93°C and 194°C. The drastic changes in the calculated reservoir temperatures are probably associated with seasonal fluctuations.

Evidence of extensive CO_2 degassing was found in a flowing well. This probably indicates that Sou Hot Springs is connected in some way to a CO_2-producing reservoir at depth.

In conclusion, Sou is probably a relatively shallow hot spring system. The low SiO_2 temperature, low F, B and Cl and high Ca and Mg are indicative of relatively shallow circulating meteoric water that is heated to low temperatures.

5.2.4.4 Well SR2-A

The measured temperature of the discharge water was 65°C (DV30).

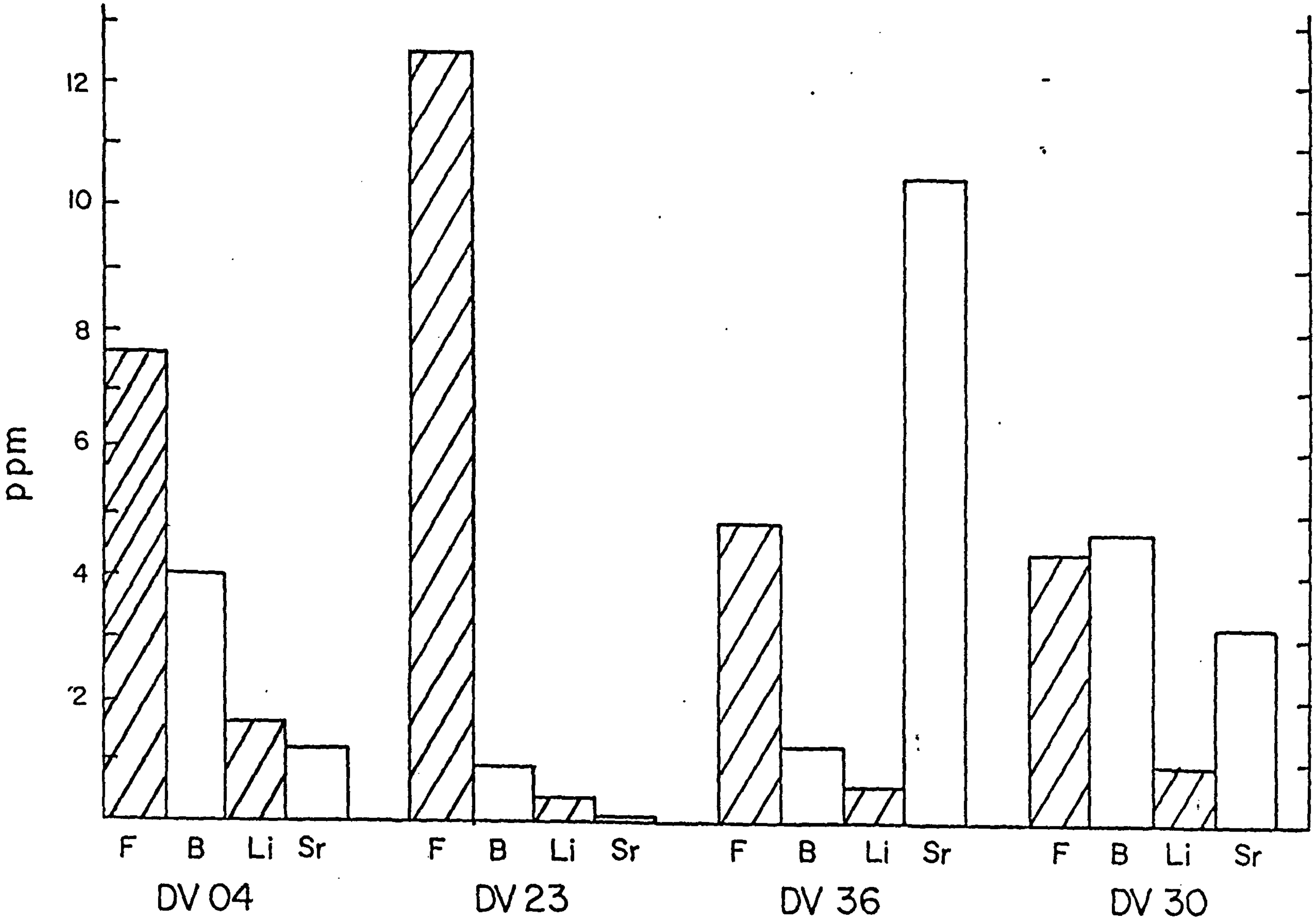

Figure 5-4. Fluoride, Boron, Lithium and Strontium in Selected Dixie Valley Waters.

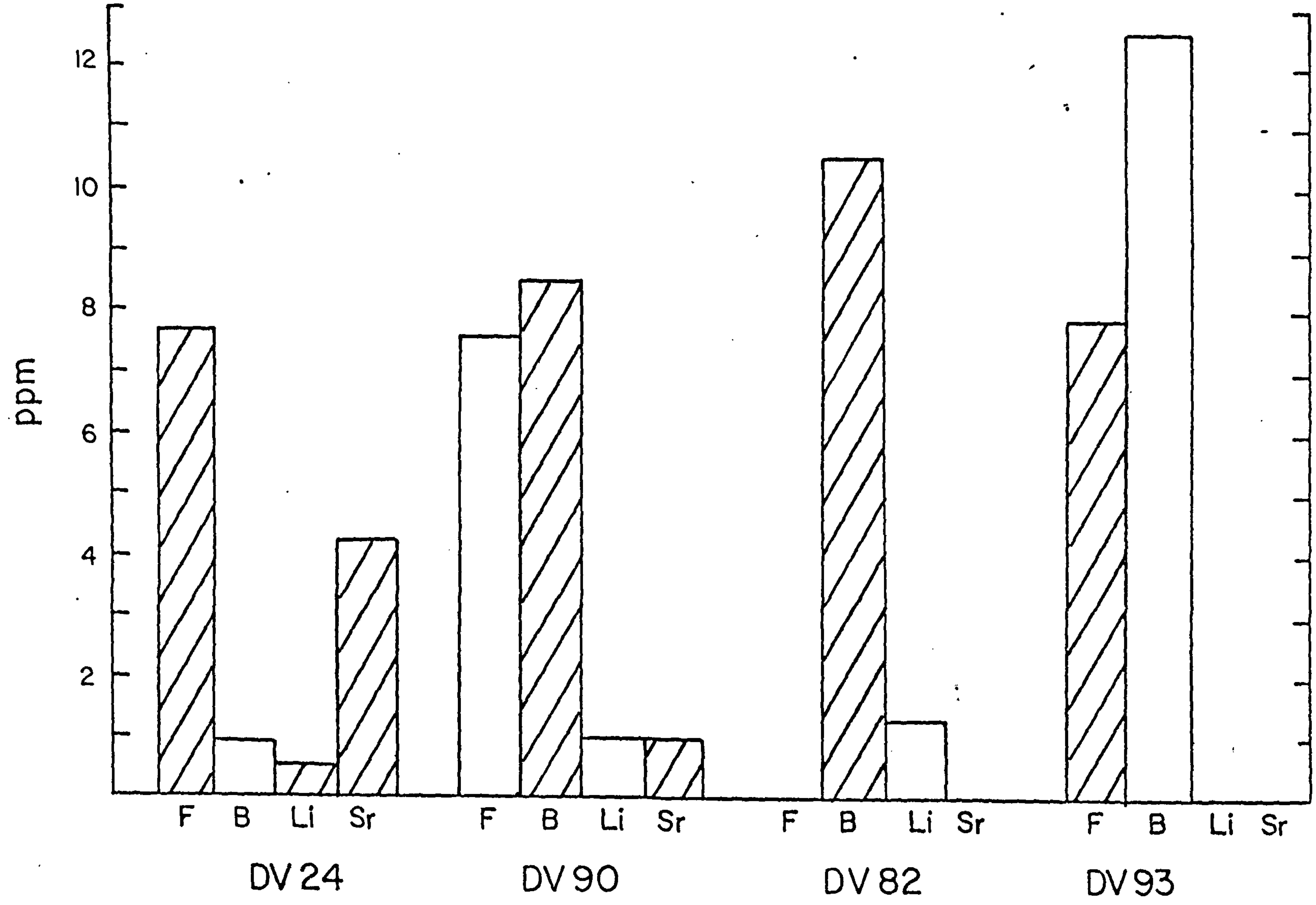

Figure 5-4 (con't.) Fluoride, Boron, Lithium and Strontium in Selected Dixie Valley Waters.

Ca and Mg levels are significant, indicating the influence of cold water. The Cl/SO_4 is very similar to that of the water from White Rock Canyon, indicating the influx of water from the Stillwater Range. F, B and Sr are also significant. Application of chemical geothermometers yields 91°C for the cation method and 139°C for the silica method. The different results indicate inadequate chemical equilibration of warm water at depth. However, the silica method seems to be more reliable. SR2-A is probably fed by a mixture of hot water from depth and cold recharge water from the Stillwater Range.

5.2.4.5 Deep Wells DF 45-14 and DF 66-21

A discussion of the water chemistry with special reference to the alteration mineralogy was given in Chapter 4. In this section the deep wells will be compared to the hot spring systems and the recharge waters. It must be indicated that more than 95% of our data is related to shallow groundwater systems and hot springs. The deep well samples are the only ones that represent deep thermal waters. However, the samples from DF 45-14 and DF 66-21 are not the most reliable because of suspected contamination from drilling operations and/or shallow groundwater. This is especially true of the samples from DF 66-21. Nevertheless, certain gross chemical features of the deep waters can be inferred from the existing samples.

DF 45-14 (DV90) has relatively low levels of Mg and Ca and high Cl and SO_4, which clearly indicate thermal waters. However, HCO_3 is low, much lower than in Sou Hot Springs. F is comparable to Hyder Hot Springs but much lower than in Dixie Hot Springs, whereas B is much higher than in any of the hot springs.

Application of the silica geothermometer (assuming no steam loss) indicates a reservoir temperature of 216°C for DF 45-14. Since the silica content at the sampling temperature is at the saturation level of amorphous silica, precipitation of amorphous silica might be expected in the ascending hot water. Thus, the silica temperature might be even higher. The cation geothermometer yields 193°C.

In DF 66-21 (DV82, DV93) the Cl and Na levels are about three times as high as in DF 45-14, although samples DV82 and DV93 are probably contaminated to a large extent. The SO_4 levels are comparable to the hot spring systems. HCO_3 levels are extremely high. B and F are comparable to those of DF 45-14. Generally the fluids from DF 66-21 can be considered as Na-Cl waters, high in HCO_3.

The silica geothermometer yields a temperature of 190°C (assuming no steam loss) and the cation geothermometer gives 139°C for DV82. For DV93 176°C was calculated with the silica method and 148°C with the cation method. The silica method is considered to be more reliable. DV82 is from a depth of about 4700 feet and DV93 from about 9500 feet in DF 66-21.

5.3 Conclusions

The preceding discussion about the chemistry of the three hot spring systems indicates that it is unlikely all three systems are linked to a common source. The Dixie Hot Springs system seems to be isolated from a deep CO_2-supplying reservoir, and its waters probably originate from the Stillwater Range and/or other sources. The Sou and Hyder systems are different from each other as well as from the Dixie system as was seen in Figure 5-1. The comparatively low Cl levels in all three systems make a connection to a deep geothermal reservoir that supplies the deep wells unlikely. High HCO_3 levels could be produced by the upward diffusion of CO_2 from a source at depth. The fact that the maximum temperatures in all three systems are about the same (75°C) is conspicuous. F increases with SiO_2 if F is greater than 1 ppm, a relationship that applies to all the hot springs but not to the deep wells (Figure 5-5).

It is clear that the two deep wells tap waters that are different from all the other thermal waters in the valley. Additionally, DF 45-14 is apparently different from DF 66-21. The most significant differences are the higher HCO_3 in DF 66-21 and a TDS level almost double that of DF 45-14. However, since samples from DF 66-21 are undoubtedly contaminated to an unknown extent, these differences may be more apparent than real.

The origin of HCO_3 is unclear. One source could be the oxidation of organic materials at depth, evidence of which was found in some of the sedimentary rocks at depth (T. Bard, personal communication). Another source could be the dissolution of limestones under

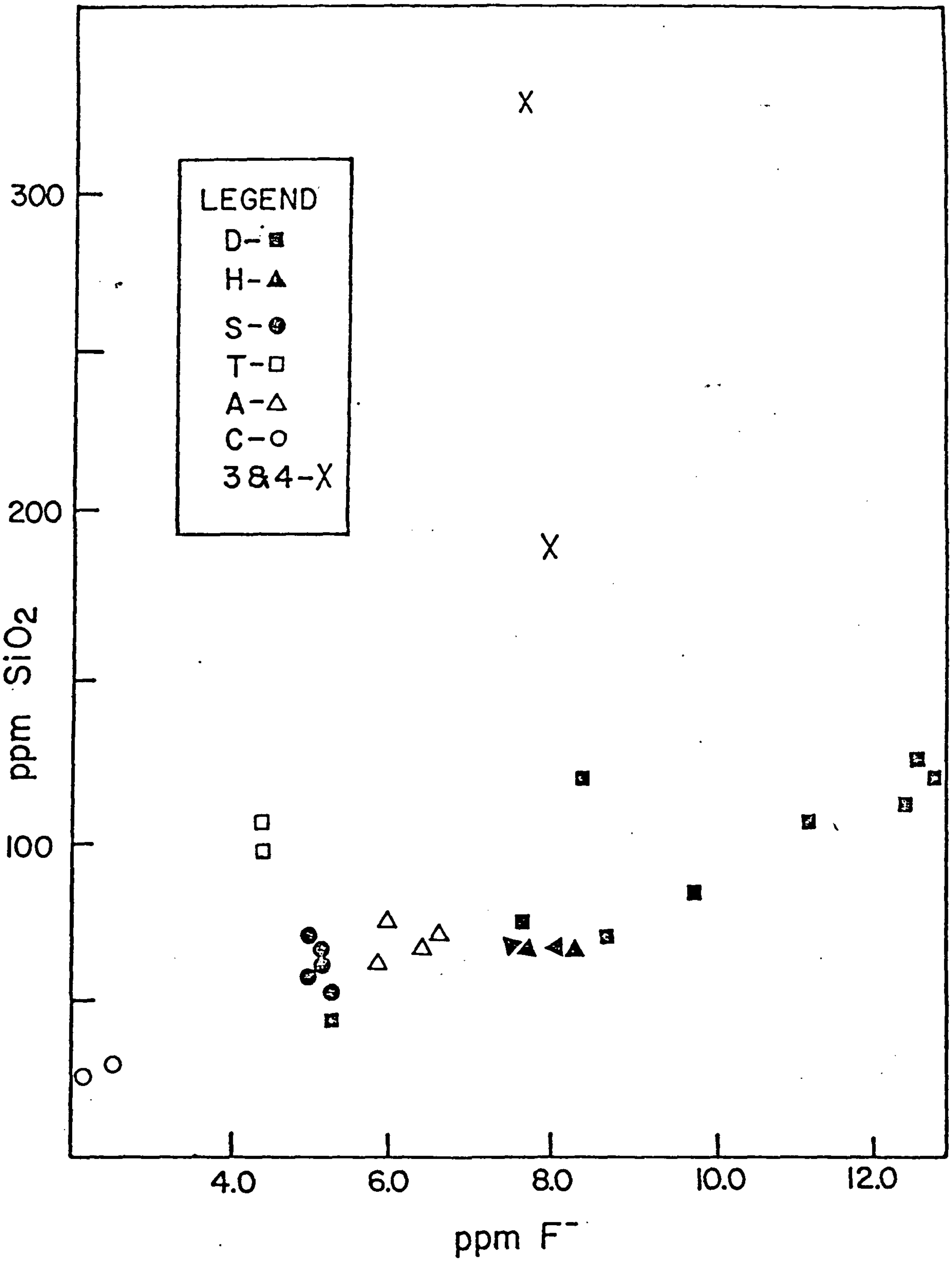

Figure 5-5. Silica versus Fluoride in Selected Dixie Valley Waters. (See legend opposite Table 5-1 for letter and number code.)

acidic conditions. Fracture zones could allow the CO_2 to escape to shallow aquifers, thus accounting for the high P_{CO_2} in most shallow groundwaters.

SO_4 probably originates from the oxidation of sulfides as well as the solution of SO_4 minerals. However, the level of SO_4 is probably limited at depth by the limited supply of free oxygen due to lack of deep-reaching circulation. This constraint might be active in both DF 45-14 and DF 66-21, thus accounting for the comparable levels of SO_4.

It is still not clear how the three hot springs are related to the deep reservoir(s) tapped by DF 45-14 and DF 66-21. The collection and analysis of valid samples from the deep wells might provide more information, as might the isotope data. Age determinations using ^{14}C would prove useful in determining circulation depths. Sulfur isotopes would be helpful in determining the sources of SO_4.

In summary, there appear to be different thermal systems in Dixie Valley. Their interrelationships are not clear, but it seems that there is little interaction among them other than occasional CO_2 transfer and conductive heat transfer.

5.4 References

Cohen, P., and Everett, D.E., 1963, A brief appraisal of the groundwater hydrology of the Dixie-Fairview Valley area, Nevada: Dept. of Conservation and Natural Resources, Ground-Water Resources Reconnaissance Series, Report 23, 40 p.

GeothermEx, Inc., 1976, Geothermal potential of the Quest Leasehold, Dixie Valley, Nevada: Rept. prepared for Dow Chemical Company, December, 1976.

Keplinger and Associates, Inc., 1977, Phase II preliminary evaluation of Dixie Valley, Nevada: geothermal potential and associated economics: Rept. prepared for Millican Oil Company, Sept. 1977.

Keplinger and Associates, Inc., 1978, Interim evaluation of exploration and development status, geothermal potential and associated economics of Dixie Valley, Nevada: Rept. prepared for Millican Oil Oil Company, Sept. 1978, 60 p.

Zones, C.P., 1957, Changes in hydrologic conditions in the Dixie Valley and Fairview Valley areas, Nevada, after the earthquake of December 16, 1954: Seis. Soc. America Bull., v. 47, no. 4, p. 387-396.