

**A PROGRESS REPORT OF
GEOHERMAL INVESTIGATIONS
IN THE CLIFTON AREA**

by

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IN THE CLIFTON AREA

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Clifton Hot Springs are adjacent to one of two KGRA's (known geothermal resource area) in Arizona, the Clifton Hot Springs KGRA. Hot water up to 61°C discharges from numerous seeps and small springs 2 miles north of Clifton along the San Francisco River into Clifton.

J. D. Hem (1950) calculated the total discharge of the hot springs using measured river discharges above and below the hot springs. Hem's calculations gave a hot springs discharge of 2.5 cubic feet per second. This flow is rather large, especially when considering the small discharges observed in the springs along the river. However, Hem's calculations are probably accurate because large unobserved discharges no doubt occur in the San Francisco River. Data from Swanberg (1977) confirm large discharges in the river. Swanberg's data show a significant increase in the temperature and chloride content in the San Francisco River between an upstream measurement and a downstream measurement from the hot springs. The hot springs degrade the chemical quality of the San Francisco River.

Lindgren (1905) comments on the high salinity of these springs in his paper on the Clifton-Morenci mining district. The hot springs are very salty and salt crystals

are sometimes seen growing on rocks adjacent to spring discharges. The source of the sodium chloride is not readily apparent because there are no evaporite deposits observed in the area. However, the salt may be from brines discharged from a high temperature reservoir ($>150^{\circ}\text{C}$). The high magnesium content of the springs presents problems concerning geothermometry interpretation. Magnesium content of the hot springs is somewhat high compared to their in situ temperatures because the solubility of magnesium carbonates is very low at higher temperatures. The relatively high magnesium content may be evidence of the reservoir lithology or simply water-rock interactions that have taken place after the hot water left the reservoir.

Mariner, et al., 1977, present deuterium and chloride data that suggest that the spring discharges are mixes of hot and cold water. A plot of boron concentration versus chloride concentration of hot springs and river agrees very well with Mariner's conclusion. Chloride and boron concentrations have a linear relationship which is expected if very low concentration cold water mixes with high concentration hot water (See Figure 1). Chloride and boron are not assumed to be involved in water-rock reactions after the hot water has left the reservoir. The different concentrations are mostly the result of different mixes of hot and cold water.

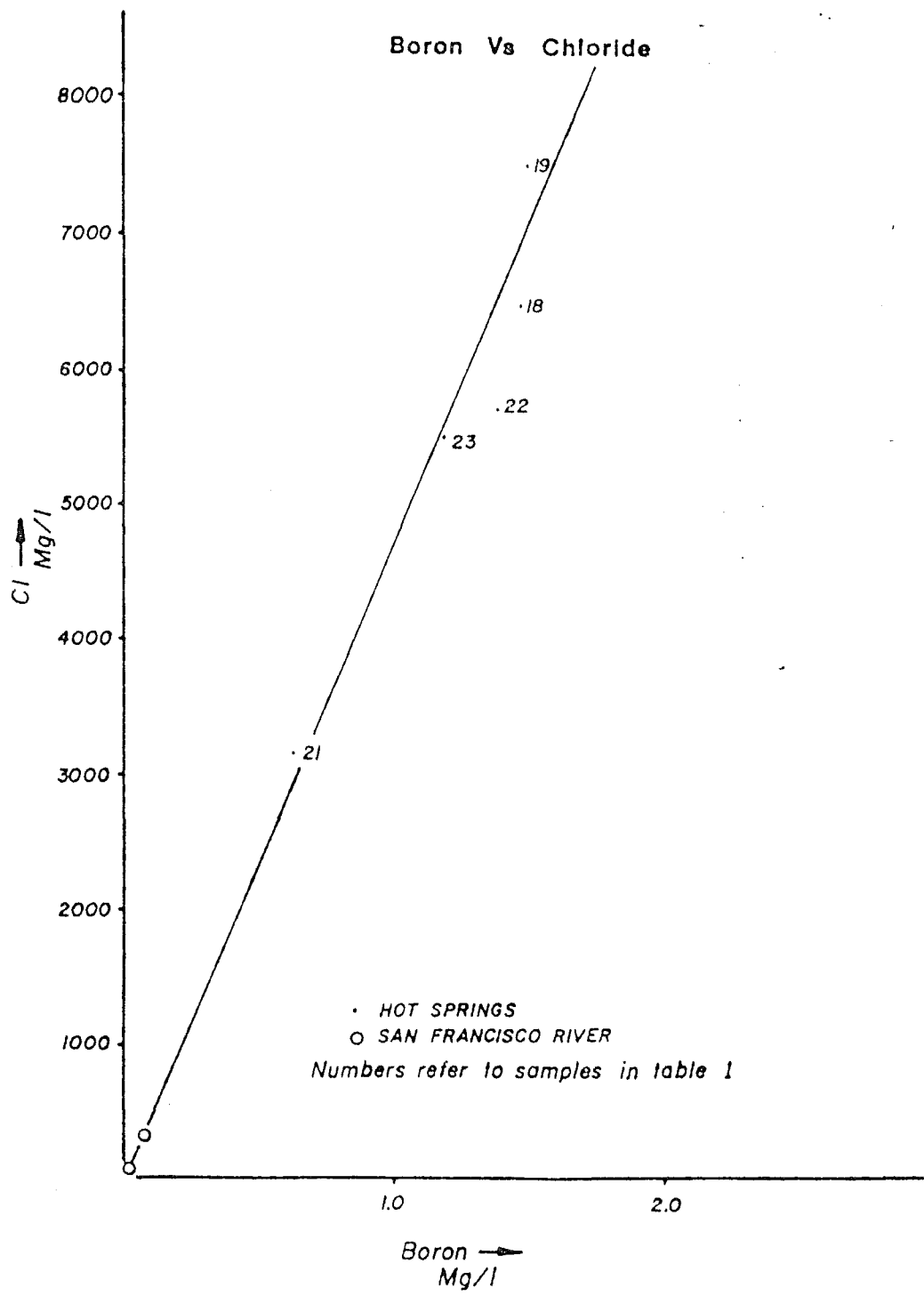


FIGURE 1

Even though these hot springs are mixed waters, silica geothermometry will provide minimum reservoir temperatures. The spring with the highest chloride content, 7485 mg/l, also has the highest silica content, 131 mg/l. This spring, reported by Swanberg (1977), gives a quartz geothermometer of 150°C and a chalcedony geothermometer of 136°C. The spring with the highest discharge temperature, 61°C, was sampled by the geothermal group. The chloride content is 4400 mg/l and the silica content is 95 mg/l. The quartz and chalcedony geothermometers are 134°C and 109°C respectively. The quartz geothermometer calculations assume conductive cooling of the waters after they leave the reservoir. The last silica equilibrium is assumed to have occurred at reservoir temperature.

Figure 2 is a plot of silica and temperature of hot springs and the river versus chloride. The numbers refer to analyses in Table 1. If silica content and temperature are the result of mixing, then they will plot on a straight dilution line. However, this is certainly not the case for samples 16, 18, 22 and 23. They are most likely cooled (conductively) and silica deficient due to precipitation. Figure 3 is a plot of calcium versus chloride. Samples 16, 18, 22 and 23 also appear to be involved in a water-rock reaction involving calcium in addition to being cooled and

Silica & Temperature Vs Chloride

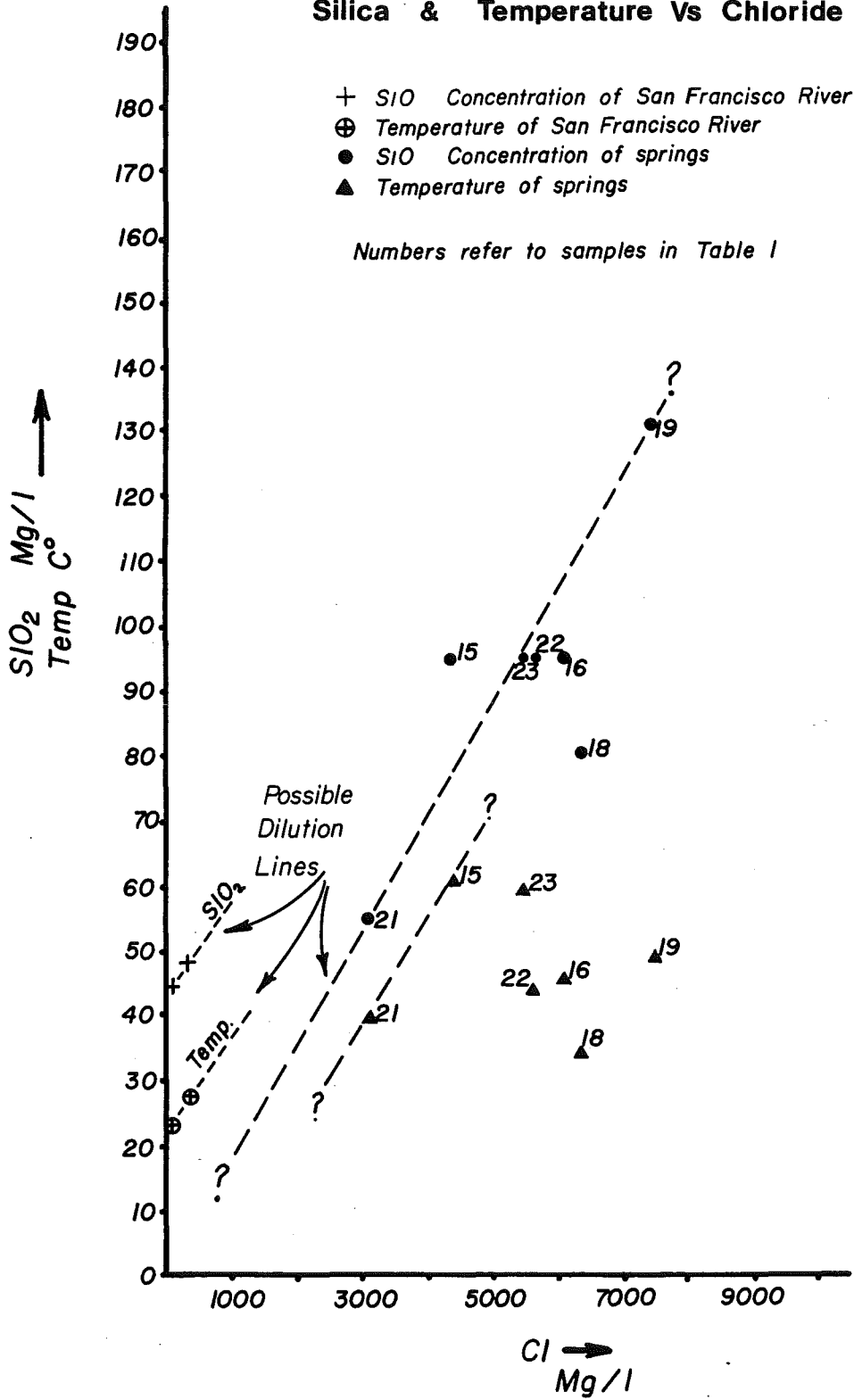


FIGURE 2

TABLE 1 (CONTINUED)

CHEMISTRY OF CLIFTON AREA GROUND WATER

<u>Number</u>	<u>F</u>	<u>B</u>	<u>TDS</u>	<u>SiO₂</u>	<u>Reference</u>
1	4.3	-	8740	-	1
2	4.1	-	8880	-	1
3	5.0	-	8940	-	1
4	3.6	-	7490	-	1
5	3.0	4.0	9790	58	1
6	4.0	-	8330	-	1
7	-	-	8830	-	1
8	4.1	2.5	5320	57	1
9	1.8	-	1920	-	1
10	1.0	1.5	2380	42	1
11	1.0	1.2	2160	39	1
12	.4	-	256	-	1
13	1.1	-	434	-	1
14	-	-	643	37	2
15	-	-	7205	95	2
16	-	-	10141	95	2
17	.65	.02	380	44.6	3
18	1.8	1.48	12576	81.7	3
19	3.5	1.51	14548	131.4	3
20	.83	.08	808	47.9	3
21	2.3	.64	5526	55	4
22	2.7	1.4	9696	94	4
23	2.8	1.2	9352	95	4

References

- 1 - Hem, J.D., 1950
- 2 - This Report
- 3 - Swanberg, et. al., 1977
- 4 - Mariner, et. al., 1977

TABLE 1

CHEMISTRY OF CLIFTON AREA GROUND WATER

<u>Number</u>	<u>Location</u>	<u>Temperature</u>	<u>Na</u>	<u>K</u>	<u>Ca</u>	<u>Mg</u>	<u>Cl</u>	<u>SO₄</u>	<u>HCO₃</u>	<u>pH</u>	<u>Ref.</u>
1	T4S, R30E, 30BD	48.8	2540*	-	767	37	5230	110	111	-	1
2	T4S, R30E, 30BD	40.0	2570*	-	782	43	5280	138	136	-	1
3	T4S, R30E, 30BD	37.8	2620*	-	754	41	5280	178	129	-	1
4	T4S, R30E, 30BD	40.6	2212*	-	619	38	4470	68	152	-	1
5	T4S, R30E, 30BD	43.3	2608	142	860	41	5800	153	109	-	1
6	T4S, R30E, 30AD	48.8	2426*	-	711	48	5000	75	126	-	1
7	T4S, R30E, 30AD	-	2000*	-	750	33	5260	120	128	-	1
8	T4S, R30E, 30AD	-	1596	74	355	17	3030	99	168	-	1
9	T4S, R30E, 30AD	-	583*	-	145	13	1050	46	181	-	1
10	T4S, R30E, 30AD	-	652	37	184	17	1300	44	208	-	1
11	T4S, R30E, 30AD	-	591	35	168	16	1160	43	209	-	1
12	San Francisco R	-	37*	-	44	13	45	21	190	-	1
13	San Francisco R	-	90*	-	58	14	147	25	196	-	1
14	T4S, R30E, 18C	20.3	160	5.9	74	15	104	40	198	7.25	2
15	T4S, R30E, 18C	61.0	2015	175	601	13	4400	58	114	7.45	2
16	T4S, R30E, 18C	45.0	2502	239	959	23	6060	59	130	7.45	2
17	San Francisco R	22.5	49.7	3.9	42	10.1	57.8	48.4	183.2	8.12	3
18	T4S, R30E, 19AC	34.8	3207	210	1064	52.2	6460	-	91.5	7.74	3
19	T4S, R30E, 18DC	48.0	3586	243	926	22.9	7485	-	150	7.86	3
20	San Francisco R	27.0	187	12	74	11.4	307	46.1	190.3	8.22	3
21	T4S, R30E, 30AC	39.0	1500	82	430	16	3150	72	163	7.00	4
22	T4S, R30E, 18C	44.0	2700	170	790	21	5700	62	146	6.58	4
23	T4S, R30E, 18C	59.0	2600	170	740	20	5500	68	145	7.07	4

Analyses from Reference 2 reported in parts per million (ppm), all others in milligrams per liter (Mg/l), temperature in °C.

*No analyses reported as Na and K.

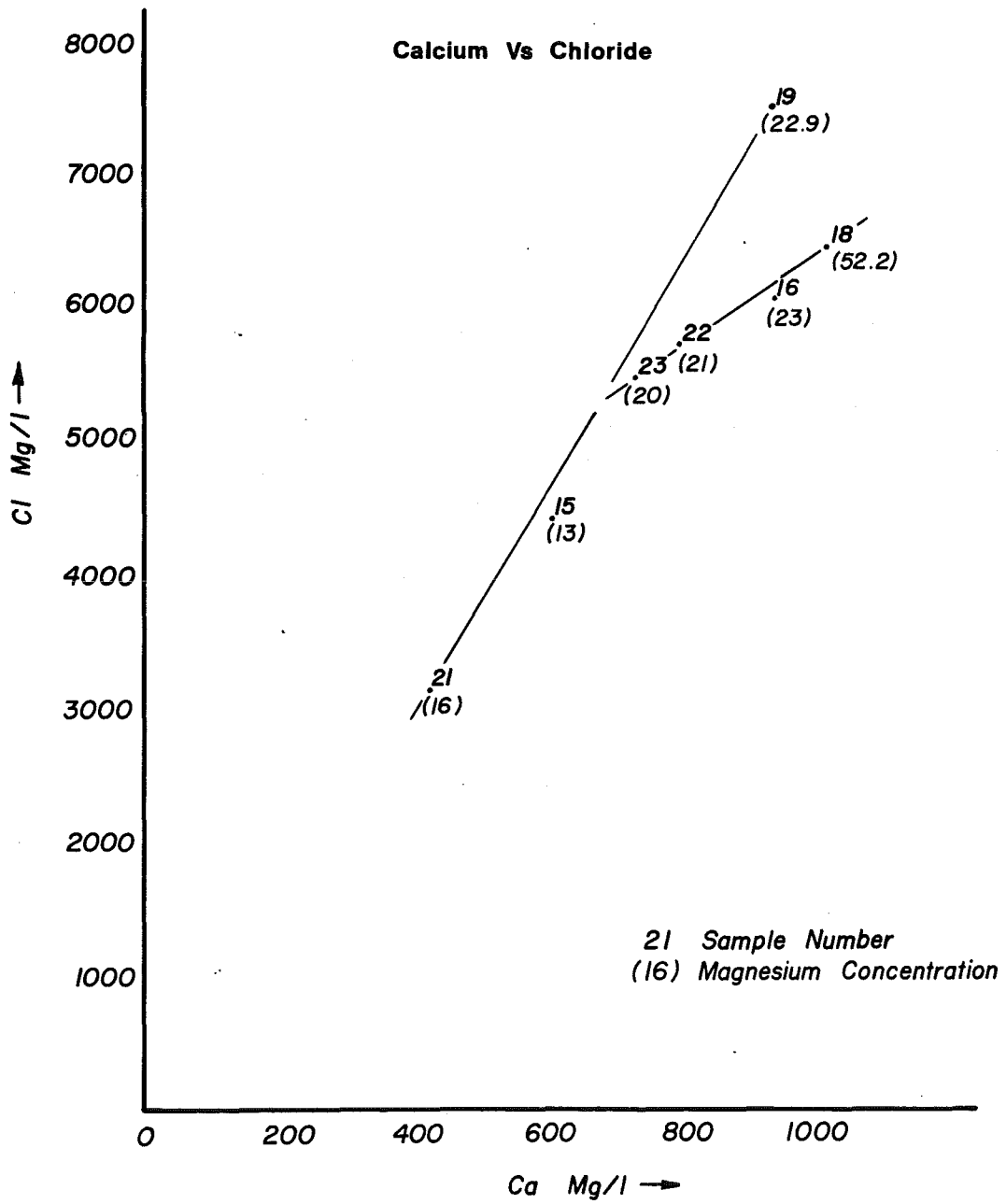


FIGURE 3

silica deficient. The numbers in parantheses are magnesium and they suggest that a major portion of the magnesium is dervied from post reservoir water-rock reactions. As a result, samples 16, 18, 22 and 23 are probably useless for geothermometer calculations.

Figure 4 is a plot of silica versus temperature. Lines A and B are assumed dilution lines from the cold well sample through Samples 21 and 15 respectively. Minor temperature and silica losses are likely from causes other than mixing, but these springs are probably nearest to a true dilution. Quartz mixing models of Lines A and B give 150°C and 188°C respectively. Table 2 and Figure 5 show the mixing model results of dilution line B. Na-K-Ca geothermometers, 160-170°C, agree with the mixing model calculations.

The preliminary chemical geothermometer studies of the Clifton Hot Springs point toward a high temperature reservoir that is greater than 150°C. Total dissolved solids of 25,000 to 50,000 or greater are likely in the reservoir. Further study of this area is warranted. Development of the indicated resource may provide hot water for electricity, space heating and cooling, and industrial applications. In addition, the inflow of salty water to the San Francisco River and Duncan Basin could be curtailed by the use of this resource thereby improving water quality downstream and providing additional good quality water supplies.

Silica Vs Temperature

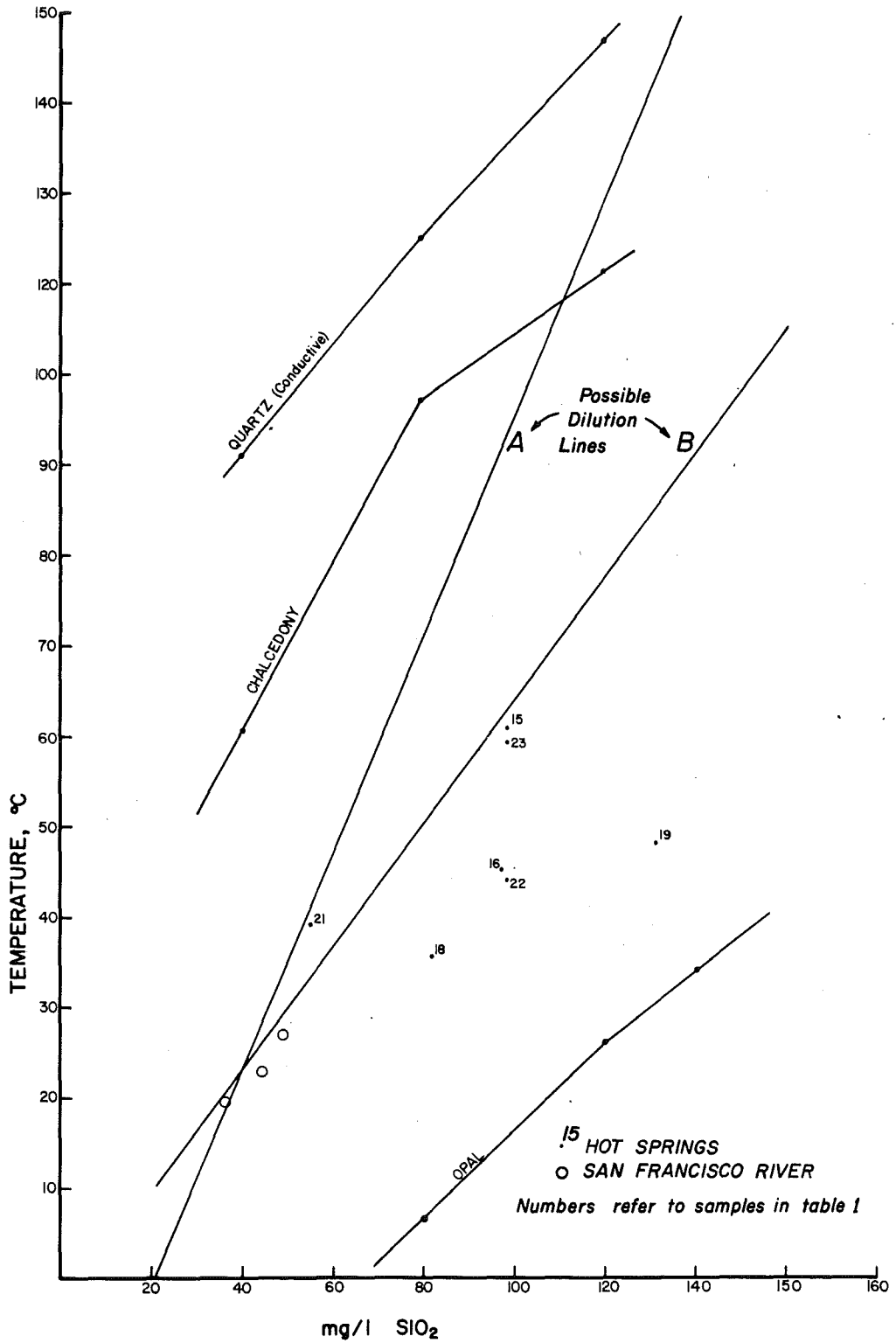


FIGURE 4

TABLE 2

MIXING MODEL CALCULATIONS

DILUTION LINE B

Cold Water	20°C	37 mg/l SiO ₂
Hot Spring	61°C	95 mg/l SiO ₂

$$H_c (x) + H_h (1 - x) = H_{spr}$$

<u>x</u>	<u>Hh</u>
.1	65.5
.2	71.3
.3	78.5
.4	88.3
.5	102.0
.6	122.5
.7	156.7
.8	225
.9	430

$$Si_c (x) + Si_h (1 - x) = Si_{spr}$$

<u>x</u>	<u>Si spr</u>	<u>SiO₂ Temp.</u>
.2	109.5	137
.3	119.9	141.2
.4	133.7	146.9
.5	153.0	153.9
.6	182.0	163.1
.7	230.0	176.2
.8	327.0	197.4
.9	617.0	

Temperature in Degrees Celsius - Assumed to be Equivalent to Enthalpy in Calories per Gram.

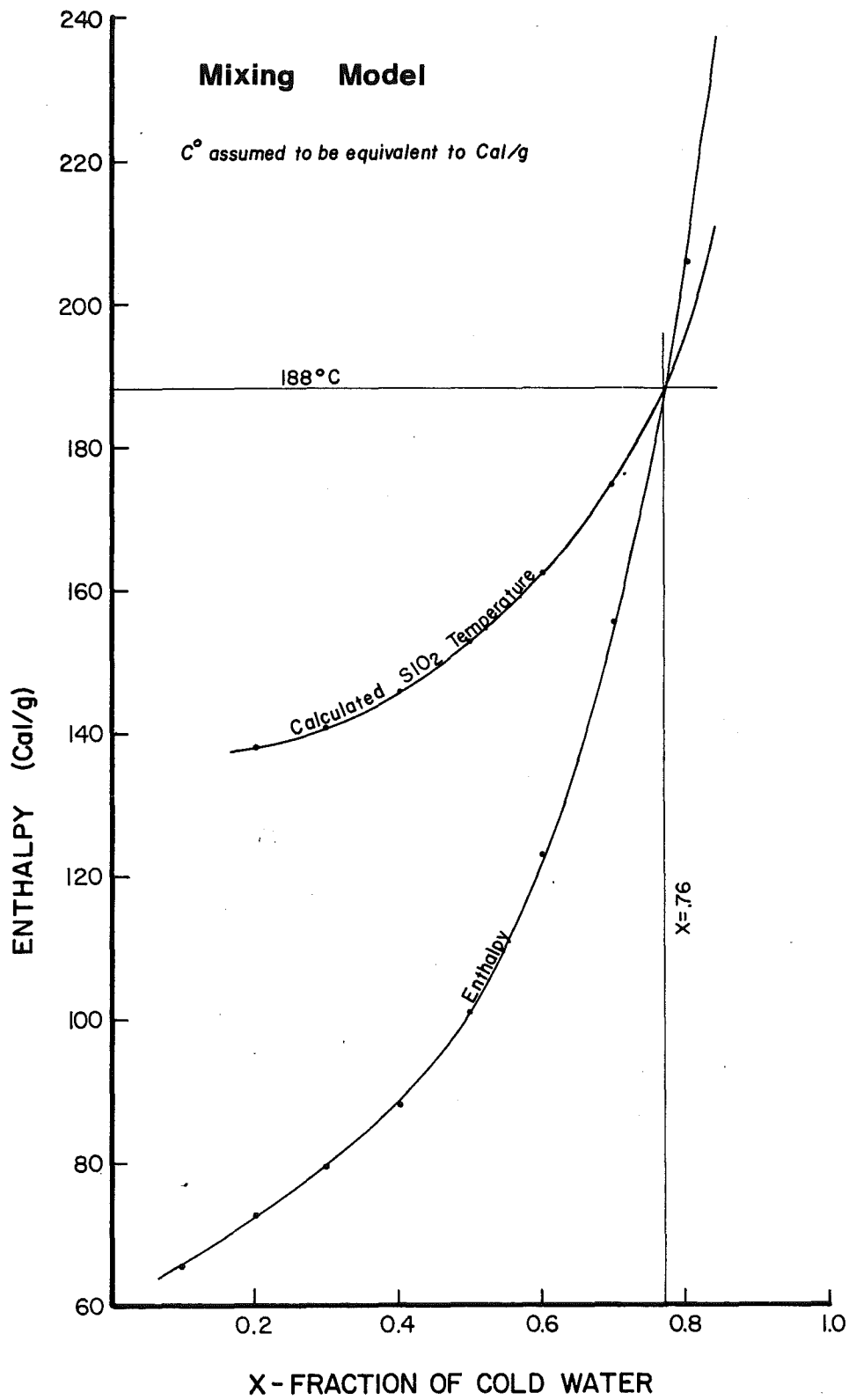


FIGURE 5 (See Table 2 for Calculations)

Geologic mapping is in progress in the area and additional geochemical surveys are planned when high river waters recede late this spring. One or two shallow gradient holes may be drilled during 1979.

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