AMAX EXPLORATION, INC.
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GEOTHERMAL BRANCH

INTER-OFFICE MEMORANDUM

SUBJECT: Preliminary Hydrogeochemical Analysis of the Alum Area, Nevada

January 10, 1983

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On March 16, 1981, I prepared a memorandum on the hydrogeochemistry of Esmeralda County, Nevada to provide some background data for the Alum and Fish Lake prospects. The memo contained the chemical analyses and the chemical geothermometers for 56 AMAX samples, 21 samples from U.S.G.S. Open-File Report 80-672 (Asher-Bolinder et al, 1980) and 9 samples from a paper by Davis and Vine (1979).

Two hot springs are reported in the Clayton Valley area by Garside and Schilling (1979). The Silverpeak (Waterworks) Hot Springs (center SE 1/4 15 T2S R35E) at one time consisted of eleven (11) separate springs which supplied water for the town of Silverpeak (Plate I). The spring temperatures are reported to have ranged from 21 to 47°C with a total flow of 500 gpm. The springs have dried up now and the only chemical data available appears to be that reported by Davis and Vine (1980) as shown below:

Mg/l

Ca	Mg	Na	K	Li	SiO_2	Cl	SO_4
443	64	9220	934	38	---	13,700	500

The second thermal spring in the area is known as Pearl Hot Springs (Garside and Schilling, 1979) and are located in Sec 25 T1SR40E. The water temperature is reported to be 37°C. The chemistry of the water (Davis and Vine, 1980) is given in Table I sample X10029 and is very similar to that for the Silverpeak (Waterworks) Springs.

Three water wells in the southern part of the Big Smoky Valley have anomalous water temperatures (Garside and Schilling, 1979). The wells are the Emigrant Well (NW 1/4 S6 T1N R38E) which encountered 27°C water at a depth of 94 meters, an unnamed well (NW 1/4 S14 T1N R37E) with water temperatures of 22°C at some depth less than 160 meters, and the Fishlake Livestock Co. Well (SE 1/4 S5 T1S R39E) which encountered "hot" water (10 gal/hr) at a depth of 50 meters.

GEOCHEMICAL DATA BASE

Within the area of the Alum property we now have a total of 38 water samples whose locations are shown on Plate I. The chemical analyses from all sources are shown in Table I along with the chemical geothermometers.

GEOCHEMICAL CHARACTERISTICS

The Alum area waters are shown graphically on a trilinear diagram (Fig. 1). The brines from Clayton Valley and the waters from the geothermal gradient wells plot within a very small area and may have a similar origin.

The thermal waters are sodium-chloride waters with variable amounts of bicarbonate and sulfate. The brines from Clayton Valley are sodium-chloride waters with variable amounts of sulfate and bicarbonate. The brines from Big Smoky Valley vary from sodium-chloride-sulfate watere to sodium-sulfate-chloride to sodium-bicarbonate-chloride-sulfate waters depending upon depth and location in the valley.

Mixed Waters

The discrepencies between the silica and alkali geothermometers (Table I) may be related to mixing of geothemal water and meteoric waters. A plot of boron versus sodium for most of the Alum area waters is shown in Figure 2. Samples X10021 through X10029 taken from Davis and Vine (1979) do not have boron analyses and thus cannot be plotted. If the geothermal system represents one parent reservoir fluid with progressive dilution by meteoric water there should be a constant B/Na slope from meteoric waters near the origin to the thermal waters. Such a line does go from the average cold spring waters through many of the samples from both the Big Smoky Valley and from the Clayton Valley and through the points for the waters from our geothermal gradient wells. Note that the points for the Fumerol Well (W14274) and a Foote Minerals brine well (W11123) both plot far to the right of the line.

A plot of boron vs chlorine for the Alum waters, with B analyses, shows similar relationships (Fig. 3) as seen on the B vs Na diagram. Note that both the Fumerol Well (W14274) and a Foote Minerals brine well (W11123) plot far to the right of the lines drawn through the thermal waters in the gradient wells and average meteoric waters near the origin. he scatter of points array from the lines near the origin suggests the water chemistry is not entirely controlled by simple mixing.

Table I - Chemical Analyses of Waters from the Alum Area, Nevada

	X10009 Big Smokey DH14(135') Esmeralda	X10010 Big Smokey DH14(195') Esmeralda	X10013 Alkali Flat DH16(100') Esmeralda
Temp (°C)	18.0	21.0	20.0
Flow (gpm)	---	---	---
pH	8.4	8.4	7.8
Cl	420.0	490.0	220.0
F	1.9	2.7	2.7
SO_4	200.0	220.0	290.0
HCO_3	---	---	---
CO_3	---	---	---
SiO_2	82.0	78.0	31.0
Na	600.0	650.0	280.0
K	58.0	58.0	32.0
Ca	13.0	12.0	49.0
Mg	6.7	7.3	5.2
Li	1.3	0.82	0.18
B	11.0	14.0	5.2
MO	---	---	---
NH_3	---	---	---
TDS	1750.0	1920.0	1030.0
Ec(k)	2750.0	3107.0	1627.0
T_qSiO_2	124	121	84
T_cSiO_2	96	96	50
TNa-K	214	207	229
TNa-K-Ca	150	147	142
TLi/Na	123	89	55
TLi	163	147	
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Note: Samples X10009 through X10013 from U.S.G.S. Open-File Report 80-672.

Table I - Continued

	X10014 Alkali Flat DH16(315') NWSW30T1NR41E Esmeralda	X10015 Alkali Flat DH16(515') NWSW30T1NR41E Esmeralda	X10017 Big Smokey DH13(245') NWSW7T2NR39E Esmeralda
Temp (^{o}C)	21.0	22.0	9.0
Flow (gpm)	---	---	---
pH	8.1	8.3	8.0
Cl	61.0	65.0	210.0
F	2.1	4.2	2.7
SO_4	170.0	230.0	74.0
HCO_3	---	---	---
CO_3	---	---	---
SiO_2	73.0	84.0	74.0
Na	180.0	220.0	240.0
K	19.0	20.0	15.0
Ca	14.0	12.0	10.0
Mg	1.90	2.7	0.88
Li	0.25	0.49	0.16
B	1.90	2.7	0.88
MO	---	---	---
NH_3	---	---	---
TDS	648.0	781.0	744.0
Ec(k)	947.0	1133.0	1217.0
T_qSiO_2	118	125	119
T_cSiO_2	92	100	93
TNa-K	222	209	180
TNa-K-Ca	144	140	126
TLi/Na	95	125	56
TLi	111	131	98

Note: Samples X10014 through X10017 from U.S.G.S. Open-File Report 80-672.

Table I - Continued

	X10018 Big Smokey DH13(395') NWSW7T2NR39E Esmeralda	X10019 Big Smokey DH13(495') NWSW7T2NR39E Esmeralda	X10020 Big Smokey DH13(620') NWSW7T2NR39E Esmeralda
Temp (^{o}C)	21.0	22.0	24.0
Flow (gpm)	---	---	---
pH	7.7	8.1	8.1
Cl	640.0	26.0	300.0
F	2.4	9.7	11.0
SO_4	77.0	58.0	97.0
HCO_3	---	---	---
CO_3	---	---	---
SiO_2	71.0	85.0	86.0
Na	450.0	190.0	350.0
K	39.0	7.2	10.0
Ca	26.0	7.6	3.0
Mg	6.3	1.0	0.1
Li	1.7	0.1	0.17
B	2.0	2.8	4.0
MO	---	---	---
NH_3	---	---	---
TDS	1430.0	586.0	1020.0
Ec(k)	2524.0	823.0	1680.0
T_qSiO_2	117	125	126
T_cSiO_2	90	101	101
TNa-K	205	146	129
TNa-K-Ca	137	106	105
TLi/Na	165	46	42
TLi	174	86	100

Note: Samples X10018 through X10020 from U.S.G.S. Open-File Report 80-672.

Table I - Continued

	X10021 Clayton Valley DH-1(315') NE12T2SR39E Esmeralda	X10022 Clayton Valley(155') NE6T2SR40E Esmeralda	X10023 Clayton Valley DH-2A(195') 21T1SR40E Esmeralda
Temp (^oC)	22.0	21.0	38.0
Flow (gpm)	---	---	---
pH	7.8	8.0	8.0
Cl	12,000.0	11,000.0	15,000.0
F	1.5	2.7	4.9
SO_4	500.0	590.0	510.0
HCO_3	710.0	1000.0	32.0
CO_3	---	---	---
SiO_2	64.0	78.0	53.0
Na	7200.0	7200.0	8400.0
K	520.0	730.0	850.0
Ca	450.0	150.0	240.0
Mg	180.0	92.0	30.0
Li	27.0	27.0	38.0
B	2.0	2.8	4.0
MO	---	---	---
NH_3	---	---	---
TDS	---	---	---
Ec(k)	31,000.0	29,100.0	37,500.0
T_qSiO_2	113	121	105
T_cSiO_2	85	96	75
TNa-K	191	218	218
TNa-K-Ca	129	152	150
TLi/Na	202*	202*	227*
TLi	313*	313*	337*

Note: Samples X10021 through X10023 from Davis and Vine, 1979.

*Geothermometers probably reflect concentrations related to brine development.

Table I - Continued

	X10024 Clayton Valley DH-3(415') 23T1SR40E Esmeralda	X10025 Clayton Valley DH4 35T1SR40E Esmeralda	X10026 Clayton Valley DH-5(235') 35T1SR40E Esmeralda
Temp (^{o}C)	33.0	36.0	22.0
Flow (gpm)	---	---	---
pH	8.0	7.8	8.0
Cl	16,000.0	21,000.0	10,000.0
F	2.9	1.7	1.8
SO_4	860.0	1200.0	550.0
HCO_3	660.0	640.0	580.0
CO_3	---	---	---
SiO_2	71.0	86.0	34.0
Na	10,000.0	13,000.0	6000.0
K	920.0	1300.0	490.0
Ca	320.0	270.0	120.0
Mg	87.0	78.0	41.0
Li	44.0	58.0	26.0
B	---	---	---
MO	---	---	---
NH_3	---	---	---
TDS	---	---	---
Ec(k)	42,500.0	51,000.0	27,500.0
T_qSiO_2	117	126	88
T_cSiO_2	90	101	54
TNa-K	210	217	200
TNa-K-Ca	144	152	143
TLi/Na	238*	261*	200*
TLi	348*	369*	311*

Note: Samples X10021 through X10023 from Davis and Vine, 1979.

*Anomalous geothermometry thought to be related to concentration by evaporation.

Table I - Continued

	X10027 Clayton Valley DH5A(715') NENW2T2SR40E Esmeralda	X10028 Foote Minerals DH7 NW20T2SR40E Esmeralda	X10029 Hot Spring 25T1SR40E Esmeralda
Temp (^oC)	19.5	19.4	36.5
Flow (gpm)	---	---	---
pH	7.1	7.3	7.3
Cl	150,000.0	37,000.0	14,000.0
F	0.5	0.4	4.2
SO_4	6,600.0	160.0	590.0
HCO_3	650.0	151.0	609.0
CO_3	---	---	---
SiO_2	11.0	55.0	46.0
Na	93,000.0	20,000.0	8800.0
K	8000.0	2100.0	850.0
Ca	710.0	840.0	300.0
Mg	360.0	400.0	37.0
Li	320.0	89.0	34.0
B	---	---	---
MO	---	---	---
NH_3	---	---	---
TDS	---	---	---
Ec(k)	260,000.0	75,500.0	37,400.0
T_qSiO_2	50	106	99
T_cSiO_2	10	77	68
TNa-K	204	221	214
TNa-K-Ca	153	149	146
TLi/Na	465*	301*	219*
TLi	540*	405*	329*

Note: Samples X10027 through X10029 from Davis and Vine, 1979.

*Anomalous geothermometry thought to be related to concentration by evaporation.

Table I - Continued

	W11109 McLean Spring 22T2NR39E Esmeralda	W11112 Coyote Spring NESW15T25R38E Esmeralda	W11113 Cave Spring NENW2T25R37E Esmeralda
Temp (^{o}C)	28.0	21.0	17.0
Flow (gpm)	1.0	4.0	10.0
pH	7.8	7.62	8.4
Cl	170.0	59.0	15.0
F	6.0	0.4	0.3
SO_4	200.0	---	80.0
HCO_3	424.2	147.8	71.8
CO_3	0.0	0.0	2.4
SiO_2	46.0	21.0	31.0
Na	410.0	65.0	71.0
K	14.0	3.4	2.0
Ca	9.0	290.0	11.0
Mg	1.2	27.0	0.0
Li	0.1	---	0.2
B	2.6	0.4	0.0
MO	100.0	2.0	0.0
NH_3	0.24	0.13	0.0
TDS	1283.3	614.1	284.7
T_qSiO_2	99	70	84
T_cSiO_2	67	33	49
TNa-K	139	167	128
TNa-K-Ca	105	89	87
TLi/Na	15	---	142
TLi	86	---	104

Note: Samples W11109 through W11113 from AMAX data file, 1977.

Table I - Continued

	W11119 Rhyolite Ridge Spr. NWSW1T2SR37E Esmeralda	W11122 North Spring SWSW29T1SR38E Esmeralda	W11123 Tailings Pond Well SENE17T2SR40E Esmeralda
Temp (^{o}C)	15.0	15.0	22.0
Flow (gpm)	11.0	2.0	---
pH	7.55	7.02	6.70
Cl	57.0	31.0	46,000.0
F	0.3	0.4	1.6
SO_4	---	46.0	2100.0
HCO_3	169.8	76.0	587.6
CO_3	0.0	0.0	0.0
SiO_2	49.0	77.0	70.0
Na	75.0	76.0	29,000.0
K	6.1	1.6	280.0
Ca	48.0	1.0	60.0
Mg	10.0	1.0	290.0
Li	0.1	0.1	120.0
B	0.7	0.4	49.0
MO	8.0	0.0	0.0
NH_3	0.0	0.0	2.21
TDS	416.0	310.6	78,560.4
T_qSiO_2	102	121	117
T_cSiO_2	71	95	90
TNa-K	200	112	3
TNa-K-Ca	118	91	23
TLi/Na	93	92	332*
TLi	86	86	432*

Note: Samples W11119 through W11123 from AMAX data file, 1977.

*Anomalous geothermometry thought to be related to concentration by evaporation.

Table I - Continued

	W11646 Rhyolite Ridge Well NE30T1SR37E Esmeralda	W11648 Devils Gate Well SW28T3NR38E Esmeralda	W11650 Cholla Spring NW26T2NR40E Esmeralda
Temp (^{o}C)	22.0	16.0	17.0
Flow (gpm)	---	2.0	5.0
pH	8.02	7.51	7.10
Cl	22.0	74.0	42.0
F	0.6	8.6	3.5
SO_4	90.0	48.0	42.0
HCO_3	139.0	363.0	190.0
CO_3	0.0	0.0	0.0
SiO_2	45.0	42.0	45.0
Na	88.0	140.0	39.0
K	5.1	0.6	2.2
Ca	25.0	69.0	80.0
Mg	5.0	20.0	19.0
Li	0.2	0.1	0.0
B	4.6	1.1	0.0
MO	7.0	2.0	0.8
NH_3	0.0	0.0	0.0
TDS	424.5	765.4	463.5
T_qSiO_2	98	96	98
T_cSiO_2	67	63	67
TNa-K	174	43	172
TNa-K-Ca	110	28	96
TLi/Na	126	60	---
TLi	104	86	---

Note: Samples W11646 through W11650 from AMAX data file, 1978.

Table I - Continued

	W14271 Cold Spring NWNW23T1SR38E	W14272 Water Well NENE34T1NR38E	W14273 Minnesota Spring SESE16T1SR38E
Temp (^{o}C)	11.0	11.0	11.0
Flow (gpm)	2.0	5.0	3.0
pH	7.7	8.1	7.5
Cl	34.0	38.0	70.0
F	0.2	0.3	0.2
SO_4	280.0	57.0	240.0
HCO_3	170.0	114.0	260.0
CO_3	0.0	0.0	0.0
SiO_2	21.0	71.0	22.0
Na	56.0	60.0	61.0
K	2.4	12.0	3.1
Ca	140.0	29.0	150.0
Mg	30.0	17.0	51.0
Li	0.1	0.1	0.1
B	0.6	0.6	0.7
TDS	734.3	399.0	858.1
Ec(k)	1000.0	580.0	1200.0
T_qSiO_2	65	117	67
T_cSiO_2	33	90	35
TNa-K	154	285	165
TNa-K-Ca	17	91	22
TLi/Na	110	105	105
TLi	86	86	86

Note: Samples W14271 through W14273 from AMAX data file, 1981.

Table I - Continued

	W14274 Fumerol Well SESE10T2SR39E	W14275 Cold Spr. NESE9T1NR39E	W14287 Water Well NESE10T1NR38E
Temp (^{o}C)	79.0	6.0	12.0
Flow (gpm)	---	1.0	5.0
pH	6.6	7.6	8.1
Cl	17,000.0	83.0	97.0
F	4.8	0.9	2.8
SO_4	370.0	200.0	170.0
HCO_3	370.0	170.0	37.0
CO_3	0.0	0.0	0.0
SiO_2	170.0	24.0	89.0
Na	8700.0	88.0	350.0
K	800.0	3.6	12.0
Ca	670.0	130.0	12.0
Mg	65.0	11.0	7.0
Li	47.0	0.1	0.2
B	0.8	0.8	2.5
TDS	28,197.6	711.4	779.5
Ec(k)	46,000.0	980.0	1700.0
T_qSiO_2	159	70	127
T_cSiO_2	146	39	103
TNa-K	210	392	140
TNa-K-Ca	218	31	143
TLi/Na	244*	84	49
TLi	353*	86	104

Note: Samples W14274 through W14287 from AMAX data file, 1981.

*Anomalous geothermometry thought to be related to concentration by evaporation.

Table I - Continued

	W14280 24-33 @ 1226'	W14282 24-33 @ 1226'	W14288 Blair Jct. Well NWNE20T2NR38E
Temp (^{o}C)	72.0	72.0	19.0
Flow (gpm)	100.0	100.0	200.0
pH	7.6	7.6	8.4
Cl	3600.0	3600.0	140.0
F	4.8	4.8	2.6
SO_4	160.0	170.0	280.0
HCO_3	242.0	240.0	214.0
CO_3	0.0	0.0	9.0
SiO_2	150.0	140.0	50.0
Na	2500.0	2400.0	390.0
K	290.0	280.0	12.0
Ca	150.0	160.0	5.1
Mg	45.0	46.0	0.7
Li	9.5	9.3	0.1
B	40.0	36.0	6.3
TDS	7191.3	7086.1	1109.8
Ec(k)	11,000.0	12,000.0	1800.0
T_qSiO_2	153	149	101
T_cSiO_2	137	133	71
TNa-K	230	231	133
TNa-K-Ca	223	221	147
TLi/Na	166	167	17
TLi	252	250	86

Note: Samples W14200 through W14288 from AMAX data file, 1982.

Table I - Continued

	W14297 56-29 @ 785' NWSES29T1NR381/2E	W14298 56-29 @ 785 NWSE29T1NR381/2E
Temp (°C)	80.0	80.0
Flow (gpm)	60.0	60.0
pH	8.4	8.5
Cl	4700.0	4600.0
F	5.1	5.3
SO_4	210.0	230.0
HCO_3	135.0	124.0
CO_3	9.0	19.0
SiO_2	190.0	190.0
Na	2700.0	2700.0
K	320.0	320.0
Ca	87.0	87.0
Mg	20.0	20.0
Li	10.0	10.0
B	33.0	33.0
TDS	8419.1	8338.3
Ec(k)	13,000.0	13,000.0
T_qSiO_2	165	165
T_cSiO_2	154	154
TNa-K	232	232
TNa-K-Ca	232	232
TLi/Na	163	254
TLi	163	254

Note: Samples W14297 through W14298 from AMAX data file, 1982.

A final plot which illustrates the role of mixed waters is the SiO_2 vs Cl/NCO_3 mole ratio diagram shown in Figure 4. The waters encountered in well 56-29 are more primative, less mixed, than the waters from well 24-33. The scatter of points as you approach the origin suggests that the water chemistry is also affected by water-rock reactions.

Water-Rock Reactions

The chemical characteristics of groundwaters are controlled by (1) subsurface temperatures to which they are exposed, (2) mixing of thermal and meteoric waters, (3) the residence time in aquifers, and (4) the water-rock reactions which have occurred. In order to evaluate the water chemistry of an area one must attempt to determine how much the water-rock reactions have affected the chemical signature of the water.

The graphical scatter seen on the geochemical diagrams (Fig. 1-4) may be an indication of water-rock reactions. For example, both Fumerol Well (W14274) and the Foote Minerals Company brine well (W11123) plot far to the right of the line drawn through the thermal waters from the gradient wells and the average groundwaters on Figures 2, 3 and 4. Both wells show an increase in Na and Cl. Much of the increase can be attributed to evaporation; however, the playa deposits are tuffaceous and groundwaters issuing from such sediments tend to be enriched in Na (White, 1979). The amount of enrichment will be related to time of residence as well chemical composition of the sediments. On Figure 4 those groundwaters near the origin are meteoric waters which have penetrated only to shallow depths. The silica values for the waters averages 30 to 40 ppm which is 1.5 to 2.0 times the values found in most average groundwaters.

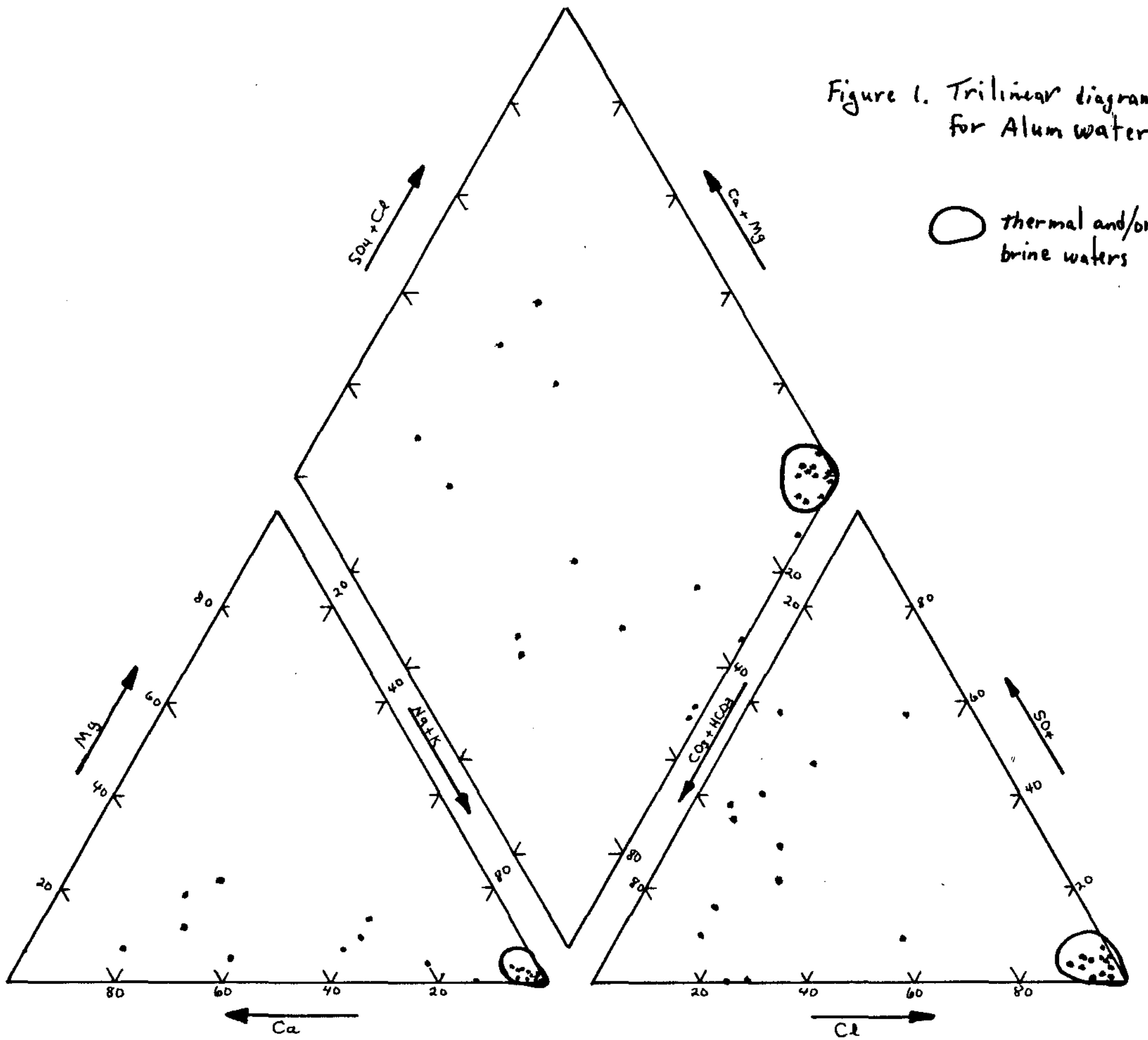
Geothermal Reservoir

The chemical geothermometers (Table I) for the thermal waters (greater than 30°C) in Clayton Valley and from the thermal gradient wells give subsurface temperatures of 99-165°C for SiO_2, 218-243°C for the Na-K-Ca, 163-458°C for Na/Li, and 219-261°C for lithium. Most of the Alum area waters contain a significant amount of Mg and may require a correction for the alkali geothermometer. Table II summarizes the chemical geothermometers for the thermal waters in the Alum area.

Table II. Geothermometry Summary for Alum Thermal Waters

Location	T_{SiO_2}	TNa-K-Ca	TNa-K-Ca-Mg	TNa/Li	TLi	Max Obs. T°C
Fumerol Well	159	218	161	494	243	79
NE Hot Spr.	99	231	179	429	219	36.5
CV DH2	105	235	188	458	226	38
CV DH3	117	229	125	178	238	33
CV DH4	126	243	152	455	261	36
56-29	165	232	150	163	254	80
24-33	153	223	161	166	252	72

Figure 1. Trilinear diagram for Alum waters



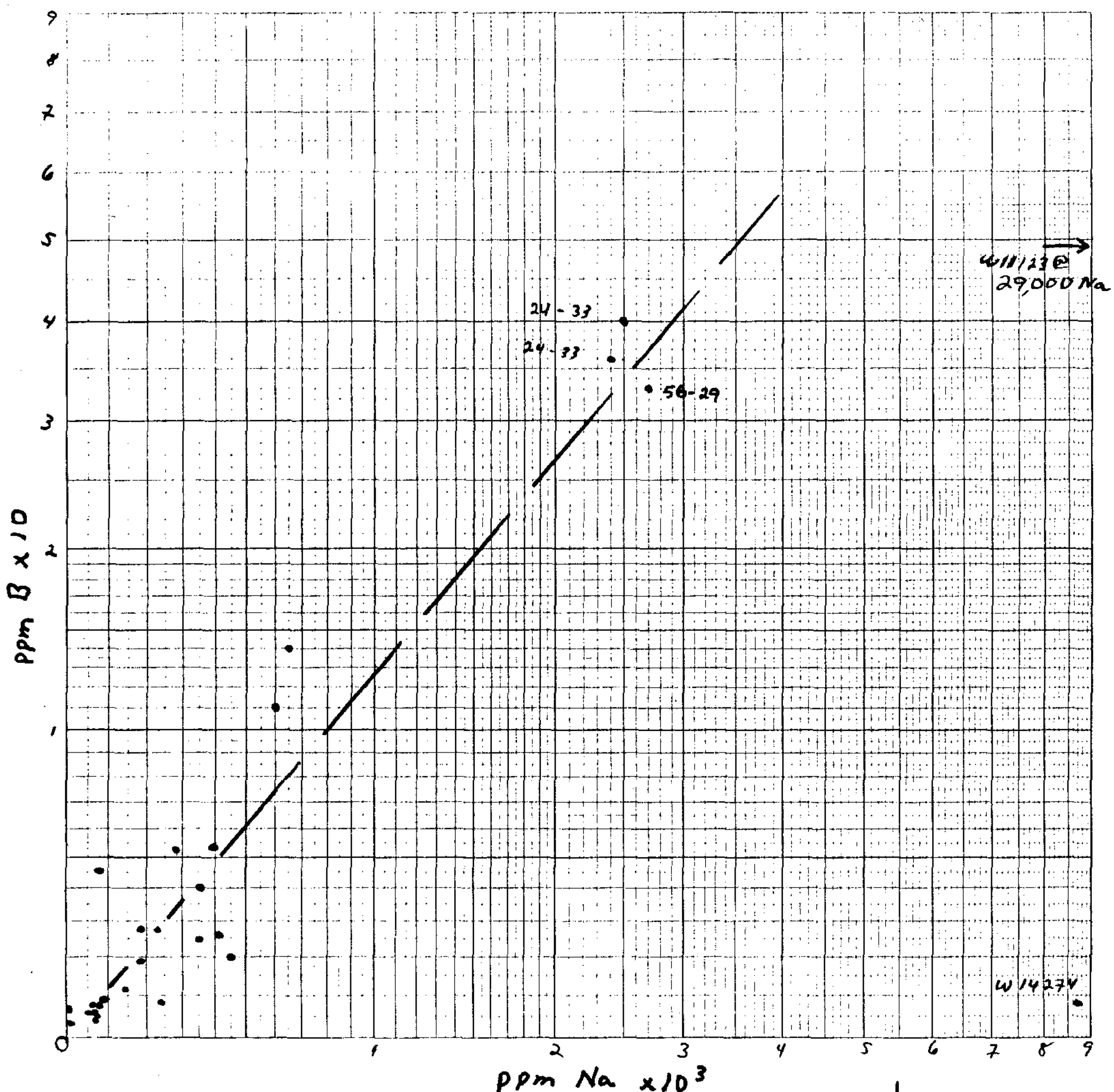


Figure 2. Boron vs sodium diagram for Alum area waters.

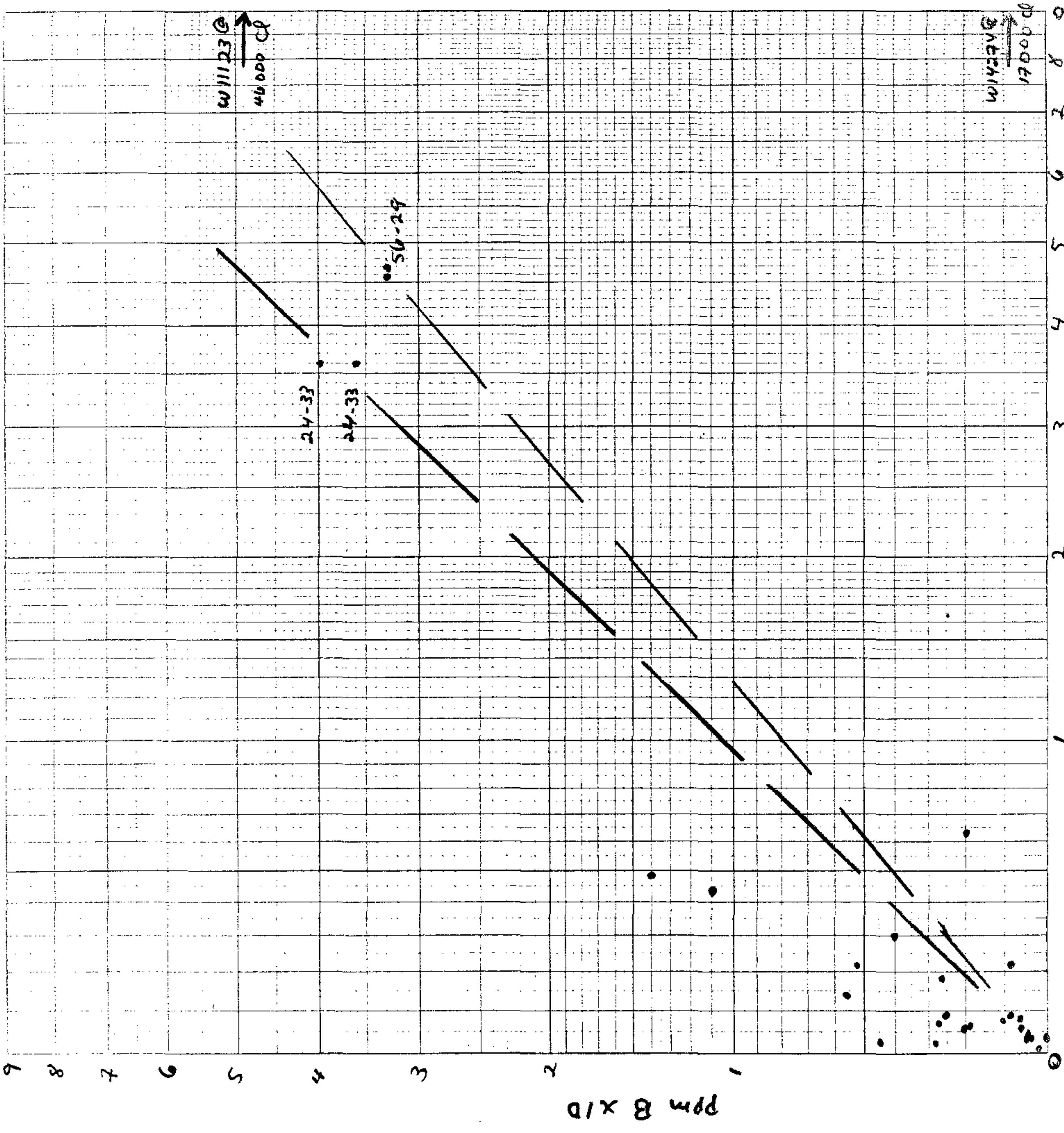


Figure 3. Boron vs chlorine plot for Alum waters.

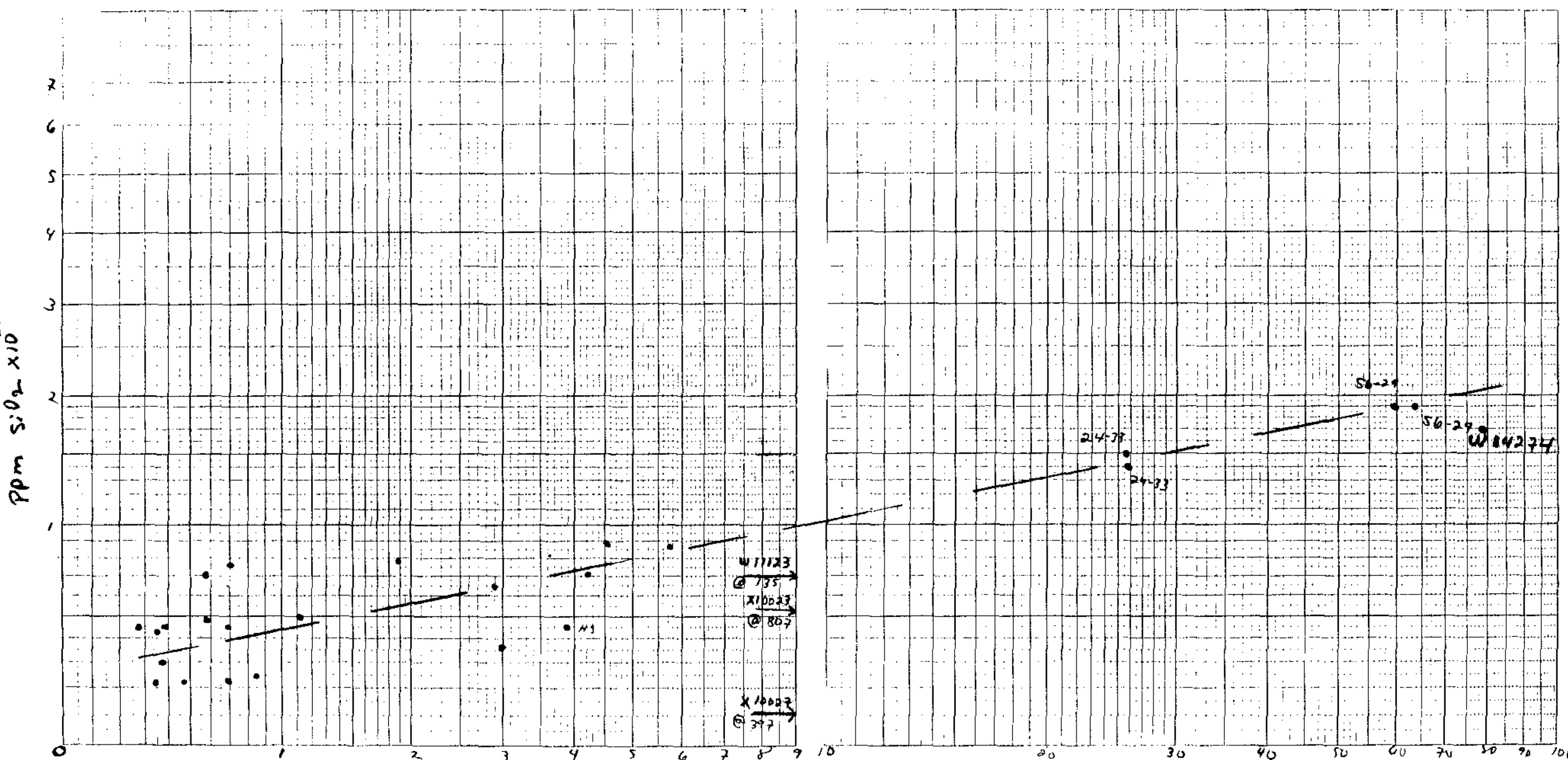


Figure 4. Relationship between SiO_2 and the Cl/HCO_3 mole ratio for Alum waters

In order to determine the nature of the parent geothermal fluids we can examine the silica concentration versus temperature (Fig. 5) diagram using the average groundwater value (Table I) and the analyses for Fumerol Well, well 56-29 and well 24-33.

The silica solubility should be plotted against enthalpy; however, for temperatures up to 250°C the values are nearly equal and for convenience the temperature values are used. On Figure 5 a line drawn from the average groundwater and through the thermal gradient well data to intersect the silica solubility curves will give possible reservoir fluids. If the fluids have boiled during ascent the reservoir fluid would have contained about 360 ppm SiO_2 at a temperature of 2[illegible]8[illegible]°C. If the parent fluid cooled conductivity during ascent then the fluid would have contained 410 ppm SiO_2 at a temperatue of 290°C. The fact that the waters from 56-29 and 24-33 fall on the same line suggests strongly that mixing has occurred. Using the lever principle the waters from well 56-29 have a thermal 31 percent contribution from the deep reservoir while well 24-33 has only a 25 percent deep component.

Another method of analysis of the thermal history of a geothermal system is to plot enthalpy against chlorine concentration (Fig. 6). When we connect well 56-29 with the enthalpy of steam at 96°C we get one point of reference. Point A represents a possible reservoir fluid whose enthalpy is equal to the fluid defined by the intersection of the dilution line and the maximum steam loss silica curve on Figure 5. Boiling of parent fluid A could give rise to the fluids encountered in well 56-29. Dilution of the fluids from 56-29 with groundwater would then give rise to the fluids encountered in well 24-33. However, if the fluids from well 56-29 are mixed, as suggested by the discrepency between the silica mixing model (Fig. 5), then a parent fluid B could by conductive cooling give rise to the fluids in well 56-29 or more likely the parent fluid B would by boiling give rise to a fluid with a composition of C. Fluid C has a temperature of 110°C and a chlorine content of 6250 ppm. Fluid C could by mixing with local groundwaters give rise to fluids found in 56-29 and with further dilution could form the fluids in 24-33.

Summary

In summary, the chemical data for the Alum waters strongly suggests the fluids, thus far encountered, are the product of mixing. If we assume mixing and boiling has occurred, then the possible reservoir fluid shown on Figure 5 and the parent fluid B shown on Figure 6 might characterize the "best" reservoir fluid we can propose. For such a reservoir fluid we see tht the TNa-K-Ca geothermometer and the TLi geothermometers predict, very closely, the reservoir temperatures.

When one examines the diverse subsurface temperatures predicted from the various chemical geothermometes alone it is difficult to know which ones to use. In the Alum area the groundwaters exhibit an enrichment in Na, Ca, K and through water-rock reactions with no apparent changes in the relative ratios between the elements. Within the brines in Clayton Valley Na, Ca, K, Mg, Cl and Li are all enriched by evaporation. Therefore, it appears that the TNa-K-Ca geothermometers gives reasonable

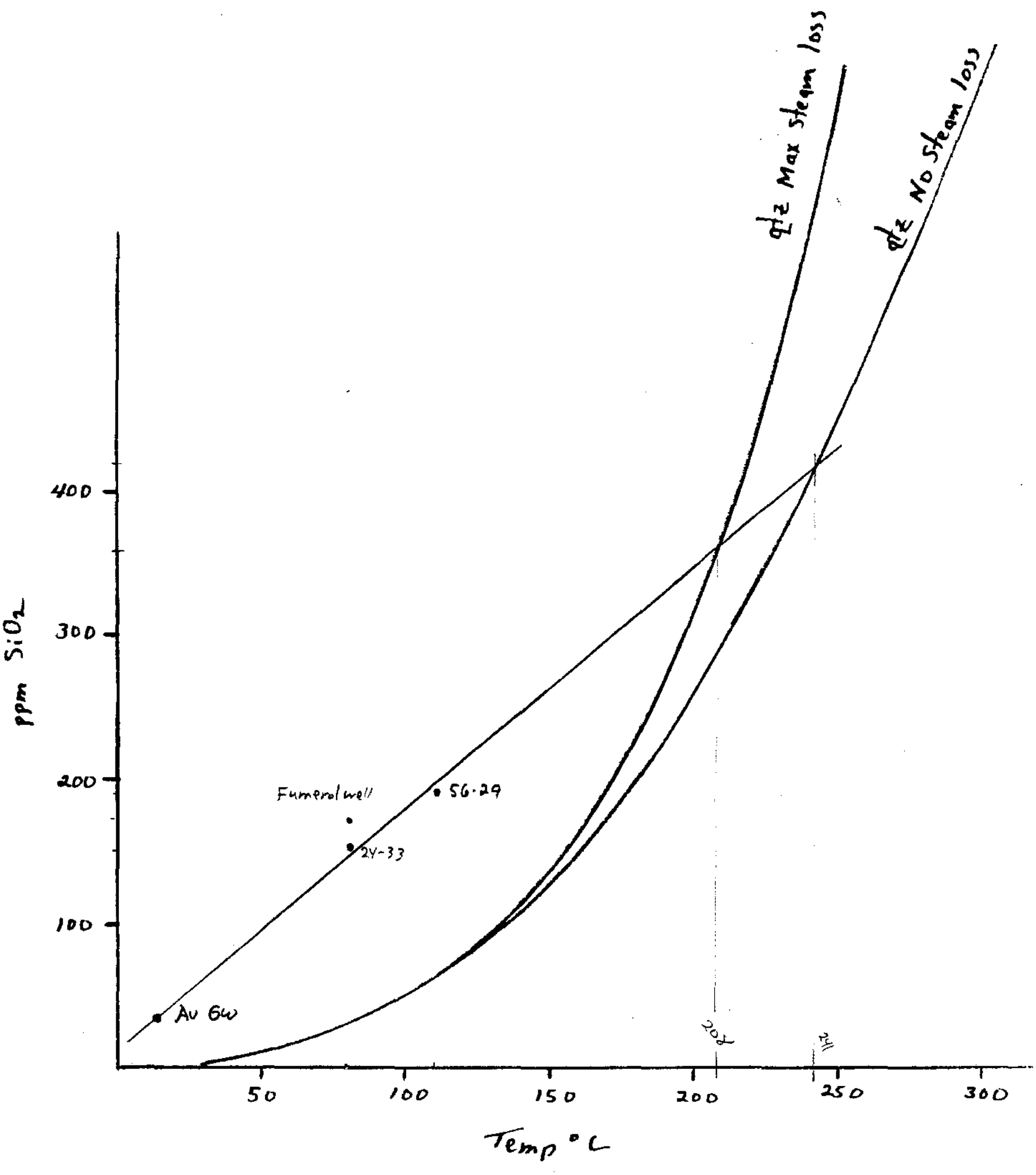


Figure 5 Silica mixing model for Alum waters

temperature estimates while the Mg corrected alkali geothermometer yields "low" temperatures because of the Mg concentation by evaporation. Likewise, the TNa/Li geothermometer yields anomalously "high" temperatures for the brine waters because of the Na enrichment during evaporation.

In conclusion, the best estimate of subsurface temperatures for the Alum area is a geothermal fluid at 238°C.

H. D. Pilkington

HDP/c

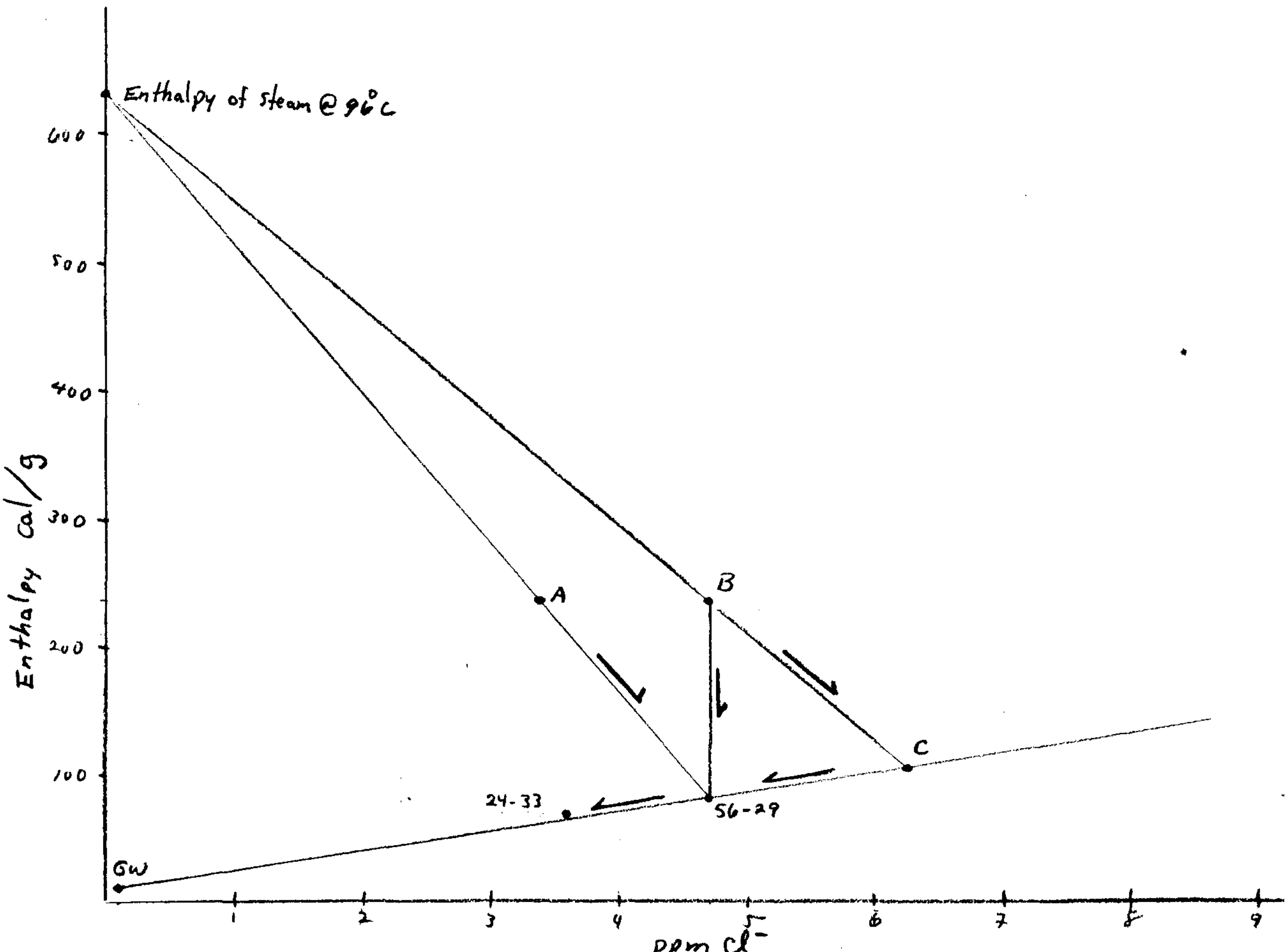


Figure 6. Entholpy vs chlorine concentration for Alum waters

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