THE GEOCHEMISTRY OF THERMAL WATERS FROM THE MOUNT MEAGER HOTSPRINGS AREA, B.C.

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The chemical analyses of the thermal waters of the Mount Meager, B.C., hotsprings area indicate two distinct water chemistries: (1) a predominantly sodium chloride water from the Meager Creek hotsprings and (2) a predominantly sodium bicarbonate water from the Lillooet River hotsprings. Distribution of species calculations and activity diagrams show that the thermal waters are probably in equilibrium with the observed alteration assemblage of kaolinite, laumontite, calcite, and chalcedony at temperatures of 60°C to 80°C. Mass transfer calculations for the reaction of plagioclase, representing the host rock, with an aqueous solution predict kaolinite, laumontite, calcite, and chalcedony as reaction products and an aqueous solution composition similar to the observed chemistry of the hotsprings. Because the thermal waters of the Mount Meager area appear to be near equilibrium with the near surface alteration assemblages, there is no indication as to the previous history of the thermal waters.

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INTRODUCTION

The Mount Meager hotsprings area, located 160 km north of Vancouver, B.C. (see Figure 1), is a potential geothermal energy source that has been the object of recent studies. The Department of Energy, Mines, and Resources (Souther,1977; Read,1977) and the British Columbia Hydro and Power Authority (Nevin et al, 1975) have conducted geothermal related projects in the area for the past four years. This present study was funded by the Department of Energy, Mines, and Resources under project 730067 for the period June 1, 1976 to March 31, 1977.

The purpose of this study is to determine the chemistry of the thermal and fresh waters in the area and to analyze the results to determine the possible equilibrium temperature, origin, and history of the thermal waters.

PREVIOUS WORK

The pertinent previous work in the Mount Meager hotsprings area includes the drilling of six test holes in the Meager Creek valley. Two holes were drilled in 1973 in the Meager main vent hotspring area to depths of 48 m (GSC1) and 130 m (GSC2) under contract to the Geological Survey of Canada. One hole was drilled to a depth of 400 m (74-H-1) in 1974 by Nevin, Sadlier-Brown, Goodbrand, Ltd. under contract to B.C. Hydro. Three more holes were drilled the following year by the same firm to a maximum depth of 100 m.

P. B. Read (1975) examined the drill cores from these holes to determine the alteration minerals and relative ages of the rock units. The host rock is predominantly a quartz diorite gneiss with 10%-30% quartz, <5% orthoclase, and the remainder

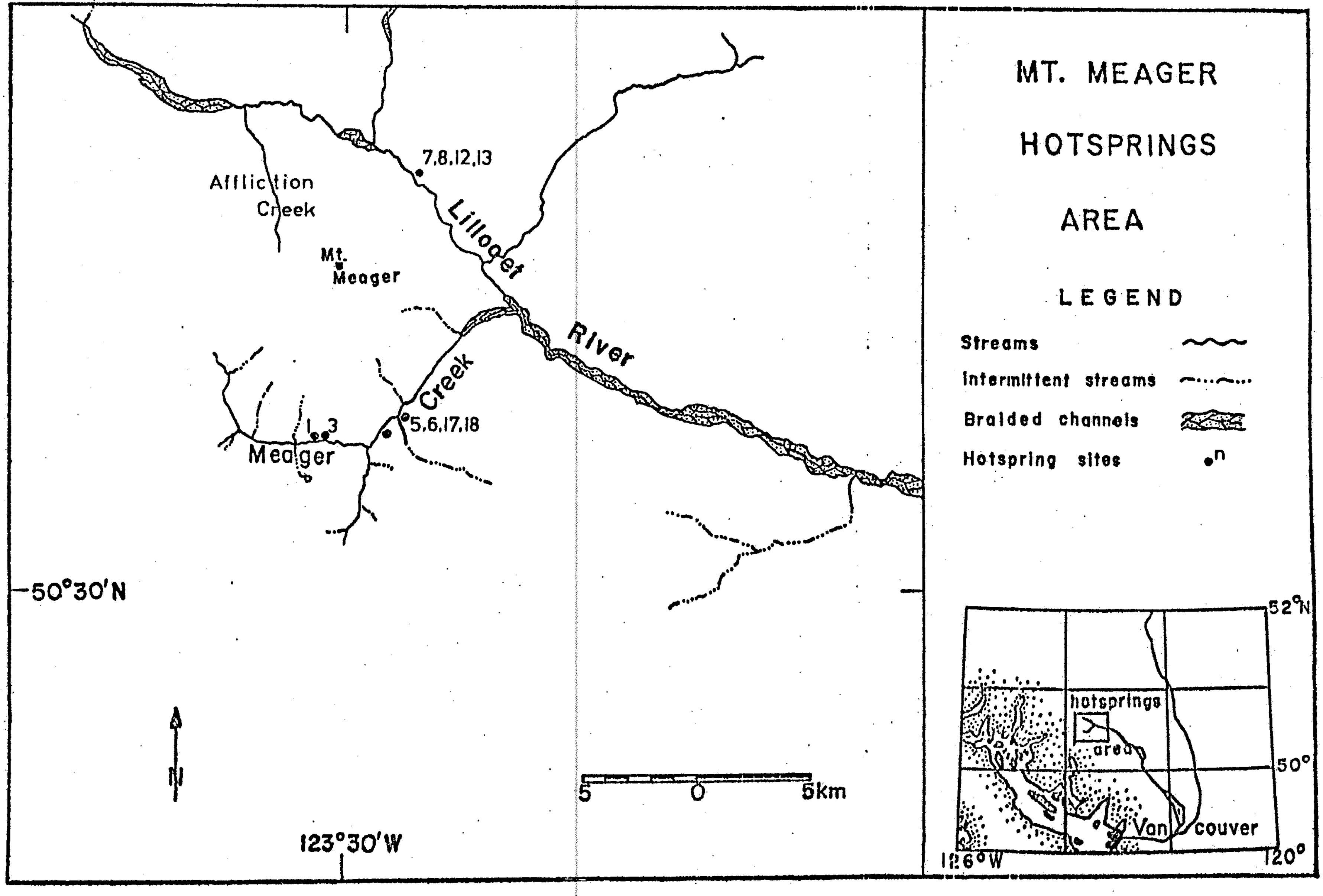

FIGURE 1: Hotsprings locations (●ⁿ) in the Mt. Meager area, B.C.

plagioclase (An_{32}-An_{40}). The fracture filling minerals observed were a calcium rich assemblage of calcite and/or clay minerals (kaolinite, illite, montmorillonite), laumontite, and minor amounts of heulandite. Gypsum was observed in minor amounts in half of the cores, while quartz was observed in one drill core. The sinter observed around the hotsprings vents was calcite, aragonite, and opaline silica (chalcedony).

SAMPLE SITES

The sample sites are located in the Meager Creek valley and the Lillooet River valley in the immediate vicinity of Mount Meager (see Figure 1). The samples are numbered according to their collection date. Therefore a site with more than one sampling period will have more than one sample number associated with it. Sample numbers 01 through 06, 17, 18, 21, and 22 are in the Meager Creek valley; 07 through 10, 12 through 14, 16, 19, and 20 are in the Lillooet River valley. The locations and collection dates of the samples are given in Table 1 and the locations of the thermal water samples are shown in Figure 1.

SAMPLING PROCEDURE

The sampling procedure used in this study is a modified version of the procedure developed by Presser and Barnes (1974) of the U.S.G.S. and requires 3.2 liters of sample water per site. The water is stored in polyethylene bottles that have been cleaned previously with a 10 per cent nitric acid solution.

At each sample site in situ water temperature and pH were recorded before the water samples were collected. The pH was determined with a meter capable of compensating for the temperature of the sample. The pH of the samples collected

Table 1: Sample numbers, collection dates, and locations

01	2/8/76	thermal seep at creek level 4.7 km upstream from GSC1
02	2/8/76	Meager Creek water adjacent to sample 01
03	2/8/76	thermal seep at creek level 4.4 km upstream from GSC1
04	2/8/76	fresh water from tributary of Meager Creek flowing from Pylon Peak, collected at Drill Camp No.2 (1975)
05	3/8/76	Meager main vent thermal spring adjacent to GSC1
06	3/8/76	thermal water from GSC1
07	1/9/76	thermal seep along Lillooet River bank
08	1/9/76	Lillooet main vent thermal spring on terrace 30 m above river
09	1/9/76	fresh water from stream adjacent to sample 08
10	2/9/76	Lillooet River water from upstream of thermal springs
11	13/11/76	fresh water from the upper reaches of Affliction Creek where it exits from the glacier ice
12	30/11/76	Same as sample 07
13	30/11/76	Same as sample 08
14	30/11/76	Same as sample 09
15	13/11/76	Same as sample 11
16	30/11/76	Same as sample 10
17	30/11/76	Same as sample 06
18	30/11/76	Same as sample 05
19	15/11/76	Lillooet River sample collected between the outlets of Pebble Creek and Meager Creek
20	15/11/76	Lillooet River sample collected 1 km downstream of the outlet of Meager Creek
21	30/11/76	fresh water from tributary entering Meager Creek 180 m upstream of GSC1
22	30/11/76	Meager Creek sample collected adjacent to drill hole 74-H-1

during the August 2 - August 3, 1976 period were determined with a portable Hach model 1975 pH meter. The pH of the remaining samples were determined with an Orion model 407A specific ion meter. Both meters used an Orion model 90-01 reference electrode and an Orion model 91-01-00 pH electrode.

The water sampling involved initial filtration with Whatman No.4 filter papers using a hand operated vacuum pump to provide the suction. Three one liter bottles were collected, two samples were acidified by adding 10 ml of concentrated nitric acid to each sample resulting in a pH of approximately 2 and one bottle was untreated. A 125 ml bottle was filled with 90 ml of distilled water and 10 ml of sample water which has been filtered at the site through a 0.01 micron Sartorius membrane filter to remove the colloidal silicic acid. A 125 ml bottle was filled with 100 ml of sample water and acidified with concentrated hydrochloric acid to approximately pH 2. During the November sampling periods only one acidified one liter bottle, one untreated one liter bottle, and the silica 125 ml bottle were collected because of transportation considerations.

ANALYTICAL PROCEDURES

The laboratory analyses for "reactive" silica, chloride, sulphate, bicarbonate, sodium, potassium, calcium, magnesium, manganese, and iron were completed in late February, 1977, with an interim analyses of available samples in September, 1976 (Hammerstrom and Brown,1977).

The "reactive" silica was determined using a colorimetric molybdate blue technique described by Rainwater and Thatcher

(1960). Because the samples had been filtered at the site to remove all colloidal material, a total silica determination was not necessary. The chloride ion concentration was determined with an Orion chloride ion electrode and the Orion model 407A specific ion meter. The sulphate ion was determined using a colorimetric technique described in Golterman (1969). The bicarbonate ion was determined using a standard alkalinity titration of the sample water with a dilute HCl acid solution as described in Golterman (1969). This latter technique measures all the anions contributing to the alkalinity; therefore, the bicarbonate concentrations represent the upper limit of total carbonate concentration. The sodium, calcium, potassium, and magnesium concentrations were determined by standard atomic absorption spectrophotometric techniques using a Varian Tectron Mark IV unit. The manganese and iron concentrations reported are for samples filtered through the 0.01 micron filter and for unfiltered duplicate samples to determine the colloidal contribution of these elements. The manganese and iron results indicate that actual ionic concentrations are lower than the total element concentrations determined with the unfiltered samples. Unfortunately, the ionic concentration is usually below detection limits. The trace metals Cu, Pb, and Zn were also analysed for using atomic absorption spectrophotometry, but all were below detection limit in concentration.

Determination of aluminum could not be done as it is present in ppb concentrations in most fresh waters and requires the use of flameless atomic absorption spectrophotometry. We are not equipped to complete this work, and the accuracy needed for the equilibrium calculations makes most commercial laboratory determinations not acceptable.

ANALYTICAL RESULTS

The analyses of the samples in parts per million concentration, their locations, in situ temperatures, and pH are listed in Table 2. The temperature and pH of the hotsprings range from 30.0°C to 59.0°C and 6.05 to 6.85 respectively, except site 07(12) which has a pH of 7.7 to 8.0. The stream waters have temperatures between -1.0 °C and 7.5 °C with a pH range of 7.10 to 7.80.

In order to determine whether analyses overlooked a major constituent of the waters, the electrical balance of each water sample was calculated. Because a solution will attain electrical neutrality, every water analysis can be checked for its completeness and accuracy by simply comparing the total molality of the anions in solution with the total molality of the cations in solution. Calculation of the total molalities of cations and anions for each water sample indicated that there was more anions than cations for some of the thermal waters(eg. 0.02 moles anions vs 0.018 moles cations). This discrepency can be attributed, in part, to the inherent error in the bicarbonate concentration.

A comparison of Meager Creek main vent hotsprings waters with the Lillooet River hotsprings waters indicates that the Meager Creek hotsprings waters have higher concentrations of reactive silica (80-102 ppm vs. 40-60 ppm), chloride (428-500 ppm vs. 67-72 ppm), potassium (44-52 ppm vs. 13.8-18.9 ppm),

Table 2 :

Analyses of samples from the Mt. Meager hotsprings area in parts per million concentrations

Sample	Date	Location	pH	T(°C)	$SiO_2(r)$	Cl	SO_4	HCO_3	Na	K	Mg	Ca	$Mn^{0.01}$	Mn	$Fe^{0.01}$	Fe
01	2/8/76	Meager	6.50	31.4	56.0	133	25	503	165	23.7	15.4	92.0	-	0.45	-	0.45
02	2/8/76	Meager	7.30	4.0	4.0	0.51	26	31	2.4	1.1	2.5	9.3	-	0.10	-	2.40
03	2/8/76	Meager	6.80	30.0	54.0	295	50	260	248	27.0	17.1	83.5	-	0.95	-	0.50
04	2/8/76	Meager	7.50	7.5	11.0	0.37	5	46	2.9	1.1	2.2	7.4	-	0.01	-	0.30
05	3/8/76	Meager	6.40	48.5	80.5	428	65	450	347	44.0	24.8	92.0	-	0.32	-	0.00
06	3/8/76	Meager	6.05	56.0	92.0	466	170	458	377	46.2	34.1	97.0	-	0.65	-	0.15
07	1/9/76	Lillooet	7.70	53.5	40.0	72	315	992	410	13.8	6.6	44.0	-	0.09	-	0.00
08	1/9/76	Lillooet	6.85	59.0	43.0	67	275	992	396	18.2	6.1	42.5	-	0.10	-	0.15
09	1/9/76	Lillooet	7.10	7.0	22.0	0.27	10	23	2.5	1.1	1.1	3.9	-	0.00	-	0.00
10	2/9/76	Lillooet	7.20	5.0	2.0	0.44	15	31	2.0	1.1	2.2	7.0	-	0.05	-	1.45
11	13/11/76	Afflict.	6.20	-1.0	10.0	2.17	50	122	8.0	2.1	10.0	47.0	-	0.53	-	1.85
12	30/11/76	Lillooet	8.00	50.5	44.0	72	340	1068	418	18.9	7.0	39.0	-	0.09	-	0.00
13	30/11/76	Lillooet	6.70	59.0	60.0	71	385	1053	405	18.9	7.0	32.5	-	0.11	-	0.15
14	30/11/76	Lillooet	7.30	6.0	18.0	0.45	3	38	2.0	1.0	0.5	3.3	-	0.00	-	0.00
15	13/11/76	Afflict.	7.80	0.0	8.5	0.61	75	183	8.0	2.0	10.5	47.0	0.40	0.50	-	1.60
16	30/11/76	Lillooet	7.40	0.0	10.0	1.01	39	76	13.5	1.7	3.0	15.7	-	0.04	-	0.30
17	30/11/76	Meager	6.15	56.5	96.0	500	180	686	410	52.0	40.5	105.0	0.50	0.65	-	0.30
18	30/11/76	Meager	6.60	50.0	102.0	500	145	595	390	48.5	31.0	92.0	0.25	0.34	-	0.00
19	15/11/76	Lillooet	7.75	1.3	4.5	0.46	24	46	3.5	1.1	2.5	14.1	-	0.03	-	0.30
20	15/11/76	Lillooet	7.75	2.0	3.0	1.56	25	53	5.5	1.2	3.0	16.3	-	0.02	-	0.25
21	30/11/76	Meager	7.50	-1.0	1.7	<.18	16	nd	2.0	1.5	1.0	15.4	-	0.00	-	0.01
22	30/11/76	Meager	7.50	0.0	1.7	1.38	25	nd	5.5	1.3	4.5	16.9	-	0.00	-	0.15

$SiO_2(r)$ refers to reactive silica

The superscript $^{0.01}$ refers to filtration through a 0.01 micron membrane filter

Afflict. refers to samples from Affliction Creek

nd refers to not determined

magnesium (24-40 ppm vs. 6.1-7.0 ppm), and calcium (92-105 ppm vs. 32-44 ppm). Lillooet River hotsprings waters have higher concentrations of sulphate (275-385 ppm vs. 65-180 ppm), bicarbonate (992-1068 ppm vs. 450-686 ppm), and a higher pH (6.7-8.0 vs 6.05-6.60). Both areas have similar sodium concentrations (347-418 ppm) and temperatures (48.5°C-59.0°C). Therefore, the Meager Creek hotsprings are basically a sodium chloride water with higher silica and major cation concentrations, and the Lillooet River hotsprings are basically a sodium bicarbonate water with a higher sulphate concentration and a higher pH.

DISTRIBUTION OF SPECIES CALCULATIONS

Whereas most analytical techniques measure the total concentration of an element, there are many ionic species which contribute to this total. For example, the analytically determined concentration of calcium consists of varying amounts of Ca^{+2}, $CaSO_4^0$, and $CaCO_3^0$ ions. In order to interpret the equilibrium conditions within the thermal waters, the concentrations of all ionic species must be known. Therefore, it is necessary to compute a distribution of species for each thermal water sample.

The distribution of species was performed using a computer program which follows the method of monotone sequences convergence developed by Wolery and Walters (1975). The program performs a similar function as the WATEQ program developed by Truesdall and Jones (1974) for interpretation of thermal water chemistry. The thermodynamic data used in the distribution of species program is from Helgeson (1969) for the aqueous species and Helgeson (1977,personal communication) and Robie and Waldbaum (1968) for minerals.

The distribution of species program also calculates the equilibrium constants (log K) for the formation of the minerals from the ionic species and calculates the log Q from the activities of the ionic species for a given water sample. If the log Q and log K values are equal, then equilibrium exists; if the log Q is less than the log K, then the solution is undersaturated with respect to the mineral; and if the log Q is greater than the log K, then the solution is supersaturated with respect to the mineral.

The initial constraints input into the distribution of species program for each water sample are the analytically determined molalities of total sodium, chloride, silicic acid, potassium, magnesium, calcium, sulphate, bicarbonate, and the pH. As stated previously the total aluminum concentration of the water samples could not be determined; thus, a constraint on aluminum was needed to compute a distribution of species on these waters. From the observations of the fracture filling minerals made by Read (1975) it was apparent that kaolinite was commonly present in the alteration assemblage and the waters would probably be in equilibrium with this mineral. Therefore kaolinite was considered as a constraint which would control the aluminum content within the waters.

The distribution of species for each thermal water sample at the in situ temperature and the minerals with which the waters are supersaturated are listed in Appendix A. In general, the thermal waters are saturated with respect to kaolinite, laumontite, quartz, chalcedony, and calcite. Some of the thermal waters are also supersaturated with respect to dolomite, but this mineral has not been observed in cores from the Meager area. Below 300°C disordered dolomite is the only polymorph that usually nucleates from an aqueous solution even though the solution may be supersaturated with respect to an ordered dolomite. The Lillooet samples 07 and 12 are interesting because their anomalous pH values of 7.7 and 8.0 result in the saturation of additional minerals including lawsonite, talc, clinochlore, chrysotile, and serpentine.

An examination of the analyses of samples 07 and 12 and of the adjacent samples 08 and 13 indicates that there are no appreciable differences in the chemistry of the waters. An explanation for the pH differences of the two sample sets is provided by the distribution of species tables in Appendix A. Observation of these tables indicates that the fugacity of CO_2 gas is much higher in samples 08 and 13 (0.28,0.32) than in samples 07 and 12 (0.034,0.016). Samples 07 and 12 are seeps from fractured bedrock cropping out along the banks of the Lillooet River, whereas samples 08 and 13 are from a single vent flowing from the bedrock on the terrace 30 m above the river. The loss of CO_2 gas from solution in the 07 and 12 samples is a result of the increase in surface area exposed to the atmosphere owing to fracturing of the bedrock. The loss of CO_2 gas from solution will cause the pH difference observed between the sampling areas.

The distribution of species for Meager main vent sample 05 at 321.65°K is given in Table 3. It indicates that the total

Table 3 : Distribution of species

MEAGER SAMPLE 05 at 321.65°K and 1 bar pressure calculated using the solution constraints determined from Table 2 analytical results

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DISTRIBUTION OF SPECIES CALLED AT STEP     0


                                                        AQUEOUS SPECIES

SPECIES        MOLALITY      LOG MOL     ACTIVITY      LOG ACT    ACT COEF     LG ACT C  GRAMS/KGM H2O       PPM         LOG PPM

 AL+++        0.39085E-13   -13.408   0.11701E-13    -13.932   0.29937E+00    -0.524    0.10546E-11        0.000       -8.978
 K+           0.11222E-02    -2.950   0.94768E-03     -3.023   0.84445E+00    -0.073    0.43882E-01       43.807        1.642
 NA+          0.15072E-01    -1.822   0.12825E-01     -1.892   0.85090E+00    -0.070    0.34650E+00      345.908        2.539
 CA++         0.22035E-02    -2.657   0.12091E-02     -2.918   0.54870E+00    -0.261    0.88317E-01       88.167        1.945
 MG++         0.96375E-03    -3.016   0.55337E-03     -3.257   0.57418E+00    -0.241    0.23431E-01       23.391        1.369
 H4SIO4       0.83750E-03    -3.077   0.83750E-03     -3.077   0.10000E+01     0.0      0.80497E-01       80.359        1.905
 SO4--        0.52931E-03    -3.276   0.27532E-03     -3.560   0.52016E+00    -0.284    0.50846E-01       50.759        1.706
 CO3--        0.11835E-05    -5.927   0.62445E-06     -6.205   0.52761E+00    -0.278    0.71023E-04        0.071       -1.149
 CL-          0.17084E-01    -1.767   0.14427E-01     -1.841   0.84445E+00    -0.073    0.60568E+00      604.650        2.782
 OH-          0.14534E-06    -6.838   0.12322E-06     -6.909   0.84774E+00    -0.072    0.24719E-05        0.002       -2.608
 H+           0.45415E-06    -6.343   0.39811E-06     -6.400   0.87661E+00    -0.057    0.45777E-06        0.000       -3.340
 H2O          0.55508E+02     1.744   0.99918E+00     -0.000   0.18001E-01    -1.745    0.10000E+04   998291.478        5.999
 AL(OH)++     0.69241E-11   -11.160   0.37993E-11    -11.420   0.54870E+00    -0.261    0.30458E-09        0.000       -6.517
 AL(OH)4-     0.67350E-09    -9.172   0.57308E-09     -9.242   0.85090E+00    -0.070    0.63990E-07        0.000       -4.195
 KSO4-        0.30552E-05    -5.515   0.25900E-05     -5.587   0.84774E+00    -0.072    0.41295E-03        0.412       -0.385
 CACO3        0.18592E-05    -5.731   0.18711E-05     -5.728   0.10064E+01     0.003    0.18609E-03        0.186       -0.731
 CASO4        0.90011E-04    -4.046   0.90587E-04     -4.043   0.10064E+01     0.003    0.12254E-01       12.233        1.088
 MGSO4        0.54202E-04    -4.266   0.54547E-04     -4.263   0.10064E+01     0.003    0.65245E-02        6.513        0.814
 HSO4-        0.22334E-07    -7.651   0.19004E-07     -7.721   0.85090E+00    -0.070    0.21680E-05        0.002       -2.665
 HCO3-        0.43808E-02    -2.358   0.37409E-02     -2.427   0.85393E+00    -0.069    0.26731E+00      266.850        2.426
 H2CO3        0.29911E-02    -2.524   0.30102E-02     -2.521   0.10064E+01     0.003    0.18553E+00      185.208        2.268
 HCL          0.42627E-13   -13.370   0.42898E-13    -13.368   0.10064E+01     0.003    0.15542E-11        0.000       -8.809
 MG(OH)+      0.45212E-07    -7.345   0.38471E-07     -7.415   0.85090E+00    -0.070    0.18681E-05        0.002       -2.729

 IONIC STRENGTH =  0.262270E-01                ELECTRICAL BALANCE =  0.850942E-13

                          GASES
                          -----

 NAME                     LOG K        ACTIVITY       LOG ACTIVITY


CARBON DIOXIDE           -8.17481     0.22292E+00       -0.65186
STEAM                     0.94784     0.11267E+00       -0.94820
```

concentrations of the ionic species correspond to the analytical total concentrations of the elements given in Table 2. For example, the distribution of the carbonate species CO_3^{-2} (0.071 ppm), HCO_3^- (266.8 ppm), $H_2CO_3^0$ (185.2 ppm), and $CaCO_3^0$ (0.186 ppm) totals 452.3 ppm, which corresponds to the analytical total bicarbonate of 450.0 ppm The computed Cl^- species concentration is 604.7 ppm, which is substantially greater than the analytical total chloride of 428.0 ppm. This is a result of choosing the chloride ion to maintain the electrical balance of the solution during the distribution of species calculations. The analytical bicarbonate total was 450.0 ppm, but in the distribution of the carbonate species the $H_2CO_3^0$ ion (which has a neutral charge) is 185 ppm of that total. Because chloride ion was used to maintain the electrical neutrality within the solution, more Cl^- ions were added to the solution to compensate for the loss of negatively charged bicarbonate ions. The distribution of the aluminum species Al^{+3}, $Al(OH)^{+2}$, and $Al(OH)^{-4}$ indicates a total of less than 1 ppb for equilibrium with kaolinite. This further substantiates the assumption that analytical techniques for determining ionic aluminum in waters are generally not sensitive enough.

Meager sample 05 is supersaturated with respect to laumontite, quartz, chalcedony, and cristobalite It is near equilibrium with calcite (log K = 1.344, log Q = 1.055) and is assumed to be in equilibrium with kaolinite.

When a distribution of species is performed on the same sample at 353.15°K, 20 ppm is changed from HCO_3^- ion to the $H_2CO_3^0$ ion (266 ppm and 185 ppm to 246 ppm and 205 ppm), and the

Cl^- ion is correspondingly increased (see Appendix A.1). There is a 3 ppb concentration of $Al(OH)^{-4}$ ion indicated for equilibrium of the solution with kaolinite to be maintained, which means more aluminum in solution can be expected at higher temperatures. The important observation is that now the solution is also supersaturated with respect to calcite (log K = 0.890, log Q = 0.996).

ACTIVITY DIAGRAMS

Activity diagrams are useful in portraying the stability relationships among minerals on a two dimensional surface. They are constructed using the method outlined in Garrels and Christ (1965). The diagrams are drawn using the computer program, DIAGRAM (Brown,1970), which utilizes the log K values of the minerals calculated by the distribution of species program. Examples of the DIAGRAM program's capabilities are the series of activity diagrams for various systems and temperatures in Helgeson et al (1969).

Constructing activity diagrams at various temperatures show that the equilibrium boundaries between the minerals will shift relative to the coordinate values. However, the coordinate values of the actual water analyses are basically independent of temperature and will plot in one position with respect to the axes coordinates, Therefore the equilibrium boundaries will shift with respect to the water analyses.

An equilibrium temperature for a solution can be estimated by determining the temperature at which the solution composition will plot along equilibrium boundaries of the minerals that are assumed to be in equilibrium. Therefore, equilibrium temperatures for the thermal waters in Appendix A can be estimated by varying the temperature at which the activity diagrams are constructed until the thermal waters plot along the boundaries of the assumed equilibrium assemblage minerals.

System $CaO-Al_2O_3-SiO_2-H_2O$

Activity diagrams for the system at 50°C, 80°C, 100°C, 125°C, and 150°C are given in Appendix B. These diagrams depict the stability relationships of the aluminum bearing minerals in the system. The diagrams are calculated conserving aluminum (ie. balancing on Al), and assuming the activity of water is one. The positions of the thermal water samples calculated from the distribution of ionic species in Appendix A are plotted on each diagram.

Figures 2, 3, and 4 are $\log \alpha Ca^{+2}/\log \alpha^2 H^+$ versus $\log \alpha H_4SiO_4^0$ diagrams at 50°C, 80°C, and 100°C respectively. The fracture filling assemblage observed by Read (1975) included laumontite, kaolinite, and heulandite. In order to estimate the equilibrium temperature it will be necessary to determine the temperature at which the thermal waters plot nearest to the equilibrium boundaries of the observed mineral assemblage. At 50°C (Figure 2) the thermal waters plot entirely within the heulandite stability field, and at 100°C (Figure 4) they plot entirely within the laumontite stability field. The equilibrium temperature is therefore between 50°C and 100°C and the best estimate of the temperature is 80°C (Figure 3). At this temperature the thermal waters plot near the boundaries of kaolinite-laumontite-heulandite equilibrium.

Figure 2 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 50°C and 1 bar pressure. Numbered dots correspond to thermal water samples in Appendix A.

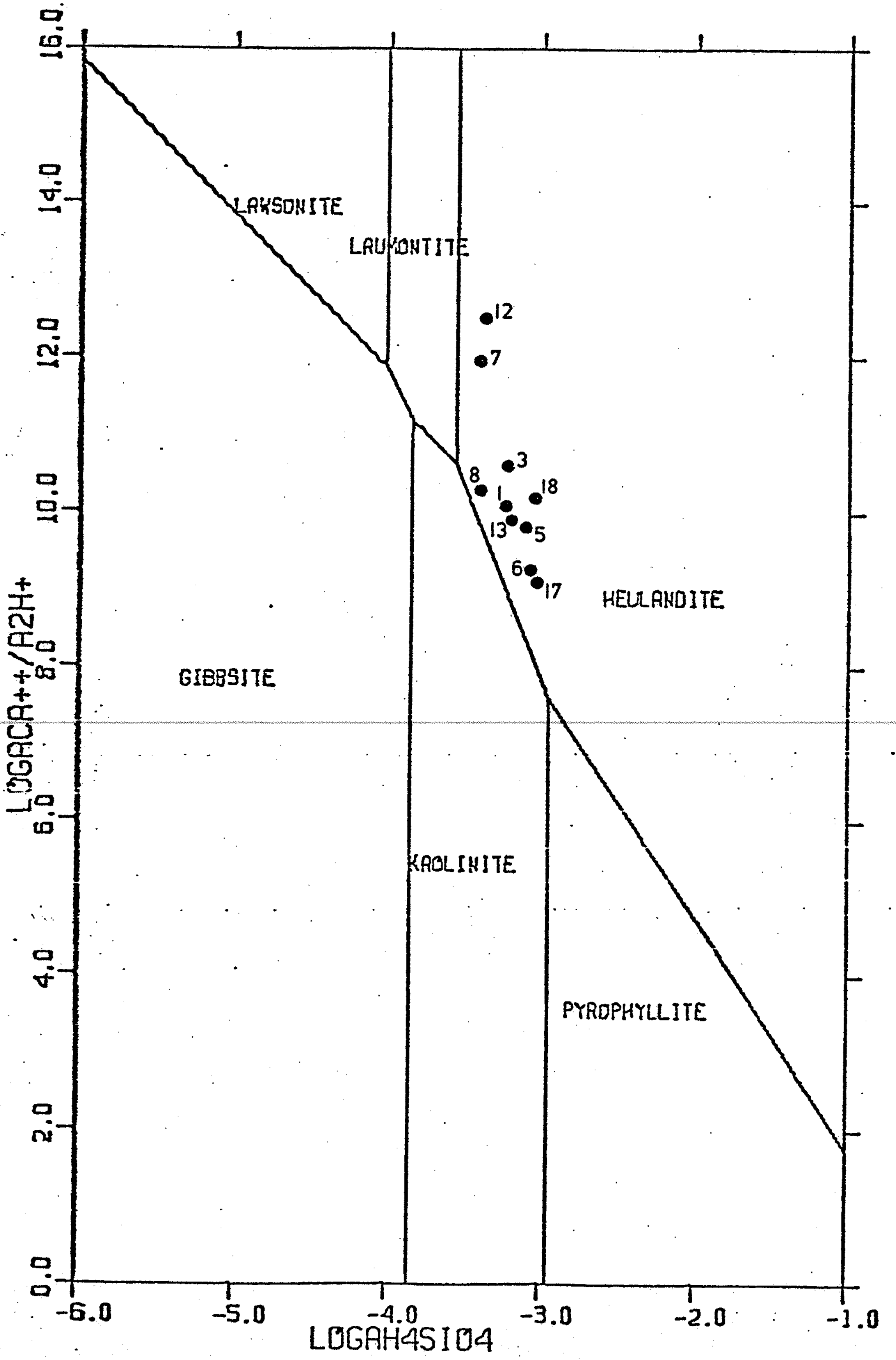


Figure 3 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 80°C and 1 bar pressure. Dots correspond to thermal water samples numbered in Figure 2.

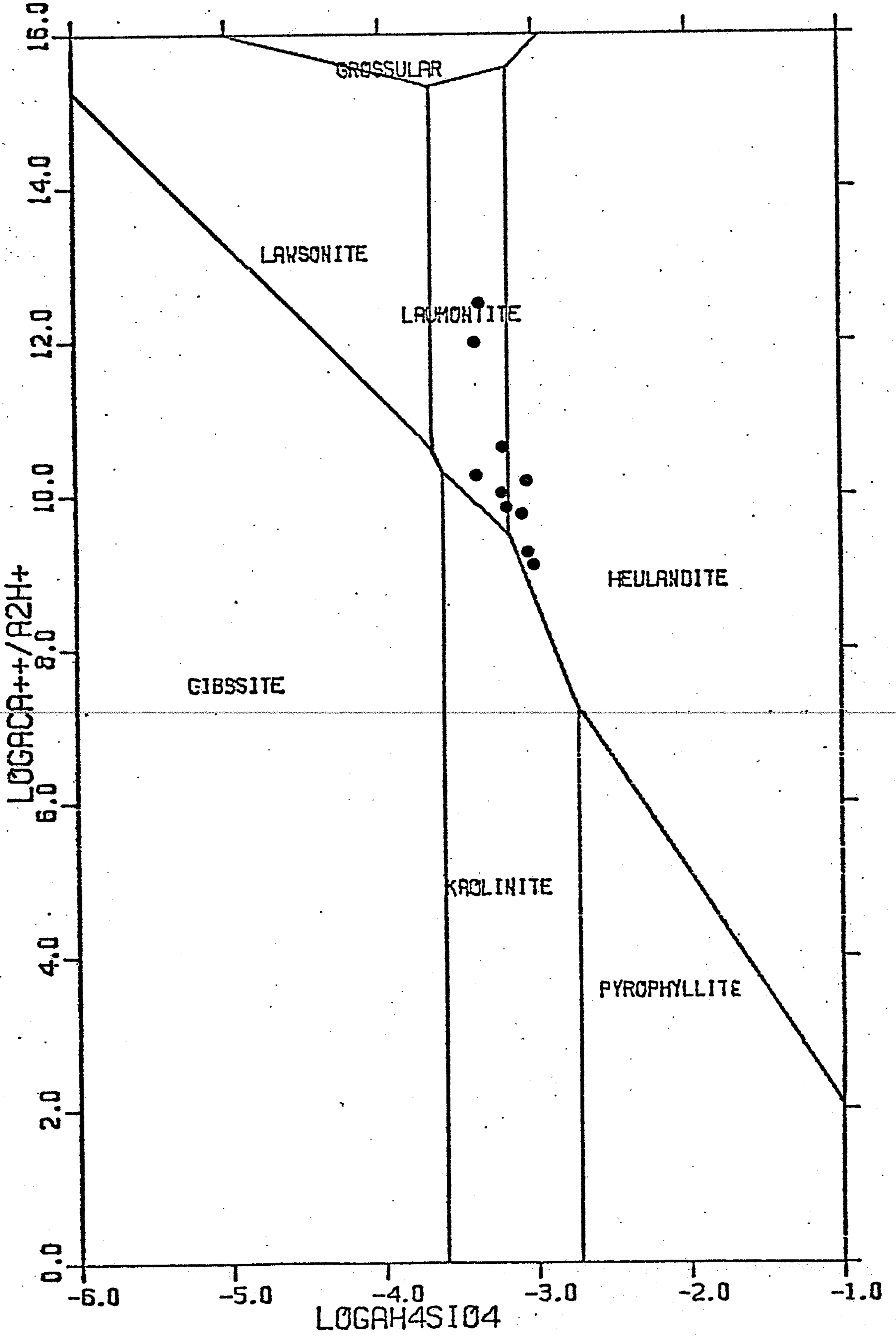
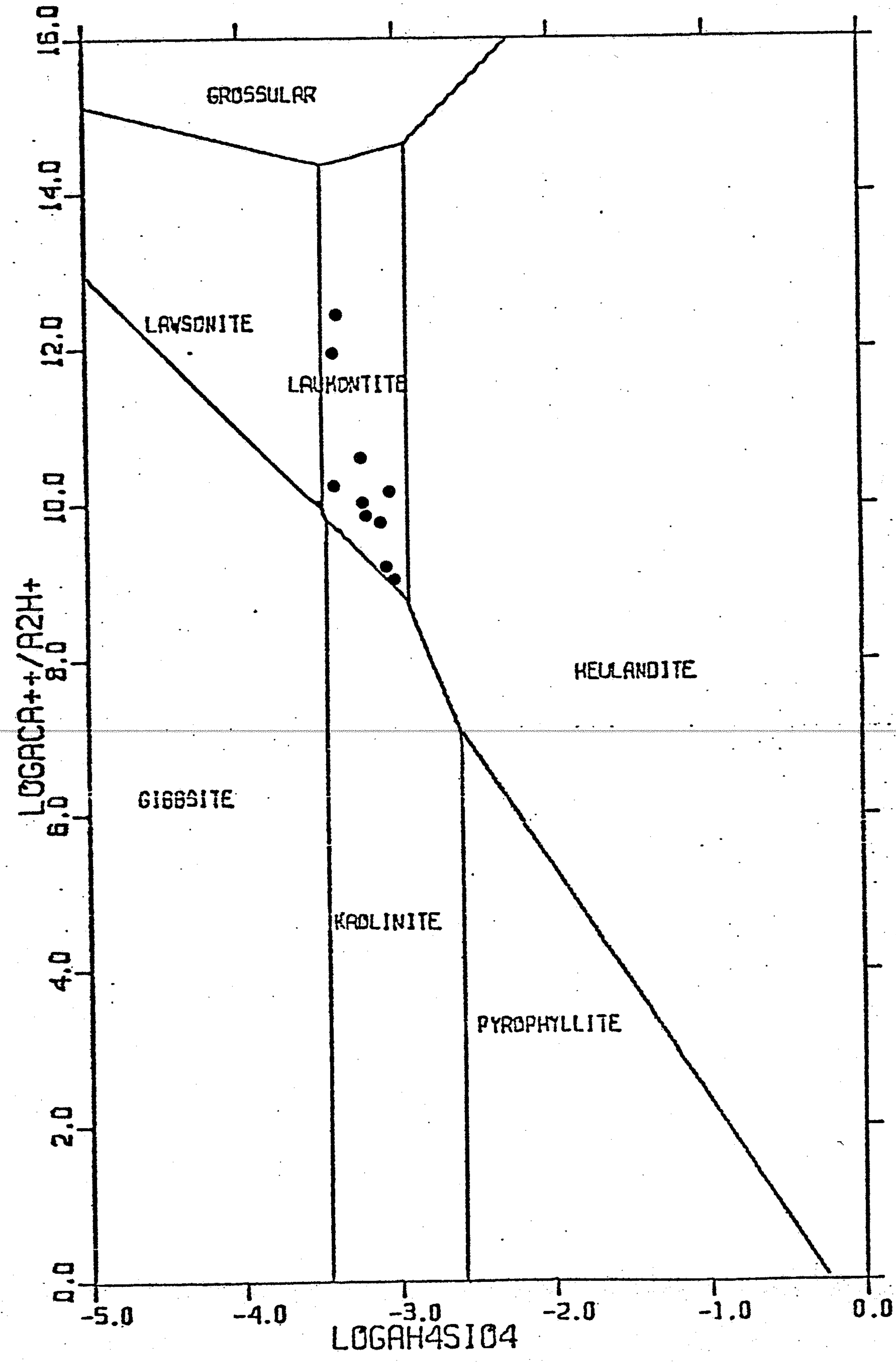


Figure 4 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 100°C and 1 bar pressure. Dots correspond to thermal water samples numbered in Figure 2.



The two anomalous thermal water sample positions which plot a log unit above the others on the $\log a\mathrm{Ca}^{+2}/\log a^2\mathrm{H}^+$ axis correspond to the Lillooet samples 07 and 12. These samples have relatively high pH values of 7.7 and 8.0 and because the axis coordinate is pH dependent, their higher pH is reflected in their plotted position.

System $CaO-MgO-Al_2O_3-SiO_2-H_2O$

Activity diagrams for this system at 50°C, 80°C, 85°C, 100°C, and 125°C are given in Appendix C.1 and Appendix C.2. These diagrams provide the stability relationships of the silicates in the system and are constructed conserving silicic acid (ie. balancing on $H_4SiO_4^0$), assuming the activity of water is one, and allowing the aluminum content ($\log a\mathrm{Al}^{+3}/\log a^3\mathrm{H}^+$) to be a variable. The variability of the aluminum ion within the thermal waters is not known, and, therefore, these diagrams are not as useful for estimating an equilibrium temperature as are the previous diagrams. The positions of the thermal waters calculated from the distributed species in Appendix A are plotted on each diagram.

An upper limit of aluminum within the waters can be determined by calculating the activity of aluminum ion needed to equilibrate with gibbsite, a mineral which was not observed within the alteration assemblage. The diagrams with $\log a\mathrm{Al}^{+3}/\log a^3\mathrm{H}^+$ values at gibbsite saturation for the various temperatures are in Appendix C.1. An arbitrarily set lower $\log a\mathrm{Al}^{+3}/\log a^3\mathrm{H}^+$ value of 3.0 was used to construct the diagrams in Appendix C.2 and the 85°C diagram is repeated as Figure 5.

Figure 5 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 85°C, 1 bar pressure, and $\log QAl^{+3}/\log Q^{3}H^{+} = 3.0$. Numbered dots correspond to thermal water samples in Appendix A.

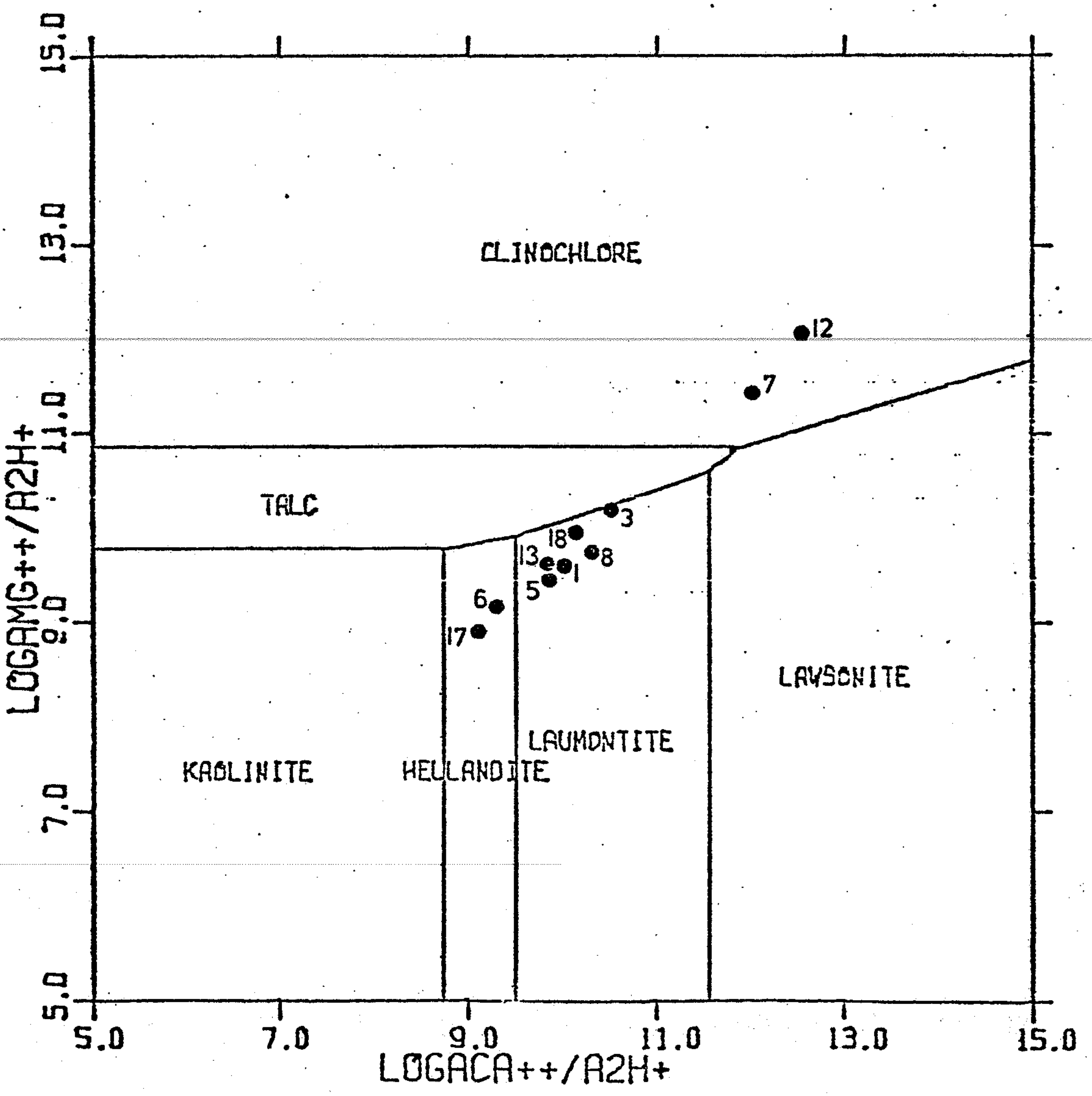


Figure 5 indicates that the thermal waters plot in the area of the laumontite, talc, and heulandite equilibria. However, the diagrams in Appendix C.1 (gibbsite saturation) show that heulandite and talc are not stable for this higher $\log\alpha Al^{+3}/\log\alpha^{3}H^{+}$ value. The stable minerals are now laumontite, kaolinite, and clinochlore, which means the probable $\log\alpha Al^{+3}/\log\alpha^{3}H^{+}$ value is between gibbsite saturation and 3.0. The diagrams in Appendix C.2 also indicate that heulandite becomes less stable with respect to laumontite at higher temperatures which is consistent with the observed abundance of the two minerals in the drill cores.

EQUILIBRIUM ASSEMBLAGE CALCULATION

The distribution of species program will accept solid phases as initial constraints and will calculate a distribution of ionic species for an aqueous solution in equilibrium with the solid phases. An equilibrium temperature of a solution and a mineral assemblage can be estimated by varying the temperature of the solid constrainted distribution of species calculation until the calculated species concentrations approximate the observed solution composition.

This principle can be applied to the thermal waters with the observed alteration assemblage of kaolinite, quartz, laumontite, and calcite specified as constraints on the aluminum, silica, calcium, and bicarbonate in the system. For example, the desired solution composition will be that of Meager sample 05 given in Table 3. The equilibrium temperature can be estimated when the computed total concentrations of calcium, bicarbonate, and silicic acid are approximately equal to the observed totals in Table 3.

The distribution of species using the mineral constraints were calculated at 5°C intervals from 70°C to 100°C. The results were very sensitive to temperature and the distributions of species at 75°C, 80°C, and 85°C are given in Appendix D. The estimated equilibrium temperature of the mineral assemblage and the Meager 05 solution is 80°C (see Table 4). At this temperature the calcium total is 70.6 ppm and the carbonate total is 492.5 ppm These correspond to the observed calcium total of 100.6 ppm and carbonate total of 452.3 ppm. An increase in temperature of 5°C results in a lower calcium total (50 ppm) and a higher carbonate total (630 ppm). A decrease in temperature of 5°C reverses the trend and results in a higher calcium total (102 ppm) and a lower carbonate total (382 ppm). The best estimate of equilibrium temperature is obtainable by interpolating between 75°C and 80°C and at 78°C results of 88 ppm for the calcium total and 447 ppm for the carbonate total were calculated.

The silicic acid concentrations of 42.8 ppm (75°C), 48.5 ppm (80°C), and 54.8 ppm (85°C) are indicating the increasing solubility of quartz with increasing temperature. A 100°C distribution of species indicates a concentration of 77.5 ppm for $H_4SiO_4^0$, which approximates the sample 05 value of 80.4 ppm, but the calcium total is only 20.7 ppm and the carbonate total is 1274.4 ppm (see Appendix D.1). Therefore the silicic acid concentration can not be used to predict the equilibrium temperature of the Meager sample 05 solution and the mineral

Table 4 : Distribution of species

MEAGER SAMPLE 05 at 353.15°K and 1 bar pressure calculated using alpha quartz, kaolinite, laumontite, and calcite as solid constraints replacing $H_4SiO_4^\circ$, Al^{+3}, Ca^{+2}, and HCO_3^- solution constraints used to calculate Table 3

```
DISTRIBUTION OF SPECIES CALLED AT STEP      0

                                                      AQUEOUS SPECIES

SPECIES        MOLALITY     LOG MOL    ACTIVITY      LOG ACT    ACT COEF     LG ACT C  GRAMS/KGM H2O        PPM         LOG PPM

 AL+++        0.56755E-14   -14.246  0.17471E-14   -14.758  0.30783E+00    -0.512   0.15313E-12          0.000       -9.816
 K+           0.11210E-02    -2.950  0.95319E-03    -3.021  0.85033E+00    -0.070   0.43832E-01         43.769        1.641
 NA+          0.11509E-01    -1.939  0.98511E-02    -2.007  0.85598E+00    -0.068   0.26458E+00        264.202        2.422
 CA++         0.14735E-02    -2.832  0.82402E-03    -3.084  0.55921E+00    -0.252   0.59060E-01         58.975        1.771
 MG++         0.89012E-03    -3.051  0.51835E-03    -3.285  0.58233E+00    -0.235   0.21641E-01         21.610        1.335
 H4SIO4       0.50558E-03    -3.296  0.50558E-03    -3.296  0.10000E+01     0.0     0.48594E-01         48.525        1.686
 SO4--        0.45802E-03    -3.339  0.24436E-03    -3.612  0.53350E+00    -0.273   0.43999E-01         43.936        1.643
 CO3--        0.12597E-05    -5.900  0.68047E-06    -6.167  0.54019E+00    -0.267   0.75593E-04          0.075       -1.122
 CL-          0.12059E-01    -1.919  0.10254E-01    -1.989  0.85033E+00    -0.070   0.42754E+00        426.931        2.630
 OH-          0.72311E-06    -6.141  0.61697E-06    -6.210  0.85321E+00    -0.069   0.12298E-04          0.012       -1.911
 H+           0.45295E-06    -6.344  0.39811E-06    -6.400  0.87893E+00    -0.056   0.45656E-06          0.000       -3.341
 H2O          0.55508E+02     1.744  0.99935E+00    -0.000  0.18004E-01    -1.745   0.10000E+04     998571.520        5.999
 AL(OH)++     0.11838E-10   -10.927  0.66201E-11   -11.179  0.55921E+00    -0.252   0.52076E-09          0.000       -6.284
 AL(OH)4-     0.57773E-07    -7.238  0.49453E-07    -7.306  0.85598E+00    -0.068   0.54891E-05          0.005       -2.261
 KSO4-        0.43378E-05    -5.363  0.37010E-05    -5.432  0.85321E+00    -0.069   0.58631E-03          0.585       -0.232
 CACO3        0.29264E-05    -5.534  0.29391E-05    -5.532  0.10043E+01     0.002   0.29291E-03          0.292       -0.534
 CASO4        0.86681E-04    -4.062  0.87057E-04    -4.060  0.10043E+01     0.002   0.11801E-01         11.784        1.071
 MGSO4        0.12751E-03    -3.894  0.12806E-03    -3.893  0.10043E+01     0.002   0.15348E-01         15.326        1.185
 HSO4-        0.51015E-07    -7.292  0.43668E-07    -7.360  0.85598E+00    -0.068   0.49520E-05          0.005       -2.306
 HCO3-        0.43746E-02    -2.359  0.37562E-02    -2.425  0.85865E+00    -0.066   0.26692E+00        266.543        2.426
 H2CO3        0.36470E-02    -2.438  0.36629E-02    -2.436  0.10043E+01     0.002   0.22621E+00        225.886        2.354
 HCL          0.45966E-12   -12.338  0.46166E-12   -12.336  0.10043E+01     0.002   0.16760E-10          0.000       -7.776
 MG(OH)+      0.37463E-06    -6.426  0.32067E-06    -6.494  0.85598E+00    -0.068   0.15479E-04          0.015       -1.811

 IONIC STRENGTH =   0.201807E-01                      ELECTRICAL BALANCE = -0.466522E-10

                                   GASES
                                   -----

 NAME                              LOG K           ACTIVITY          LOG ACTIVITY


CARBON DIOXIDE                     0.39254         0.40448E+00         -0.39310
STEAM                              0.33365         0.46352E+00         -0.33393
```

assemblage.

Gypsum was observed by Read (1975) in three drill cores, but its addition to the constraining mineral assemblage in the form of anhydrite resulted in large total calcium and sulphate being required for equilibrium, The distribution of species at 80°C and 85°C are given in Appendix E. They indicate a total calcium of 382.0 ppm and a total sulphate of 2096.8 ppm are required for equilibrium at 80°C, and a total calcium of 338.4 ppm and a total sulphate of 2750.7 ppm are required for equilibrium at 85°C. None of the thermal waters analysed in this study have calcium or sulphate total concentrations at those levels, and, therefore, equilibrium with anhydrite or gypsum is unlikely. In Nevin et al (1975) an analysis for a thermal water from drill hole 74-H-1, between 406' and 1140' depths, reported a calcium total of 380 ppm and a sulphate total of 1880 ppm in solution. These concentrations correspond to the predicted equilibrium concentrations at 80°C and therefore it is possible that equilibrium between that thermal solution and anhydrite or gypsum does exist.

MASS TRANSFER CALCULATION

The introduction of an aqueous phase into a mineral assemblage with which it is not in equilibrium results in the production of new minerals in response to changes in the composition of the aqueous phase as the system tends toward overall equilibrium. In order to test this hypothesis in the genesis of the Meager thermal waters, we have carried out mass transfer calculations, using the method of Helgeson et al (1970).

Because the dominant host rock observed in the drill cores by Read (1975) was a quartz diorite gneiss containing 70% - 90% plagioclase (An_{32}-An_{40}) the initial reactant chosen for the mass transfer calculation was a plagioclase of An_{33}. The initial solution composition used in the calculation is given in Table 5 and is a modified Meager thermal water with a slightly lower pH.

The calculation of the reaction of this solution with the plagioclase was completed for a temperature of 50°C and a total pressure of 1 bar. The results of the calculation are given in Figure 6 and in Table 5. Figure 6 is a plot of the mass of minerals produced and destroyed (kgm H_2O)$^{-1}$ as a function of the reaction progress (ξ). Table 5 gives the solution composition, in log molalitites, at each mineral producing or destroying event.

The reaction of albite + anorthite with the aqueous phase is depicted in Figure 6. The initial reaction remains congruent until the solution becomes saturated with kaolinite at (a), which is not shown in Figure 6, but occurs at a log ξ of -9.697. Kaolinite then precipitates until (b) where the solution becomes saturated with respect to chalcedony. Kaolinite and chalcedony then coprecipitate between (b) and (c) where the solution becomes saturated with respect to calcite. As the reaction of albite + anorthite with the solution continues, kaolinite, chalcedony, and calcite coprecipitate until the solution becomes saturated with respect to laumontite at (d). As the reaction continues, laumontite precipitates, while kaolinite, chalcedony, and calcite dissolve until the calcite is completely destroyed at (e). If the reaction is allowed to

Figure 6 : Diagram of log grams of minerals produced and destroyed per kgm H_2O versus log reaction progress (logξ) for the reaction of a plagioclase (An_{33}) and a solution of the composition given in Table 5.
The reaction occurs at 50°C and 1 bar pressure.

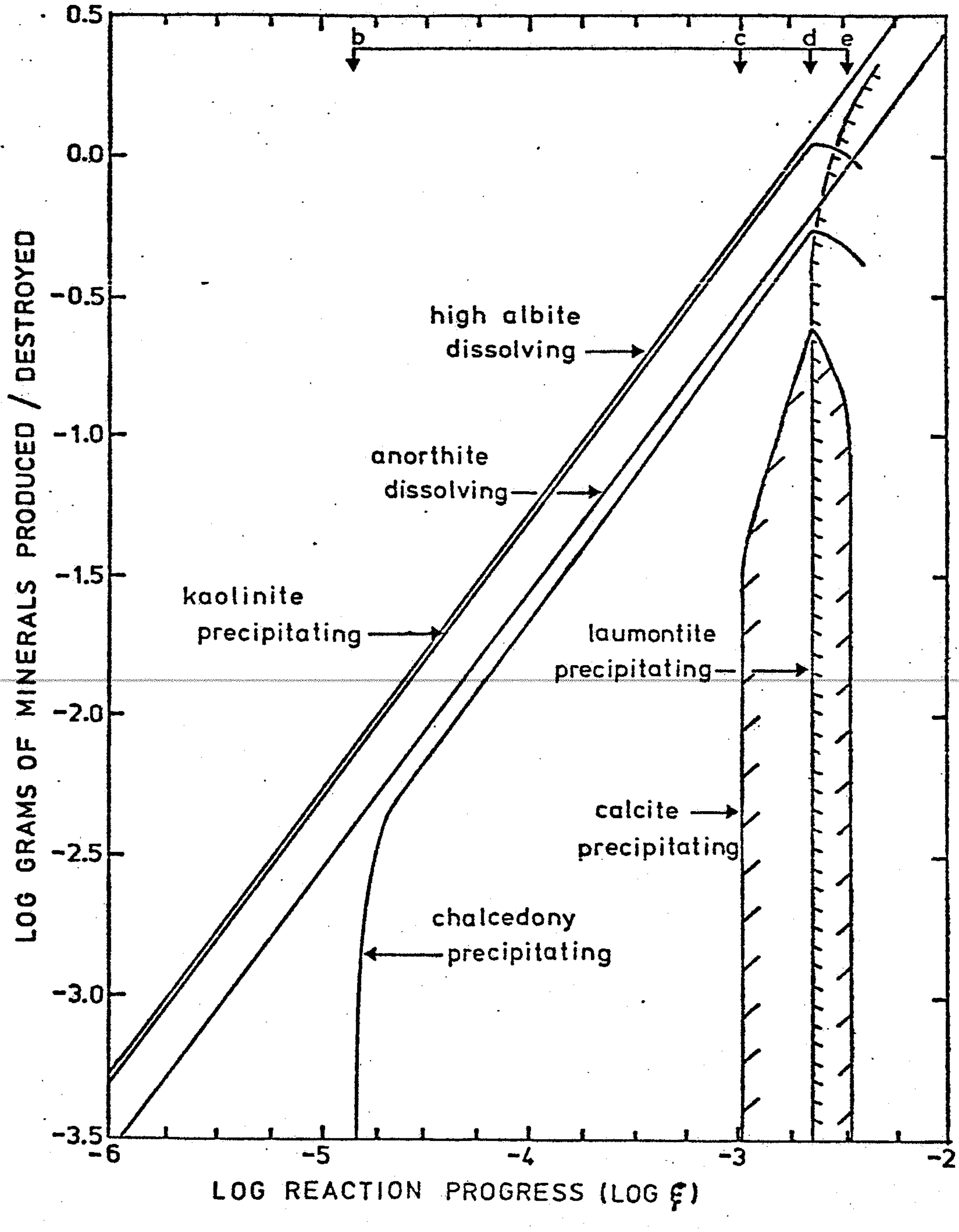


TABLE 5 : Solution Distribution of Species (log molality) at Mass Transfer Events

SPECIES	Initial	kaolinite(a)	chalcedony(b)	calcite(c)	laumontite(d)	calcite(e)
AL+++	-12.859	-11.915	-12.018	-13.542	-14.782	-14.982
K+	-2.950	-2.950	-2.950	-2.950	-2.950	-2.950
NA+	-1.822	-1.822	-1.820	-1.758	-1.689	-1.645
CA++	-3.247	-3.245	-3.224	-2.855	-3.315	-3.450
MG++	-3.022	-3.022	-3.022	-3.018	-3.020	-3.019
H4SIO4	-3.472	-3.463	-3.404	-3.404	-3.404	-3.404
SO4--	-3.238	-3.238	-3.239	-3.257	-3.230	-3.225
CO3--	-6.259	-6.258	-6.232	-5.456	-4.993	-4.845
CL-	-1.892	-1.892	-1.892	-1.892	-1.892	-1.892
OH-	-7.205	-7.204	-7.188	-6.663	-6.249	-6.177
H2O	1.744	1.744	1.744	1.744	1.744	1.744
AL(OH)++	-10.943	-9.998	-10.086	-11.106	-11.933	-12.067
AL(OH)4-	-10.053	-9.105	-9.149	-8.624	-8.210	-8.138
KSO4-	-5.445	-5.445	-5.446	-5.486	-5.461	-5.463
CACO3	-6.598	-6.595	-6.549	-5.444	-5.445	-5.445
CASO4	-4.547	-4.546	-4.527	-4.217	-4.653	-4.796
MGSO4	-4.174	-4.174	-4.176	-4.229	-4.207	-4.214
HSO4-	-7.178	-7.179	-7.196	-7.750	-8.138	-8.209
HCO3-	-2.280	-2.280	-2.270	-2.029	-1.981	-1.908
H2CO3	-2.040	-2.040	-2.046	-2.330	-2.696	-2.696
HCL°	-13.028	-13.029	-13.044	-13.570	-13.984	-14.057
MG(OH)+	-7.691	-7.690	-7.675	-7.163	-6.751	-6.684
pH	6.000	6.001	6.016	6.535	6.949	7.020

continue, then kaolinite, chalcedony, and laumontite form as the plagioclase is destroyed. Later events in the reaction include talc and K-mica precipitation, but for this simplified model the talc and K-mica equilibria are very dependent on the initial choice of solution composition.

The changes in composition of the aqueous solution are given in Table 5. The major changes in the solution are the constant increasing of the pH and the decreasing of calcium after laumontite equilibrates.

The relative mass of each of the minerals in the system at each event in the reaction are given in Table 6. There is a constant decrease in the amount of the reactant minerals present with a corresponding increase in the mass of kaolinite, chalcedony, and calcite until laumontite equilibrates. At the point where laumontite equilibrates (d) there are 1.23 gm of kaolinite, 0.57 gm of chalcedony, and 0.24 gm of calcite in the system. When calcite is completely destroyed at reaction event (e), the mass of kaolinite is 0.92 gm, the mass of chalcedony is 0.43 gm, and the mass of laumontite is 1.89 gm.

The mass transfer calculation indicated that it is possible to form the observed alteration assemblage of kaolinite, laumontite, calcite, and chalcedony by simply reacting a solution similar to the thermal water solution with a plagioclase host rock. Precipitation of laumontite results in the destruction of calcite in the system, which is consistent with the observed non-association of the two minerals.

At a higher temperature of 80°C the reaction of the same host rock and solution resulted in precipitation of laumontite

Table 6 : Relative mass (grams) of each of the minerals present at the mass transfer events depicted in Figure 6 and Table 5.

MINERAL	EVENTS				
	kaolinite(a)	chalcedony(b)	calcite(c)	laumontite(d)	calcite(e)
anorthite	3.0000 gm	2.9960 gm	2.7180 gm	2.3360 gm	1.9460 gm
albite	5.0000	4.9930	4.4680	3.7480	3.0130
kaolinite	0.0000	0.0074	0.5237	1.2320	0.9209
chalcedony	0.0000	0.0000	0.2403	0.5702	0.4252
calcite	0.0000	0.0000	0.0000	0.2423	0.0000
laumontite	0.0000	0.0000	0.0000	0.0000	1.8860

before the solution could saturate with respect to calcite and calcite was never produced as a reaction product. Therefore, at temperatures of 50°C kaolinite, chalcedony, calcite, and laumontite can be produced, but at temperatures of 80°C and higher laumontite prevents the formation of calcite.

GEOTHERMOMETERS

The currently available geothermometers for the estimation of subsurface temperatures of thermal waters are not applicable to the thermal waters in this study.

Fournier and Truesdall (1973) state that the Na-K-Ca geothermometer will give high estimated temperatures for a high carbonate and calcium thermal water because of calcite precipitation. The thermal waters in the Mount Meager area are carbonate and calcium rich and do precipitate calcite and other calcium-bearing minerals. Therefore the Na-K-Ca geothermometer should not be used for estimation of subsurface temperatures of these thermal waters.

Fournier and Truesdall (1974) state that the silica geothermometer (Fournier and Rowe, 1966) is reliable for high silica content waters characterized by sinter deposits and boiling temperatures. For warm spring waters they recommend caution in using the silica geothermometer because the silica content may be a result of solution and precipitation of other silicates.

The thermal waters under study, as well as most low temperature thermal waters, are supersaturated with respect to quartz and the silica geothermometer predicts subsurface temperatures of 92°C to 138°C. The silica geothermometer is based on the equilibrium of quartz with the water, but as has been stated quartz generally does not control the silica content of low temperature waters. Therefore the silica geothermometer will give high estimated subsurface temperatures for warm thermal waters and should, in general, not be used.

CONCLUSIONS

The chemical analyses of the thermal waters from the Mount Meager hotsprings area show two distinct water chemistries. The Meager Creek hotsprings are basically a sodium chloride water with higher silica and major cation concentrations and the Lillooet River hotsprings are basically a sodium bicarbonate water with a higher sulphate concentration and a higher pH.

The distribution of species calculations for the thermal waters and the plotting of the water chemistries on activity diagrams indicate that the waters are near equilibrium with kaolinite, laumontite, chalcedony, and calcite. This predicted assemblage is matched closely by the observed fracture filling minerals determined by Read (1975). The "best" estimated temperature of formation of the observed alteration assemblage using the activity diagrams and chemical equilibria calculations appears to be 60°C to 80°C.

The mass transfer calculations support the model that the water chemistry and the alteration assemblage are the result of a reaction of the ascending waters with a plagioclase-rich host rock. The inferred temperatures from the mass transfer calculations are in the 50°C to 80°C range.

The currently available geothermometers are not applicable to the Mount Meager hotsprings. The use of the silica and Na-K-

Ca geothermometers are applicable only to the special types of waters for which they were derived. Because of potential reactions between thermal waters and rocks, there can be no panacea for predicting subsurface water temperatures.

Because the thermal waters of the Mount Meager area appear to be near equilibrium with the near surface alteration assemblages, there is no indication in the chemistry of these waters as to their previous history. This conclusion neither supports nor denies the existence of higher subsurface water temperatures in the Mount Meager area. However, the simplest model would point to a shallow groundwater circulation with the water temperatures reaching a maximum of approximately 100°C.

REFERENCES

BROWN, T.H., ms, 1970. Theoretical predictions of equilibria and mass transfer in the system CaO-MgO-SiO_2-H_2O-CO_2-NaCl-HCl. Ph.D. dissert., Northwestern Univ., Evanston, Ill.

FOURNIER, R.O. and ROWE, J.J., 1966. Estimation of underground temperatures from the silica content of water from hot springs and wet-steam wells. Amer. Jour. Sci., Vol. 264, p. 685-697.

FOURNIER, R.O. and TRUESDALL, A.H., 1973. An empirical Na-K-Ca geothermometer for natural waters. Geochim. Cosmochim. Acta, Vol. 37, p. 1255-1275.

FOURNIER, R.O. and TRUESDALL, A.H., 1974. Geochemical indicators of subsurface temperature - Part 2, Estimation of temperature and fraction of hot water mixed with cold water. Jour. Res. U.S.G.S., Vol. 2, No. 3, p. 263-270.

GARRELS, R.M. and CHRIST, C.L., 1965. Solutions, Minerals, and Equilibria. Freeman, Cooper & Co. San Fransisco. pp. 450.

GOLTERMAN, H.L., 1969. (editor). Methods for Chemical Analysis of Fresh Waters. IBP Handbook No. 8. Blackwell Scientific Publications, Oxford. pp. 166.

HAMMERSTROM, L.T. and BROWN, T.H., 1977. Geochemistry of thermal waters in the Mount Meager Hotsprings area, British Columbia. Report of Activities, Part A, GSC Paper 77-1A (1977). p. 283-285.

HELGESON, H.C., 1969. Thermodynamics of hydrothermal systems at elevated temperatures and pressures. Amer. Jour. Sci., Vol. 267, p. 729-804.

HELGESON, H.C., BROWN, T.H., and LEEPER, R.H., 1969. Handbook of Theoretical Activity Diagrams depicting Chemical Equilibria in Geologic systems involving an aqueous phase at one atm. and 0-300°C. Freeman, Cooper & Co., San Fransisco. pp. 253.

HELGESON, H.C., BROWN, T.H., NIGRINI, Andrew, and JONES, Thomas A., 1970. Calculation of mass transfer in geochemical processes involving aqueous solutions. Geochim. Cosmochim. Acta, Vol. 34, p. 569-592.

NEVIN, SADLIER - BROWN, GOODBRAND, LTD., 1975. Report on Detailed Geothermal Investigation at Meager Creek. B.C. Hydro and Power Authority, internal report.

PRESSER, T.S. and BARNES, I., 1974. Special Techniques for determining Chemical Properties of Geothermal Water. U.S.G.S. Water Resour. - Invest. 22-74, pp. 11.

RAINWATER, F.H. and THATCHER, L.L., 1960. Methods for calculation and analysis of water samples. U.S.G.S. Water Supply Paper 1454, pp.301

READ, P.B., 1975. In: Report on Detailed Geothermal Investigation at Meager Creek. Nevin, Sadlier-Brown, Goodbrand, Ltd. B.C. Hydro and Power Authority, internal report. Appendix F.

READ, P.B., 1977. Meager Creek Volcanic Complex, Southwestern British Columbia. Report of Activities, Part A, GSC Paper 77-1A (1977) p.277-281.

ROBIE, R.A. and WALDBAUM, D.R., 1968. Thermodynamic Properties of Minerals and Related Substances at 298.15°K(25.0°C) and One Atmosphere (1.013 bars) Pressure and at Higher Temperatures. U.S.G.S. Bull. 1259. pp.256.

SOUTHER, J.G., 1977. Geothermal Potential of Western Canada. 2 nd U.N. Symposium on the Development and Use of Geothermal Power.

TRUESDALL, A.H. and JONES, B.F., 1974. WATEQ, A computer program for calculating chemical equilibria of natural waters. U.S.G.S. Jour. Res. Vol.2, No.2, p. 233-248.

WOLERY, T.J. and WALTERS, L.J. Jr., 1975. Calculations of equilibrium distribution of chemical species in aqueous solutions by means of monotone sequences. Jour. Math. Geol. Vol. 7, No. 2, p. 99-115.

APPENDIX A

1. Tables of distribution of species for each thermal water sample calculated at the in situ water temperature and 1 bar pressure using the solution constaints determined from Table 2 (assuming kaolinite constrains Al).
2. Tables of minerals with which the thermal waters are supersaturated and the log K and log Q values in each case.

Table A-1 : Distribution of species

```
MEAGER SAMPLE 01      at 304.55°K and 1 bar pressure calculated using solution constraints from Table 2


DISTRIBUTION OF SPECIES CALLED AT STEP     0


                                                     AQUEOUS SPECIES

SPECIES      MOLALITY     LOG MOL    ACTIVITY     LOG ACT   ACT COEF    LG ACT C  GRAMS/KGM H2O      PPM        LOG PPM

 AL+++      0.10999E-12   -12.959  0.40604E-13   -13.391  0.36915E+00   -0.433   0.29678E-11        0.000      -8.528
 K+         0.60422E-03    -3.219  0.52824E-03    -3.277  0.87424E+00   -0.058   0.23626E-01       23.599       1.373
 NA+        0.71771E-02    -2.144  0.63056E-02    -2.200  0.87857E+00   -0.056   0.16500E+00      164.808       2.217
 CA++       0.22554E-02    -2.647  0.13857E-02    -2.858  0.61441E+00   -0.212   0.90395E-01       90.289       1.956
 MG++       0.62289E-03    -3.206  0.39476E-03    -3.404  0.63375E+00   -0.198   0.15144E-01       15.126       1.180
 H4SIO4     0.58200E-03    -3.235  0.58200E-03    -3.235  0.10000E+01    0.0     0.55939E-01       55.874       1.747
 SO4--      0.21093E-03    -3.676  0.12508E-03    -3.903  0.59298E+00   -0.227   0.20263E-01       20.239       1.306
 CO3--      0.12920E-05    -5.889  0.77333E-06    -6.112  0.59855E+00   -0.223   0.77533E-04        0.077      -1.111
 CL-        0.79309E-02    -2.101  0.69335E-02    -2.159  0.87424E+00   -0.058   0.28117E+00      280.846       2.448
 OH-        0.58240E-07    -7.235  0.51044E-07    -7.292  0.87645E+00   -0.057   0.99051E-06        0.001      -3.005
 H+         0.35276E-06    -6.453  0.31623E-06    -6.500  0.89645E+00   -0.047   0.35557E-06        0.000      -3.450
 H2O        0.55508E+02     1.744  0.99950E+00    -0.000  0.18006E-01   -1.745   0.10000E+04   998836.719       5.999
 AL(OH)++   0.65110E-11   -11.186  0.40004E-11   -11.398  0.61441E+00   -0.212   0.28641E-09        0.000      -6.544
 AL(OH)4-   0.11903E-09    -9.924  0.10457E-09    -9.981  0.87857E+00   -0.056   0.11309E-07        0.000      -4.947
 KSO4-      0.57921E-06    -6.237  0.50765E-06    -6.294  0.87645E+00   -0.057   0.78288E-04        0.078      -1.107
 CACO3      0.18633E-05    -5.730  0.18714E-05    -5.728  0.10044E+01    0.002   0.18649E-03        0.186      -0.730
 CASO4      0.38184E-04    -4.418  0.38351E-04    -4.416  0.10044E+01    0.002   0.51984E-02        5.192       0.715
 MGSO4      0.10499E-04    -4.979  0.10545E-04    -4.977  0.10044E+01    0.002   0.12638E-02        1.262       0.101
 HSO4-      0.50388E-08    -8.298  0.44270E-08    -8.354  0.87857E+00   -0.056   0.48912E-06        0.000      -3.311
 HCO3-      0.51822E-02    -2.285  0.45636E-02    -2.341  0.88063E+00   -0.055   0.31620E+00      315.837       2.499
 H2CO3      0.30646E-02    -2.514  0.30780E-02    -2.512  0.10044E+01    0.002   0.19008E+00      189.863       2.278
 HCL        0.30856E-14   -14.511  0.30991E-14   -14.509  0.10044E+01    0.002   0.11250E-12        0.000      -9.949
 MG(OH)+    0.10034E-07    -7.999  0.88157E-08    -8.055  0.87857E+00   -0.056   0.41460E-06        0.000      -3.383

 IONIC STRENGTH =  0.166286E-01                ELECTRICAL BALANCE =  0.396047E-11


                         GASES
                         -----

 NAME                    LOG K        ACTIVITY       LOG ACTIVITY


CARBON DIOXIDE          -8.04071     0.15858E+00       -0.79976
STEAM                    1.34352     0.45317E-01       -1.34373
```

Table A-2 : Distribution of species

```
MEAGER SAMPLE 03     at 303.15°K and 1 bar pressure calculated using the solution constraints from Table 2


DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                    AQUEOUS SPECIES

SPECIES         MOLALITY      LOG MOL    ACTIVITY     LOG ACT    ACT COEF     LG ACT C  GRAMS/KGM H2O       PPM        LOG PPM

 AL+++         0.17586E-13  -13.755  0.60820E-14  -14.216  0.34585E+00   -0.461   0.47449E-12        0.000      -9.324
 K+            0.68793E-03   -3.162  0.59491E-03   -3.226  0.86479E+00   -0.063   0.26899E-01       26.867       1.429
 NA+           0.10804E-01   -1.966  0.93973E-02   -2.027  0.86981E+00   -0.061   0.24838E+00      248.084       2.395
 CA++          0.20173E-02   -2.695  0.11964E-02   -2.922  0.59305E+00   -0.227   0.80854E-01       80.758       1.907
 MG++          0.68021E-03   -3.167  0.41802E-03   -3.379  0.61454E+00   -0.211   0.16537E-01       16.518       1.218
 H4SIO4        0.56180E-03   -3.250  0.56180E-03   -3.250  0.10000E+01    0.0     0.53998E-01       53.933       1.732
 SO4--         0.43408E-03   -3.362  0.24704E-03   -3.607  0.56912E+00   -0.245   0.41698E-01       41.648       1.620
 CO3--         0.16390E-05   -5.785  0.94299E-06   -6.025  0.57535E+00   -0.240   0.98354E-04        0.098      -1.008
 CL-           0.12739E-01   -1.895  0.11016E-01   -1.958  0.86479E+00   -0.063   0.45162E+00      451.083       2.654
 OH-           0.10626E-06   -6.974  0.92165E-07   -7.035  0.86735E+00   -0.062   0.18072E-05        0.002      -2.744
 H+            0.17803E-06   -6.750  0.15849E-06   -6.800  0.89023E+00   -0.050   0.17945E-06        0.000      -3.747
 H2O           0.55508E+02    1.744  0.99942E+00   -0.000  0.18005E-01   -1.745   0.10000E+04   998809.622       5.999
 AL(OH)++      0.17887E-11  -11.747  0.10608E-11  -11.974  0.59305E+00   -0.227   0.78681E-10        0.000      -7.105
 AL(OH)4-      0.20482E-09   -9.689  0.17815E-09   -9.749  0.86981E+00   -0.061   0.19460E-07        0.000      -4.711
 KSO4-         0.12750E-05   -5.895  0.11058E-05   -5.956  0.86735E+00   -0.062   0.17233E-03        0.172      -0.764
 CACO3         0.19088E-05   -5.719  0.19189E-05   -5.717  0.10053E+01    0.002   0.19105E-03        0.191      -0.719
 CASO4         0.64073E-04   -4.193  0.64412E-04   -4.191  0.10053E+01    0.002   0.87231E-02        8.713       0.940
 MGSO4         0.21071E-04   -4.676  0.21182E-04   -4.674  0.10053E+01    0.002   0.25364E-02        2.533       0.404
 HSO4-         0.48760E-08   -8.312  0.42412E-08   -8.373  0.86981E+00   -0.061   0.47332E-06        0.000      -3.325
 HCO3-         0.32757E-02   -2.485  0.28570E-02   -2.544  0.87218E+00   -0.059   0.19987E+00      199.636       2.300
 H2CO3         0.97076E-03   -3.013  0.97589E-03   -3.011  0.10053E+01    0.002   0.60211E-01       60.140       1.779
 HCL           0.21275E-14  -14.672  0.21388E-14  -14.670  0.10053E+01    0.002   0.77571E-13        0.000     -10.111
 MG(OH)+       0.19022E-07   -7.721  0.16546E-07   -7.781  0.86981E+00   -0.061   0.78598E-06        0.001      -3.105

 IONIC STRENGTH =  0.200203E-01                 ELECTRICAL BALANCE = -0.893737E-11


                               GASES
                               -----

 NAME                          LOG K       ACTIVITY       LOG ACTIVITY


CARBON DIOXIDE                -8.02997    0.48544E-01      -1.31387
STEAM                          1.37819    0.41837E-01      -1.37844
```

Table A-3 : Minerals with which samples 01 and 03 are supersaturated

```
MEAGER SAMPLE 01

     THE LOG K FOR ALPHA-QUARTZ              HAS BEEN EXCEEDED
      LOG K =      -3.9082587   LOG Q =       -3.2346438


     THE LOG K FOR BETA-QUARTZ               HAS BEEN EXCEEDED
      LOG K =      -3.8146148   LOG Q =       -3.2346438


     THE LOG K FOR A-CRISTOBALITE            HAS BEEN EXCEEDED
      LOG K =      -3.3735883   LOG Q =       -3.2346438


     THE LOG K FOR CHALCEDONY                HAS BEEN EXCEEDED
      LOG K =      -3.6442288   LOG Q =       -3.2346438

 MEAGER SAMPLE 03

     THE LOG K FOR LAUMONTITE                HAS BEEN EXCEEDED
      LOG K =       3.8278664   LOG Q =        4.1772830


     THE LOG K FOR ALPHA-QUARTZ              HAS BEEN EXCEEDED
      LOG K =      -3.9288730   LOG Q =       -3.2499135


     THE LOG K FOR BETA-QUARTZ               HAS BEEN EXCEEDED
      LOG K =      -3.8349871   LOG Q =       -3.2499135


     THE LOG K FOR A-CRISTOBALITE            HAS BEEN EXCEEDED
      LOG K =      -3.3912202   LOG Q =       -3.2499135


     THE LOG K FOR CHALCEDONY                HAS BEEN EXCEEDED
      LOG K =      -3.6636085   LOG Q =       -3.2499135
```

Table A-4 : Distribution of species

```
MEAGER SAMPLE 05    at 321.65°K and 1 bar pressure calculated using solution constraints from Table 2


DISTRIBUTION OF SPECIES CALLED AT STEP     0


                                                           AQUEOUS SPECIES

SPECIES       MOLALITY      LOG MOL    ACTIVITY      LOG ACT    ACT COEF      LG ACT C   GRAMS/KGM H2O      PPM        LOG PPM

 AL+++        0.39085E-13   -13.408   0.11701E-13   -13.932   0.29937E+00    -0.524    0.10546E-11       0.000      -8.978
 K+           0.11222E-02    -2.950   0.94768E-03    -3.023   0.84445E+00    -0.073    0.43882E-01      43.807       1.642
 NA+          0.15072E-01    -1.822   0.12825E-01    -1.892   0.85090E+00    -0.070    0.34650E+00     345.908       2.539
 CA++         0.22035E-02    -2.657   0.12091E-02    -2.918   0.54870E+00    -0.261    0.88317E-01      88.167       1.945
 MG++         0.96375E-03    -3.016   0.55337E-03    -3.257   0.57418E+00    -0.241    0.23431E-01      23.391       1.369
 H4SIO4       0.83750E-03    -3.077   0.83750E-03    -3.077   0.10000E+01     0.0      0.80497E-01      80.359       1.905
 SO4--        0.52931E-03    -3.276   0.27532E-03    -3.560   0.52016E+00    -0.284    0.50846E-01      50.759       1.706
 CO3--        0.11835E-05    -5.927   0.62445E-06    -6.205   0.52761E+00    -0.278    0.71023E-04       0.071      -1.149
 CL-          0.17084E-01    -1.767   0.14427E-01    -1.841   0.84445E+00    -0.073    0.60568E+00     604.650       2.782
 OH-          0.14534E-06    -6.838   0.12322E-06    -6.909   0.84774E+00    -0.072    0.24719E-05       0.002      -2.608
 H+           0.45415E-06    -6.343   0.39811E-06    -6.400   0.87661E+00    -0.057    0.45777E-06       0.000      -3.340
 H2O          0.55508E+02     1.744   0.99918E+00    -0.000   0.18001E-01    -1.745    0.10000E+04  998291.478       5.999
 AL(OH)++     0.69241E-11   -11.160   0.37993E-11   -11.420   0.54870E+00    -0.261    0.30458E-09       0.000      -6.517
 AL(OH)4-     0.67350E-09    -9.172   0.57308E-09    -9.242   0.85090E+00    -0.070    0.63990E-07       0.000      -4.195
 KSO4-        0.30552E-05    -5.515   0.25900E-05    -5.587   0.84774E+00    -0.072    0.41295E-03       0.412      -0.385
 CACO3        0.18592E-05    -5.731   0.18711E-05    -5.728   0.10064E+01     0.003    0.18609E-03       0.186      -0.731
 CASO4        0.90011E-04    -4.046   0.90585E-04    -4.043   0.10064E+01     0.003    0.12254E-01      12.233       1.088
 MGSO4        0.54202E-04    -4.266   0.54547E-04    -4.263   0.10064E+01     0.003    0.65245E-02       6.513       0.814
 HSO4-        0.22334E-07    -7.651   0.19004E-07    -7.721   0.85090E+00    -0.070    0.21680E-05       0.002      -2.665
 HCO3-        0.43808E-02    -2.358   0.37409E-02    -2.427   0.85393E+00    -0.069    0.26731E+00     266.850       2.426
 H2CO3        0.29911E-02    -2.524   0.30102E-02    -2.521   0.10064E+01     0.003    0.18553E+00     185.208       2.268
 HCL          0.42627E-13   -13.370   0.42898E-13   -13.368   0.10064E+01     0.003    0.15542E-11       0.000      -8.809
 MG(OH)+      0.45212E-07    -7.345   0.38471E-07    -7.415   0.85090E+00    -0.070    0.18681E-05       0.002      -2.729

 IONIC STRENGTH =  0.262270E-01             ELECTRICAL BALANCE =  0.850942E-13

                             GASES
                             -----

 NAME                        LOG K         ACTIVITY        LOG ACTIVITY


CARBON DIOXIDE              -8.17481      0.22292E+00        -0.65186
STEAM                        0.94784      0.11267E+00        -0.94820
```

Table A-5 : Distribution of species

MEAGER SAMPLE 06 at 329.15°K and 1 bar pressure calculated using the solution constraints from Table 2

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                         AQUEOUS SPECIES

SPECIES        MOLALITY      LOG MOL    ACTIVITY      LOG ACT    ACT COEF     LG ACT C  GRAMS/KGM H2O       PPM          LOG PPM

 AL+++        0.21774E-12   -12.662  0.61458E-13   -13.211   0.28226E+00    -0.549    0.58749E-11        0.000         -8.232
 K+           0.11729E-02    -2.931  0.98059E-03    -3.009   0.83606E+00    -0.078    0.45862E-01       45.773          1.661
 NA+          0.16388E-01    -1.785  0.13817E-01    -1.860   0.84315E+00    -0.074    0.37675E+00      376.020          2.575
 CA++         0.21881E-02    -2.660  0.11627E-02    -2.935   0.53136E+00    -0.275    0.87698E-01       87.528          1.942
 MG++         0.12011E-02    -2.920  0.67076E-03    -3.173   0.55844E+00    -0.253    0.29202E-01       29.145          1.465
 H4SIO4       0.95720E-03    -3.019  0.95720E-03    -3.019   0.10000E+01     0.0      0.92002E-01       91.823          1.963
 SO4--        0.13280E-02    -2.877  0.66530E-03    -3.177   0.50096E+00    -0.300    0.12757E+00      127.326          2.105
 CO3--        0.38644E-06    -6.413  0.19666E-06    -6.706   0.50891E+00    -0.293    0.23190E-04        0.023         -1.636
 CL-          0.18719E-01    -1.728  0.15650E-01    -1.805   0.83606E+00    -0.078    0.66364E+00      662.354          2.821
 OH-          0.10081E-06    -6.996  0.84651E-07    -7.072   0.83968E+00    -0.076    0.17146E-05        0.002         -2.767
 H+           0.10231E-05    -5.990  0.89125E-06    -6.050   0.87114E+00    -0.060    0.10312E-05        0.001         -2.987
 H2O          0.55508E+02     1.744  0.99910E+00    -0.000   0.17999E-01    -1.745    0.10000E+04   998061.858          5.999
 AL(OH)++     0.30672E-10   -10.513  0.16298E-10   -10.788   0.53136E+00    -0.275    0.13492E-08        0.000         -5.871
 AL(OH)4-     0.70231E-09    -9.153  0.59215E-09    -9.228   0.84315E+00    -0.074    0.66727E-07        0.000         -4.177
 KSO4-        0.86296E-05    -5.064  0.72461E-05    -5.140   0.83968E+00    -0.076    0.11664E-02        1.164          0.066
 CACO3        0.66551E-06    -6.177  0.67004E-06    -6.174   0.10068E+01     0.003    0.66610E-04        0.066         -1.177
 CASO4        0.23146E-03    -3.636  0.23303E-03    -3.633   0.10068E+01     0.003    0.31511E-01       31.450          1.498
 MGSO4        0.20142E-03    -3.696  0.20280E-03    -3.693   0.10068E+01     0.003    0.24246E-01       24.199          1.384
 HSO4-        0.15065E-06    -6.822  0.12702E-06    -6.896   0.84315E+00    -0.074    0.14624E-04        0.015         -1.836
 HCO3-        0.29555E-02    -2.529  0.25017E-02    -2.602   0.84647E+00    -0.072    0.18033E+00      179.984          2.255
 H2CO3        0.45435E-02    -2.343  0.45745E-02    -2.340   0.10068E+01     0.003    0.28181E+00      281.266          2.449
 HCL          0.20532E-12   -12.688  0.20672E-12   -12.685   0.10068E+01     0.003    0.74861E-11        0.000         -8.127
 MG(OH)+      0.43094E-07    -7.366  0.36335E-07    -7.440   0.84315E+00    -0.074    0.17806E-05        0.002         -2.750

 IONIC STRENGTH =  0.290577E-01               ELECTRICAL BALANCE = -0.421325E-11

                               GASES
                               -----

 NAME                          LOG K        ACTIVITY        LOG ACTIVITY


CARBON DIOXIDE                -8.23504     0.38341E+00        -0.41634
STEAM                          0.78918     0.16234E+00        -0.78957
```

Table A-6 : Minerals with which samples 05 and 06 are supersaturated

```
MEAGER SAMPLE 05

   THE LOG K FOR LAUMONTITE               HAS BEEN EXCEEDED
    LOG K =       3.5355988    LOG Q =        3.7287819


   THE LOG K FOR ALPHA-QUARTZ             HAS BEEN EXCEEDED
    LOG K =      -3.6710570    LOG Q =       -3.0763058


   THE LOG K FOR BETA-QUARTZ              HAS BEEN EXCEEDED
    LOG K =      -3.5809425    LOG Q =       -3.0763058


   THE LOG K FOR A-CRISTOBALITE           HAS BEEN EXCEEDED
    LOG K =      -3.1709754    LOG Q =       -3.0763058


   THE LOG K FOR CHALCEDONY               HAS BEEN EXCEEDED
    LOG K =      -3.4214621    LOG Q =       -3.0763058


MEAGER SAMPLE 06

   THE LOG K FOR ALPHA-QUARTZ             HAS BEEN EXCEEDED
    LOG K =      -3.5749258    LOG Q =       -3.0182165


   THE LOG K FOR BETA-QUARTZ              HAS BEEN EXCEEDED
    LOG K =      -3.4866210    LOG Q =       -3.0182165


   THE LOG K FOR A-CRISTOBALITE           HAS BEEN EXCEEDED
    LOG K =      -3.0889982    LOG Q =       -3.0182165


   THE LOG K FOR CHALCEDONY               HAS BEEN EXCEEDED
    LOG K =      -3.3312837    LOG Q =       -3.0182165
```

Table A-7 : Distribution of species

LILIOCET SAMPLE 07   at 326.65°K and 1 bar pressure calculated using the solution constraints in Table 2

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                         AQUEOUS SPECIES

SPECIES        MOLALITY      LOG MOL    ACTIVITY      LOG ACT   .ACT COEF      LG ACT C  GRAMS/KGM H2O       PPM         LOG PPM

 AL+++         0.63742E-17   -17.196  0.19456E-17   -17.711   0.30523E+00    -0.515   0.17198E-15        0.000       -12.765
 K+            0.34580E-03    -3.461  0.29309E-03    -3.533   0.84758E+00    -0.072   0.13521E-01       13.499         1.130
 NA+           0.17823E-01    -1.749  0.15216E-01    -1.818   0.85373E+00    -0.069   0.40975E+00      409.066         2.612
 CA++          0.83957E-03    -3.076  0.46589E-03    -3.332   0.55492E+00    -0.256   0.33650E-01       33.594         1.526
 MG++          0.19646E-03    -3.707  0.11386E-03    -3.944   0.57956E+00    -0.237   0.47763E-02        4.768         0.678
 H4SIO4        0.41620E-03    -3.381  0.41620E-03    -3.381   0.10000E+01     0.0     0.40003E-01       39.937         1.601
 SO4--         0.29862E-02    -2.525  0.15748E-02    -2.803   0.52736E+00    -0.278   0.28686E+00      286.382         2.457
 CO3--         0.67006E-04    -4.174  0.35818E-04    -4.446   0.53455E+00    -0.272   0.40210E-02        4.014         0.604
 CL-           0.20366E-02    -2.691  0.17262E-02    -2.763   0.84758E+00    -0.072   0.72204E-01       72.083         1.858
 OH-           0.38651E-05    -5.413  0.32881E-05    -5.483   0.85072E+00    -0.070   0.65735E-04        0.066        -1.183
 H+            0.22716E-07    -7.644  0.19953E-07    -7.700   0.87837E+00    -0.056   0.22897E-07        0.000        -4.641
 H2O           0.55508E+02     1.744  0.99932E+00    -0.000   0.18003E-01    -1.745   0.10000E+04   998331.081         5.999
 AL(OH)++      0.34016E-13   -13.468  0.18876E-13   -13.724   0.55492E+00    -0.256   0.14963E-11        0.000        -8.826
 AL(OH)4-      0.51684E-07    -7.287  0.44124E-07    -7.355   0.85373E+00    -0.069   0.49105E-05        0.005        -2.310
 KSO4-         0.58048E-05    -5.236  0.49382E-05    -5.306   0.85072E+00    -0.070   0.78460E-03        0.783        -0.106
 CACO3         0.45939E-04    -4.338  0.46204E-04    -4.335   0.10058E+01     0.003   0.45980E-02        4.590         0.662
 CASO4         0.21229E-03    -3.673  0.21352E-03    -3.671   0.10058E+01     0.003   0.28902E-01       28.854         1.460
 MGSO4         0.74774E-04    -4.126  0.75206E-04    -4.124   0.10058E+01     0.003   0.90008E-02        8.986         0.954
 HSO4-         0.73391E-08    -8.134  0.62656E-08    -8.203   0.85373E+00    -0.069   0.71240E-06        0.001        -3.148
 HCO3-         0.12088E-01    -1.918  0.10355E-01    -1.985   0.85662E+00    -0.067   0.73761E+00      736.374         2.867
 H2CO3         0.41838E-03    -3.378  0.42079E-03    -3.376   0.10058E+01     0.003   0.25950E-01       25.907         1.413
 HCL           0.40503E-15   -15.393  0.40737E-15   -15.390   0.10058E+01     0.003   0.14768E-13        0.000       -10.831
 MG(OH)+       0.26886E-06    -6.570  0.22953E-06    -6.639   0.85373E+00    -0.069   0.11109E-04        0.011        -1.955

 IONIC STRENGTH =  0.243305E-01                 ELECTRICAL BALANCE =  0.285513E-11


                              GASES
                              -----

 NAME                         LOG K         ACTIVITY         LOG ACTIVITY


CARBON DIOXIDE               -8.21488      0.33911E-01        -1.46967
STEAM                         0.84113      0.14407E+00        -0.84142
```

Table A-8 : Minerals with which sample 07 is supersaturated

```
LILLOOET SAMPLE 07


    THE LOG K FOR LAUMONTITE                    HAS BEEN EXCEEDED
     LOG K =        3.4635501    LOG Q =         5.3071832


    THE LOG K FOR LAWSONITE                     HAS BEEN EXCEEDED
     LOG K =       11.4014128    LOG Q =        12.0679913


    THE LOG K FOR CALCITE                       HAS BEEN EXCEEDED
     LOG K =        1.2701333    LOG Q =         2.3834463


    THE LOG K FOR ARAGONITE                     HAS BEEN EXCEEDED
     LOG K =        1.4321048    LOG Q =         2.3834463


    THE LOG K FOR ORDERED DOLOMITE              HAS BEEN EXCEEDED
     LOG K =        1.7340537    LOG Q =         4.1549753


    THE LOG K FOR DOLOMITE                      HAS BEEN EXCEEDED
     LOG K =        1.7341676    LOG Q =         4.1549753


    THE LOG K FOR DISORDERED DOLOMITE           HAS BEEN EXCEEDED
     LOG K =        3.0913275    LOG Q =         4.1549753


    THE LOG K FOR ALPHA-QUARTZ                  HAS BEEN EXCEEDED
     LOG K =       -3.6064666    LOG Q =        -3.3801102


    THE LOG K FOR BETA-QUARTZ                   HAS BEEN EXCEEDED
     LOG K =       -3.5175445    LOG Q =        -3.3801102


    THE LOG K FOR TALC                          HAS BEEN EXCEEDED
     LOG K =       19.6532061    LOG Q =        20.8474875
```

Table A-9 : Distribution of species

LILLOOET SAMPLE 08 at 332.15°K and 1 bar pressure calculated using the solution constraints from Table 2

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                              AQUEOUS SPECIES

SPECIES        MOLALITY     LOG MOL    ACTIVITY      LOG ACT    ACT COEF     LG ACT C  GRAMS/KGM H2O      PPM        LOG PPM

 AL+++        0.13422E-14  -14.872  0.41159E-15   -15.386   0.30664E+00   -0.513   0.36216E-13        0.000     -10.442
 K+           0.45697E-03   -3.340  0.38775E-03    -3.411   0.84854E+00   -0.071   0.17868E-01       17.836       1.251
 NA+          0.17225E-01   -1.764  0.14720E-01    -1.832   0.85456E+00   -0.068   0.39600E+00      395.281       2.597
 CA++         0.85004E-03   -3.071  0.47317E-03    -3.325   0.55664E+00   -0.254   0.34070E-01       34.008       1.532
 MG++         0.17822E-03   -3.749  0.10353E-03    -3.985   0.58091E+00   -0.236   0.43330E-02        4.325       0.636
 H4SIO4       0.44740E-03   -3.349  0.44740E-03    -3.349   0.10000E+01    0.0     0.43002E-01       42.924       1.633
 SO4--        0.25826E-02   -2.588  0.13676E-02    -2.864   0.52953E+00   -0.276   0.24809E+00      247.639       2.394
 CO3--        0.10191E-04   -4.992  0.54683E-05    -5.262   0.53660E+00   -0.270   0.61154E-03        0.610      -0.214
 CL-          0.18758E-02   -2.727  0.15917E-02    -2.798   0.84854E+00   -0.071   0.66503E-01       66.382       1.822
 OH-          0.73865E-06   -6.132  0.62904E-06    -6.201   0.85161E+00   -0.070   0.12563E-04        0.013      -1.902
 H+           0.16074E-06   -6.794  0.14125E-06    -6.850   0.87876E+00   -0.056   0.16202E-06        0.000      -3.791
 H2O          0.55508E+02    1.744  0.99928E+00    -0.000   0.18002E-01   -1.745   0.10000E+04   998185.421       5.999
 AL(OH)++     0.15700E-11  -11.804  0.87394E-12   -12.059   0.55664E+00   -0.254   0.69063E-10        0.000      -7.162
 AL(OH)4-     0.13733E-07   -7.862  0.11735E-07    -7.931   0.85456E+00   -0.068   0.13047E-05        0.001      -2.885
 KSO4-        0.72338E-05   -5.141  0.61603E-05    -5.210   0.85161E+00   -0.070   0.97775E-03        0.976      -0.011
 CACO3        0.80813E-05   -5.093  0.81249E-05    -5.090   0.10054E+01    0.002   0.80885E-03        0.807      -0.093
 CASO4        0.20228E-03   -3.694  0.20337E-03    -3.692   0.10054E+01    0.002   0.27539E-01       27.489       1.439
 MGSO4        0.70524E-04   -4.152  0.70905E-04    -4.149   0.10054E+01    0.002   0.84892E-02        8.474       0.928
 HSO4-        0.52854E-07   -7.277  0.45167E-07    -7.345   0.85456E+00   -0.068   0.51305E-05        0.005      -2.291
 HCO3-        0.12669E-01   -1.897  0.10863E-01    -1.964   0.85740E+00   -0.067   0.77304E+00      771.642       2.887
 H2CO3        0.31684E-02   -2.499  0.31855E-02    -2.497   0.10054E+01    0.002   0.19652E+00      196.164       2.293
 HCI          0.43285E-14  -14.364  0.43519E-14   -14.361   0.10054E+01    0.002   0.15782E-12        0.000      -9.803
 MG(OH)+      0.51396E-07   -7.289  0.43921E-07    -7.357   0.85456E+00   -0.068   0.21237E-05        0.002      -2.674

 IONIC STRENGTH =   0.233598E-01                ELECTRICAL BALANCE =   0.112234E-09

                              GASES
                              -----

 NAME                         LOG K        ACTIVITY        LOG ACTIVITY


CARBON DIOXIDE              -8.25933     0.27898E+00        -0.55443
STEAM                        0.72803     0.18692E+00        -0.72834
```

Table A-10 : Minerals with which sample 08 is supersaturated

```
LILLOOET SAMPLE 08


 THE LOG K FOR LAUMONTITE                        HAS BEEN EXCEEDED
  LOG K =        3.3874014    LOG Q =              3.6767156


 THE LOG K FOR CALCITE                           HAS BEEN EXCEEDED
  LOG K =        1.1895329    LOG Q =              1.5609452


 THE LOG K FOR ARAGONITE                         HAS BEEN EXCEEDED
  LOG K =        1.3510894    LOG Q =              1.5609452


 THE LOG K FOR ORDERED DOLOMITE                  HAS BEEN EXCEEDED
  LOG K =        1.5598087    LOG Q =              2.4619582


 THE LOG K FOR DOLOMITE                          HAS BEEN EXCEEDED
  LOG K =        1.5599690    LOG Q =              2.4619582


 THE LOG K FOR ALPHA-QUARTZ                      HAS BEEN EXCEEDED
  LOG K =       -3.5377218    LOG Q =             -3.3486820


 THE LOG K FOR BETA-QUARTZ                       HAS BEEN EXCEEDED
  LOG K =       -3.4501743    LOG Q =             -3.3486820
```

Table A-11 : Distribution of species

LILLOOET SAMPLE 12 at 323.65°K and 1 bar pressure calculated using the solution constraints from Table 2

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                        AQUEOUS SPECIES

SPECIES          MOLALITY     LOG MOL    ACTIVITY      LOG ACT    ACT COEF      LG ACT C  GRAMS/KGM H2O       PPM          LOG PPM

 AL+++          0.95796E-18   -18.019  0.28611E-18   -18.543   0.29866E+00   -0.525    0.25847E-16        0.000       -13.588
 K+             0.48340E-03    -3.316  0.40809E-03    -3.389   0.84420E+00   -0.074    0.18902E-01       18.869         1.276
 NA+            0.18160E-01    -1.741  0.15448E-01    -1.811   0.85066E+00   -0.070    0.41750E+00      416.775         2.620
 CA++           0.97310E-03    -3.012  0.53335E-03    -3.273   0.54809E+00   -0.261    0.39002E-01       38.934         1.590
 MG++           0.28790E-03    -3.541  0.16513E-03    -3.782   0.57356E+00   -0.241    0.69994E-02        6.987         0.844
 H4SIO4         0.45780E-03    -3.339  0.45780E-03    -3.339   0.10000E+01    0.0      0.44002E-01       43.925         1.643
 SO4--          0.35394E-02    -2.451  0.18389E-02    -2.735   0.51956E+00   -0.284    0.34000E+00      339.410         2.531
 CO3--          0.12887E-03    -3.890  0.67918E-04    -4.168   0.52701E+00   -0.278    0.77337E-02        7.720         0.888
 CL-            0.20366E-02    -2.691  0.17193E-02    -2.765   0.84420E+00   -0.074    0.72204E-01       72.078         1.858
 OH-            0.65137E-05    -5.186  0.55203E-05    -5.258   0.84750E+00   -0.072    0.11078E-03        0.111        -0.956
 H+             0.11411E-07    -7.943  0.10000E-07    -8.000   0.87637E+00   -0.057    0.11502E-07        0.000        -4.940
 H2O            0.55508E+02     1.744  0.99931E+00    -0.000   0.18003E-01   -1.745    0.10000E+04   998263.874         5.999
 AL(OH)++       0.79364E-14   -14.100  0.43499E-14   -14.362   0.54809E+00   -0.261    0.34911E-12        0.000        -9.458
 AL(OH)4-       0.63747E-07    -7.196  0.54227E-07    -7.266   0.85066E+00   -0.070    0.60567E-05        0.006        -2.219
 KSO4-          0.90573E-05    -5.043  0.76760E-05    -5.115   0.84750E+00   -0.072    0.12242E-02        1.222         0.087
 CACO3          0.93216E-04    -4.031  0.93801E-04    -4.028   0.10063E+01    0.003    0.93299E-02        9.314         0.969
 CASO4          0.27235E-03    -3.565  0.27406E-03    -3.562   0.10063E+01    0.003    0.37079E-01       37.014         1.568
 MGSO4          0.11506E-03    -3.939  0.11578E-03    -3.936   0.10063E+01    0.003    0.13850E-01       13.826         1.141
 HSO4-          0.39614E-08    -8.402  0.33698E-08    -8.472   0.85066E+00   -0.070    0.38453E-06        0.000        -3.416
 HCO3-          0.11777E-01    -1.929  0.10054E-01    -1.998   0.85369E+00   -0.069    0.71863E+00      717.381         2.856
 H2CO3          0.20233E-03    -3.694  0.20360E-03    -3.691   0.10063E+01    0.003    0.12549E-01       12.528         1.098
 HCL            0.15359E-15   -15.814  0.15455E-15   -15.811   0.10063E+01    0.003    0.56000E-14        0.000       -11.253
 MG(OH)+        0.62479E-06    -6.204  0.53148E-06    -6.275   0.85066E+00   -0.070    0.25816E-04        0.026        -1.589

 IONIC STRENGTH =  0.260955E-01               ELECTRICAL BALANCE = -0.177147E-13

                              GASES
                              -----

 NAME                         LOG K         ACTIVITY         LOG ACTIVITY


CARBON DIOXIDE               -8.19080      0.15612E-01        -1.80655
STEAM                         0.90470      0.12445E+00        -0.90500
```

Table A-12 : Minerals with which sample 12 is supersaturated

```
LILLOOET SAMPLE 12


        THE LOG K FOR LAUMONTITE                 HAS BEEN EXCEEDED
         LOG K =        3.5064479   LOG Q =       6.0486642


        THE LOG K FOR 14A CLINOCHLORE            HAS BEEN EXCEEDED
         LOG K =       55.7474547   LOG Q =      57.7482795


        THE LOG K FOR LAWSONITE                  HAS BEEN EXCEEDED
         LOG K =       11.5163917   LOG Q =      12.7267095


        THE LOG K FOR CALCITE                    HAS BEEN EXCEEDED
         LOG K =        1.3145311   LOG Q =       2.7293615


        THE LOG K FOR ARAGONITE                  HAS BEEN EXCEEDED
         LOG K =        1.4767492   LOG Q =       2.7293615


        THE LOG K FOR MAGNESITE                  HAS BEEN EXCEEDED
         LOG K =        2.0033087   LOG Q =       2.2201727


        THE LOG K FOR ORDERED DOLOMITE           HAS BEEN EXCEEDED
         LOG K =        1.8302826   LOG Q =       4.9495342


        THE LOG K FOR DOLOMITE                   HAS BEEN EXCEEDED
         LOG K =        1.8303744   LOG Q =       4.9495342


        THE LOG K FOR DISORDERED DOLOMITE        HAS BEEN EXCEEDED
         LOG K =        3.2057081   LOG Q =       4.9495342


        THE LOG K FOR ALPHA-QUARTZ               HAS BEEN EXCEEDED
         LOG K =       -3.6449758   LOG Q =      -3.3387211


        THE LOG K FOR BETA-QUARTZ                HAS BEEN EXCEEDED
         LOG K =       -3.5553311   LOG Q =      -3.3387211


        THE LOG K FOR CHALCEDONY                 HAS BEEN EXCEEDED
         LOG K =       -3.3969907   LOG Q =      -3.3387211
```

Table A-13 : Minerals with which sample 12 is supersaturated (cont.)

```
LILLOOET SAMPLE 12

   THE LOG K FOR CHRYSOTILE                  HAS BEEN EXCEEDED
    LOG K =      29.1473996   LOG Q =      29.9745169


   THE LOG K FOR TALC                        HAS BEEN EXCEEDED
    LOG K =      19.8940673   LOG Q =      23.2973763


   THE LOG K FOR PHLOGOPITE                  HAS BEEN EXCEEDED
    LOG K =      34.2650840   LOG Q =      34.5857237


   THE LOG K FOR TREMOLITE                   HAS BEEN EXCEEDED
    LOG K =      56.6651239   LOG Q =      59.8309525


   THE LOG K FOR HUNTITE                     HAS BEEN EXCEEDED
    LOG K =       8.8806387   LOG Q =       9.3898795


   THE LOG K FOR SERPENTINE                  HAS BEEN EXCEEDED
    LOG K =      28.6213926   LOG Q =      29.9745169
```

Table A-14 : Distribution of species

LILLOOET SAMPLE 13 at 332.15°K and 1 bar pressure calculated using the solution constraints from Table 2

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                    AQUEOUS SPECIES

SPECIES        MOLALITY      LOG MOL     ACTIVITY      LOG ACT   ACT COEF      LG ACT C  GRAMS/KGM H2O       PPM          LOG PPM

 AL+++        0.28057E-14    -14.552   0.83146E-15    -15.080   0.29634E+00    -0.528    0.75703E-13        0.000        -10.122
 K+           0.48340E-03     -3.316   0.40774E-03     -3.390   0.84349E+00    -0.074    0.18902E-01       18.866          1.276
 NA+          0.17616E-01     -1.754   0.14973E-01     -1.825   0.84992E+00    -0.071    0.40500E+00      404.236          2.607
 CA++         0.81090E-03     -3.091   0.44291E-03     -3.354   0.54620E+00    -0.263    0.32501E-01       32.440          1.511
 MG++         0.28790E-03     -3.541   0.16455E-03     -3.784   0.57157E+00    -0.243    0.69994E-02        6.986          0.844
 H4SIO4       0.62420E-03     -3.205   0.62420E-03     -3.205   0.10000E+01     0.0      0.59995E-01       59.882          1.777
 SO4--        0.40078E-02     -2.397   0.20752E-02     -2.683   0.51780E+00    -0.286    0.38500E+00      384.269          2.585
 CO3--        0.59412E-05     -5.226   0.31204E-05     -5.506   0.52521E+00    -0.280    0.35653E-03        0.356         -0.449
 CL-          0.19928E-02     -2.701   0.16809E-02     -2.774   0.84349E+00    -0.074    0.70651E-01       70.517          1.848
 OH-          0.52591E-06     -6.279   0.44532E-06     -6.351   0.84677E+00    -0.072    0.89443E-05        0.009         -2.049
 H+           0.22788E-06     -6.642   0.19953E-06     -6.700   0.87559E+00    -0.058    0.22969E-06        0.000         -3.640
 H2O          0.55508E+02      1.744   0.99928E+00     -0.000   0.18002E-01    -1.745    0.10000E+04   998112.577          5.999
 AL(OH)++     0.22882E-11    -11.640   0.12498E-11    -11.903   0.54620E+00    -0.263    0.10066E-09        0.000         -6.998
 AL(OH)4-     0.70061E-08     -8.155   0.59546E-08     -8.225   0.84992E+00    -0.071    0.66566E-06        0.001         -3.178
 KSO4-        0.11609E-04     -4.935   0.98301E-05     -5.007   0.84677E+00    -0.072    0.15691E-02        1.566          0.195
 CACO3        0.43145E-05     -5.365   0.43399E-05     -5.363   0.10059E+01     0.003    0.43184E-03        0.431         -0.365
 CASO4        0.28719E-03     -3.542   0.28888E-03     -3.539   0.10059E+01     0.003    0.39099E-01       39.025          1.591
 MGSO4        0.17001E-03     -3.770   0.17101E-03     -3.767   0.10059E+01     0.003    0.20465E-01       20.426          1.310
 HSO4-        0.11391E-06     -6.943   0.96815E-07     -7.014   0.84992E+00    -0.071    0.11057E-04        0.011         -1.957
 HCO3-        0.10265E-01     -1.989   0.87557E-02     -2.058   0.85294E+00    -0.069    0.62636E+00      625.176          2.796
 H2CO3        0.36057E-02     -2.443   0.36269E-02     -2.440   0.10059E+01     0.003    0.22365E+00      223.224          2.349
 HCL          0.64539E-14    -14.190   0.64918E-14    -14.188   0.10059E+01     0.003    0.23531E-12        0.000         -9.629
 MG(OH)+      0.58146E-07     -7.235   0.49420E-07     -7.306   0.84992E+00    -0.071    0.24026E-05        0.002         -2.620

 IONIC STRENGTH =  0.254103E-01                 ELECTRICAL BALANCE =  0.773133E-14

                             GASES
                             -----

 NAME                        LOG K        ACTIVITY       LOG ACTIVITY

CARBON DIOXIDE              -8.25933     0.31764E+00       -0.49807
STEAM                        0.72803     0.18692E+00       -0.72835
```

Table A-15 : Minerals with which sample 13 is supersaturated

```
LILLOOET SAMPLE 13

     THE LOG K FOR LAUMONTITE                HAS BEEN EXCEEDED
      LOG K =        3.3874014    LOG Q =        3.6372773

     THE LOG K FOR CALCITE                   HAS BEEN EXCEEDED
      LOG K =        1.1895329    LOG Q =        1.2886051

     THE LOG K FOR ORDERED DOLOMITE          HAS BEEN EXCEEDED
      LOG K =        1.5598087    LOG Q =        2.1472033

     THE LOG K FOR DOLOMITE                  HAS BEEN EXCEEDED
      LOG K =        1.5599690    LOG Q =        2.1472033

     THE LOG K FOR ALPHA-QUARTZ              HAS BEEN EXCEEDED
      LOG K =       -3.5377218    LOG Q =       -3.2040476

     THE LOG K FOR BETA-QUARTZ               HAS BEEN EXCEEDED
      LOG K =       -3.4501743    LOG Q =       -3.2040476

     THE LOG K FOR CHALCEDONY                HAS BEEN EXCEEDED
      LOG K =       -3.2963966    LOG Q =       -3.2040476
```

Table A-16 : Distribution of species

MEAGER SAMPLE 17 at 329.65°K and 1 bar pressure calculated using the solution constraints from Table 2

```
DISTRIBUTION OF SPECIES CALLED AT STEP      0


                                                      AQUEOUS SPECIES

SPECIES          MOLALITY      LOG MOL   ACTIVITY      LOG ACT   ACT COEF      LG ACT C  GRAMS/KGM H2O      PPM       LOG PPM

 AL+++          0.10731E-12   -12.969  0.28353E-13   -13.547   0.26422E+00   -0.578    0.28954E-11        0.000      -8.540
 K+             0.13299E-02    -2.876  0.10986E-02    -2.959   0.82609E+00   -0.083    0.52002E-01       51.848       1.715
 NA+            0.17834E-01    -1.749  0.14875E-01    -1.828   0.83406E+00   -0.079    0.41000E+00      408.790       2.612
 CA++           0.26198E-02    -2.582  0.13411E-02    -2.873   0.51192E+00   -0.291    0.10500E+00      104.692       2.020
 MG++           0.16658E-02    -2.778  0.90141E-03    -3.045   0.54113E+00   -0.267    0.40499E-01       40.379       1.606
 H4SIO4         0.99880E-03    -3.001  0.99880E-03    -3.001   0.10000E+01    0.0      0.96000E-01       95.717       1.981
 SO4--          0.18738E-02    -2.727  0.89757E-03    -3.047   0.47901E+00   -0.320    0.18000E+00      179.469       2.254
 CO3--          0.19181E-05    -5.717  0.93528E-06    -6.029   0.48762E+00   -0.312    0.11510E-03        0.115      -0.940
 CL-            0.12721E-01    -1.895  0.10509E-01    -1.978   0.82609E+00   -0.083    0.45100E+00      449.665       2.653
 OH-            0.13193E-06    -6.880  0.10952E-06    -6.961   0.83017E+00   -0.081    0.22437E-05        0.002      -2.650
 H+             0.81830E-06    -6.087  0.70795E-06    -6.150   0.86515E+00   -0.063    0.82482E-06        0.001      -3.085
 H2O            0.55508E+02     1.744  0.99884E+00    -0.001   0.17994E-01   -1.745    0.10000E+04   997047.653       5.999
 AL(OH)++       0.19236E-10   -10.716  0.98474E-11   -11.007   0.51192E+00   -0.291    0.84618E-09        0.000      -6.074
 AL(OH)4-       0.91243E-09    -9.040  0.76102E-09    -9.119   0.83406E+00   -0.079    0.86691E-07        0.000      -4.063
 KSO4-          0.13292E-04    -4.876  0.11035E-04    -4.957   0.83017E+00   -0.081    0.17966E-02        1.791       0.253
 CACO3          0.36888E-05    -5.433  0.37180E-05    -5.430   0.10079E+01    0.003    0.36921E-03        0.368      -0.434
 CASO4          0.36232E-03    -3.441  0.36519E-03    -3.437   0.10079E+01    0.003    0.49326E-01       49.181       1.692
 MGSO4          0.37071E-03    -3.431  0.37365E-03    -3.428   0.10079E+01    0.003    0.44624E-01       44.492       1.648
 HSO4-          0.16559E-06    -6.781  0.13811E-06    -6.860   0.83406E+00   -0.079    0.16073E-04        0.016      -1.795
 HCO3-          0.11250E-01    -1.949  0.94251E-02    -2.026   0.83778E+00   -0.077    0.68644E+00      684.418       2.835
 H2CO3          0.13606E-01    -1.866  0.13714E-01    -1.863   0.10079E+01    0.003    0.84389E+00      841.399       2.925
 HCL            0.11440E-12   -12.942  0.11531E-12   -12.938   0.10079E+01    0.003    0.41711E-11        0.000      -8.381
 MG(OH)+        0.76402E-07    -7.117  0.63724E-07    -7.196   0.83406E+00   -0.079    0.31569E-05        0.003      -2.502

 IONIC STRENGTH =  0.338973E-01              ELECTRICAL BALANCE =  0.295655E-13


                             GASES
                             -----

 NAME                        LOG K          ACTIVITY        LOG ACTIVITY


CARBON DIOXIDE              -8.23908       0.11584E+01        0.06387
STEAM                        0.77890       0.16619E+00       -0.77940
```

Table A-17 : Minerals with which sample 17 is supersaturated

```
MEAGER SAMPLE 17

     THE LOG K FOR LAUMONTITE                HAS BEEN EXCEEDED
      LOG K =       3.4216213   LOG Q =       3.4269326


     THE LOG K FOR CALCITE                   HAS BEEN EXCEEDED
      LOG K =       1.2260435   LOG Q =       1.2517536


     THE LOG K FOR ORDERED DOLOMITE          HAS BEEN EXCEEDED
      LOG K =       1.6386673   LOG Q =       2.3309590


     THE LOG K FOR DOLOMITE                  HAS BEEN EXCEEDED
      LOG K =       1.6388057   LOG Q =       2.3309590


     THE LOG K FOR ALPHA-QUARTZ              HAS BEEN EXCEEDED
      LOG K =      -3.5686767   LOG Q =      -2.9995098


     THE LOG K FOR BETA-QUARTZ               HAS BEEN EXCEEDED
      LOG K =      -3.4804969   LOG Q =      -2.9995098


     THE LOG K FOR A-CRISTOBALITE            HAS BEEN EXCEEDED
      LOG K =      -3.0836718   LOG Q =      -2.9995098


     THE LOG K FOR CHALCEDONY                HAS BEEN EXCEEDED
      LOG K =      -3.3254232   LOG Q =      -2.9995098
```

Table A-18 : Distribution of species

MEAGER SAMPLE 18 at 323.15°K and 1 bar pressure calculated using the solution constraints in Table 2

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                      AQUEOUS SPECIES

SPECIES        MOLALITY      LOG MOL    ACTIVITY     LOG ACT   ACT COEF     LG ACT C  GRAMS/KGM H2O        PPM       LOG PPM

 AL+++       0.72704E-14   -14.138   0.20410E-14   -14.690   0.28073E+00   -0.552   0.19617E-12          0.000     -9.708
 K+          0.12403E-02    -2.906   0.10355E-02    -2.985   0.83489E+00   -0.078   0.48498E-01         48.393      1.685
 NA+         0.16964E-01    -1.770   0.14286E-01    -1.845   0.84214E+00   -0.075   0.39000E+00        389.156      2.590
 CA++        0.22954E-02    -2.639   0.12151E-02    -2.915   0.52938E+00   -0.276   0.92000E-01         91.801      1.963
 MG++        0.12751E-02    -2.894   0.71010E-03    -3.149   0.55690E+00   -0.254   0.31000E-01         30.933      1.490
 H4SIO4      0.10612E-02    -2.974   0.10612E-02    -2.974   0.10000E+01    0.0     0.10200E+00        101.777      2.008
 SO4--       0.15094E-02    -2.821   0.75234E-03    -3.124   0.49843E+00   -0.302   0.14500E+00        144.682      2.160
 CO3--       0.43598E-05    -5.361   0.22083E-05    -5.656   0.50652E+00   -0.295   0.26163E-03          0.261     -0.583
 CL-         0.12558E-01    -1.901   0.10485E-01    -1.979   0.83489E+00   -0.078   0.44523E+00        444.272      2.648
 OH-         0.25445E-06    -6.594   0.21336E-06    -6.671   0.83860E+00   -0.076   0.43274E-05          0.004     -2.365
 H+          0.28849E-06    -6.540   0.25119E-06    -6.600   0.87069E+00   -0.060   0.29079E-06          0.000     -3.537
 H2O         0.55508E+02     1.744   0.99908E+00    -0.000   0.17999E-01   -1.745   0.10000E+04     997837.516      5.999
 AL(OH)++    0.22406E-11   -11.650   0.11861E-11   -11.926   0.52938E+00   -0.276   0.98560E-10          0.000     -7.007
 AL(OH)4-    0.10352E-08    -8.985   0.87182E-09    -9.060   0.84214E+00   -0.075   0.98359E-07          0.000     -4.008
 KSO4-       0.94314E-05    -5.025   0.79092E-05    -5.102   0.83860E+00   -0.076   0.12748E-02          1.272      0.104
 CACO3       0.68223E-05    -5.166   0.68724E-05    -5.163   0.10073E+01    0.003   0.68284E-03          0.681     -0.167
 CASO4       0.25191E-03    -3.599   0.25376E-03    -3.596   0.10073E+01    0.003   0.34295E-01         34.221      1.534
 MGSO4       0.19905E-03    -3.701   0.20051E-03    -3.698   0.10073E+01    0.003   0.23960E-01         23.908      1.379
 HSO4-       0.40553E-07    -7.392   0.34152E-07    -7.467   0.84214E+00   -0.075   0.39365E-05          0.004     -2.406
 HCO3-       0.97500E-02    -2.011   0.82440E-02    -2.084   0.84554E+00   -0.073   0.59492E+00        593.632      2.774
 H2CO3       0.41602E-02    -2.381   0.41908E-02    -2.378   0.10073E+01    0.003   0.25804E+00        257.482      2.411
 HCL         0.22443E-13   -13.649   0.22608E-13   -13.646   0.10073E+01    0.003   0.81829E-12          0.000     -9.088
 MG(OH)+     0.10404E-06    -6.983   0.87616E-07    -7.057   0.84214E+00   -0.075   0.42988E-05          0.004     -2.368

IONIC STRENGTH =   0.304300E-01                 ELECTRICAL BALANCE =   0.132294E-14


                              GASES
                              -----

NAME                          LOG K          ACTIVITY          LOG ACTIVITY


CARBON DIOXIDE               -8.18679       0.31866E+00          -0.49667
STEAM                         0.91543       0.12139E+00          -0.91583
```

Table A-19 : Minerals with which sample 18 is supersaturated

```
MEAGER SAMPLE 18

    THE LOG K FOR LAUMONTITE                HAS BEEN EXCEEDED
     LOG K =        3.5136938   LOG Q =        4.3366201


    THE LOG K FOR CALCITE                   HAS BEEN EXCEEDED
     LOG K =        1.3219611   LOG Q =        1.6007633


    THE LOG K FOR ARAGONITE                 HAS BEEN EXCEEDED
     LOG K =        1.4842217   LOG Q =        1.6007633


    THE LOG K FOR ORDERED DOLOMITE          HAS BEEN EXCEEDED
     LOG K =        1.8464040   LOG Q =        2.9682224


    THE LOG K FOR DOLOMITE                  HAS BEEN EXCEEDED
     LOG K =        1.8464923   LOG Q =        2.9682224


    THE LOG K FOR ALPHA-QUARTZ              HAS BEEN EXCEEDED
     LOG K =       -3.6514651   LOG Q =       -2.9734002


    THE LOG K FOR BETA-QUARTZ               HAS BEEN EXCEEDED
     LOG K =       -3.5617021   LOG Q =       -2.9734002


    THE LOG K FOR A-CRISTOBALITE            HAS BEEN EXCEEDED
     LOG K =       -3.1542619   LOG Q =       -2.9734002


    THE LOG K FOR CHALCEDONY                HAS BEEN EXCEEDED
     LOG K =       -3.4030791   LOG Q =       -2.9734002
```

APPENDIX A.1

1. Table of distribution of species for Meager sample 05 at 353.15°K and 1 bar pressure calculated using the solution constraints determined from Table 2 (assuming kaolinite constrains Al).

Table A.1-1 : Distribution of species

```
MEAGER SAMPLE M-05      at 353.15°K and 1 bar pressure, calculated using solution constraints from Table 2

DISTRIBUTION OF SPECIES CALLED AT STEP      0

                                                  AQUEOUS SPECIES

SPECIES        MOLALITY     LOG MOL   ACTIVITY      LOG ACT   ACT COEF      LG ACT C  GRAMS/KGM H2O        PPM     LOG PPM

 AL+++         0.38045E-14  -14.420   0.10548E-14   -14.977   0.27724E+00   -0.557    0.10265E-12          0.000    -9.989
 K+            0.11213E-02   -2.950   0.93633E-03    -3.029   0.83502E+00   -0.078    0.43846E-01         43.771     1.641
 NA+           0.15072E-01   -1.822   0.12689E-01    -1.897   0.84189E+00   -0.075    0.34650E+00        345.904     2.539
 CA++          0.21809E-02   -2.661   0.11511E-02    -2.939   0.52778E+00   -0.278    0.87412E-01         87.261     1.941
 MG++          0.90483E-03   -3.043   0.50139E-03    -3.300   0.55413E+00   -0.256    0.21998E-01         21.960     1.342
 H4SIO4        0.83750E-03   -3.077   0.83750E-03    -3.077   0.10000E+01    0.0      0.80497E-01         60.358     1.905
 SO4--         0.44903E-03   -3.348   0.22377E-03    -3.650   0.49833E+00   -0.302    0.43135E-01         43.061     1.634
 CO3--         0.12255E-05   -5.912   0.62012E-06    -6.208   0.50601E+00   -0.296    0.73542E-04          0.073    -1.134
 CL-           0.17410E-01   -1.759   0.14538E-01    -1.838   0.83502E+00   -0.078    0.61723E+00        616.167     2.790
 OH-           0.73565E-06   -6.133   0.61686E-06    -6.210   0.83852E+00   -0.076    0.12512E-04          0.012    -1.903
 H+            0.45800E-06   -6.339   0.39811E-06    -6.400   0.86922E+00   -0.061    0.46165E-06          0.000    -3.336
 H2O           0.55508E+02    1.744   0.99918E+00    -0.000   0.18001E-01   -1.745    0.10000E+04     998279.627     5.999
 AL(OH)++      0.75715E-11  -11.121   0.39961E-11   -11.398   0.52778E+00   -0.278    0.33306E-09          0.000    -6.478
 AL(OH)4-      0.35440E-07   -7.451   0.29836E-07    -7.525   0.84189E+00   -0.075    0.33672E-05          0.003    -2.473
 KSO4-         0.39703E-05   -5.401   0.33292E-05    -5.478   0.83852E+00   -0.076    0.53665E-03          0.536    -0.271
 CACO3         0.37208E-05   -5.429   0.37415E-05    -5.427   0.10056E+01    0.002    0.37242E-03          0.372    -0.430
 CASO4         0.11075E-03   -3.956   0.11136E-03    -3.953   0.10056E+01    0.002    0.15077E-01         15.051     1.178
 MGSO4         0.11280E-03   -3.948   0.11343E-03    -3.945   0.10056E+01    0.002    0.13579E-01         13.555     1.132
 HSO4-         0.47499E-07   -7.323   0.39988E-07    -7.398   0.84189E+00   -0.075    0.46107E-05          0.005    -2.337
 HCO3-         0.40505E-02   -2.392   0.34231E-02    -2.466   0.84511E+00   -0.073    0.24715E+00        246.726     2.392
 H2CO3         0.33195E-02   -2.479   0.33380E-02    -2.477   0.10056E+01    0.002    0.20590E+00        205.542     2.313
 HCL           0.65085E-12  -12.187   0.65448E-12   -12.184   0.10056E+01    0.002    0.23731E-10          0.000    -7.625
 MG(OH)+       0.36838E-06   -6.434   0.31013E-06    -6.508   0.84189E+00   -0.075    0.15221E-04          0.015    -1.818

 IONIC STRENGTH =  0.259016E-01                   ELECTRICAL BALANCE = -0.205367E-11

                              GASES
                              -----

 NAME                         LOG K         ACTIVITY        LOG ACTIVITY

 CARBON DIOXIDE              -8.43186       0.36867E+00      -0.43336
 STEAM                        0.33365       0.46344E+00      -0.33400
```

APPENDIX B

1. Activity diagrams of the system $CaO-Al_2O_3-SiO_2-H_2O$ at 1 bar pressure and 50°C, 80°C, 100°C, 125°C, and 150°C.

   Thermal water samples from Appendix A are shown as dots on all diagrams and as numbered dots on Figure B-1.

Figure B-1 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 50°C and 1 bar pressure. Numbered dots correspond to thermal water samples in Appendix A.

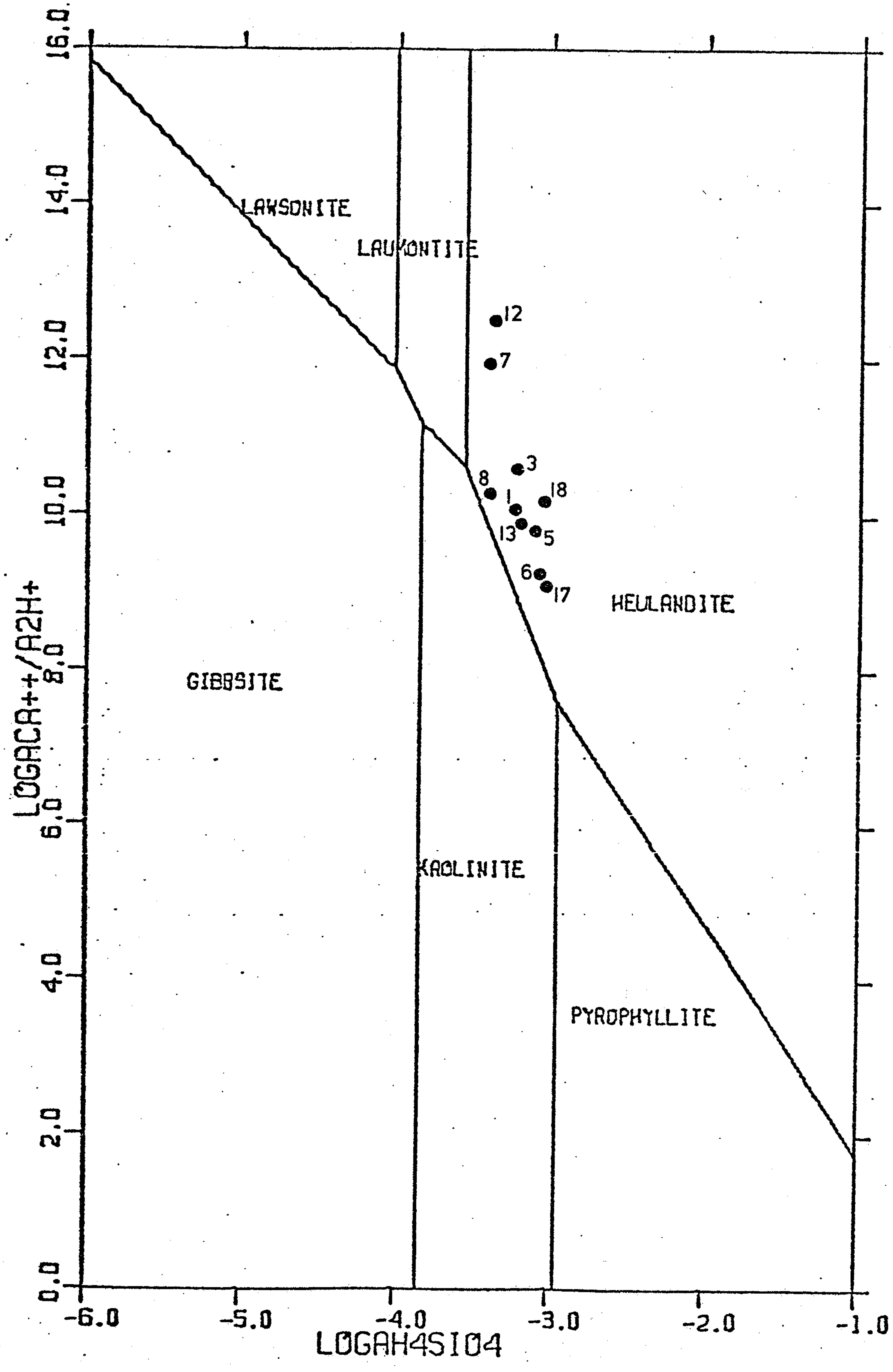


Figure B-2 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 80°C and 1 bar pressure. Dots correspond to thermal water samples numbered in Figure B-1.

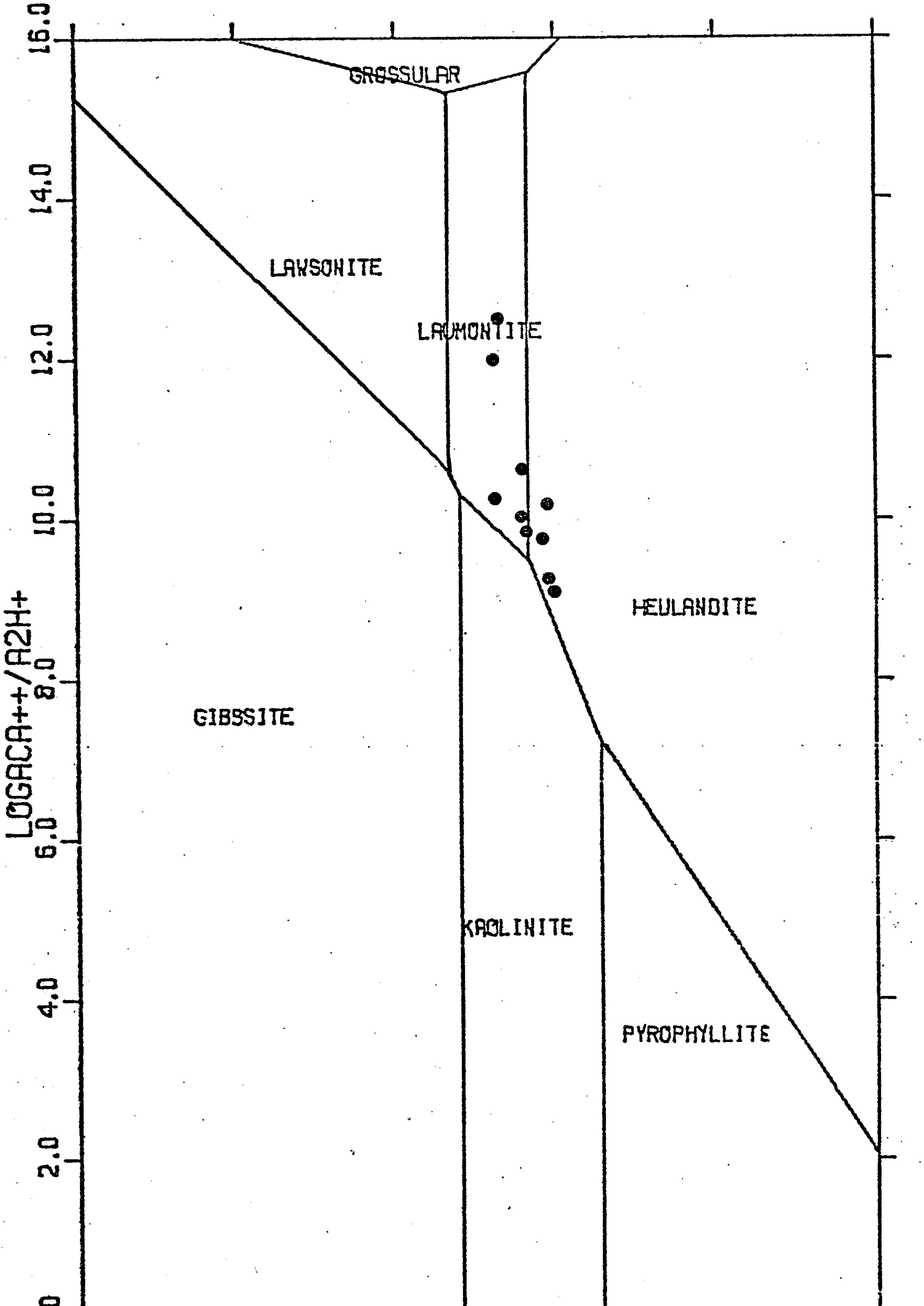


Figure B-3 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 100°C and 1 bar pressure. Dots correspond to thermal water samples numbered in Figure B-1.

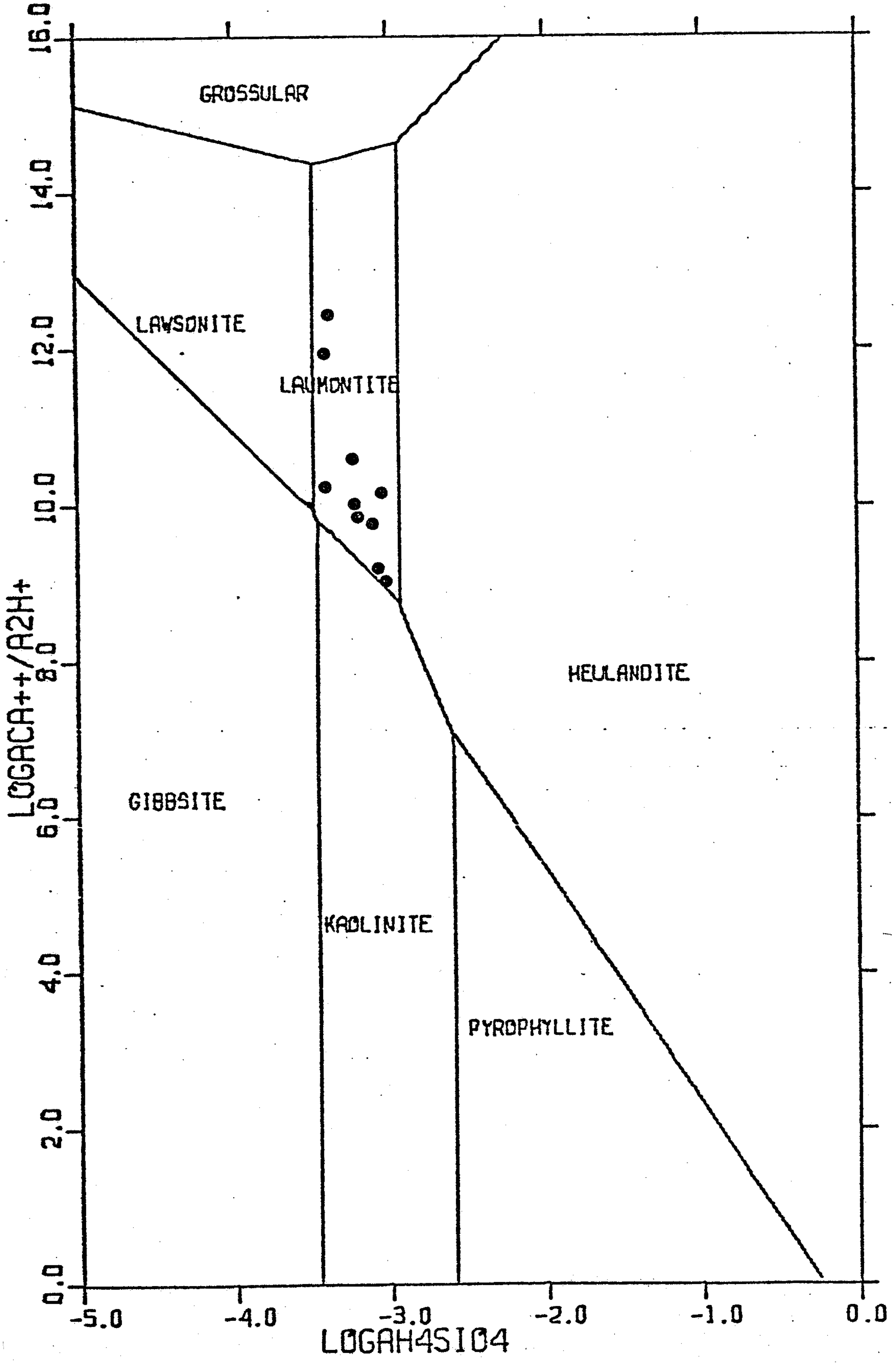


Figure B-4 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 125°C and 1 bar pressure. Dots correspond to thermal water samples numbered in Figure B-1.

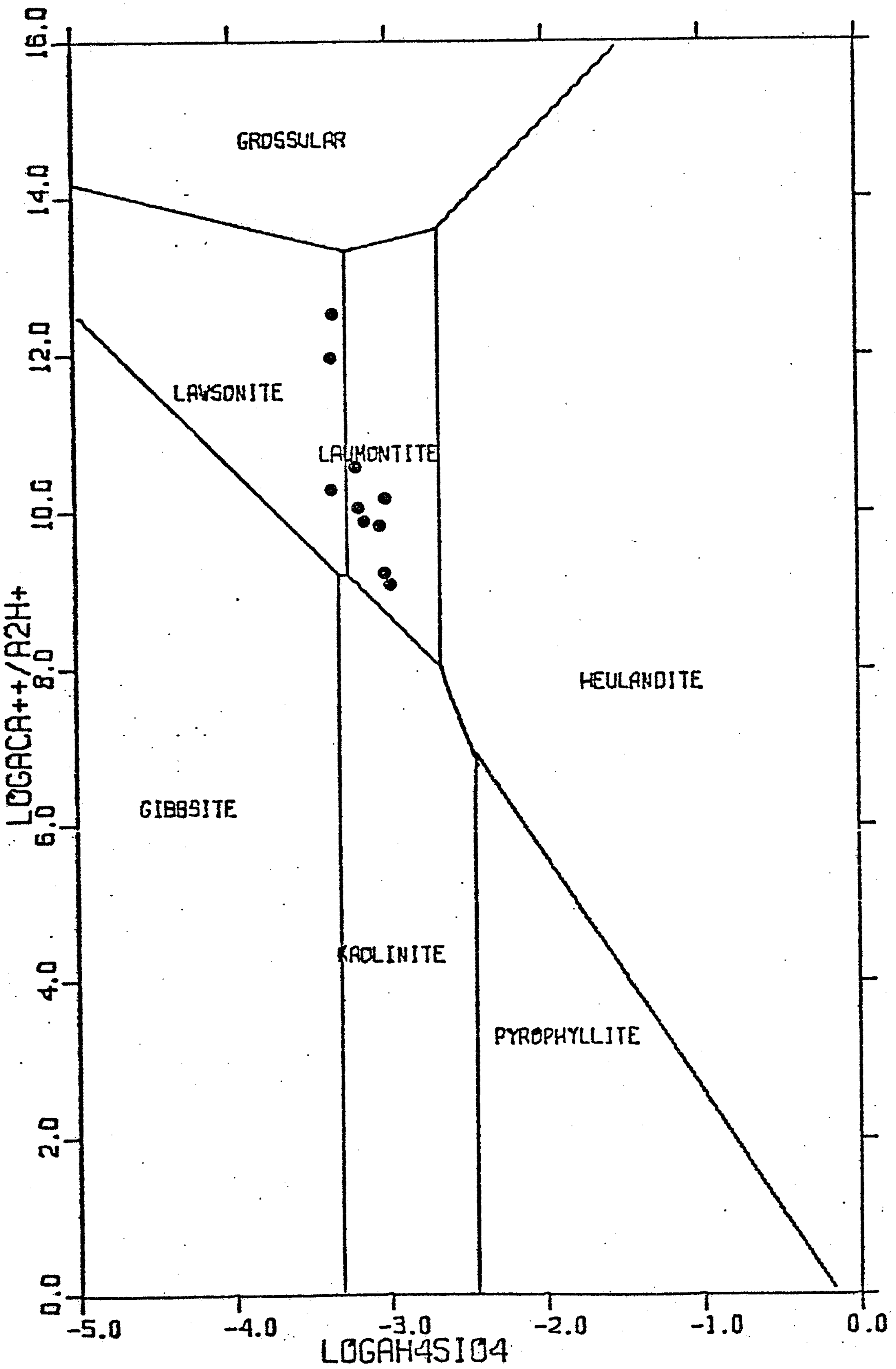
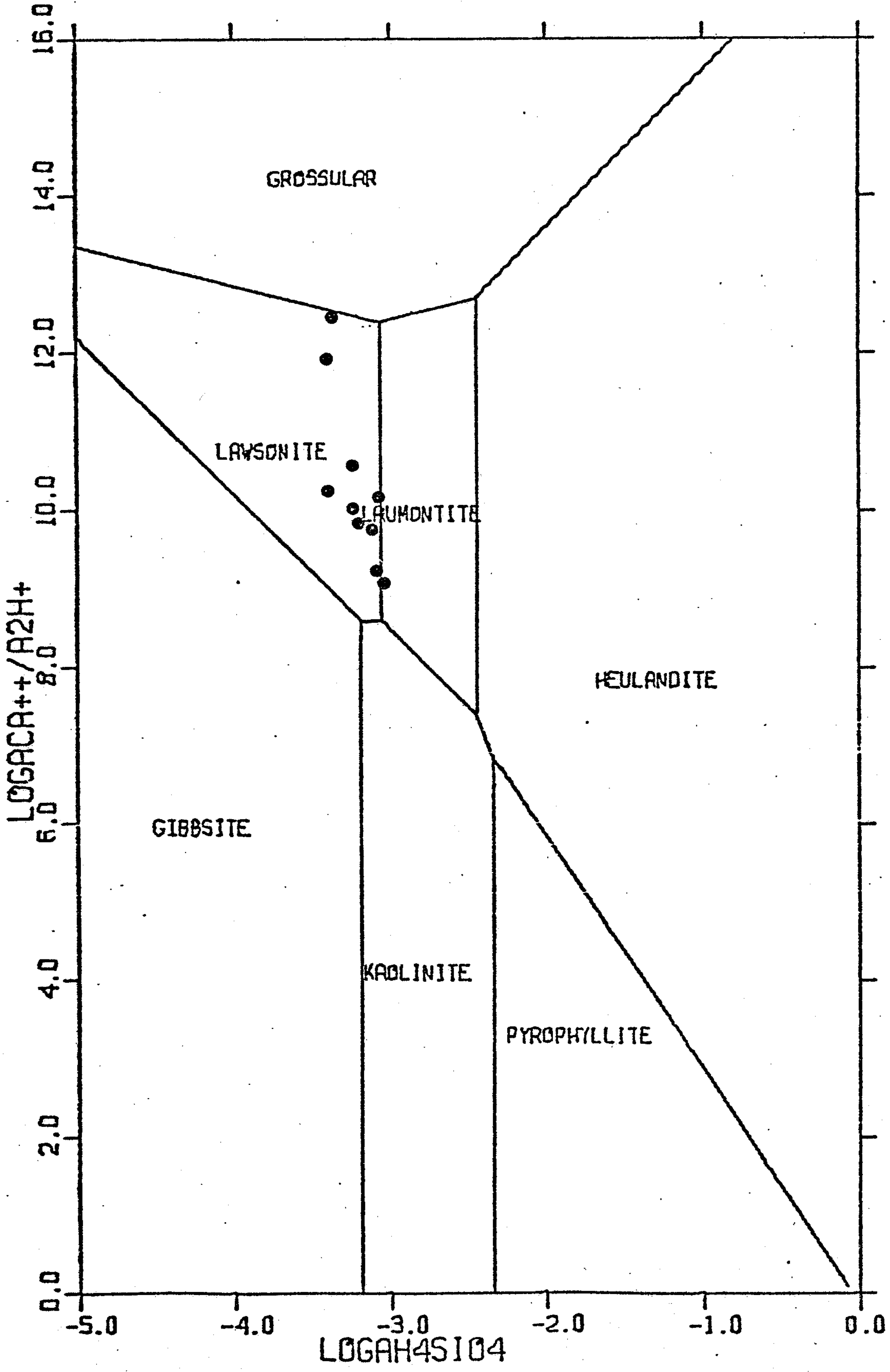


Figure B-5 : The system $CaO-Al_2O_3-SiO_2-H_2O$ at 150°C and 1 bar pressure. Dots correspond to thermal water samples numbered in Figure B-1.



APPENDIX C.1

1. Activity diagrams of the system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 1 bar pressure and 50°C, 80°C, 85°C, 100°C, and 125°C. The diagrams are constructed at gibbsite saturation ($\log \alpha Al^{+3}/\log \alpha^3 H^+ = \log K_{gibbsite}$) Thermal water samples from Appendix A are shown as dots on all diagrams and as numbered dots on Figure C.1-1.

Figure C.1-1 : The system CaO-MgO-Al_2O_3-SiO_2-H_2O at 50°C, 1 bar pressure, and $\log Q Al^{+3}/\log Q^{3}H^{+} = 3.851$ (gibbsite saturation). Numbered dots correspond to thermal water samples in Appendix A.

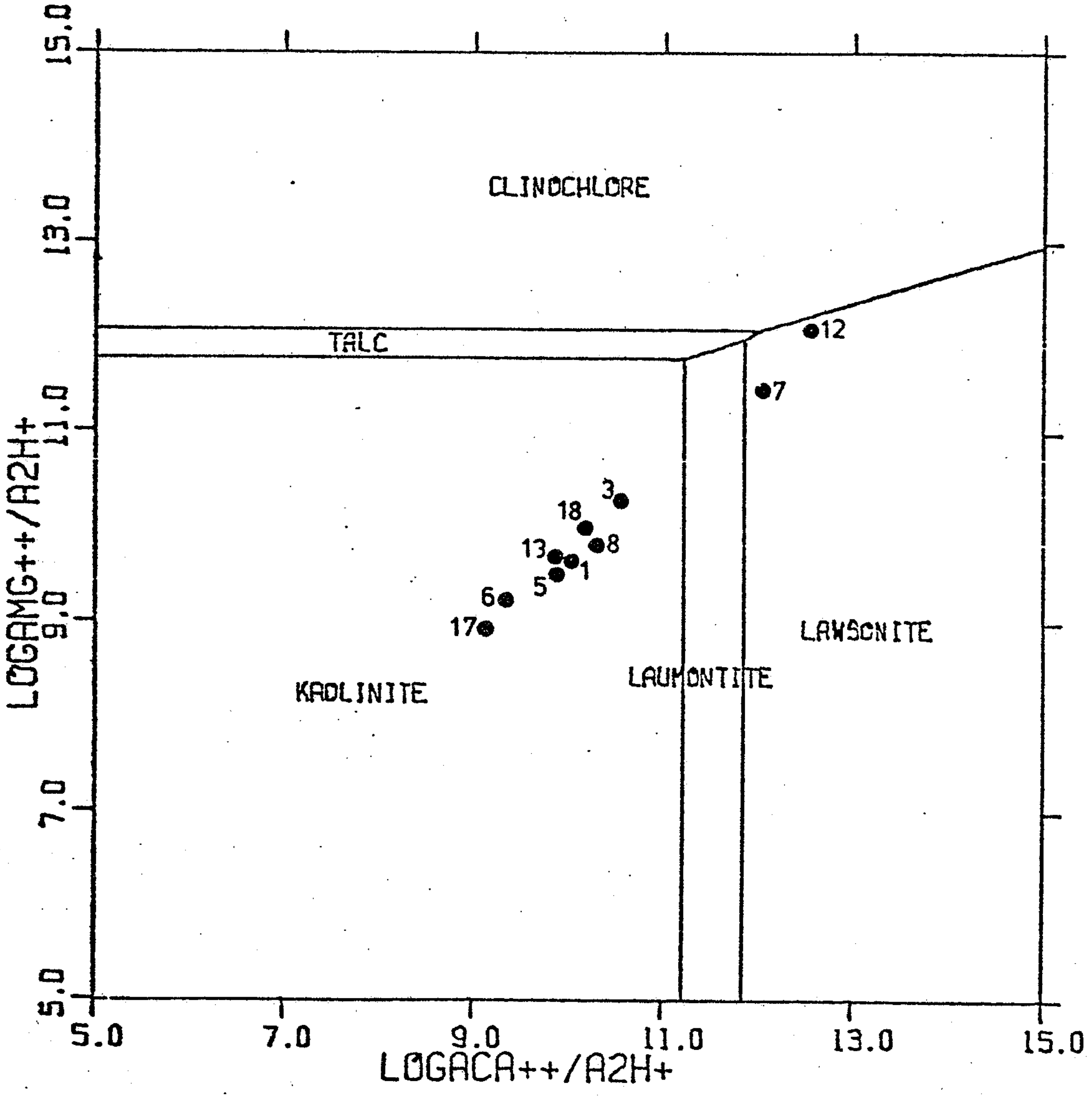


Figure C.1-2 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 80°C, 1 bar pressure, and $\log a Al^{+3}/\log a^3 H^+ = 3.602$ (gibbsite saturation). Dots correspond to thermal water samples numbered in Figure C.1-1.

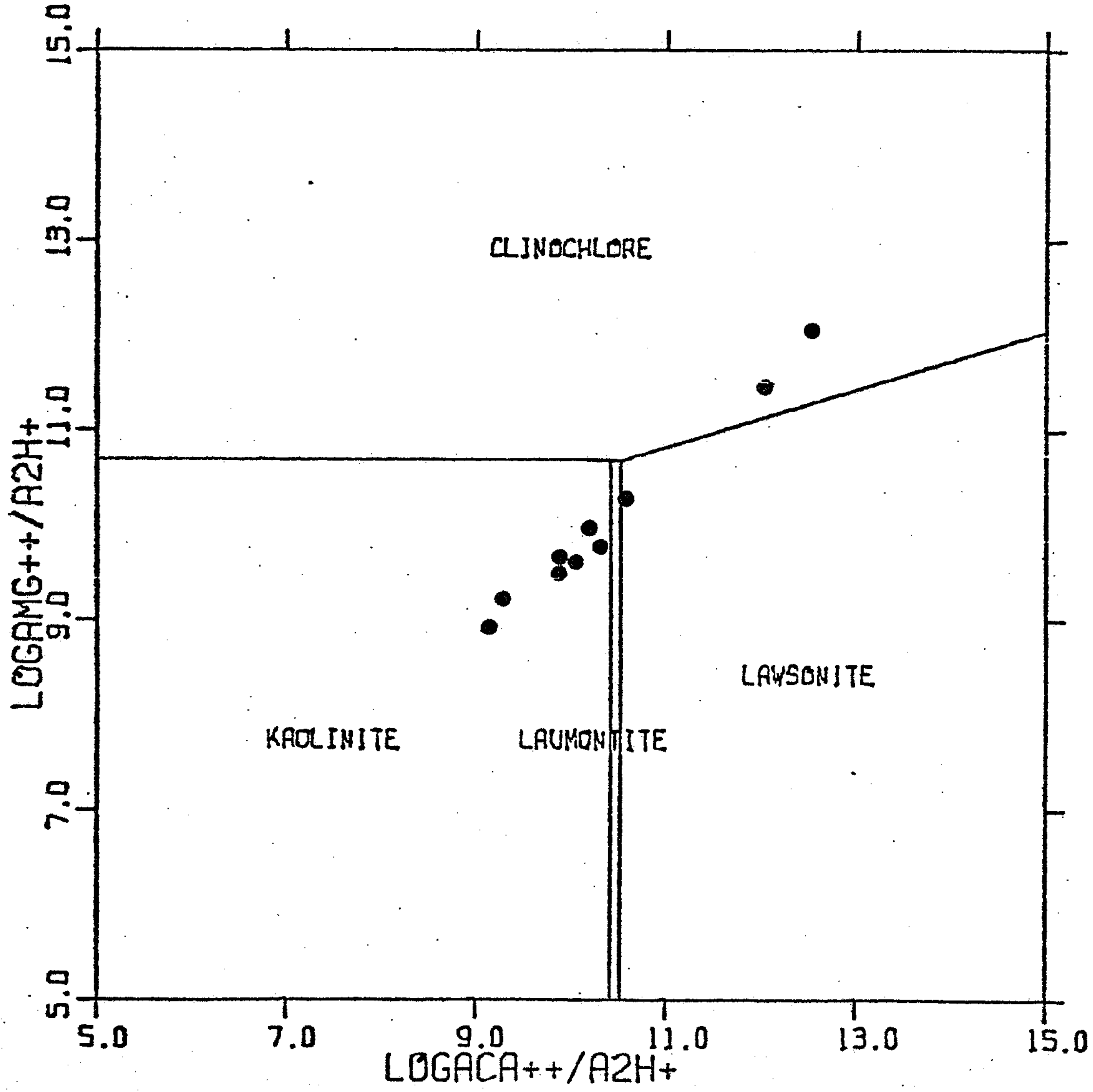


Figure C.1-3 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 85°C, 1 bar pressure, and $\log a\mathrm{Al}^{+3}/\log a^3\mathrm{H}^+ = 3.566$ (gibbsite saturation). Dots correspond to thermal water samples numbered in Figure C.1-1.

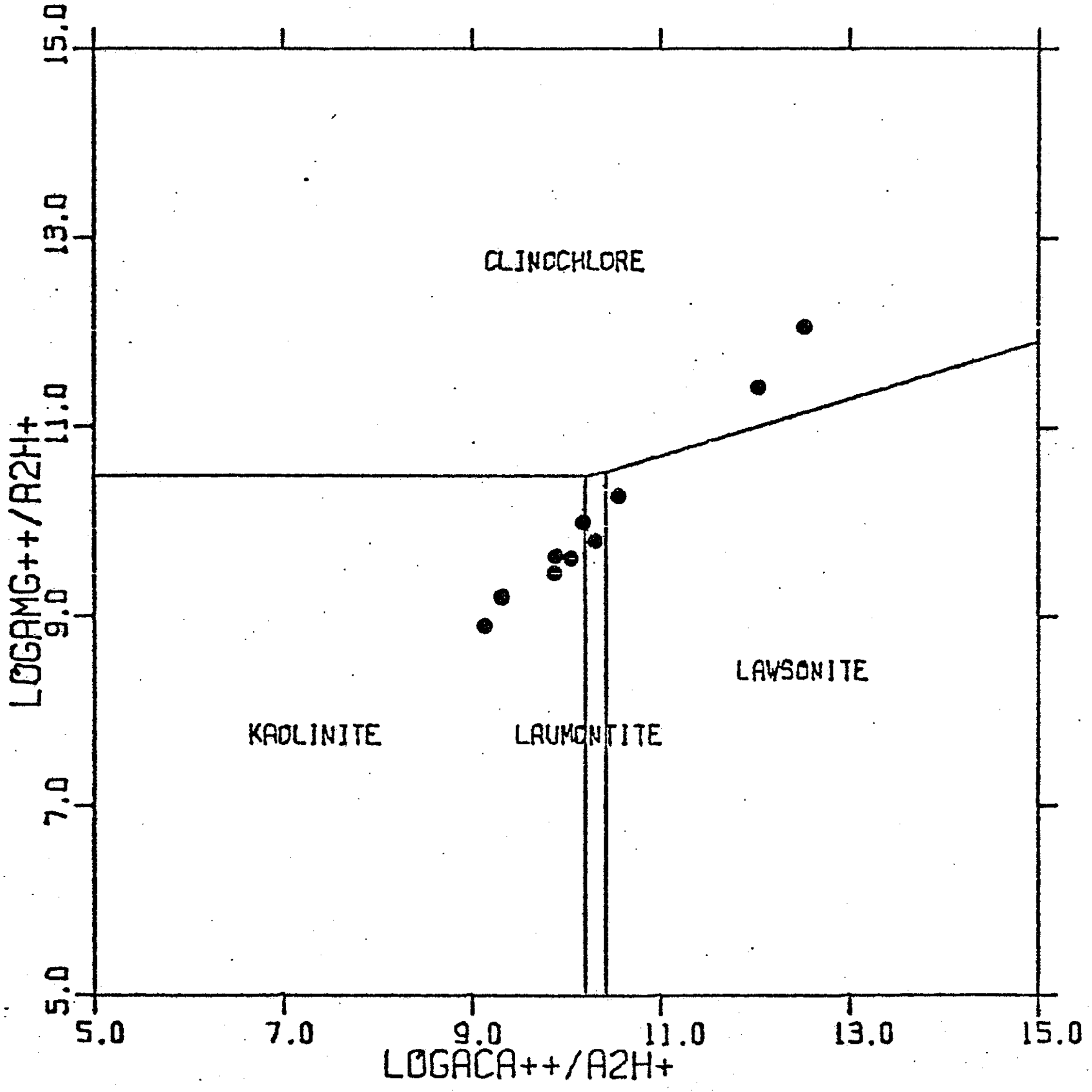


Figure C.1-4 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 100°C, 1 bar pressure, and $\log a\mathrm{Al}^{+3}/\log a^{3}\mathrm{H}^{+} = 3.464$ (gibbsite saturation). Dots correspond to thermal water samples numbered in Figure C.1-1.

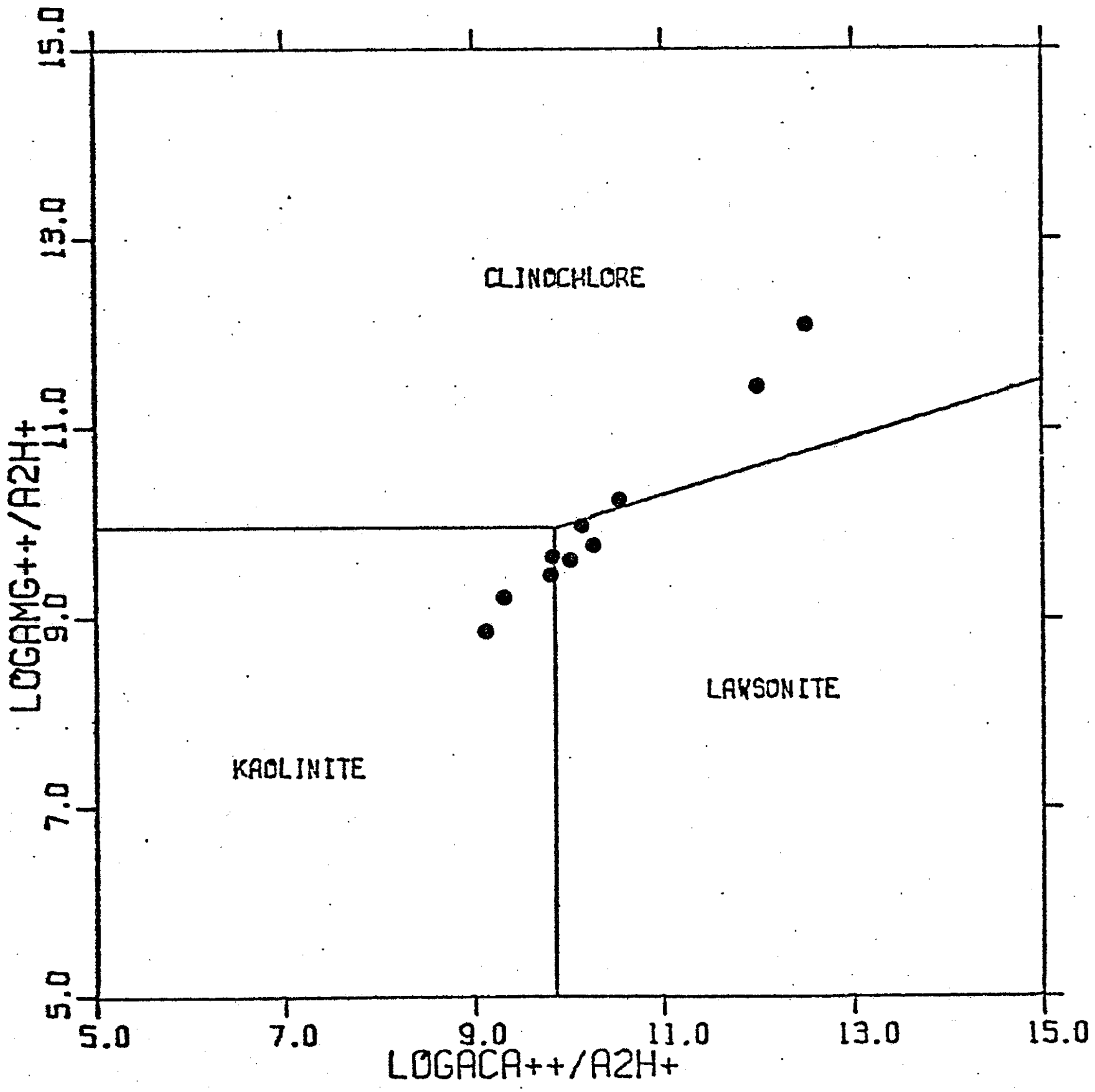
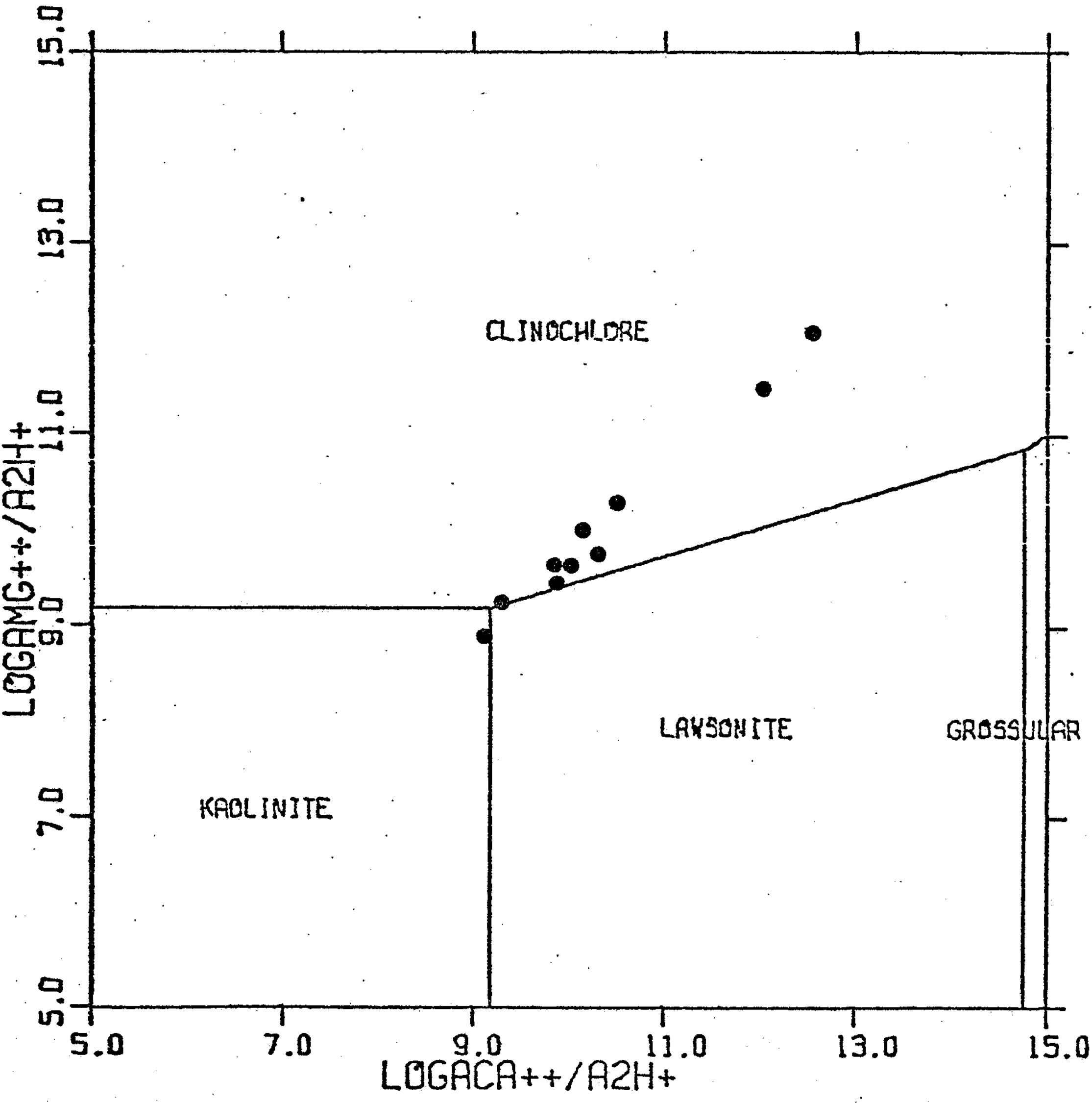


Figure C.1-5 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 125°C, 1 bar pressure, and $\log a_{Al^{+3}}/\log a^{3}_{H^{+}} = 3.318$ (gibbsite saturation). Dots correspond to thermal water samples numbered in Figure C.1-1.



APPENDIX C.2

1. Activity diagrams of the system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 1 bar pressure and 50°C, 80°C, 85°C, 100°C, 125°C. The diagrams are constructed at a $\log \alpha Al^{+3}/\log \alpha^3 H^+ = 3.0$ constant value. Thermal water samples from Appendix A are shown as dots on all diagrams and as numbered dots on Figure C.2-1.

Figure C.2-1 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 50°C, 1 bar pressure, and $\log \alpha Al^{+3}/\log \alpha^3 H^+ = 3.0$. Numbered dots correspond to thermal water samples in Appendix A.

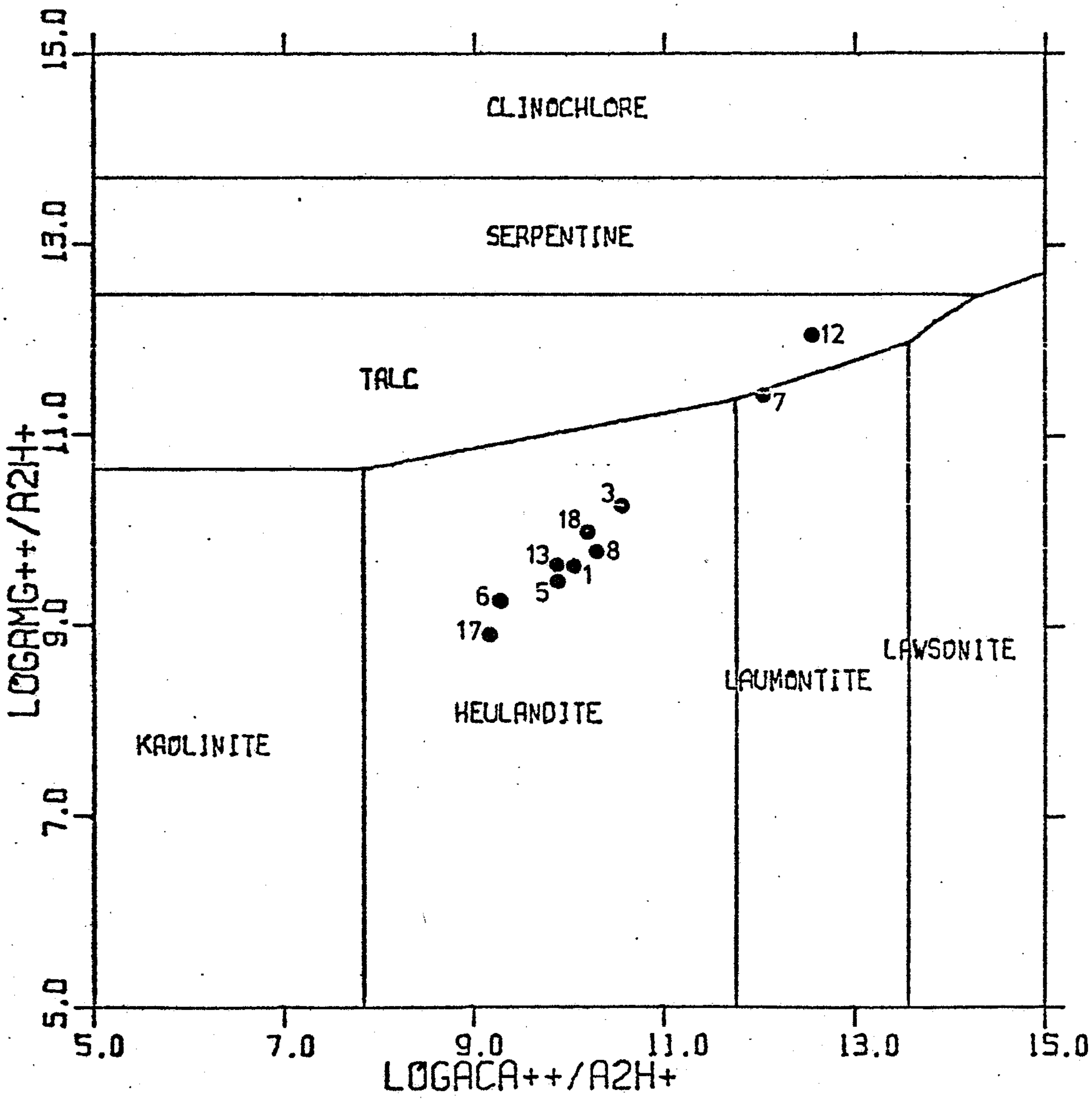


Figure C.2-2 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 80°C, 1 bar pressure, and $\log a_{Al^{+3}}/\log a^{3}_{H^{+}} = 3.0$. Dots correspond to thermal water samples numbered in Figure C.2-1.

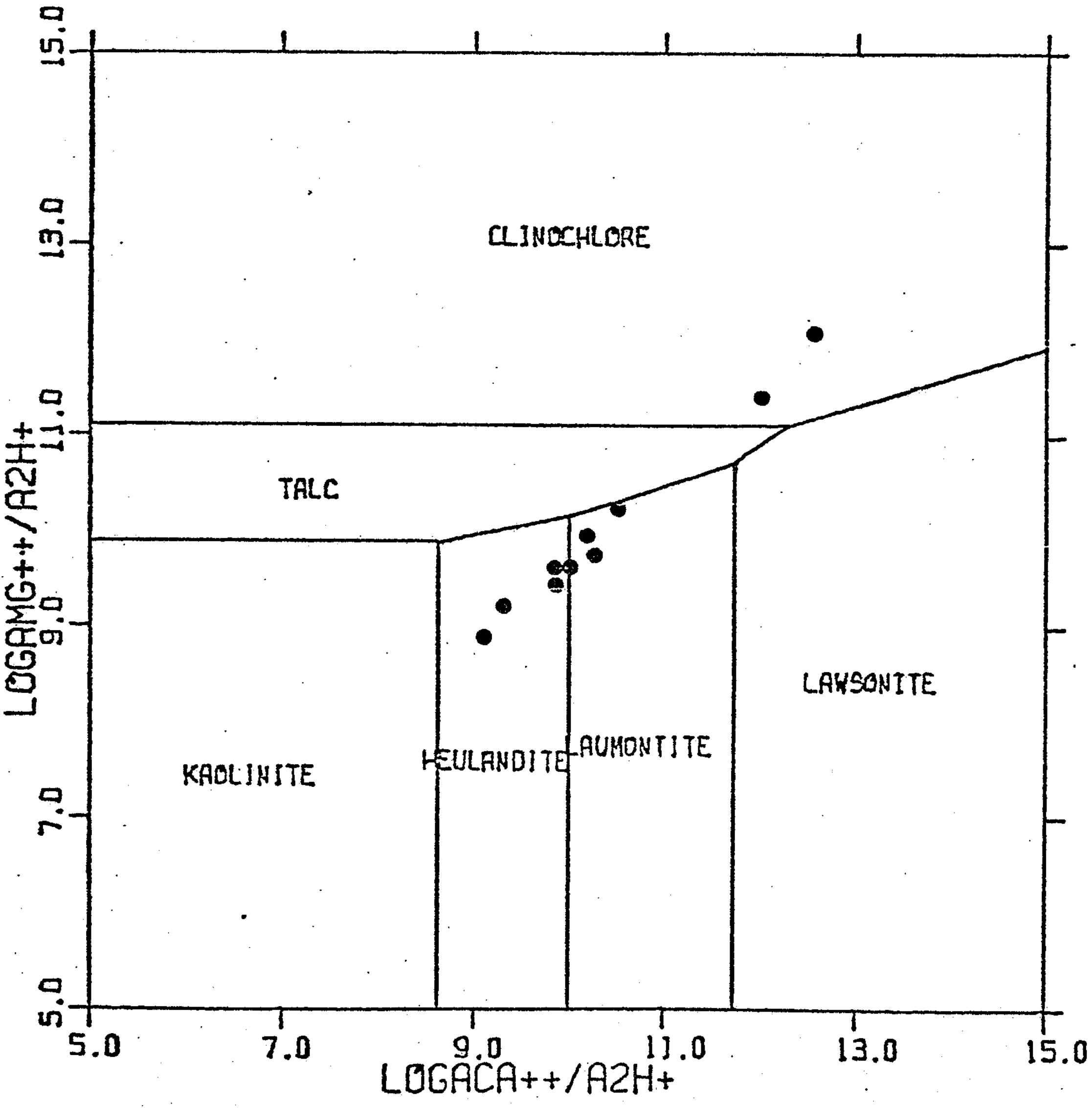


Figure C.2-3 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 85°C, 1 bar pressure, and $\log a_{Al^{+3}}/\log a^{3}_{H^+} = 3.0$. Dots correspond to thermal water samples numbered in Figure C.2-1

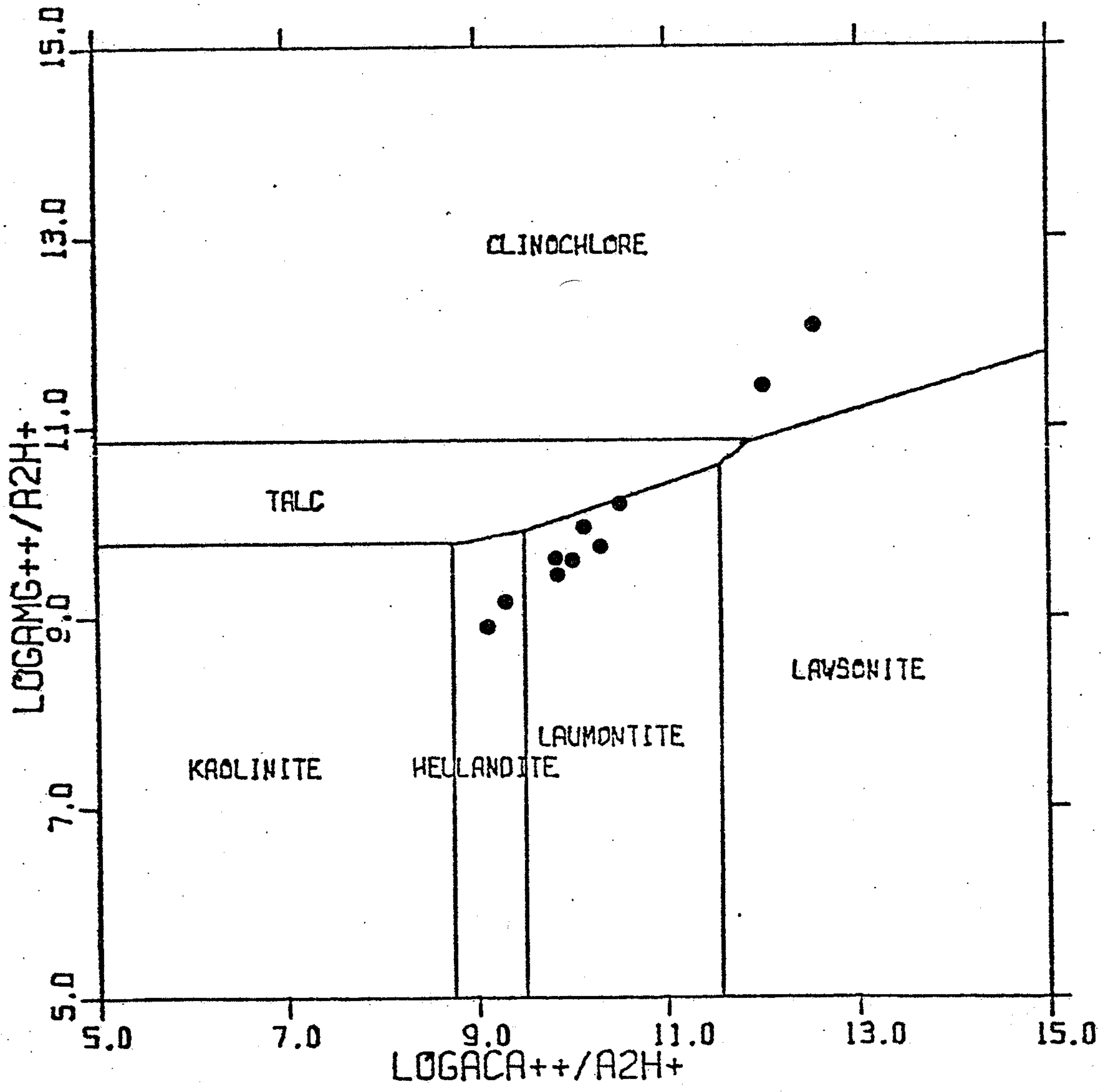


Figure C.2-4 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 100°C, 1 bar pressure, and $\log \alpha_{Al^{+3}}/\log \alpha^{3}_{H^{+}} = 3.0$. Dots correspond to thermal water samples numbered in Figure C.2-1

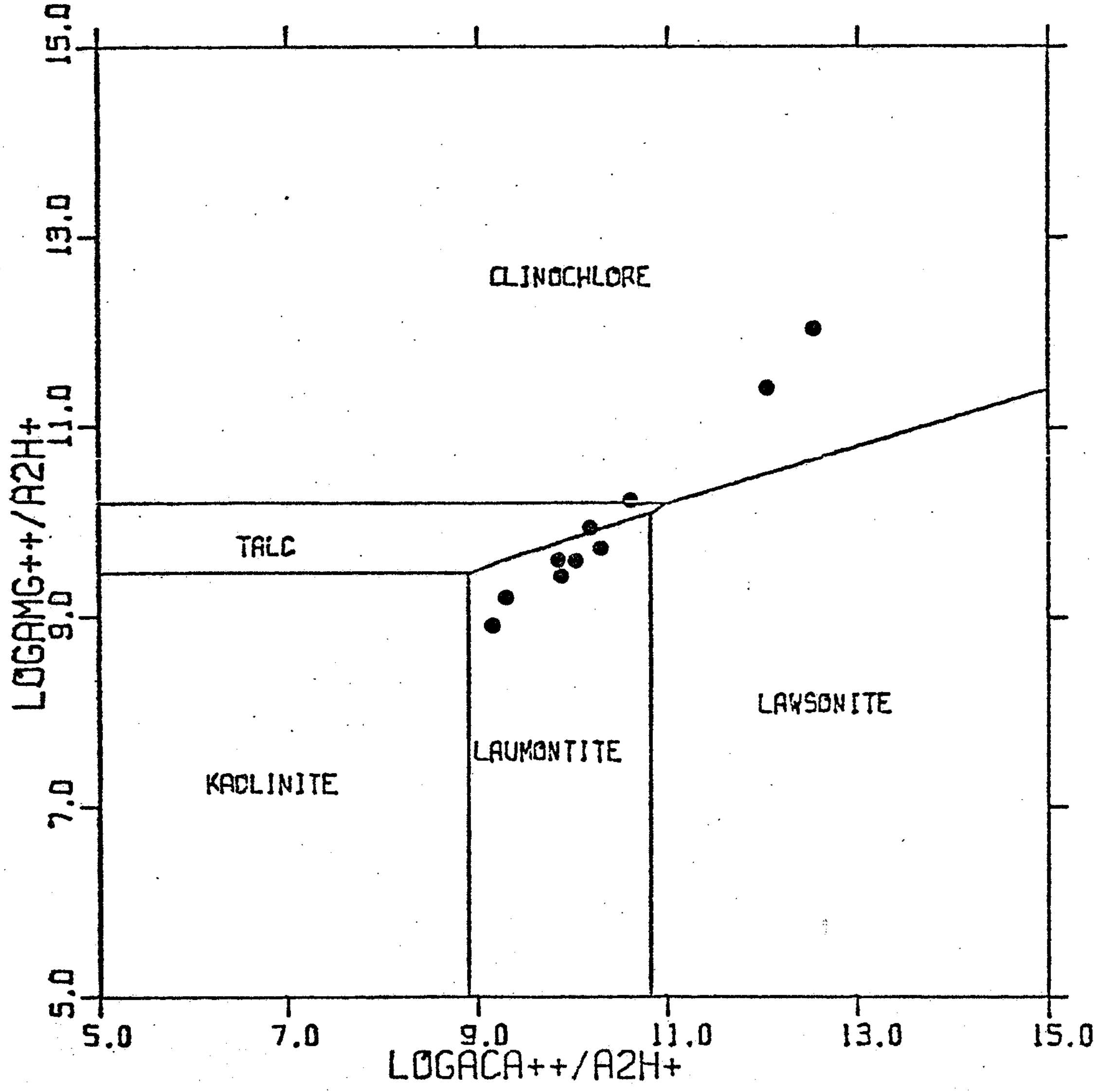
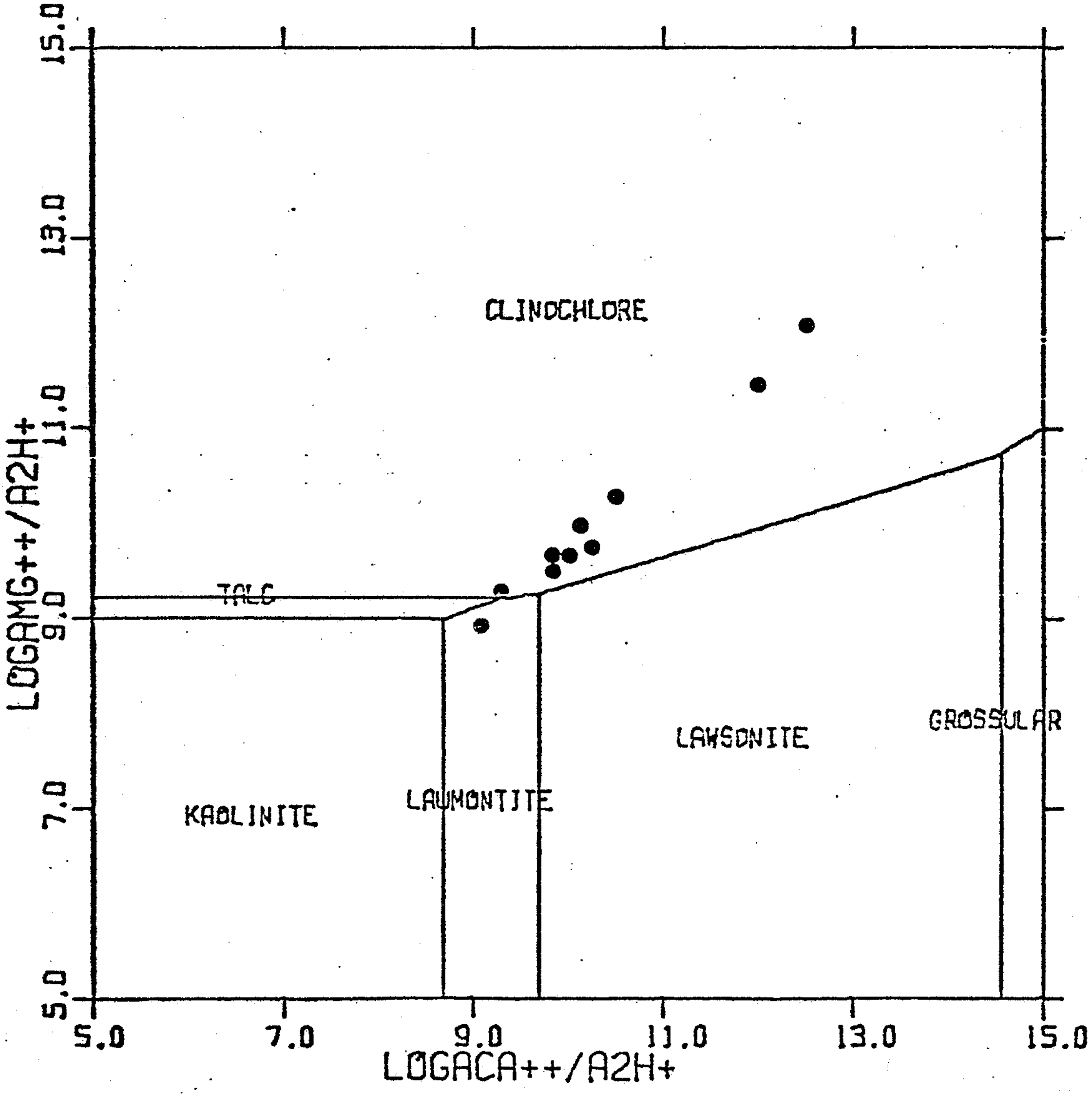


Figure C.2-5 : The system $CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 125°C, 1 bar pressure, and $\log a_{Al^{+3}}/\log a^3_{H^+} = 3.0$. Dots correspond to thermal water samples numbered in Figure C.2-1



APPENDIX D

1. Distribution of species for Meager sample 05 calculated using the minerals alpha quartz, kaolinite, laumontite, and calcite as constraints replacing $H_4SiO_4^o$, Al^{+3}, Ca^{+2}, and HCO_3^- respectively in the original solution constraints.

   Calculated at 1 bar pressure and 348.15°K, 353.15°K, 358.15°K.

Table D-1 : Distribution of species

MEAGER SAMPLE 05 at 348.15°K and 1 bar pressure calculated using alpha quartz, kaolinite, laumontite, and calcite as solid constraints replacing $H_4SiO_4^{\circ}$, Al^{+3}, Ca^{+2}, and HCO_3^-

```
DISTRIBUTION OF SPECIES CALLED AT STEP      0

                                           AQUEOUS SPECIES

SPECIES      MOLALITY      LOG MOL   ACTIVITY      LOG ACT   ACT COEF     LG ACT C  GRAMS/KGM H2O      PPM        LOG PPM

 AL+++       0.89372E-14   -14.049  0.28005E-14   -14.553   0.31335E+00   -0.504   0.24114E-12       0.000      -9.618
 K+          0.11213E-02    -2.950  0.95607E-03    -3.020   0.85262E+00   -0.069   0.43846E-01      43.790       1.641
 NA+         0.91892E-02    -2.037  0.78858E-02    -2.103   0.85815E+00   -0.066   0.21126E+00     210.987       2.324
 CA++        0.21536E-02    -2.667  0.12154E-02    -2.915   0.56435E+00   -0.248   0.86314E-01      86.203       1.936
 MG++        0.90861E-03    -3.042  0.53351E-03    -3.273   0.58717E+00   -0.231   0.22090E-01      22.062       1.344
 H4SIO4      0.44563E-03    -3.351  0.44563E-03    -3.351   0.10000E+01    0.0     0.42832E-01      42.777       1.631
 SO4--       0.44701E-03    -3.350  0.24094E-03    -3.618   0.53899E+00   -0.268   0.42941E-01      42.886       1.632
 CO3--       0.10032E-05    -5.999  0.54732E-06    -6.262   0.54559E+00   -0.263   0.60199E-04       0.060      -1.221
 CL-         0.12059E-01    -1.919  0.10282E-01    -1.988   0.85262E+00   -0.069   0.42754E+00     426.991       2.630
 OH-         0.57702E-06    -6.239  0.49360E-06    -6.307   0.85544E+00   -0.068   0.98135E-05       0.010      -2.009
 H+          0.45207E-06    -6.345  0.39811E-06    -6.400   0.88064E+00   -0.055   0.45567E-06       0.000      -3.342
 H2O         0.55508E+02     1.744  0.99941E+00    -0.000   0.18005E-01   -1.745   0.10000E+04  998711.731       5.999
 AL(OH)++    0.12902E-10   -10.889  0.72811E-11   -11.138   0.56435E+00   -0.248   0.56753E-09       0.000      -6.247
 AL(OH)4-    0.35714E-07    -7.447  0.30648E-07    -7.514   0.85815E+00   -0.066   0.33933E-05       0.003      -2.470
 KSO4-       0.39723E-05    -5.401  0.33981E-05    -5.469   0.85544E+00   -0.068   0.53691E-03       0.536      -0.271
 CACO3       0.30604E-05    -5.514  0.30737E-05    -5.512   0.10044E+01    0.002   0.30631E-03       0.306      -0.514
 CASO4       0.11646E-03    -3.934  0.11697E-03    -3.932   0.10044E+01    0.002   0.15855E-01      15.834       1.200
 MGSO4       0.10911E-03    -3.962  0.10959E-03    -3.960   0.10044E+01    0.002   0.13134E-01      13.117       1.118
 HSO4-       0.42712E-07    -7.369  0.36654E-07    -7.436   0.85815E+00   -0.066   0.41461E-05       0.004      -2.383
 HCO3-       0.34756E-02    -2.459  0.29916E-02    -2.524   0.86077E+00   -0.065   0.21207E+00     211.796       2.326
 H2CO3       0.27588E-02    -2.559  0.27708E-02    -2.557   0.10044E+01    0.002   0.17112E+00     170.896       2.233
 HCL         0.30752E-12   -12.512  0.30887E-12   -12.510   0.10044E+01    0.002   0.11213E-10       0.000      -7.951
 MG(OH)+     0.27879E-06    -6.555  0.23925E-06    -6.621   0.85815E+00   -0.066   0.11520E-04       0.012      -1.939

 IONIC STRENGTH =   0.199458E-01              ELECTRICAL BALANCE = -0.264626E-11

                                GASES
                                -----

 NAME                           LOG K         ACTIVITY        LOG ACTIVITY

CARBON DIOXIDE                   0.53288      0.29283E+00        -0.53339
STEAM                            0.42251      0.37777E+00        -0.42277
```

Table D-2 : Distribution of species

MEAGER SAMPLE 05 at 353.15°K and 1 bar pressure calculated using alpha quartz, kaolinite, laumontite, and calcite as solid constraints replacing $H_4SiO_4^\circ$, Al^{+3}, Ca^{+2}, and HCO_3^-

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                         AQUEOUS SPECIES

SPECIES        MOLALITY     LOG MOL    ACTIVITY      LOG ACT    ACT COEF      LG ACT C   GRAMS/KGM H2O        PPM        LOG PPM

 AL+++        0.56755E-14   -14.246   0.17471E-14   -14.758   0.30783E+00    -0.512     0.15313E-12         0.000        -9.816
 K+           0.11210E-02    -2.950   0.95319E-03    -3.021   0.85033E+00    -0.070     0.43832E-01        43.769         1.641
 NA+          0.11509E-01    -1.939   0.98511E-02    -2.007   0.85598E+00    -0.068     0.26458E+00       264.202         2.422
 CA++         0.14735E-02    -2.832   0.82402E-03    -3.084   0.55921E+00    -0.252     0.59060E-01        58.975         1.771
 MG++         0.89012E-03    -3.051   0.51835E-03    -3.285   0.58233E+00    -0.235     0.21641E-01        21.610         1.335
 H4SIO4       0.50558E-03    -3.296   0.50558E-03    -3.296   0.10000E+01     0.0       0.48594E-01        48.525         1.686
 SO4--        0.45802E-03    -3.339   0.24436E-03    -3.612   0.53350E+00    -0.273     0.43999E-01        43.936         1.643
 CO3--        0.12597E-05    -5.900   0.68047E-06    -6.167   0.54019E+00    -0.267     0.75593E-04         0.075        -1.122
 CL-          0.12059E-01    -1.919   0.10254E-01    -1.989   0.85033E+00    -0.070     0.42754E+00       426.931         2.630
 OH-          0.72311E-06    -6.141   0.61697E-06    -6.210   0.85321E+00    -0.069     0.12298E-04         0.012        -1.911
 H+           0.45295E-06    -6.344   0.39811E-06    -6.400   0.87893E+00    -0.056     0.45656E-06         0.000        -3.341
 H2O          0.55508E+02     1.744   0.99935E+00    -0.000   0.18004E-01    -1.745     0.10000E+04    998571.520         5.999
 AL(OH)++     0.11838E-10   -10.927   0.66201E-11   -11.179   0.55921E+00    -0.252     0.52076E-09         0.000        -6.284
 AL(OH)4-     0.57773E-07    -7.238   0.49453E-07    -7.306   0.85598E+00    -0.068     0.54891E-05         0.005        -2.261
 KSO4-        0.43378E-05    -5.363   0.37010E-05    -5.432   0.85321E+00    -0.069     0.58631E-03         0.585        -0.232
 CACO3        0.29264E-05    -5.534   0.29391E-05    -5.532   0.10043E+01     0.002     0.29291E-03         0.292        -0.534
 CASO4        0.86681E-04    -4.062   0.87057E-04    -4.060   0.10043E+01     0.002     0.11801E-01        11.784         1.071
 MGSO4        0.12751E-03    -3.894   0.12806E-03    -3.893   0.10043E+01     0.002     0.15348E-01        15.326         1.185
 HSO4-        0.51015E-07    -7.292   0.43668E-07    -7.360   0.85598E+00    -0.068     0.49520E-05         0.005        -2.306
 HCO3-        0.43746E-02    -2.359   0.37562E-02    -2.425   0.85865E+00    -0.066     0.26692E+00       266.543         2.426
 H2CO3        0.36470E-02    -2.438   0.36629E-02    -2.436   0.10043E+01     0.002     0.22621E+00       225.886         2.354
 HCL          0.45966E-12   -12.338   0.46166E-12   -12.336   0.10043E+01     0.002     0.16760E-10         0.000        -7.776
 MG(OH)+      0.37463E-06    -6.426   0.32067E-06    -6.494   0.85598E+00    -0.068     0.15479E-04         0.015        -1.811

 IONIC STRENGTH =  0.201807E-01                     ELECTRICAL BALANCE = -0.466522E-10

                              GASES
                              -----

 NAME                         LOG K        ACTIVITY        LOG ACTIVITY

CARBON DIOXIDE                0.39254      0.40448E+00       -0.39310
STEAM                         0.33365      0.46352E+00       -0.33393
```

Table D-3 : Distribution of species

MEAGER SAMPLE 05 at 358.15°K and 1 bar pressure calculated using alpha quartz, kaolinite, laumontite, and calcite as solid constraints replacing $H_4SiO_4^o$, Al^{+3}, Ca^{+2}, and HCO_3^-

```
DISTRIBUTION OF SPECIES CALLED AT STEP     0

                                                      AQUEOUS SPECIES

SPECIES          MOLALITY      LOG MOL     ACTIVITY      LOG ACT     ACT COEF     LG ACT C   GRAMS/KGM H2O        PPM         LOG PPM

 AL+++         0.36910E-14   -14.433   0.11073E-14   -14.956   0.30001E+00    -0.523    0.99588E-13          0.000      -10.002
 K+            0.11207E-02    -2.951   0.94908E-03    -3.023   0.84689E+00    -0.072    0.43820E-01         43.750        1.641
 NA+           0.13531E-01    -1.869   0.11539E-01    -1.938   0.85275E+00    -0.069    0.31108E+00        310.582        2.492
 CA++          0.10252E-02    -2.989   0.56560E-03    -3.247   0.55169E+00    -0.258    0.41090E-01         41.025        1.613
 MG++          0.87186E-03    -3.060   0.50164E-03    -3.300   0.57537E+00    -0.240    0.21197E-01         21.163        1.326
 H4SIO4        0.57146E-03    -3.243   0.57146E-03    -3.243   0.10000E+01     0.0      0.54926E-01         54.838        1.739
 SO4--         0.46216E-03    -3.335   0.24280E-03    -3.615   0.52536E+00    -0.280    0.44395E-01         44.324        1.647
 CO3--         0.15611E-05    -5.807   0.83084E-06    -6.080   0.53222E+00    -0.274    0.93680E-04          0.094       -1.029
 CL-           0.12059E-01    -1.919   0.10213E-01    -1.991   0.84689E+00    -0.072    0.42754E+00        426.858        2.630
 OH-           0.89758E-06    -6.047   0.76283E-06    -6.118   0.84988E+00    -0.071    0.15265E-04          0.015       -1.817
 H+            0.45421E-06    -6.343   0.39811E-06    -6.400   0.87648E+00    -0.057    0.45783E-06          0.000       -3.340
 H2O           0.55508E+02     1.744   0.99928E+00    -0.000   0.18002E-01    -1.745    0.10000E+04     998400.511        5.999
 AL(OH)++      0.11033E-10   -10.957   0.60868E-11   -11.216   0.55169E+00    -0.258    0.48533E-09          0.000       -6.315
 AL(OH)4-      0.93171E-07    -7.031   0.79451E-07    -7.100   0.85275E+00    -0.069    0.88522E-05          0.009       -2.054
 KSO4-         0.46400E-05    -5.333   0.39434E-05    -5.404   0.84988E+00    -0.071    0.62715E-03          0.626       -0.203
 CACO3         0.27882E-05    -5.555   0.28004E-05    -5.553   0.10044E+01     0.002    0.27907E-03          0.279       -0.555
 CASO4         0.64102E-04    -4.193   0.64383E-04    -4.191   0.10044E+01     0.002    0.87269E-02          8.713        0.940
 MGSO4         0.14564E-03    -3.837   0.14628E-03    -3.835   0.10044E+01     0.002    0.17532E-01         17.504        1.243
 HSO4-         0.59958E-07    -7.222   0.51129E-07    -7.291   0.85275E+00    -0.069    0.58201E-05          0.006       -2.236
 HCO3-         0.54544E-02    -2.263   0.46664E-02    -2.331   0.85552E+00    -0.068    0.33281E+00        332.283        2.522
 H2CO3         0.48025E-02    -2.319   0.48236E-02    -2.317   0.10044E+01     0.002    0.29788E+00        297.400        2.473
 HCL           0.67984E-12   -12.168   0.68282E-12   -12.166   0.10044E+01     0.002    0.24787E-10          0.000       -7.606
 MG(OH)+       0.49779E-06    -6.303   0.42449E-06    -6.372   0.85275E+00    -0.069    0.20568E-04          0.021       -1.687

 IONIC STRENGTH =   0.208077E-01                 ELECTRICAL BALANCE =   0.436252E-10

                                 GASES
                                 -----

 NAME                            LOG K        ACTIVITY       LOG ACTIVITY

CARBON DIOXIDE                   0.25663     0.55302E+00        -0.25726
STEAM                            0.24769     0.56494E+00        -0.24800
```

APPENDIX D.1

1. Distribution of species for Meager sample 05 calculated using the minerals alpha quartz, kaolinite, laumontite, and calcite as constraints replacing $H_4SiO_4^{\circ}$, Al^{+3}, Ca^{+2}, and HCO_3^{-} respectively in the original solution constraints.

   Calculated at 373.15°K and 1 bar pressure.

Table D.1-1 : Distribution of species

Meager sample 05 at 373.15°K and 1 bar pressure calculated using alpha quartz, kaolinite, laumontite, and calcite ~~as solid constraints replacing $H_4SiO_4^\circ$, Al^{+3}, Ca^{+2}, and HCO_3^-~~

```
DISTRIBUTION OF SPECIES CALLED AT STEP      0

                                                  AQUEOUS SPECIES

SPECIES         MOLALITY     LOG MOL   ACTIVITY     LOG ACT   ACT COEF      LG ACT C  GRAMS/KGM H2O        PPM       LOG PPM

 AL+++          0.11680E-14  -14.933  0.30801E-15  -15.511   0.26370E+00    -0.579   0.31515E-13        0.000     -10.503
 K+             0.11253E-02   -2.949  0.93284E-03   -3.030   0.82897E+00    -0.081   0.44001E-01       43.895       1.642
 NA+            0.19545E-01   -1.709  0.16341E-01   -1.787   0.83609E+00    -0.078   0.44933E+00      448.241       2.652
 CA++           0.38086E-03   -3.419  0.19601E-03   -3.708   0.51464E+00    -0.289   0.15265E-01       15.228       1.183
 MG++           0.10180E-02   -2.992  0.55119E-03   -3.259   0.54145E+00    -0.266   0.24750E-01       24.690       1.393
 H4SIO4         0.80801E-03   -3.093  0.80801E-03   -3.093   0.10000E+01     0.0     0.77662E-01       77.474       1.889
 SO4--          0.67660E-03   -3.170  0.32795E-03   -3.484   0.48471E+00    -0.315   0.64995E-01       64.838       1.812
 CO3--          0.27777E-05   -5.556  0.13680E-05   -5.864   0.49251E+00    -0.308   0.16669E-03        0.166      -0.779
 CL-            0.12059E-01   -1.919  0.99969E-02   -2.000   0.82897E+00    -0.081   0.42754E+00      426.505       2.630
 OH-            0.16305E-05   -5.788  0.13576E-05   -5.867   0.83260E+00    -0.080   0.27730E-04        0.028      -1.558
 H+             0.46055E-06   -6.337  0.39811E-06   -6.400   0.86442E+00    -0.063   0.46422E-06        0.000      -3.334
 H2O            0.55508E+02    1.744  0.99698E+00   -0.000   0.17997E-01    -1.745   0.10000E+04   997574.148       5.999
 AL(OH)++       0.97740E-11  -11.010  0.50301E-11  -11.298   0.51464E+00    -0.289   0.42995E-09        0.000      -6.368
 AL(OH)4-       0.38410E-06   -6.416  0.32114E-06   -6.493   0.83609E+00    -0.078   0.36494E-04        0.036      -1.439
 KSO4-          0.78442E-05   -5.105  0.65311E-05   -5.185   0.83260E+00    -0.080   0.10602E-02        1.058       0.024
 CACO3          0.23637E-05   -5.626  0.23758E-05   -5.624   0.10051E+01     0.002   0.23658E-03        0.236      -0.627
 CASO4          0.38593E-04   -4.413  0.38791E-04   -4.411   0.10051E+01     0.002   0.52542E-02        5.241       0.719
 MGSO4          0.36525E-03   -3.437  0.36712E-03   -3.435   0.10051E+01     0.002   0.43967E-01       43.860       1.642
 HSO4-          0.13739E-06   -6.862  0.11487E-06   -6.940   0.83609E+00    -0.078   0.13337E-04        0.013      -1.876
 HCO3-          0.10041E-01   -1.998  0.84291E-02   -2.074   0.83943E+00    -0.076   0.61271E+00      611.219       2.786
 H2CO3          0.10716E-01   -1.970  0.10771E-01   -1.968   0.10051E+01     0.002   0.66468E+00      663.068       2.822
 HCL            0.20689E-11  -11.684  0.20794E-11  -11.682   0.10051E+01     0.002   0.75433E-10        0.000      -7.123
 MG(OH)+        0.13609E-05   -5.866  0.11378E-05   -5.944   0.83609E+00    -0.078   0.56232E-04        0.056      -1.251

 IONIC STRENGTH =  0.255479E-01                   ELECTRICAL BALANCE = -0.146773E-10

                              GASES
                              -----

 NAME                         LOG K         ACTIVITY        LOG ACTIVITY

CARBON DIOXIDE               -0.12611      0.13342E+01       0.12522
STEAM                         0.00601      0.98525E+00      -0.00645
```

APPENDIX E

1. Distribution of species for Meager sample 05 calculated using the minerals alpha quartz, kaolinite, laumontite, anhydrite, and calcite as constraints replacing $H_4SiO_4^\circ$, Al^{+3}, Ca^{+2}, SO_4^{-2}, and HCO_3^- respectively in the original solution constraints.

   Calculated at 1 bar pressure and 353.15°K and 358.15°K.

Table E-1 : Distribution of species

Meager sample 05 at 353.15°K and 1 bar pressure calculated using alpha quartz, kaolinite, laumontite, anhydrite, and calcite as solid constraints replacing $H_4SiO_4^0$, Al^{+3}, Ca^{+2}, SO_4^{-2}, HCO_3^-

```
 DISTRIBUTION OF SPECIES CALLED AT STEP      0

                                             AQUEOUS SPECIES

 SPECIES        MOLALITY      LOG MOL   ACTIVITY      LOG ACT    ACT COEF     LG ACT C  GRAMS/KGM H2O       PPM        LOG PPM

  AL+++         0.10106E-13   -12.995  0.17514E-14   -14.757   0.17330E+00   -0.761   0.27268E-12        0.000       -9.566
  K+            0.10240E-02    -2.990  0.78013E-03    -3.108   0.76162E+00   -0.118   0.40042E-01       39.870        1.601
  NA+           0.46683E-01    -1.331  0.36234E-01    -1.441   0.77618E+00   -0.110   0.10732E+01     1068.646        3.029
  CA++          0.20596E-02    -2.686  0.82649E-03    -3.083   0.40129E+00   -0.397   0.82548E-01       82.195        1.915
  MG++.         0.27027E-03    -3.568  0.11951E-03    -3.923   0.44218E+00   -0.354   0.65708E-02        6.543        0.816
  H4SIO4        0.50457E-03    -3.297  0.50457E-03    -3.297   0.10000E+01    0.0     0.48497E-01       48.289        1.684
  SO4--         0.17708E-01    -1.752  0.62841E-02    -2.202   0.35487E+00   -0.450   0.17011E+01     1693.801        3.229
  CO3--         0.18484E-05    -5.733  0.67843E-06    -6.168   0.36703E+00   -0.435   0.11092E-03        0.110       -0.957
  CL-           0.12059E-01    -1.919  0.91871E-02    -2.037   0.76182E+00   -0.118   0.42754E+00      425.711        2.629
  OH-           0.80127E-06    -6.096  0.61635E-06    -6.210   0.76921E+00   -0.114   0.13628E-04        0.014       -1.867
  H+            0.48049E-06    -6.318  0.39811E-06    -6.400   0.82855E+00   -0.082   0.48432E-06        0.000       -3.317
  H2O           0.55508E+02     1.744  0.99835E+00    -0.001   0.17986E-01   -1.745   0.10000E+04   995718.638        5.998
  AL(OH)++      0.16522E-10   -10.782  0.66301E-11   -11.178   0.40129E+00   -0.397   0.72678E-09        0.000       -6.140
  AL(OH)4-      0.63618E-07    -7.196  0.49379E-07    -7.306   0.77618E+00   -0.110   0.60444E-05        0.006       -2.221
  KSO4-         0.10127E-03    -3.995  0.77898E-04    -4.108   0.76921E+00   -0.114   0.13688E-01       13.629        1.134
  CACO3         0.28941E-05    -5.538  0.29391E-05    -5.532   0.10156E+01    0.007   0.28967E-03        0.288       -0.540
  CASO4         0.22111E-02    -2.655  0.22456E-02    -2.649   0.10156E+01    0.007   0.30103E+00      299.739        2.477
  MGSO4         0.74764E-03    -3.126  0.75928E-03    -3.120   0.10156E+01    0.007   0.89996E-01       89.610        1.952
  HSO4-         0.14468E-05    -5.840  0.11230E-05    -5.950   0.77618E+00   -0.110   0.14044E-03        0.140       -0.854
  HCO3-         0.47844E-02    -2.320  0.37450E-02    -2.427   0.78275E+00   -0.106   0.29193E+00      290.683        2.463
  H2CO3         0.35959E-02    -2.444  0.36519E-02    -2.437   0.10156E+01    0.007   0.22304E+00      222.083        2.347
  HCL           0.40726E-12   -12.390  0.41360E-12   -12.383   0.10156E+01    0.007   0.14849E-10        0.000       -7.830
  MG(OH)+       0.95157E-07    -7.022  0.73859E-07    -7.132   0.77618E+00   -0.110   0.39318E-05        0.004       -2.407


  IONIC STRENGTH =  0.724076E-01                 ELECTRICAL BALANCE = -0.131786E-08


                                GASES
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 NAME                           LOG K          ACTIVITY        LOG ACTIVITY


 CARBON DIOXIDE                  0.39254       0.40367E+00       -0.39397
 STEAM                           0.33365       0.46306E+00       -0.33436
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Table E-2 : Distribution of species

Meager sample 05 at 358.15°K and 1 bar pressure calculated using alpha quartz, kaolinite, laumontite, anhydrite, and calcite as solid constraints replacing $H_4SiO_4^\circ$, Al^{+3}, Ca^{+2}, SO_4^{-2}, HCO_3^-

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DISTRIBUTION OF SPECIES CALLED AT STEP      0

                                                  AQUEOUS SPECIES

SPECIES        MOLALITY      LOG MOL   ACTIVITY      LOG ACT    ACT COEF     LG ACT C   GRAMS/KGM H2O        PPM      LOG PPM

 AL+++        0.74132E-14   -14.130  0.11112E-14   -14.954   0.14989E+00    -0.824   0.20002E-12           0.000     -9.701
 K+           0.99384E-03    -3.003  0.73397E-03    -3.134   0.73852E+00    -0.132   0.38861E-01          38.650      1.587
 NA+          0.63175E-01    -1.199  0.47742E-01    -1.321   0.75571E+00    -0.122   0.14524E+01        1444.475      3.160
 CA++         0.15456E-02    -2.811  0.56796E-03    -3.246   0.36747E+00    -0.435   0.61947E-01          61.610      1.790
 MG++         0.21219E-03    -3.673  0.87466E-04    -4.058   0.41221E+00    -0.385   0.51587E-02           5.131      0.710
 H4SIO4       0.56988E-03    -3.244  0.56988E-03    -3.244   0.10000E+01     0.0     0.54774E-01          54.476      1.736
 SO4--        0.24700E-01    -1.607  0.78224E-02    -2.107   0.31670E+00    -0.499   0.23727E+01        2359.781      3.373
 CO3--        0.25073E-05    -5.601  0.82739E-06    -6.082   0.33000E+00    -0.481   0.15046E-03           0.150     -0.825
 CL-          0.12059E-01    -1.919  0.89061E-02    -2.050   0.73852E+00    -0.132   0.42754E+00         425.216      2.629
 OH-          0.10192E-05    -5.992  0.76177E-06    -6.118   0.74740E+00    -0.126   0.17335E-04           0.017     -1.763
 H+           0.48730E-06    -6.312  0.39811E-06    -6.400   0.81697E+00    -0.088   0.49118E-06           0.000     -3.311
 H2O          0.55508E+02     1.744  0.99789E+00    -0.001   0.17977E-01    -1.745   0.10000E+04      994559.445      5.998
 AL(OH)++     0.16599E-10   -10.780  0.60995E-11   -11.215   0.36747E+00    -0.435   0.73015E-09           0.000     -6.139
 AL(OH)4-     0.10492E-06    -6.979  0.79286E-07    -7.101   0.75571E+00    -0.122   0.99682E-05           0.010     -2.004
 KSO4-        0.13146E-03    -3.881  0.98251E-04    -4.008   0.74740E+00    -0.126   0.17768E-01          17.672      1.247
 CACO3        0.27458E-05    -5.561  0.28004E-05    -5.553   0.10199E+01     0.009   0.27483E-03           0.273     -0.563
 CASO4        0.20423E-02    -2.690  0.20829E-02    -2.681   0.10199E+01     0.009   0.27804E+00         276.528      2.442
 MGSO4        0.80571E-03    -3.094  0.82174E-03    -3.085   0.10199E+01     0.009   0.96987E-01          96.459      1.984
 HSO4-        0.21797E-05    -5.662  0.16472E-05    -5.783   0.75571E+00    -0.122   0.21158E-03           0.210     -0.677
 HCO3-        0.60863E-02    -2.216  0.46470E-02    -2.333   0.76352E+00    -0.117   0.37137E+00         369.347      2.567
 H2CO3        0.47099E-02    -2.327  0.48036E-02    -2.318   0.10199E+01     0.009   0.29213E+00         290.545      2.463
 HCL          0.58384E-12   -12.234  0.59545E-12   -12.225   0.10199E+01     0.009   0.21287E-10           0.000     -7.674
 MG(OH)+      0.97804E-07    -7.010  0.73912E-07    -7.131   0.75571E+00    -0.122   0.40412E-05           0.004     -2.396

IONIC STRENGTH =   0.941447E-01                  ELECTRICAL BALANCE = -0.190491E-08

                             GASES
                             -----

NAME                         LOG K        ACTIVITY        LOG ACTIVITY

CARBON DIOXIDE               0.25663      0.55149E+00       -0.25846
STEAM                        0.24769      0.56416E+00       -0.24860
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