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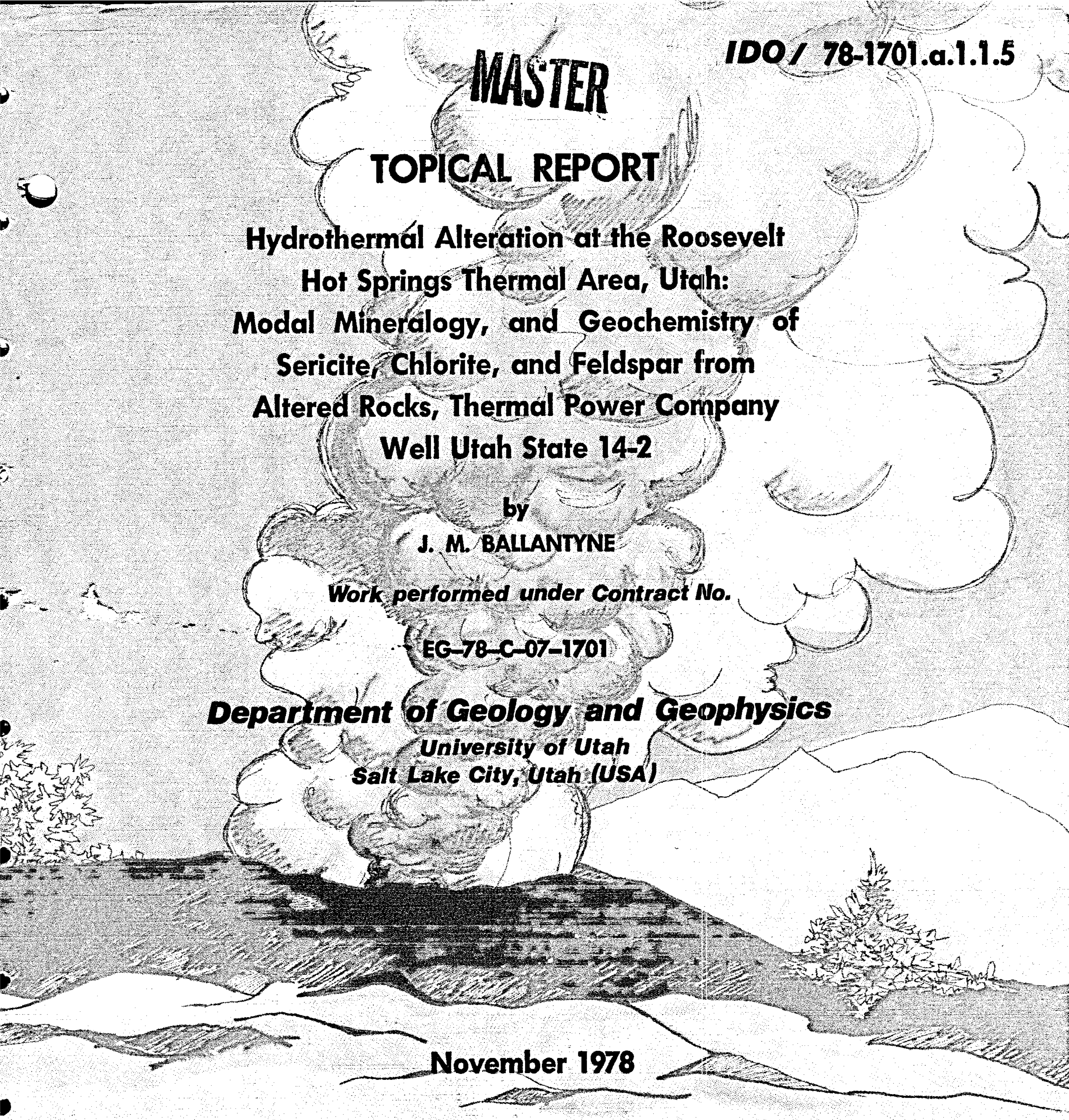

TOPICAL REPORT

Hydrothermal Alteration at the Roosevelt Hot Springs Thermal Area, Utah: Modal Mineralogy, and Geochemistry of Sericite, Chlorite, and Feldspar from Altered Rocks, Thermal Power Company Well Utah State 14-2

by

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ABSTRACT

Sericites, chlorites, feldspars, biotite and hornblende from hydrothermally altered rocks at several depths in Thermal Power Company well Utah State 14-2, Roosevelt Hot Springs Thermal Area, Utah, have been analysed using the electron microprobe. Sericites and ferromagnesian minerals have been analysed for 12 major elements, and feldspars for 3. The results have been used, along with whole rock chemical analyses, to computer calculate modal mineralogy for samples from the drillhole. Calculated modes for hydrothermal minerals are in reasonable agreement with observations from thin sections.

Chlorite compositions plotted in terms of ions on a graph of Si^{4+} versus $Mg^{2+}/(Mg^{2+} + Fe^{2+} + Fe^{3+})$ fall in the ripidolite-pycnochlorite-brunsvigite field and show distinct differences due to host mineral type. Tetrahedral occupancy in chlorite by Si^{4+} ions increases according to host mineral in the order: biotite, plagioclase, hornblende; and octahedral occupancy by Mg^{2+} ions increases in the order: plagioclase, hornblende, biotite. A ternary plot of Mg^{2+}, $Fe^{2+} + Fe^{3+}$, and Al^{3+} ions in octahedral positions shows a less distinct effect of host mineral control. No systematic compositional trends within the drillhole are evident but compositions do vary with depth.

Sericites replace plagioclase and rarely biotite. No host mineral effect is evident. All of the sericites are phengitic, having $Si^{4+}:Al^{3+}$ ratios greater than 3:1, and Si^{4+} content shows an overall downhole increase with depth in the drillhole. An overall downhole decrease is exhibited by F^- relative to Mg^{2+}.

INTRODUCTION

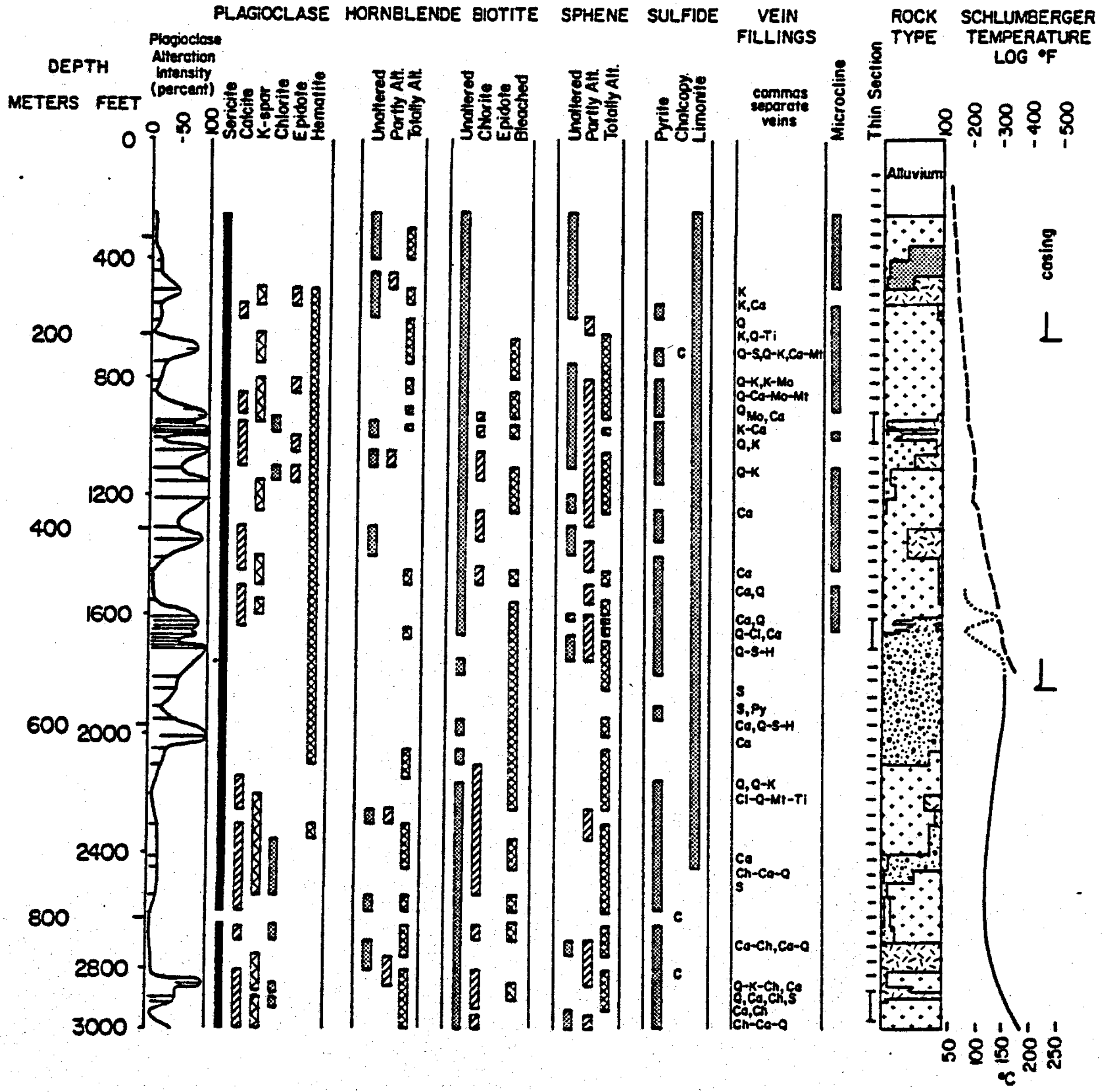
Microprobe chemical analyses of mineral phases have been obtained from samples of cuttings taken at several depths in Thermal Power Company's well Utah State 14-2, Roosevelt Hot Springs, Utah.

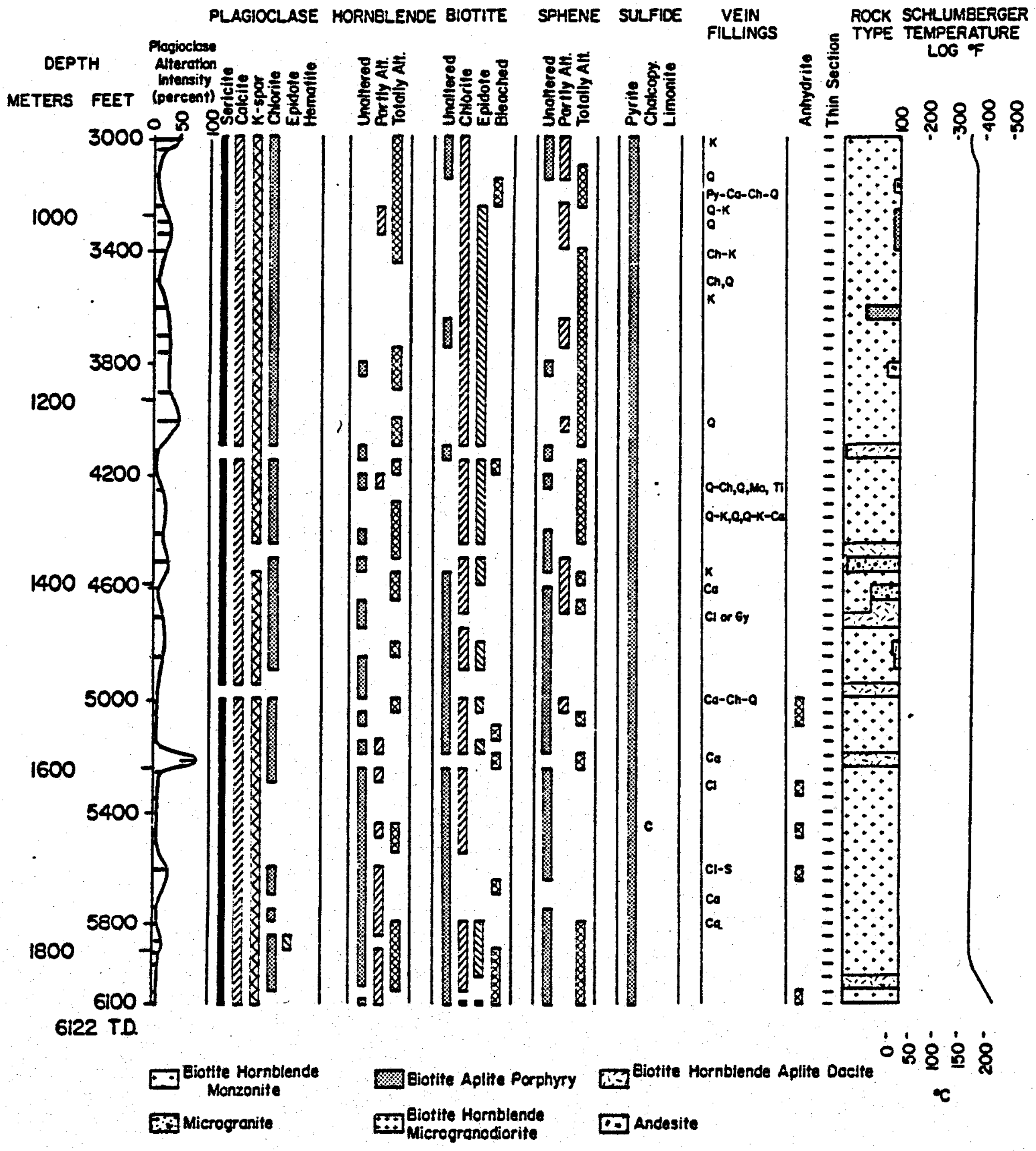
Minerals were analysed: (1) to provide input data for a computer program which calculates a modal rock composition, given mineral compositions and a whole rock chemical analysis; and (2) to detect any compositional zoning in hydrothermal minerals within the drillhole.

The well was drilled to a depth of 6100 feet in a biotite hornblende monzonite which has been intruded by numerous silicic to intermediate dikes. Three zones of relatively strongly altered and fractured rock occur in the upper half of the drillhole and are assumed to be conduits for hot water inflow to the well. The lithologies and alteration have been described by Ballantyne and Parry (1978) and are summarized in Figure 1, reproduced here from that report.

Sericite, chlorite, hornblende and biotite have been analysed for 12 elements: Si, Ti, Al, Fe, Mn, Mg, Ca, K, Na, Ba, Cl, F. Feldspars have been analysed for Ca, K, and Na. Minerals for analysis have been chosen from 8 samples from different depths in the drillhole.

Figure 1. Hydrothermal Alteration in Well 14-2: Products and extent of alteration. Horizontal bars on plagioclase destruction graph indicate range of plagioclase destruction observed in a thin section. Abbreviations: B, barite; C, chalcopyrite; Ca, Calcite; Ch, chlorite; Cl, clay; Gy, gypsum; H, hematite; K, k-feldspar; Mo, montmorillonite; Mt, magnetite; Py, pyrite; Q, quartz; S, sericite; Ti, Leuxocene. (From Ballantyne and Parry, 1978.)


DEPTH
METERS FEET
Plagioclase Alteration Intensity (percent)
0 -50 100
PLAGIOCLASE
Sericite
Calcite
K-spar
Chlorite
Epidote
Hematite
HORNBLENDE
Unaltered
Partly Alt.
Totally Alt.
BIOTITE
Unaltered
Chlorite
Epidote
Bleached
SPHENE
Unaltered
Partly Alt.
Totally Alt.
SULFIDE
Pyrite
Chalcopy.
Limonite
VEIN FILLINGS
commas separate veins
Microcline
Thin Section
ROCK TYPE
SCHLUMBERGER TEMPERATURE LOG °F
100 -200 -300 -400 -500
0
400
200
800
1200
400
1600
600 2000
2400
800
2800
3000
c
c
c
K
K,Ca
Q
K,Q-Ti
Q-S,Q-K,Ca-Mt
Q-K,K-Mo
Q-Ca-Mo-Mt
Q Mo, Ca
K-Ca
Q,K
Q-K
Ca
Ca
Ca,Q
Ca,Q
Q-Cl,Ca
Q-S-H
S
S,Py
Ca,Q-S-H
Ca
Q, Q-K
Cl-Q-Mt-Ti
Ca
Ch-Ca-Q
S
Ca-Ch,Ca-Q
Q-K-Ch, Ca
Q,Ca,Ch,S
Ca,Ch
Ch-Ca-Q
Alluvium
casing
50 100 150 200 250
°C


PLAGIOCLASE
HORNBLENDE
BIOTITE
SPHENE
SULFIDE
VEIN FILLINGS
ROCK TYPE
SCHLUMBERGER TEMPERATURE LOG °F
DEPTH
METERS
FEET
Plagioclase Alteration Intensity (percent)
0
50
100
Sericite
Calcite
K-spar
Chlorite
Epidote
Hematite
Unaltered
Partly Alt.
Totally Alt.
Unaltered
Chlorite
Epidote
Bleached
Unaltered
Partly Alt.
Totally Alt.
Pyrite
Chalcopy.
Limonite
Anhydrite
Thin Section
100
-200
-300
-400
-500
3000
1000
3400
3800
1200
4200
1400
4600
5000
1600
5400
5800
1800
6100
6122 T.D.
K
Q
Py-Ca-Ch-Q
Q-K
Q
Ch-K
Ch,Q
K
Q
Q-Ch,Q,Mo, Ti
Q-K,Q,Q-K-Ca
K
Ca
Cl or Gy
Ca-Ch-Q
Ca
Cl
C
Cl-S
Ca
Ca
0
50
100
150
200
°C
Biotite Hornblende Monzonite
Biotite Aplite Porphyry
Biotite Hornblende Aplite Dacite
Microgranite
Biotite Hornblende Microgranodiorite
Andesite

ANALYTICAL TECHNIQUES

Minerals were analysed using a 3-channel ARL electron microprobe at an acceleration voltage of 15kv for a fixed total beam current achieved in approximately 13 seconds. An attached Tracor Northern energy dispersive unit provides an energy spectrum on a visual display unit which, while not quantitative, can be used to identify mineral phases by the relative concentrations of the elements present. A beam of approximately 1 micron in diameter was used because of the fine-grained nature of many of the hydrothermal minerals. Typically ten spots were analysed for each mineral grain or, in the case of fine grained minerals, for each aggregate in a particular environment in any one chip. For each spot the energy spectrum from 0 to 10 kev was checked to ensure correct identification of the mineral phase concerned. This is particularly important with fine grained hydrothermal minerals where, for example, chlorite and sericite or albite are intermixed on a fine scale and are not optically distinguishable.

For sericite, chlorite, hornblende and biotite analyses, the standards used were amphiboles, a pyroxene, biotites, and a scapolite. X-ray counts were reduced to oxide and halide weight percentages, with standard deviations, using a Hewlett Packard 25 programable calculator. Bence-Albee matrix corrections (Bence and Albee, 1968) were then calculated using a computer program which also calculates a structural formula. Input data to the Bence-Albee routine also includes an ideal water content and a typical ferric to ferrous iron ratio for the mineral concerned. The data are corrected by an iterative routine which corrects the original oxide data each time with successively more accurate approximations of the water content.

Feldspars were analysed for only Ca, K and Na using feldspar standards. First estimates of SiO_2 and Al_2O_3 content were made, assuming stoichiometry, and these data input to the program described above. SiO_2 and Al_2O_3 weight percentages were then recalculated from the Bence-Albee corrected values for CaO, K_2O and Na_2O.

MODAL MINERALOGY

Modal mineralogy has been calculated by computer for 40 samples from Thermal Power Co. well Utah State 14-2 and the results are given in Table 1. A computer-calculated rock mode has several advantages in the current situation aside from removing the tedium of point counting:

1. For a sample of drill cuttings a calculated mode may be more representative than a mode obtained by point-counting a thin section because a thin section may not be truly representative of the rock sample.
2. A whole rock chemical analysis provides average data for an interval rather than for a point, and the mode thus calculated smooths out the effects of small dikes or other local variations in rock composition.
3. A calculated mode provides quantitative data for fine-grained, hydrothermal minerals which may not be obtainable by point-counting.

The computer program MODECALC performs a weighted least squares regression fit of a whole rock chemical analysis to the compositions of a stipulated set of minerals. Because the best mathematical fit may give negative and overly large positive numbers, an initial rough estimate of mineral abundances is also entered and positive values are obtained by weighting the solution toward this estimate. The weight is chosen by the user to be the minimum required for positive results and the same weight is used for all samples. The estimate of modal abundances need only be very

Table 1. Computer Calculated Modal Mineralogy: Well No. 14-2

Sample*	Plagioclase	K-Feldspar	Quartz	Biotite	Hornblende	Sericite	Chlorite	Calcite	Sphene	Rutile	Hematite	Pyrite
200	59	26	9.8	.31	.69	.48		.95	.40		.62	
400	56	24	11	2.2	.93	.57		.07	.62	.05	1.4	
500	52	21	8.7	6.7	2.6	.90		.24	2.4		1.7	
600	60	24	4.2	3.4	1.7	1.0		.11	1.3		1.9	
700	61	25	5.4	3.3	1.4	.91		.22	1.0		1.0	
800	58	27	4.7	2.8	1.6	1.0		.60	1.5		1.2	
900	58	21	5.1	3.3		4.5	1.1	1.3	.93	.21	1.9	
920	64	9.8	8.0	3.0		2.7	1.4	.07		.44	4.4	
940	54	9.7	10	8.8		4.1	2.2	2.4	2.4	.07	1.9	
960	56	17	9.0	5.2		3.6	1.5	.67	2.0		1.4	
980	53	15	12	5.8		4.1	1.9	.69	2.1		1.6	
1000	53	15	11	6.8		4.2	1.9	.66	2.2		1.3	
1100	60	20	6.6	2.4		4.0	.93	.18	1.4		1.2	
1200	61	20	9.9	.93		2.1	.71			.38	1.7	
1300	55	14	8.4	8.2		3.3	1.8	1.0	2.2		2.0	
1400	52	23	6.1	6.4		4.7	1.3	1.2	2.1		.90	
1500	51	25	5.7	6.4		4.7	1.3	.65	2.1		.33	
1600	55	21	14	2.3		1.2	.73	.29	.40	.36	1.5	
1620	57	17	8.9	5.8		3.5	1.4	.62	1.4		1.1	
1640	57	13	9.6	7.5		3.6	1.9	.79	1.9		1.9	
1660	58	17	15	2.1		1.5	.90	.12		.34	1.2	
1680	57	16	16	3.2		.96	1.0	.11		.36	1.0	
1700	60	13	18	2.2		.08		.11		.20	1.5	
1800	55	20	16	1.4		.80		.16		.21	1.3	
1900	54	23	16	.49		.26		.12		.19	1.3	
2000	54	19	18	1.6				.21		.19	1.1	
2100	55	25	5.9	3.0	1.4	.84	5.1	.45	1.6	.12	.42	.06
2400	47	26	11	2.6	1.8	.69	5.1	1.7	1.5		.06	.05
2800	44	29	5.5	2.6	1.9	1.3	5.9	1.8	3.2	.18	1.6	.16
2855	46	23	6.7	2.6	1.8	1.2	7.1	3.3	2.7	.53	1.9	.33
2875	42	9.1	11	6.7	2.5	1.1	14	1.7	2.0	.71	2.0	.81
2900	39	32	5.6	2.6	2.0	1.5	6.5	2.1	3.5	.31	1.8	.24
2920	44	26	4.8	4.2	2.0	1.4	8.1	2.5	2.8	.61	.66	.28
2940	41	25	5.0	5.2	2.4	1.3	9.3	2.3	3.2	.33	.84	.23
3000	41	29	4.7	4.2	2.1	1.4	7.9	2.3	3.1	.31	.82	.14
3500	57	28	4.3	1.4	.80	.88	3.0	.90	1.2	.48	1.0	.19
4000	52	28	4.5	2.0	1.3	1.0	4.2	1.4	2.0	.29	1.3	.28
5000	52	26	4.1	2.5	1.9	1.1	5.2	1.0	2.8		.88	.14
5500	56	32	4.4	.22	.90	.96	1.7	.53	1.6		1.2	.06
6095	53	33	4.9	.17	1.0	.97	1.7	1.1	1.7		1.3	.12

* Number represents depth (in feet) to top of 5 or 10 foot sample interval.
Units are Weight Percent.

Table 2 Mineral Compositions* Used in Mode Calculation

	Plagioclase	K-Feldspar	Biotite	Hornblende	Chlorite	Sericite
SiO_2	68.0	65.1	36.4	44.2	29.9	53.1
TiO_2			2.95	.93	.11	.10
Al_2O_3	19.9	18.5	13.9	8.23	19.8	30.9
Fe_2O_3			23.8	21.6	34.6	3.48
MnO			.35	.57	.81	.04
MgO			11.8	10.2	14.3	1.69
CaO	.50	.01	.05	11.9	.21	.14
K_2O	.17	15.4	10.8	1.08	.21	10.3
Na_2O	11.4	1.06	.07	1.27	.08	.18

* Recalculated to 100% excluding BaO, H_2O and halides.

All other minerals used are assumed stoichiometric.

Units are weight percent.

Table 3. Estimated Modes for Input to Mode Calculation Program

Samples	Plagioclase	K-Feldspar	Quartz	Biotite	Hornblende	Sericite	Chlorite	Calcite	Sphene	Rutile	Hematite	Pyrite
200-800	40	40	5	10	1	1		1	1	1	1	
900-1680	35	40	5	10		5	1	1	1	1	1	
1700-2000	35	40	5	10		5	1	1	1	1	1	
2100-6095	40	40	5	5	1	1	5	1	1	1	1	.2

Units are weight percent.

approximate and does not have a strong effect on the final result. The mathematical basis for the program is discussed briefly in the appendix.

The mineral compositions used are given in Table 2 and the estimated modes in Table 3. Occasional absences of sphene and especially rutile from the table occur where negative abundances were still obtained for these in the first run and they were excluded from the final run. The whole rock chemical analyses from which samples were chosen for mode calculations are reported in Parry (1978) and are not reproduced here. Note that most of the samples chosen are from the more strongly altered portions of the hole above 3000 feet.

The modes shown in Table 1 must be considered as approximate. Only one composition for each mineral phase has been used in the program, whereas in fact mineral compositions change with rock type and to some extent with position in the drillhole. The mixing inherent in samples of cuttings means that variable amounts of dike material are included in samples of host rock and vice versa. The compositions of feldspar, biotite and hornblende, and the estimated modes for these minerals are those for the biotite hornblende monzonite. Major minerals from the dikes should be included for more reliable results, but have not been analysed at the time of writing.

In spite of the above uncertainties a number of features are evident in the results:

1. Sericite abundances are computed to be higher in the zone between 900 and 1640 feet which corresponds to a zone of stronger plagioclase destruction in Figure 1. However,

plagioclase destruction is also higher between 1660 and 2000 feet, while calculated sericite abundance in this zone is low. The discrepancy is probably due to the fact that the latter interval corresponds to a microgranite dike which almost certainly has different mineral compositions. Calculated quartz abundance also jumps in this latter zone.

2. Calcite abundance increases below 2400 feet which corresponds to the beginning of abundant chlorite and calcite in plagioclase noted in thin sections. The computed high chlorite content between 2800 and 3000 feet correlates with the high chlorite abundance seen in thin sections from this zone, though chlorite is also abundant for several hundred feet above the zone.
3. Pyrite reaches a computed peak of 0.81% at 2875 feet in this set of samples and is present in amounts greater than 0.1% below 2850 feet, it's abundance decreasing again in the bottom 1000 feet of the drillhole. This correlates with observations from thin sections.
4. Hematite is the only iron oxide included in the computations, though some magnetite is present, and much of the iron in the upper section of the drillhole occurs in limonites other than hematite. Iron oxide content appears to be relatively uniform throughout the drillhole except for an increase near 920 feet, in the uppermost of the three fracture zones, and a decrease near 2400 feet of unknown origin.

When a more complete set of mineral compositions becomes available more appropriate rock modes will be computed, and the results used in the interpretation of the chemistry of hydrothermal minerals and of the hydrothermal alteration system.

MINERAL ANALYSES

Sericite, chlorite and feldspar analyses are discussed below. The data have by no means been completely interpreted but some of the results are plotted on Figures 2 through 6. All plots for sericite and chlorite are in terms of ions calculated from the structural formula rather than in weight percent. The structural formulas used are based on 4 tetrahedral cations. No statistical analysis of the data has been performed to date.

Feldspar analyses are presented in Table 4 but no interpretation of the results has been made. The plagioclases cluster around $Ab_{96.5}$ $An_{2.5}$ $Or_{1.0}$ except for those from sample 2855 which have a range of An and Ab contents: Ab_{73-80} An_{18-26} Or_{1-2}. The K-feldspars contain less than 0.5% An and have a range of 84 to 98% Or.

Forty-two chlorites from 4 environments in five sample intervals have been analysed, most for 12 components, a few for only 9 (those excluding Ba, Cl and F). Analyses are listed in Table 5. Chlorite occurs replacing hornblende, biotite and plagioclase, and in veins. The data are plotted on Figures 2, 3 and 4, again in terms of ions. Figures 2 and 3 are plots of $Mg^{2+}/(Mg^{2+} + Fe^{2+} + Fe^{3+})$ versus the number of Si^{4+} ions calculated from the structural formula (based on 4 tetrahedral cations). These figures are modified from Figure 81 of Deer, Howie and Zussman (1966). The chlorites fall in the ripidolite-pycnochlorite-brunsvigite field. Tetrahedral occupancy does not appear to distinguish samples when all environment types are averaged, but for grains within a single sample it appears that the Si^{4+} occupancy is highest in chlorite replacing hornblende and lowest in that replacing biotite. Chlorite $Mg^{2+}/(Mg^{2+} + Fe^{2+} + Fe^{3+})$ ratio

Table 4 Feldspar Analyses: Thermal Power Co. Well Utah State 14-2.

	1650 1.2A^k	1650 1.2B^a	1650 1.2A^k	1650 1.2B^a	1700 2D.2^k	1700 2C.1A^k	1700 2C.1B^a	1700 2C.2A^a	1700 2C.2B^k	1700 2C.2C^k	1700 3D.A^a	1700 3D.1B^k	1700 3D.1C^k	1700 3D.3^a	1700 3D.3^k
SiO_2*	64.7	67.6	65.0	67.8	65.8	65.5	67.1	67.7	64.7	64.4	66.8	65.6	65.5	65.9	65.0
Al_2O_3*	18.3	19.9	18.4	19.6	18.5	18.5	19.7	19.8	18.3	18.2	19.5	18.6	18.5	19.4	18.4
CaO	.02	.65	.02	.38	.02	.01	.60	.52	.01	.02	.52	.01	.02	.62	.01
K_2O	15.5	.22	15.2	.29	15.4	15.7	.12	.16	15.7	15.1	.14	15.7	15.5	.11	15.4
Na_2O	.91	11.2	1.19	11.3	1.09	.93	11.2	11.3	.76	1.13	11.2	.95	1.03	11.0	1.05
Total	99.4	99.6	99.8	99.4	100.8	100.6	98.7	99.5	99.5	98.9	98.2	100.9	100.6	97.0	99.9

	2800 4B.1A^p	2800 4B.1B^a	2800 4B.1C^k	2800 4B.3^p	2800 3B.4^k	2800 3B.3B^p	2855 2.4A^a	2855 2.9^k	4400 2B.4B^p	4400 3B.2^p	4400 3B.3^k
SiO_2*	63.1	66.4	63.4	62.5	63.6	61.9	68.0	63.6	66.2	64.5	65.4
Al_2O_3*	22.9	19.4	18.0	23.1	23.0	23.2	19.9	18.0	18.8	18.8	18.6
CaO	4.15	.53	.04	4.51	4.09	4.71	.54	.03	.04	.45	.04
K_2O	.29	.17	13.9	.30	.25	.22	.19	16.2	15.0	.16	14.81
Na_2O	9.13	11.1	1.71	8.89	9.27	8.76	11.4	.24	1.53	10.8	1.49
Total	99.6	97.6	97.0	99.3	100.2	98.8	100.0	98.1	101.6	94.7	100.3

Superscripts to sample numbers: k k-feldspar; p plagioclase; a albite

* Calculated

Table 5 Chlorite Analyses: Thermal Power Co. Well Utah State 14-2.

	2800 4D.1^{p}	2800 3D.1^{h}	2800 3D.2^{h}	2800 3D.3^{p}	2800 3D.4^{b}	2800 3D.5^{p}	2800 3B.1^{v}	2800 3B.2^{b}	2800 3B.3A^{p}	2800 3B.3B^{b}	2800 1C.1A^{p}	2800 1C.1B^{b}	2855 4.1^{p}	2855 3.1^{m}
SiO_2	26.2	28.5	29.6	26.5	26.7	26.3	27.5	26.9	28.9	26.8	27.8	27.5	26.1	32.5
TiO_2	.04	.07	.22	.07	.07	.03	.34	.09	.05	.10	.03	.54	.06	.06
Al_2O_3	18.7	17.1	15.6	18.6	18.4	16.1	16.7	19.3	19.8	17.6	18.5	19.0	19.2	21.8
FeO*	26.5	26.2	23.9	26.3	24.1	28.8	23.7	23.2	24.1	23.6	28.2	22.9	23.0	22.8
Fe_2O_3*	4.40	4.35	3.97	4.36	3.99	4.78	3.93	3.85	4.01	3.91	4.69	3.81	3.83	3.78
MnO	1.08	.67	.61	.57	.62	1.19	.57	.64	.59	.73	.79	.70	.53	.48
MgO	11.7	12.8	14.5	11.5	14.3	12.1	13.51	14.4	12.1	13.2	9.27	14.4	9.74	9.22
CaO	.09	.42	.48	.17	.05	.18	.24	.07	.33	.12	.15	.09	.09	.09
K_2O	.09	.32	.31	.28	.06	.10	.42	.37	.62	.25	.26	.36	.95	3.29
Na_2O	.02	.04	.05	.07	.01	.07	.10	.05	.75	.03	.10	.02	.04	.03
BaO	-	-	-	-	-	-	-	-	-	-	-	-	.00	.00
Cl	-	-	-	-	-	-	-	-	-	-	-	-	.01	.01
F	-	-	-	-	-	-	-	-	-	-	-	-	.25	.21
H_2O**	11.2	11.3	11.4	11.3	11.4	11.0	11.4	11.4	11.4	11.4	11.2	11.5	11.3	11.4
Total	100.0	101.8	100.6	99.7	99.7	100.7	98.4	100.3	102.7	97.7	101.0	100.8	95.1	105.7

Numbers of Ions on the Basis of 28 Total (-) Charges. 10 (O) and 8 (OH,Cl,F)

Si	2.80	2.97	3.08	2.83	2.82	2.83	2.95	2.81	2.94	2.90	2.95	2.85	2.91	3.17
Ti	.00	.01	.02	.01	.01	.00	.03	.01	.00	.01	.00	.04	.00	.00
Al(iv)	1.20	1.03	.92	1.17	1.12	1.17	1.05	1.19	1.06	1.10	1.05	1.15	1.09	.83
Al(vi)	1.15	1.06	1.00	1.19	1.11	.88	1.06	1.18	1.31	1.14	1.26	1.17	1.44	1.68
Fe^{+2*}	2.37	2.28	2.08	2.35	2.13	2.60	2.12	2.02	2.05	2.13	2.50	1.98	2.15	1.86
Fe^{+3*}	.35	.34	.31	.35	.32	.39	.32	.30	.31	.32	.37	.30	.32	.28
Mn	.10	.06	.05	.05	.06	.11	.05	.06	.05	.07	.07	.06	.05	.04
Mg	1.86	1.99	2.25	1.84	2.25	1.94	2.16	2.24	1.84	2.13	1.46	2.21	1.62	1.34
Ca	.01	.05	.05	.02	.01	.02	.03	.01	.04	.01	.02	.01	.01	.01
K	.01	.04	.04	.04	.01	.01	.06	.05	.08	.03	.04	.05	.13	.41
Na	.00	.01	.01	.01	.00	.02	.02	.01	.15	.01	.02	.00	.01	.01
Ba	-	-	-	-	-	-	-	-	-	-	-	-	.00	.00
Cl	-	-	-	-	-	-	-	-	-	-	-	-	.00	.00
F	-	-	-	-	-	-	-	-	-	-	-	-	.09	.06
OH^{**}	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	7.91	7.93

Chlorite replaces: b biotite; h hornblende; p plagioclase; v vein. m is mixed layer chlorite-illite.
• Fe partitioned by a Fe +3 to total Fe ratio of 0.13 ** Calculated H_2O

Table 5 Chlorite Analyses: Thermal Power Co. Well Utah State 14-2. (cont.)

	2940 1.1^{p}	2940 2.6^{p}	2940 4.1^{h}	2940 5.1A^{h}	2940 5.1B^{b}	2940 5.1C^{p}	2940 5.2A^{v}	2940 5.2B^{b}	2940 5.4^{h}	2940 7.1^{p}	2940 6.3^{p}	2940 6.1^{p}	2940 6.2^{p}
SiO_2	28.5	28.1	29.0	26.6	27.4	26.0	28.5	28.1	28.9	26.3	27.0	27.0	27.9
TiO_2	.03	.07	.11	.07	.09	.04	.07	.08	.05	.16	.04	.10	.03
Al_2O_3	16.5	15.8	15.2	17.4	17.6	17.3	17.0	18.0	14.9	19.9	17.8	18.1	19.8
FeO*	23.2	24.2	24.6	28.2	26.3	27.9	25.4	21.4	23.6	23.1	26.1	27.8	23.0
Fe_2O_3*	3.85	4.01	4.08	4.69	4.37	4.64	4.21	3.56	3.92	3.84	4.33	4.62	3.82
MnO	.66	.63	.57	.62	.77	.73	.57	.82	.58	.61	.91	.90	.50
MgO	14.7	12.8	14.9	11.4	13.8	11.7	13.5	17.4	14.6	15.1	12.1	10.6	12.6
CaO	.34	.37	.47	.27	.10	.35	.43	.08	.53	.05	.18	-	-
K_2O	.02	.07	.09	.10	.15	.06	.09	.10	.09	.08	.06	-	-
Na_2O	.05	.04	.03	.05	.01	.07	.06	.03	.05	.05	.04	-	-
BaO	.00	.00	.02	.03	.03	.04	.02	.01	.02	.00	.03	.05	.01
Cl	.06	.06	.04	.04	.03	.02	.02	.01	.01	.01	.02	.01	.01
F	.24	.23	.28	.17	.19	.13	.19	.11	.22	.14	.16	.16	.15
H_2O**	11.3	11.2	11.2	11.0	11.2	11.0	11.3	11.5	11.3	11.4	11.2	11.1	11.5
Total	99.5	97.6	100.6	100.6	102.0	100.0	101.4	101.2	98.8	100.7	100.0	100.4	99.3
Numbers of Ions on the Basis of 28 Total (-) Charges, 10(O) and 8 (OH, Cl, F)													
Si	3.01	3.05	3.04	2.84	2.85	2.81	2.97	2.87	3.08	2.73	2.88	2.88	2.92
Ti	.00	.01	.01	.01	.01	.00	.01	.01	.00	.01	.00	.01	.00
Al(iv)	.99	.95	.96	1.16	1.15	1.19	1.03	1.13	.92	1.27	1.12	1.12	1.08
Al(vi)	1.06	1.07	.92	1.04	1.01	1.01	1.05	1.04	.95	1.17	1.11	1.16	1.37
Fe^{+2}*	2.04	2.19	2.16	2.53	2.29	2.52	2.21	1.84	2.10	2.01	2.33	2.48	2.02
Fe^{+3}*	.31	.33	.32	.38	.34	.38	.33	.27	.31	.30	.35	.37	.30
Mn	.06	.06	.05	.06	.07	.07	.05	.07	.05	.05	.08	.08	.04
Mg	2.31	2.07	2.33	1.81	2.14	1.88	2.10	2.65	2.32	2.33	1.92	1.68	1.97
Ca	.04	.04	.05	.03	.01	.04	.05	.01	.06	.01	.02	-	-
K	.00	.01	.01	.01	.02	.01	.01	.01	.01	.01	.01	-	-
Na	.01	.01	.01	.01	.00	.02	.01	.01	.01	.01	.01	-	-
Ba	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Cl	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00	.00
F	.08	.08	.09	.06	.06	.05	.06	.04	.08	.04	.05	.06	.05
OH	7.91	7.91	7.90	7.93	7.93	7.95	7.93	7.96	7.92	7.95	7.94	7.94	7.95

Chlorite replaces: b biotite; h hornblende; p plagioclase; v vein.

*Fe partioned by a Fe^{+3} to total Fe ratio of 0.13. ** Calculated H_2O.

Table 5 Chlorite Analyses: Thermal Power Co. Well Utah State 14-2. (cont.)

	4400 3B.1^b	4400 4B.1^p	4400 4B.2^b	4400 4B.3^b	4400 4B.4^b	4400 5B.2^p	4400 1.4^b	4400 1.5^b	4400 2:1^v	4400 3.1^p	4400 3.7^v	4400 4.3^b	4400 4.7^p	4400 4.4^p	4400 0-2^p
SiO_2	25.7	26.3	26.8	27.1	26.0	25.9	26.5	26.5	27.5	28.3	27.0	26.4	26.9	25.6	27.1
TiO_2	.14	.03	.02	.15	.09	.13	.20	.09	.08	.03	.04	.13	.12	.04	.11
Al_2O_3	18.7	18.9	17.6	18.8	18.5	16.5	19.1	18.7	17.1	18.4	18.0	19.4	18.0	18.8	19.1
FeO*	27.5	27.6	26.5	26.7	27.0	29.7	22.1	23.7	23.8	19.7	22.1	22.9	19.7	26.7	22.9
Fe_2O_3*	4.56	4.58	4.40	4.43	4.48	4.94	3.67	3.94	3.95	3.27	3.66	3.80	3.28	4.44	3.80
MnO	.97	.64	.51	.93	.92	.83	.70	.72	.77	.87	.95	.69	1.64	.76	.56
MgO	11.3	10.0	12.2	12.6	12.7	9.67	14.9	14.6	15.6	13.0	12.0	15.1	17.5	11.7	15.3
CaO	.06	.10	.33	.14	.11	.17	.07	.07	.10	.17	.18	.06	.06	.11	.09
K_2O	.07	.21	.04	.24	.05	.19	.07	.12	.07	.55	.12	.08	.17	.08	.14
Na_2O	.00	.06	.05	.04	.02	.60	.02	.02	.02	.06	.05	.01	.02	.06	.02
BaO	.00	.02	.01	.03	.00	.05	.03	.04	.02	.03	.05	.03	.06	.06	.05
Cl	.00	.02	.01	.01	.02	.02	.02	.02	.02	.02	.02	.01	.02	.03	.01
F	.16	.11	.19	.15	.20	.09	.14	.21	.11	.11	.09	.19	.12	.14	.21
H_2O**	11.1	11.1	11.1	11.2	11.1	10.9	11.4	11.3	11.3	11.6	11.4	11.4	11.5	11.1	11.4
Total	100.3	99.7	99.8	102.5	101.2	99.7	98.9	100.0	100.4	96.1	95.7	100.2	99.1	99.6	100.8
Numbers of Ions on the Basis of 28 Total (-) Charges, 10(O) and 8 (OH, Cl, F)															
Si	2.76	2.83	2.87	2.81	2.75	2.84	2.80	2.79	2.88	3.05	2.96	2.76	2.82	2.75	2.81
Ti	.01	.00	.00	.01	.01	.01	.02	.01	.01	.00	.00	.01	.01	.00	.01
Al(iv)	1.24	1.17	1.13	1.19	1.25	1.16	1.20	1.21	1.12	.95	1.04	1.24	1.18	1.25	1.19
Al(vi)	1.13	1.22	1.09	1.11	1.05	.97	1.18	1.11	.99	1.39	1.29	1.15	1.04	1.13	1.14
Fe^{+2*}	2.46	2.48	2.37	2.32	2.39	2.73	1.95	2.09	2.08	1.77	2.03	2.00	1.73	2.40	1.98
Fe^{+3*}	.37	.37	.35	.35	.36	.41	.29	.31	.31	.26	.30	.30	.26	.36	.30
Mn	.09	.06	.05	.08	.08	.08	.06	.06	.07	.08	.09	.06	.15	.07	.05
Mg	1.80	1.61	1.94	1.95	2.00	1.58	2.34	2.29	2.44	2.09	1.96	2.35	2.73	1.88	2.36
Ca	.01	.01	.04	.02	.01	.02	.01	.01	.01	.02	.02	.01	.01	.01	.01
K	.01	.03	.01	.03	.01	.03	.01	.02	.01	.08	.02	.01	.02	.01	.02
Na	.00	.01	.01	.01	.00	.13	.00	.00	.00	.01	.01	.00	.00	.01	.00
Ba	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Cl*	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.01	.00
F	.06	.04	.07	.07	.07	.03	.05	.07	.04	.04	.03	.06	.04	.05	.07
OH	7.94	7.96	7.93	7.95	7.93	7.97	7.95	7.93	7.96	7.96	7.97	7.97	7.96	7.95	7.93

Chlorite replaces: b biotite; h hornblende; p plagioclase; v vein. *Fe partioned by a Fe^{+3} to total Fe ratio of 0.13. ** Calculated H_2O.

Table 6. Sericite Analyses: Thermal Power Co. Well

Utah State 14-2

	1700 20.2	1700 20.3	1700 2C.1	1700 2C.2	1700 30-1[b]	1700 30-2A[b]	1700 30-28	1700 30-3	2800 48.1	2800 38.3	2855 4.1	2855 2.2	2855 2.4	2855 2.7	2855 2.8	2855 2.9	2855 2.11
SiO_2	47.9	48.9	47.6	50.8	49.2	48.3	49.9	49.3	52.2	48.1	52.1	47.9	51.0	52.0	48.8	51.0	51.3
TiO_2	.04	.02	.45	.03	.20	.24	.00	.06	.08	.14	.07	.09	.08	.11	.03	.06	.05
Al_2O_3	28.5	33.7	28.8	32.1	27.6	28.1	32.9	31.9	26.4	30.8	29.0	31.5	28.1	26.8	32.4	28.5	28.5
Fe_2O_3	5.09	1.22	5.33	2.13	5.30	6.09	3.39	3.39	3.50	2.78	3.76	1.73	2.52	4.26	1.85	3.12	2.97
MnO	.06	.02	.07	.01	.07	.08	.04	.04	.04	.03	.06	.03	.04	.04	.01	.04	.04
MgO	2.11	.62	2.05	.85	2.96	3.13	.13	1.33	2.19	.81	2.30	.54	1.79	2.30	.68	2.06	1.98
CaO	.07	.23	.07	.04	.02	.07	.32	.06	.20	.16	.14	.15	.11	.13	.03	.08	.06
K_2O	8.43	8.00	10.0	9.55	11.0	9.98	8.25	9.76	8.53	10.2	9.61	10.9	10.4	9.12	10.9	10.4	10.7
Na_2O	.10	.33	.18	.10	.12	.14	.13	.12	.08	.34	.08	.42	.07	.09	.24	.05	.05
BaO	.02	.01	.08	.02	.04	.03	.02	-	-	-	.07	.14	.04	.21	.18	.06	.03
Cl	.01	.02	.00	.00	.02	.02	.01	-	-	-	.00	.00	.00	.02	.00	.00	.00
F	.54	.10	.26	.29	.66	.58	.37	-	-	-	.42	.34	.37	.37	.05	.41	.34
H_2O*	4.25	4.56	4.34	4.43	4.13	4.17	4.40	4.53	4.57	4.52	4.33	4.35	4.35	4.35	4.49	4.32	4.36
Total	97.1	97.7	99.2	100.4	101.3	100.9	99.9	100.5	97.8	97.9	100.9	98.0	98.9	99.8	99.7	100.1	100.4
Numbers of Ions on the Basis of 22 total (-) charges, 10 (O) and 2 (OH, Cl, F)																	
Si	3.28	3.26	3.23	3.32	3.29	3.23	3.28	3.24	3.50	3.27	3.42	3.26	3.42	3.46	3.25	3.39	3.40
Ti	.00	.00	.02	.00	.01	.01	.00	.00	.00	.01	.00	.00	.00	.01	.00	.00	.00
Al	.72	.74	.77	.68	.71	.77	.72	.76	.50	.73	.58	.74	.58	.54	.75	.61	.60
Al	1.59	1.90	1.53	1.80	1.46	1.45	1.83	1.72	1.59	1.74	1.58	1.78	1.64	1.55	1.79	1.62	1.62
Fe	.26	.06	.27	.10	.26	.31	.16	.16	.16	.14	.19	.09	.13	.21	.09	.15	.15
Mn	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Mg	.22	.06	.21	.08	.29	.31	.01	.13	.22	.08	.23	.06	.18	.23	.07	.20	.20
Ca	.01	.02	.01	.00	.00	.01	.02	.00	.01	.01	.01	.01	.01	.01	.00	.01	.00
K	.74	.68	.87	.80	.94	.85	.69	.82	.73	.88	.80	.94	.89	.77	.93	.88	.90
Na	.01	.04	.02	.01	.02	.02	.02	.02	.01	.04	.01	.06	.01	.01	.03	.01	.01
Ba	.00	.00	.00	.00	.00	.00	.00	-	-	-	.00	.00	.00	.01	.00	.00	.00
Cl	.00	.00	.00	.00	.00	.00	.00	-	-	-	.00	.00	.00	.00	.00	.00	.00
F	.12	.02	.06	.06	.14	.12	.08	-	-	-	.09	.07	.08	.08	.01	.09	.07
OH	1.88	1.98	1.94	1.94	1.86	1.88	1.92	2.00	2.00	2.00	1.91	1.93	1.92	1.92	1.99	1.91	1.93

Sericite replaces plagioclase except where [b] indicates biotite replacement.

*Calculated H_2O

Table 6 (Continued) Sericite Analyses: Thermal Power Co. Well Utah State 14-2.

	2940 5.1	2940 5.3	2940 6.1	4400 28.1	4400 48.2	5000 1.7	5000 3.7
SiO_2	49.05	50.4	49.5	52.9	51.1	54.0	49.8
TiO_2	.04	.14	.05	.02	.11	.11	.03
Al_2O_3	31.7	30.0	30.8	28.2	25.9	21.3	27.5
Fe_2O_3	2.18	1.54	1.62	3.38	3.88	4.10	3.83
MnO	.06	.04	.05	.01	.03	.03	.03
MgO	.94	1.67	1.36	1.30	2.07	2.71	.58
CaO	.19	.16	.10	.44	.20	.20	.11
K_2O	10.3	9.88	10.2	8.12	9.23	9.79	10.9
Na_2O	.16	.75	.07	.10	.12	.05	.12
BaO	.00	.05	.03	.00	.03	.09	.06
Cl	.01	.01	.01	.01	.02	.02	.01
F	.24	.25	.25	.08	.22	.45	.22
H_2O*	4.41	4.42	4.42	4.55	4.42	4.30	4.38
Total	99.2	99.3	98.5	99.1	97.3	97.2	97.6

Sericite replaces plagioclase.

* Calculated H_2O

Numbers of Ions on the Basis of 22 total (-) Changes, 10(O) and 2 (OH,Cl,F)

Si	3.27	3.35	3.32	3.48	3.48	3.70	3.41
Ti	.00	.01	.00	.00	.00	.01	.00
Al	.73	.65	.68	.52	.52	.30	.59
Al	1.76	1.70	1.76	1.67	1.56	1.42	1.63
Fe	.11	.08	.09	.16	.20	.21	.20
Mn	.00	.00	.00	.00	.00	.00	.00
Mg	.09	.17	.14	.13	.21	.28	.06
Ca	.01	.01	.01	.03	.01	.01	.01
K	.88	.84	.87	.68	.80	.85	.95
Na	.02	.10	.01	.01	.02	.01	.02
Ba	.00	.00	.00	.00	.00	.00	.00
Cl	.00	.00	.00	.00	.00	.00	.00
F	.05	.05	.05	.02	.05	.10	.05
OH	1.95	1.95	1.95	1.98	1.95	1.90	1.95

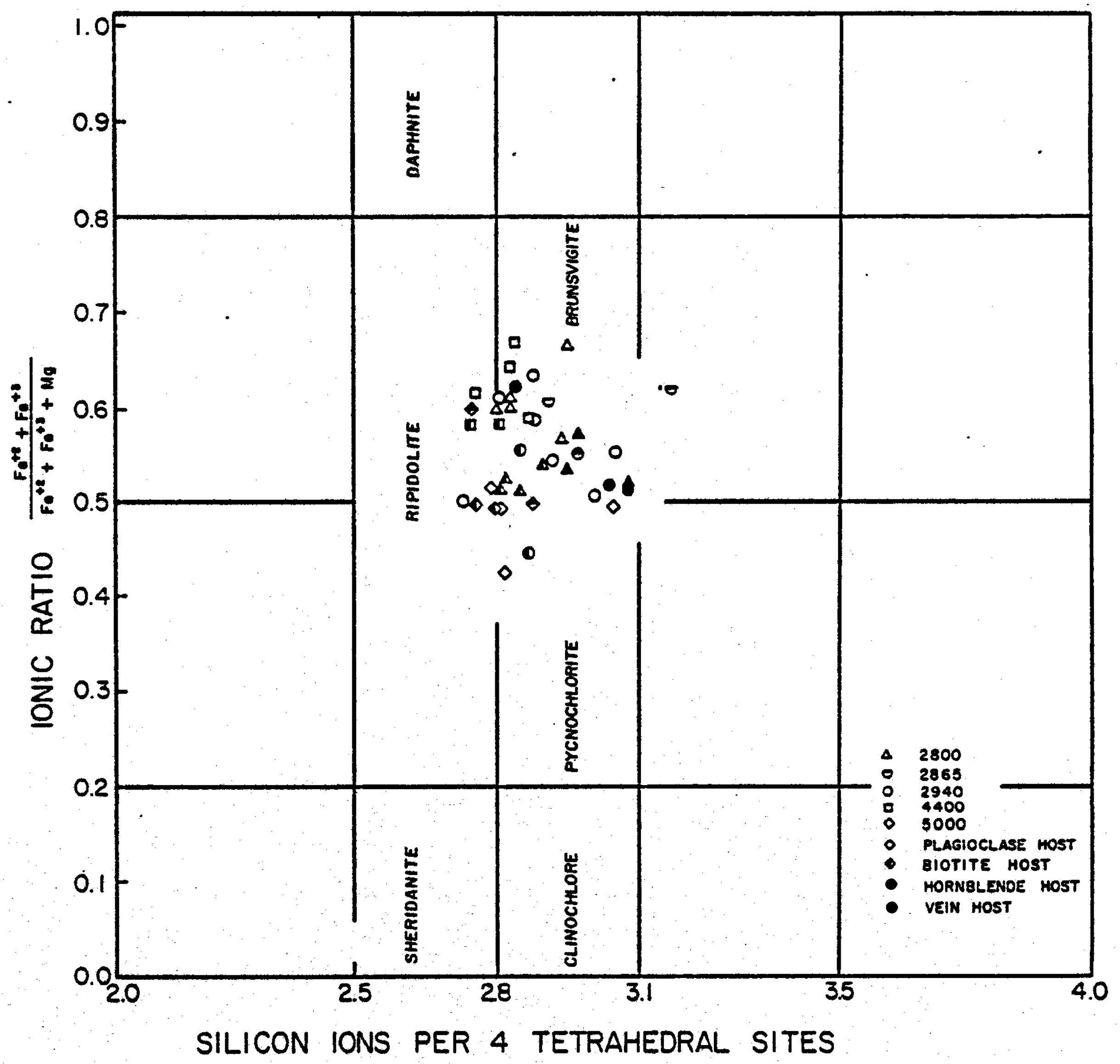


Figure 2. Compositions of chlorites from Well 14-2. Classification after Deer, Howie & Zusman (1966), Figure 81.

Figure 3. Compositions of chlorites from Well 14-2. Data is identical to that of Figure 2, with samples plotted separately to demonstrate inter- and intra- sample differences. Symbol codes are as for Figure 2.

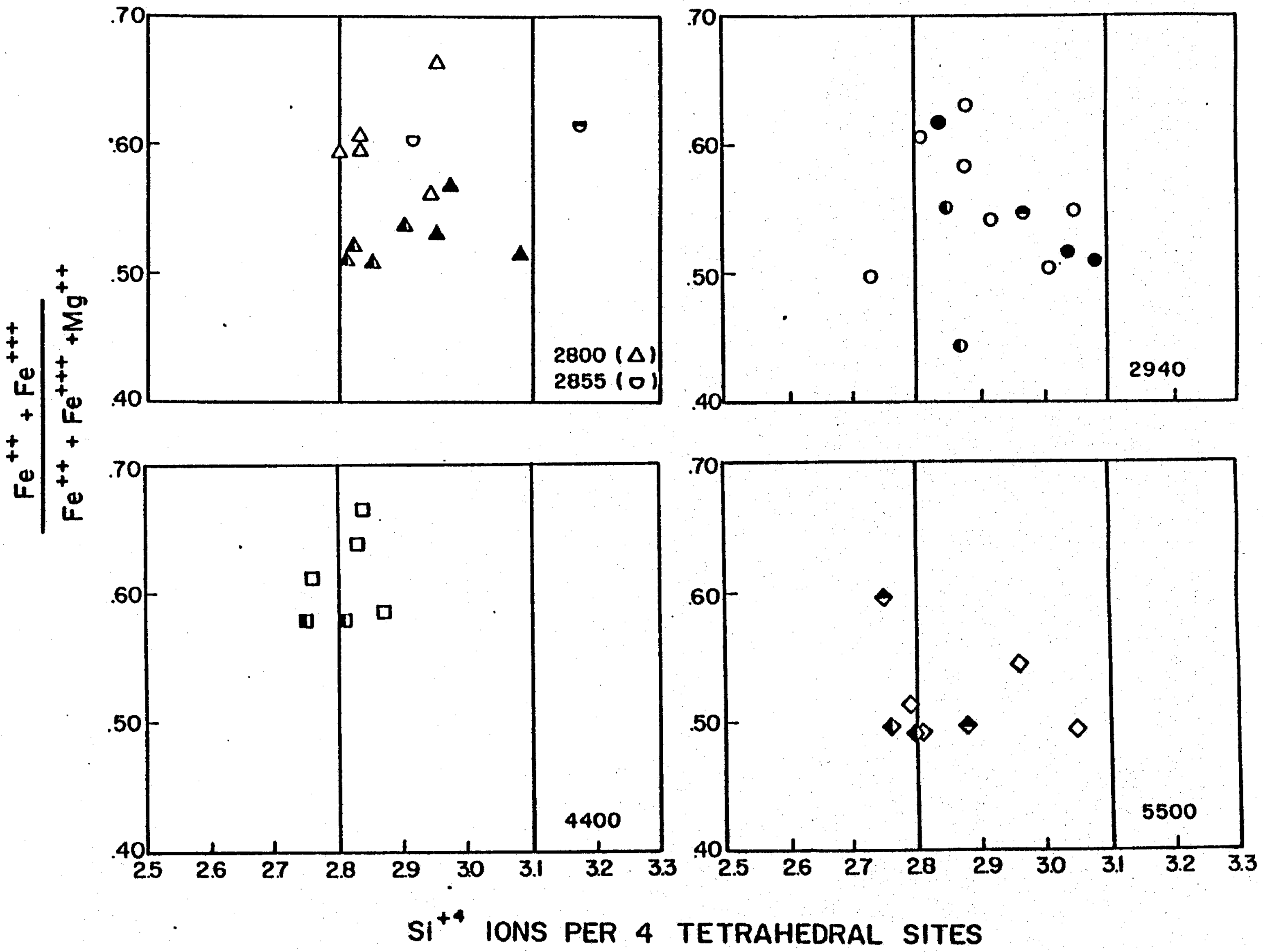
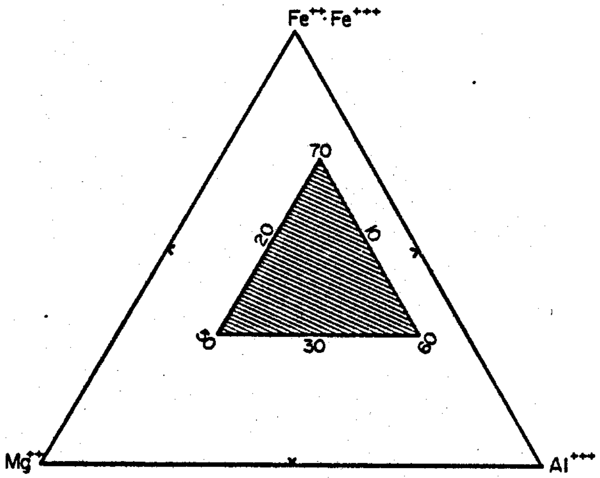
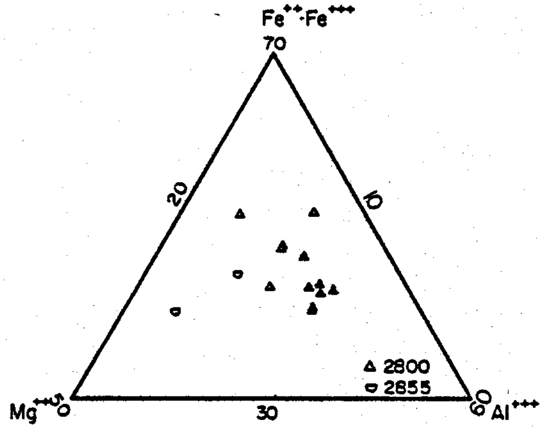
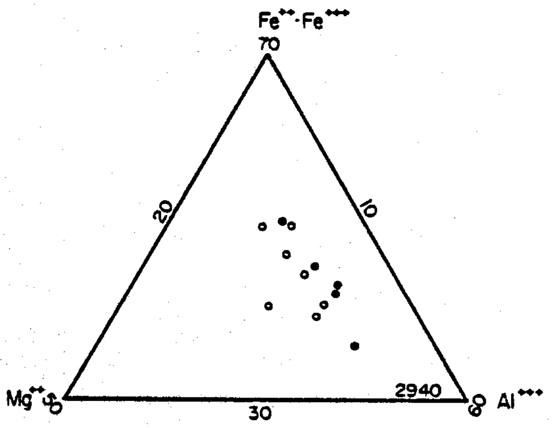

.70
.60
.50
.40
2800 (△)
2855 (◒)
2940
4400
5500
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
$\frac{Fe^{++} + Fe^{+++}}{Fe^{++} + Fe^{+++} + Mg^{++}}$
Si^{+4} IONS PER 4 TETRAHEDRAL SITES

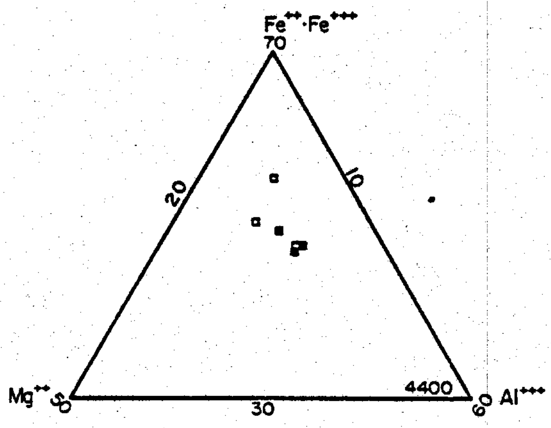
Figure 4. Composition of chlorites from Well 14-2: Octahedral cation relationships. Data for individual samples are plotted on separate diagrams and are coded for host mineral type. Open symbols, plagioclase host; filled symbols hornblende host; left half filled, biotite host; top half filled, vein host.

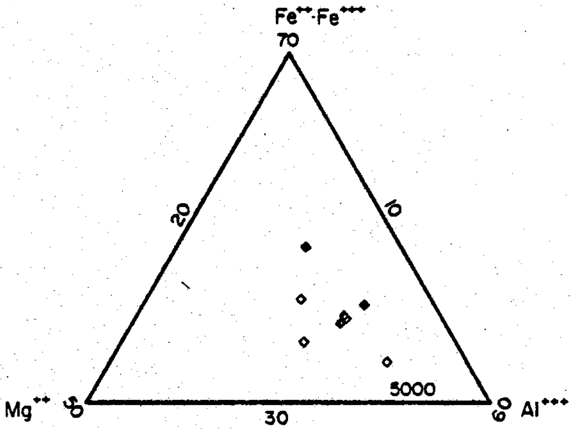


LOCATION OF COMPOSITIONAL FIELDS SHOWN BELOW







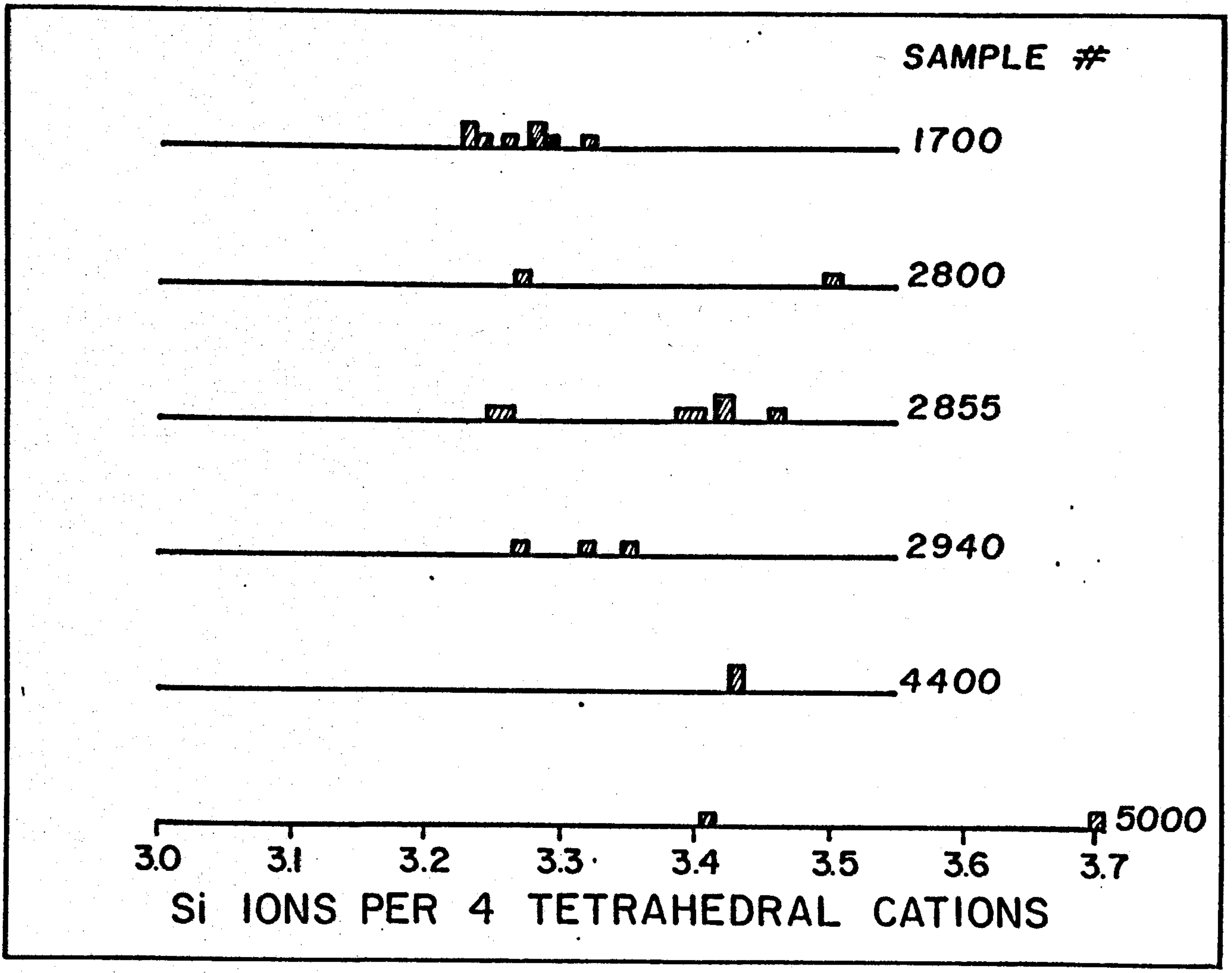


distinguishes some samples from others but is not, in general, a good sample discriminator. Within a sample, however, the ratio varies according to the chlorite host, increasing from plagioclase through hornblende to biotite. This is also the direction of MgO weight percent increase in the host minerals. When host mineral types are separated samples can be seen to fall into somewhat distinct, though overlapping, areas but no downhole compositional trend is evident. Where there is a compositional difference between two samples the chlorites replacing different host minerals show corresponding changes. For example, if sample A has a higher $Mg^{2+}/(Mg^{2+} + Fe^{2+} + Fe^{3+})$ ratio than sample B, then the chlorites replacing each host mineral in sample A have higher values than their counterparts in sample B.

Figure 4 is a ternary plot of Mg^{2+}, $Fe^{2+} + Fe^{3+}$, and Al^{3+} in octahedral positions. Although there is considerable overlap some clustering of different samples into different areas is evident. The host mineral appears to affect chlorite composition quite strongly in some samples, less so in others. The vein chlorites from sample 5000 are also quite distinct from the chlorites replacing plagioclase and biotite, but the vein sample from 2940 falls within the fields for other host minerals.

Twenty-four sericite aggregates from six sample intervals within the drillhole have been analysed for 12 elements (Ba, Cl and F data were not obtained for one sample). Analyses are listed in Table 6. All but three of the aggregates replace plagioclase. The remainder replace biotite and do not appear to be distinguishable from those replacing plagioclase. Figure 5 is a histogram of Si^{4+} in tetrahedral position. The sericites are phengites, having tetrahedral $Si^{4+}:Al^{3+}$ ratios greater than 3:1. Sericite aggregates within different samples comprise different but overlapping

Figure 5. Compositions of Sericites from Well 14-2: Si^{4+} ions per 4 tetrahedral cations.


SAMPLE #
1700
2800
2855
2940
4400
5000
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
Si IONS PER 4 TETRAHEDRAL CATIONS

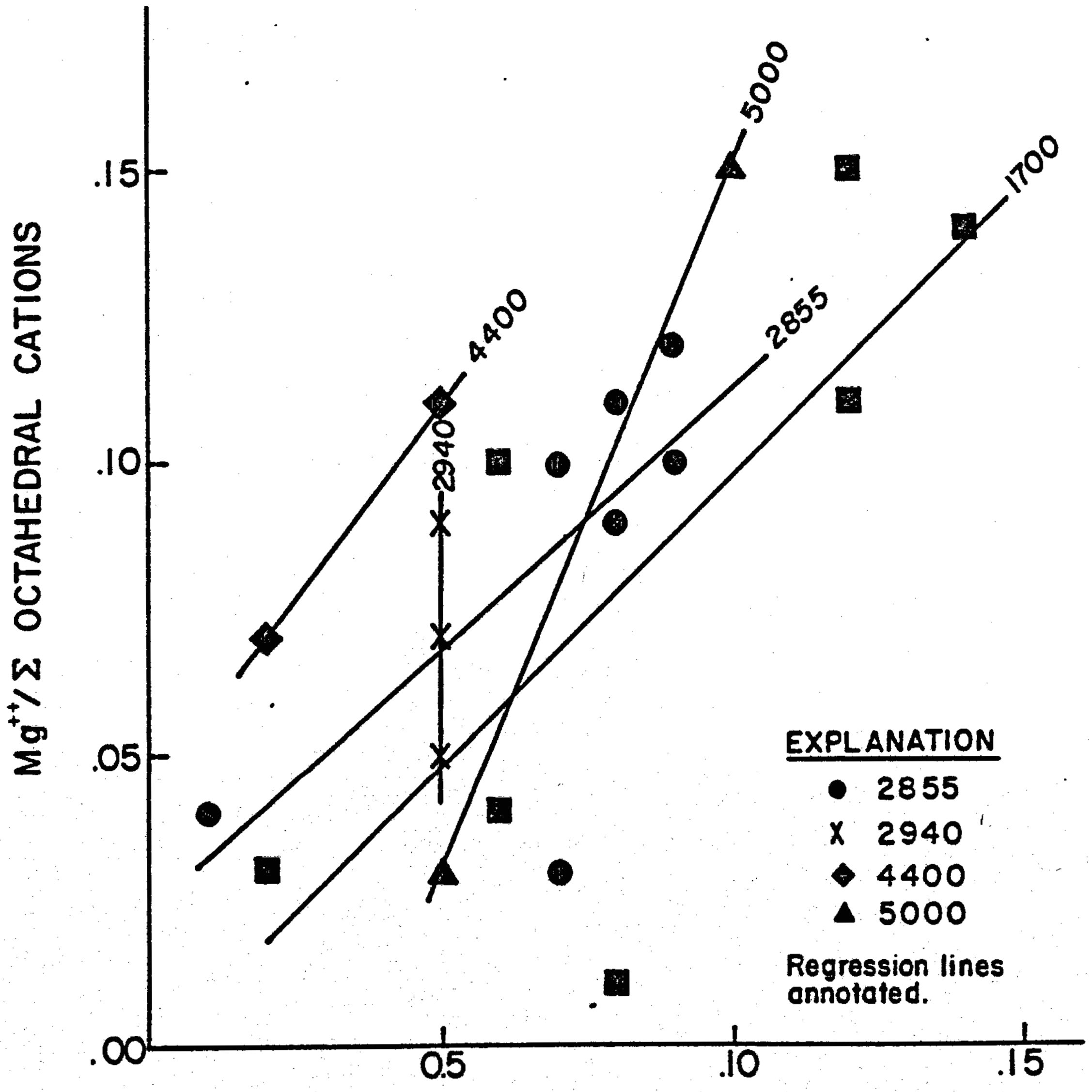


Figure 6. Compositions of sericites from Well 14-2: Computed lines of regression for each sample are shown.

populations showing an overall downhole increase in Si content. The ratios of Fe^{3+} to total octahedral cations lie in the range .03 to .16, most having means near .09.

Figure 6 is a plot of F^- against Mg^{2+}/Sum of octahedral cations showing a positive correlation between the two, and a general decrease in fluorine relative to Mg with increasing depth in the drillhole. The lines shown on Figure 6 are regression lines. Correlation coefficients (r^2) are 0.58 for sample 1700, 0.46 for 2855 and for the others, of course, 1.00 since they are straight lines joining two or three points. Three of the lines (those for 1700, 2855 and 4400) are nearly parallel, and shift to the left, i.e. to a decrease in F relative to Mg, with increasing depth in the drillhole. Sample 2940 does not conflict with this trend, while not fitting it exactly, and sample 5000 is anomalous. The small number of data points for three of the samples should be considered as a limiting factor in making this interpretation.

In comparison with chlorite, sericite compositions exhibit different effects in response to host mineral type or position in the drillhole. In the data set reported here host mineral type does not appear to control sericite composition. However results from another hydrothermal system (J.M. Ballantyne, in preparation) indicate that such a control is to be expected. The lack of evidence for it here is probably merely a function of sampling, little data being available for host minerals other than plagioclase.

The data presently available are enigmatic in that downhole compositional trends evident in the sericites are not present in the chlorites. Physico-chemical controls for major element substitutions have not been evaluated in this report, but it seems reasonable that the different compositional parameters discussed for sericites and chlorites would be controlled by different chemical or physical attributes of a hydrothermal solution.

Compositional variation in hydrothermal minerals as a function of host mineral type indicates that overall equilibrium between rock and hydrothermal solution has not been attained. It may therefore be possible to distinguish the effects of different hydrothermal events, if later events have not totally destroyed the effects of those preceding. It is hoped that further results will provide this type of information for well 14-2. In a different situation, where relationships of veins to rock are determinable, (not a feasibility in samples of drillcuttings) it may even be possible to trace the evolution of a hydrothermal fluid.

The data discussed in this report are preliminary results from a Ph.D. research project currently in progress. A more rigorous, statistical treatment of the data is underway, evaluation of different parameters will be made and more data collected. These, together with a discussion of theoretical models to explain observed compositional variation and zoning, will be included in a future publication.

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The FORTRAN computer program MODECALC is based in part on a BASIC program provided by Steve Cone, formerly of Kennecott Explorations Inc. The mathematical formula on which the program is based was modified by Ralph T. Shuey, formerly of this department.

The Bence-Albee correction and structural formula calculation FORTRAN program was written by Geoffrey H. Ballantyne of this department, based in part on a Bence-Albee correction routine provided by James W. Nicholls of the University of Calgary.

Thanks are due to William T. Parry, who coordinated the research effort of which this study is a part, for his encouragement and for many useful discussions.

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APPENDIX

The FORTRAN computer program MODECALC calculates a modal mineralogic composition for a rock given a whole rock chemical analysis and a stipulated set of mineral analyses. The program is in part a modification of a BASIC program provided by Steve Cone.

In its simplest form the solution to the problem can be reduced to solving a set of linear equations by matrix inversion methods.

$$y_i = x_{ij}\beta_j$$

where y_i is the percentage of the ith component in the whole rock analysis, x_{ij} is the percentage of the ith component in the jth mineral phase and β_j is the abundance of the jth phase.

The solution in matrix notation is:

$$[\beta] = [Y]\,[X]^{-1}$$

However, since the number of mineral phases is usually less than the number of chemical components analysed (it may not be more) the solution is overdefined and a weighted least squares method must be used. The matrix formulation for this is given by Draper and Smith (1966, page 79) as:

$$[\beta] = ([X]^T\,[W]\,[X])^{-1}\,([X]^T\,[W]\,[Y])$$

where [W] is a diagonal square matrix in which $w_{ij} = 1/y_i$. This has the effect of giving component analyses with small values the same weight as those with large values. Note that T means the transpose and $^{-1}$ the inverse of a matrix.

Unfortunately, this method works for simple test cases but tends to give negative numbers when real data, with their inherent inaccuracies, are used. A method to weight the solution toward and initial guess for the mode was devised by Ralph T. Shuey in order to obviate the problem.

The goodness of fit of the data is $\sum_i w_i (y_i' - y_i)^2$. The distance from the estimated mode is $\sum_j s_j (\beta_j - \beta°_j)^2$, where y_i is the actual and y'_i the regression calculated value of the ith component, β_j is the computed and $\beta°_j$ the estimated value for the jth phase, and $s_j = 1/\beta°_j$, a weighting factor with a similar effect to w_i.

The function to be minimized is:

$$\sum_i w_i (y'_i - y_i)^2 + \lambda A/B \sum_j s_j (\beta_j - \beta°_j)^2$$

where $A = \sum_j w_i y_i^2$ and $B = \sum_j s_j \beta°_j{}^2$. λ is the weight to the estimated mode chosen by the operator. Typical values are 0.05, 0.1. The former was used for this report.

The matrix formulation for this is:

$$[\beta] = ([X]^T [W] [X] + \lambda A/B [S])^{-1} ([X]^T [W] [Y] + \lambda A/B [S] [\beta°])$$

The FORTRAN programming was done by the writer.

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