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Thermometry And Barometry Of Precambrian Orthogneisses And Related Rocks From The Minnesota River Valley, Southwestern Minnesota

Paula J. Leier

Thermometry and Barometry of Precambrian Orthogneisses and Related Rocks from the Minnesota River Valley, southwestern Minnesota

by

Paula J. Leier

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ABSTRACT

Granulite facies metamorphism is reported to have occurred in the Granite Falls-Montivideo area of the Minnesota River Valley and a broader view of the valley is taken to determine the extend of granulite facies metamorphism. Pressures and temperatures of metamorphism were determined using two geothermometers and one geobarometer. Based upon two-feldspar and garnet-biotite thermometers, temperature of metamorphism is approximated at 600 ^{o}C. Metamorphic pressures based on the reaction cordierite= garnet + quartz + sillimanite were probably between 4 and 6 Kbars. Based on barometry and thermometry, it is suggested the Algoman orogeny (2600 m.y. ago) was at least upper amphibolite and probably marginal to granulite facies, while the basement complexes have undergone granulite facies metamorphism.

INTRODUCTION

The Minnesota River Valley provides a unique window into the Precambrian of Minnesota. Extending from New Ulm to Ortonville, the valley contains migmatites, paragneisses, orthogneisses, pelitic schists and amphibolites. Only one study (Himmelberg and Phinney, 1967) has attempted to determine pressure and temperature of metamorphism, and this study was confined to the Granite Falls-Montevideo area. In this study it was concluded that area had undergone granulite facies metamorphism, more specificly the pyroxene granulite subfacies.

The purpose of this study is to: 1. Take a broad view of the valley and attempt to determine the extend of granulite facies metamorphism; 2. Attempt to relate the gathered data to known dates of metamorphism in the Minnesota River Valley. Pressures and temperatures of metamorphism were determined using two geothermometers and one geobarometer. The two thermometers were the two-feldspar thermometer developed by Stormer (1975) and the garnet-biotite thermometer developed by Ferry and Spear (1978). The barometer was based on the reaction cordierite= garnet + sillimanite + quartz. Two models were used, one by Martignole and Sisi (1981) and the other by Newton and Wood (1979).

REGIONAL GEOLOGY OF MINNESOTA RIVER VALLEY

The Minnesota River flows to the southeast across southwestern Minnesota. The river itself is grossly underfit, occupying the channel cut by Glacial River Warren which drained Glacial Lake Agassiz in the late Pleistocene. As the ice sheets melted, the high-energy discharge scoured through glacial sediments, Cretaceous strata and in areas, the Late Precambrian Sioux Quartzite to expose knobs of Archean rock. (Wright, 1972).

The first detailed study of the Minnesota River Valley was done by Lund in 1956. Further work by Himmelberg and Phinney (1967) in the Granite Falls-Montevideo area and Grant (1972) in the remainder of the valley added to the work of Lund and better determined regional structure.

The Precambrian exposures are concentrated in four areas along the valley. The northern-most section (the Ortonville -Odessa area; Figure 1; locations OV 5, OV 6, OV 7) is dominated by a purplish-pink, foliated quartz monzonite. Locally, schlieren and lenses and bands of more mafic material are present; clinopyroxene, orthopyroxene and garnet are reported to have been found in this material.

Southeast of Ortonville is the Granite Falls-Montevideo area (locations MV 3, MV 5, MV 6, GF 11). The oldest rocks in Granite Falls consist of a sequence of layered gneisses (Grant, 1972). Units of the Montevideo gneiss, hornblende-clinopyroxene -orthopyroxene gneiss and garnet-biotite gneiss are folded in a broad, eastward plunging anticlinorium. Amphibolites and a metagabbro are seen on the southern part of the antiform. Tholeiitic dikes were later intruded and in turn cut by hornblende-andesite dikes. A small quartz monzonite body was also intruded at the time of the hornblende-andesite dike emplacement (Bauer, 1980).

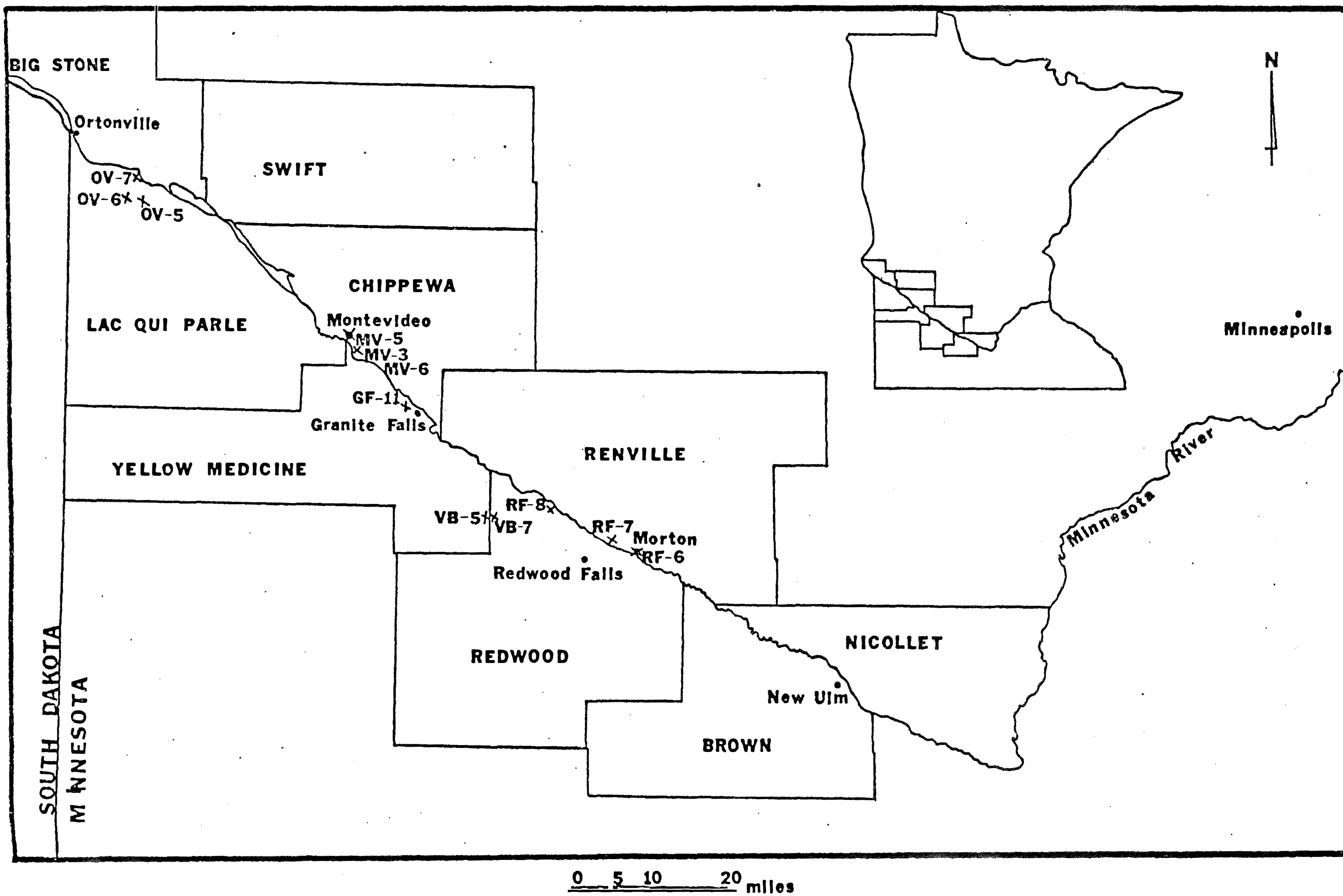

Figure 1: Map of study area and location of samples

In the Montevideo area the lowermost unit consists of banded, hematite-stained Montevideo gneiss, tonalitic to granitic in composition, with varying amounts of garnet, biotite and perthite. Isolated outcrops of hornblende-orthopyroxene gneiss and hornblende-biotite gneiss are present. Contacts between these units and the banded Montevideo units are concordant. A massive phase of the Montevideo gneiss intrudes the banded phase. It is also hematite -stained and contains minor garnet and biotite (Bauer, 1980).

Southeast of Granite Falls is the Sacred Heart-Morton area (locations RF 6, RF 7, RF 8, VB 5, VB 7). The Morton Gneiss, which is well exposed in the quarries in Morton, is a hybrid rock (Goldich et al., 1980). The oldest unit consists of a tonalitic gneiss-amphibolite complex. This has been intruded on two separate occasions by pegmatitic granite and adamellite in conjunction with two episodes of metamorphism. The second metamorphic event was roughly synchronous with emplacement of the quartz monzonite Sacred Heart pluton north of Redwood Falls.

Of special interest in this area is the only outcrop of what is believed to be metasediments in the valley, located 3.3 miles north of Delhi near the Breitkreutz farm (Figure 2; location RF 8). Present at location RF 8 are biotite-quartz -plagioclase gneisses (with or without cordierite, garnet, or sillimanite), amphibolite, rodded quartz-cummingtonite gneiss and quartzofeldspathic gneiss (Grant, 1972). Grant also reports andalusite at this site, as well as knots of sillimanite rimmed with muscovite. No andalusite was identified in samples of this study.

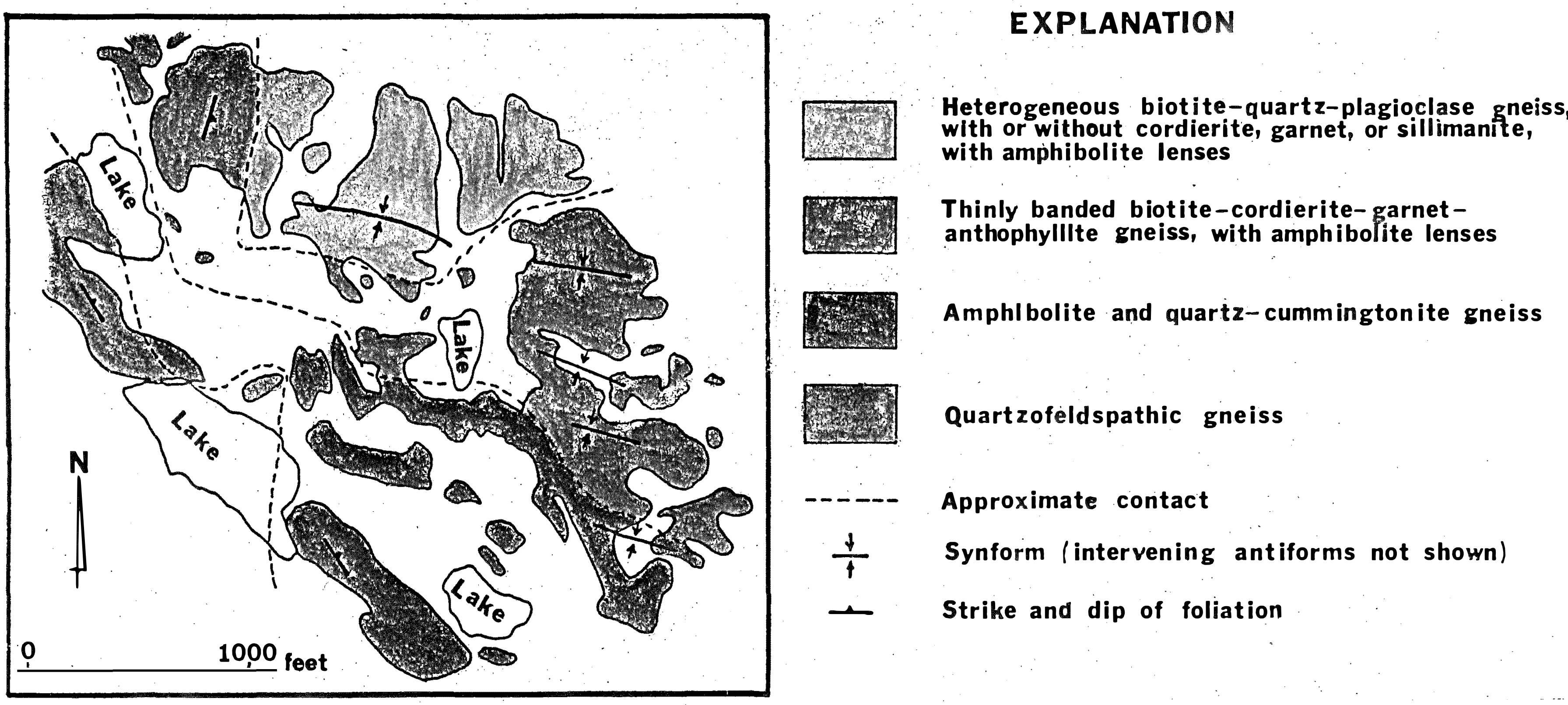

Figure 2: Generalized geologic map of location RF-8 near Breitkreutz farm (After Grant et al., 1972)

Sillimanite was found as thin, sparse needles of fibrolite. Orthopyroxene was also identified in one sample in this study from locality RF 8.

Outcrops in the remainder of the valley between Morton and New Ulm are sparse and highly weathered. Quartzofeldspathic gneisses with amphibolite rafts dominate the rock types. Northwest of New Ulm is the late-stage Cedar Mountain complex, a gabbroic body with associated diabase dikes (Grant, 1972). Overlying these older rocks is the Late Precambrian Sioux Quartzite, a well-cemented, reddish quartzite interbedded with minor sandstone and red mudstone (Austin, 1972a).

Cretaceous rocks overlie Precambrian rocks in many areas of the valley. The sequence includes a basal residuum formed from highly weathered Precambrian rocks, with overlying shales, clays and lignites (Austin, 1972b). Finally, the area has been covered by Pleistocene tills and outwash (Wright, 1972).

A generalized column of Precambrian stratigraphy of the study area from Early to Middle Precambrian is presented in Figure 3. Dashed lines separate rock units emplaced and metamorphosed during a specific metamorphic event. Units with orthopyroxene reported in other studies (shown by question marks) or with orthopyroxene positively identified are noted.

The ages shown for metamorphic events on Figure 3 are well documented in geochronologic studies (Goldlich et al., 1980; Goldlich and Wooden, 1980a; Goldlich, Hedge and Stern, 1970; Wooden, Grant and Nyquist, 1977). These radiometric ages were determined by Rb-Sr, U-Pb and K-Ar isotopes. The dates shown on Figure 3 are average values taken from the above mentioned studies.

The Morton area is the type area for the Mortonian event. The event dated at 2600 m.y. coincides with the Algoman orogeny dated elsewhere in Minnesota. The hornblende andesine dikes, tholeiitic dikes, quartz monzonite and Cedar Mountain complex emplaced during the 1800 m.y. event should not be equated with the Penokean orogeny (recognized to the north and east of the valley) in the sense of a period of folding and metamorphism. They are included here because these events fall within the time span defining the Middle Precambrian (Goldlich, Hedge and Stern, 1970).

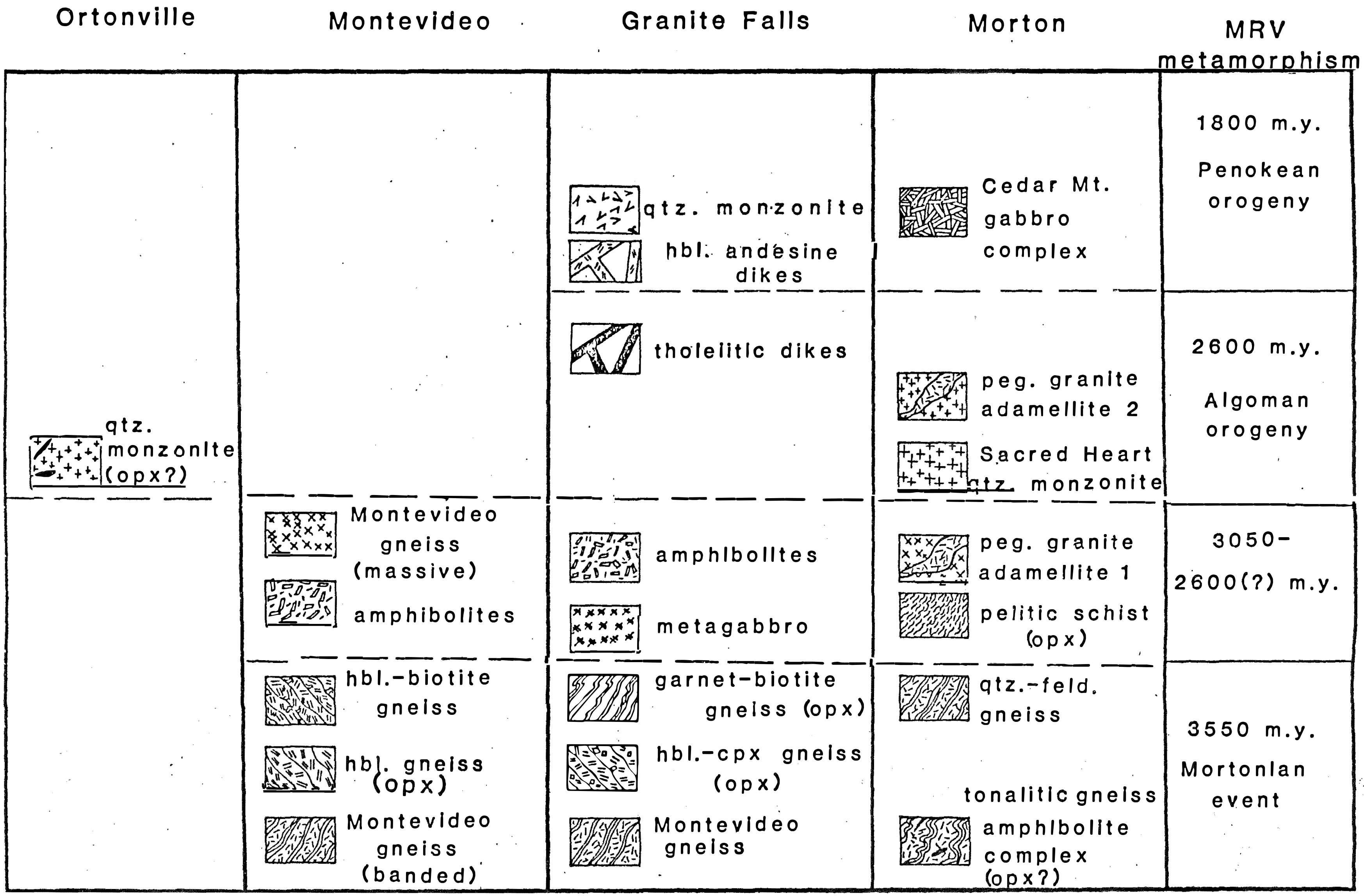

Fig. 3 : Generalized stratigraphic column, Minnesota River Valley

ANALYTICAL TECHNIQUES

Samples were collected throughout the valley, paying special attention to the metasediments at location RF 8 (Breitkreutz farm) and the granitic gneisses of Morton, Granite Falls, Montevideo and Ortonville. One hundred thin sections were examined and 32 were picked for specific analysis. Samples, locations, assemblages and rock types are listed in Appendix 1.

All reported analysis in Appendix 2 were conducted using a JEOL 35C scanning electron microscope and Li-drifted silicon detector for energy dispersive analyses. Standard operation conditions were 10 KeV accelerating voltage, 250 μA sample current and 200 seconds counting times. Polished thin sections were carbon coated after grains of interest were identified and marked. The standards used were well-analysed natural materials. The Bence-Albee matrix correction (Bence and Albee, 1968) was applied. Some of the analytical totals are significantly less than 100% (90-95%), due to long term drift in machine operating conditions and beam current. Reanalysis of the standards indicated that modal percentages are correct even though totals are low.

Minerals with obvious exsolution, such as perthite, were analysed at many spots on the grain and an average was taken. Zoning will be discussed in the appropriate sections.

METAMORPHIC TEMPERATURES AND PRESSURES

Feldspar Thermometry

The association alkali feldspar-plagioclase is common in a variety of rocks. Based on the partition of albite between two coexisiting feldspar phases a geothermometer has been developed (Stormer, 1975) and used successfully in high grade terranes (Stormer and Whitney, 1977) as long as the samples have not undergone post-metamorphic re-equilibration. If re-equilibration has occurred, the temperature determined may not be the one of crystallization, but rather the temperature at which equilibrium was last reached. The presence of microcline as the alkali feldspar in the sample would imply re-equilibration at a lower temperature has taken place.

The results are plotted in Figure 4 after Stormer (1975) determinate curves for temperature at 5 Kbar. As most of the alkali feldspars were well developed microcline, they gave unreasonably low metamorphic temperatures. Those samples where perthites were present gave more reasonable temperatures.

Note that an inferred pressure of 5 Kbar was used. If this estimate is in error by ±1 Kbar, the temperatures will only be in error by ±20°C (Perkins, Essene and Marcotty, 1982).

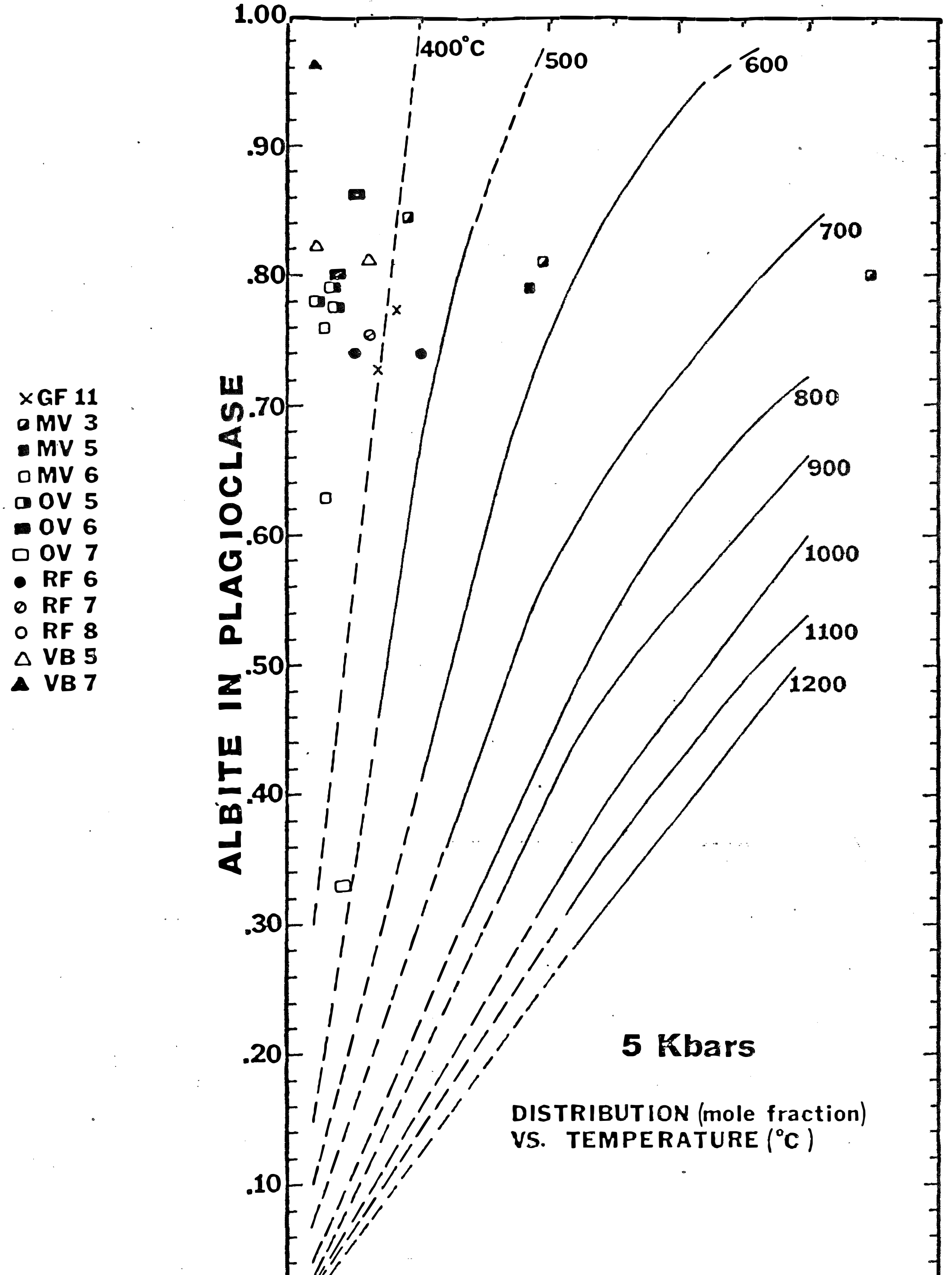

Fig. 4: Determinative curves for temperature at 5 Kbars based on albite distribution between coexisting plagioclase and alkali feldspar. Reasonable accuracy not expected in area of dashed line. (After Stormer, 1975)

Garnet-Biotite Thermometry

Ferry and Spear (1978) developed a geothermometer for rocks based on the partitioning of Fe and Mg between garnet and biotite that are close to binary Fe-Mg composition. Their model is described by the equation:

$$\ln K = -2109/T(^{O}K)+0.782$$

where K=(Mg/Fe)garnet/(Mg/Fe)biotite.

Caution should be used in systems containing significant amounts of Ca and Mn in the garnet and Ti in the biotite, as the abundances of these elements can affect the value of K. Garnet-biotite thermometry is useful for systems where up to 0.2 (Ca+Mn/Ca+Mn+Fe+Mg) is found in the garnet and up to 0.15 (Al+Ti/Al+Ti+Fe+Mg) is found in the biotite (Ferry and Spear, 1978).

The garnets in each sample were analysed at many points to check for zoning. In a study of garnet found in the metasediments of the Breitkreutz farm outcrop (location RF 8) Grant and Weiblen (1971) state garnets were found with low Mn in the core and high Fe and Mg in the core relative to the margin. This zoning was attributed to retrogression across the second sillimanite isograd. No apparent zoning was noted in this study, even in samples from the same locality.

Figure 5 shows the results of the garnet-biotite analysis modified from Ferry and Spear (1978). There is a large degree of scatter, but in general the samples from the Breitkreutz farm cluster in two groups at $600^{O}C$ and $650^{O}C$. The garnets in the Montevideo samples contain a

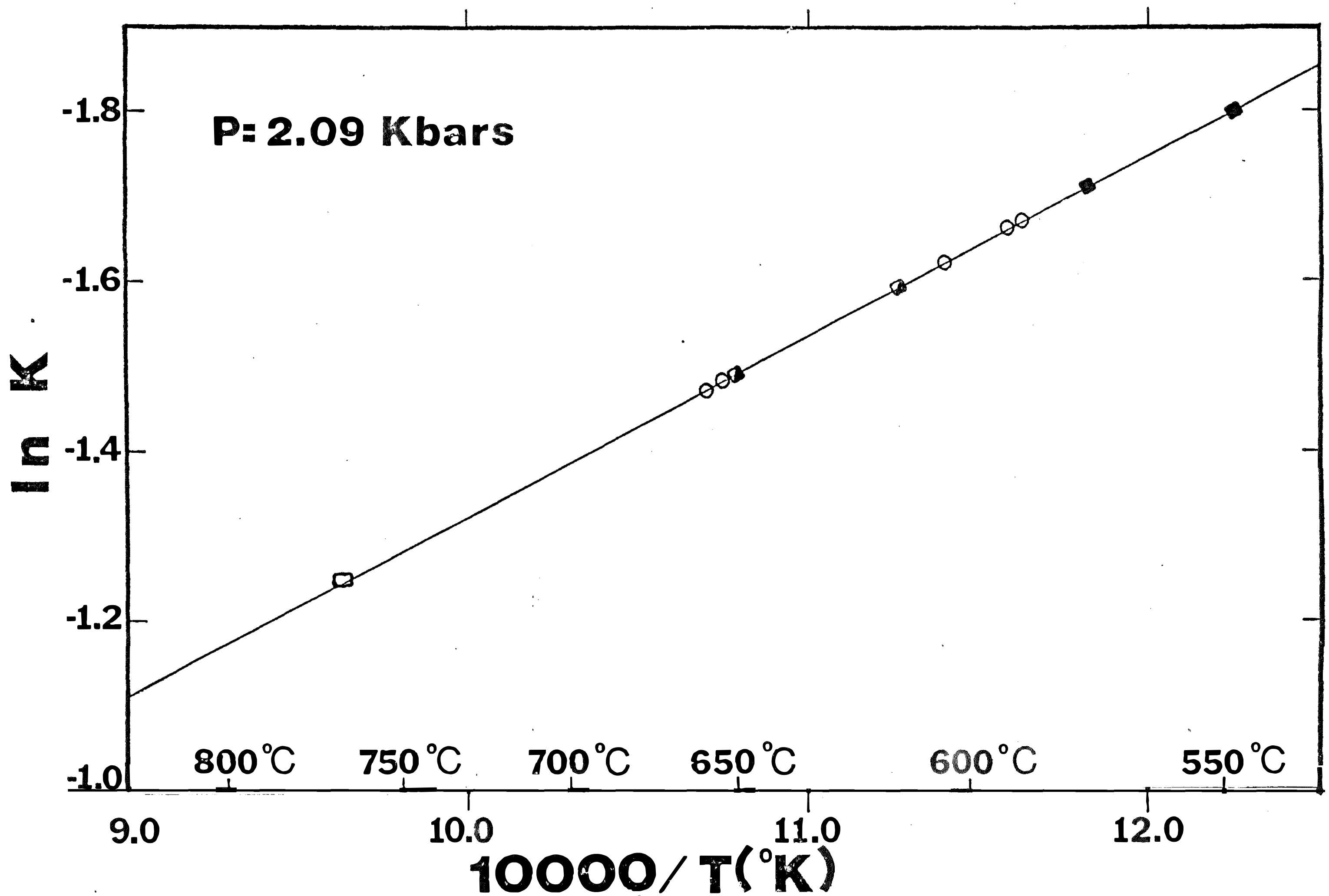

Figure 5: Curve of ln K={(Mg/Fe)$_{garnet}$ / (Mg/Fe)$_{biotite}$} vs. 1/T(°K) modified from Ferry and Spear (1978). Symbols used: ○ RF 8; MV 3; MV 5; OV 7.

significant amount of Mn and it is quite possible this is affecting the value of K.

Reactions Involving Cordierite

Geothermometers-barometers based on the reaction:

cordierite = garnet + sillimanite + quartz

have been modelled by Newton and Wood (1979) and Martignole and Sisi (1981) based upon thermodynamic data from selected experimental studies. This reaction has been difficult to study experimentally because of complex solid solutions of the phases involved and because cordierite may contain variable amounts of water.

Three samples from location RF 8 (Breitkreutz farm) were found to contain cordierite. One sample, RF 8-24, contains the complete assemblage cordierite + sillimanite + garnet + quartz, while samples RF 8-14 and RF 8-26 contain everything but sillimanite.

Figures 6 and 7 show the garnet-cordierite isopeths for models by Martignole and Sisi and Newton and Wood respectively for both P H2O = P total and P H2O = 0. The pressures and temperatures indicated for RF 8-14 and RF 8-26 in Figures 8,9,10 and 11 must be regarded as minumums as sillimanite was not found in these samples.

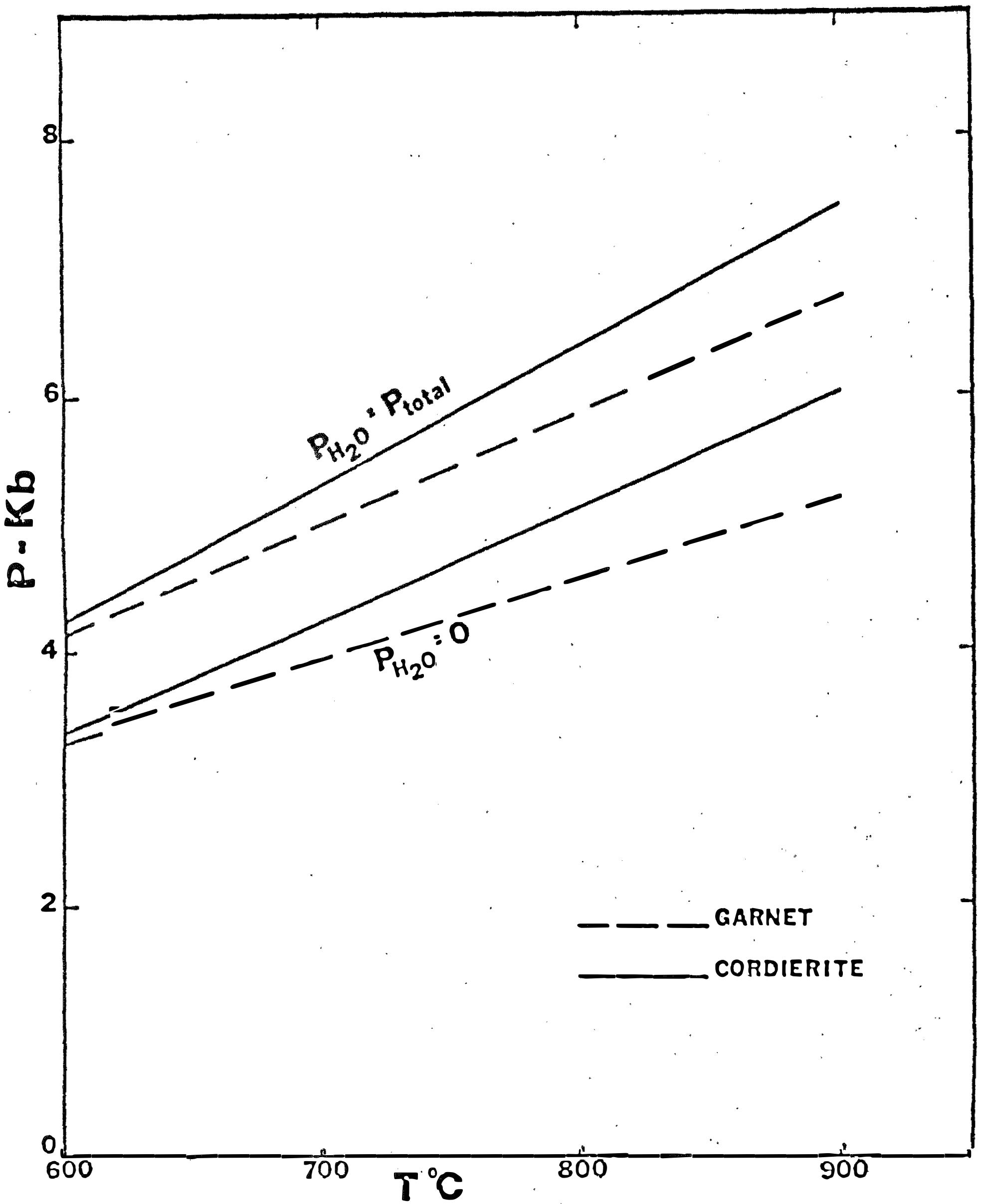

Fig. 6: Garnet and cordierite isopleths for sample RF 8-24 based on model by Martingnole and Sisi (1981). Complete assemblage present.

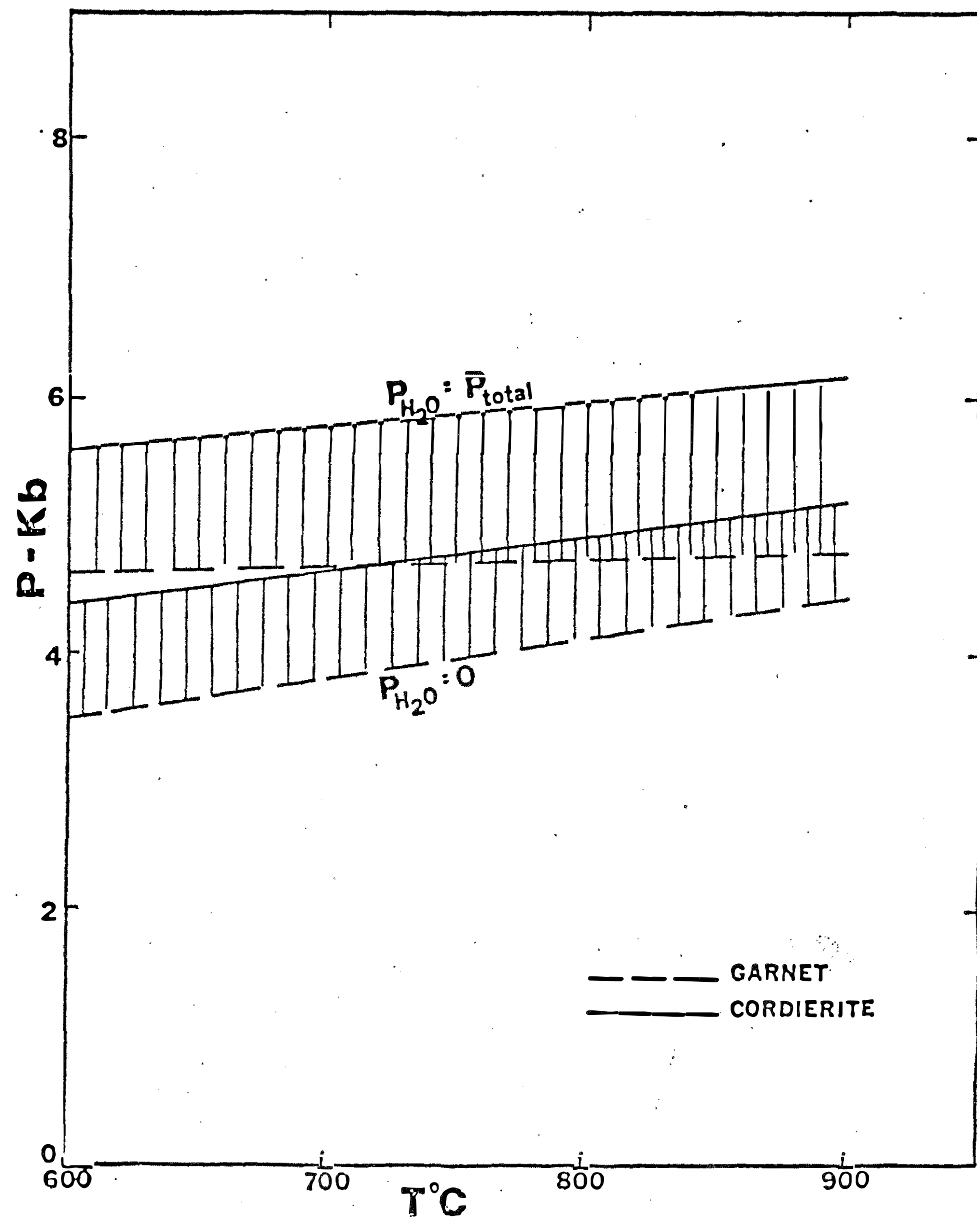

Fig. 7 : Garnet and cordierite isopleths for sample RF 8-24 based on model by Newton and Wood (1979). Complete assemblage present.

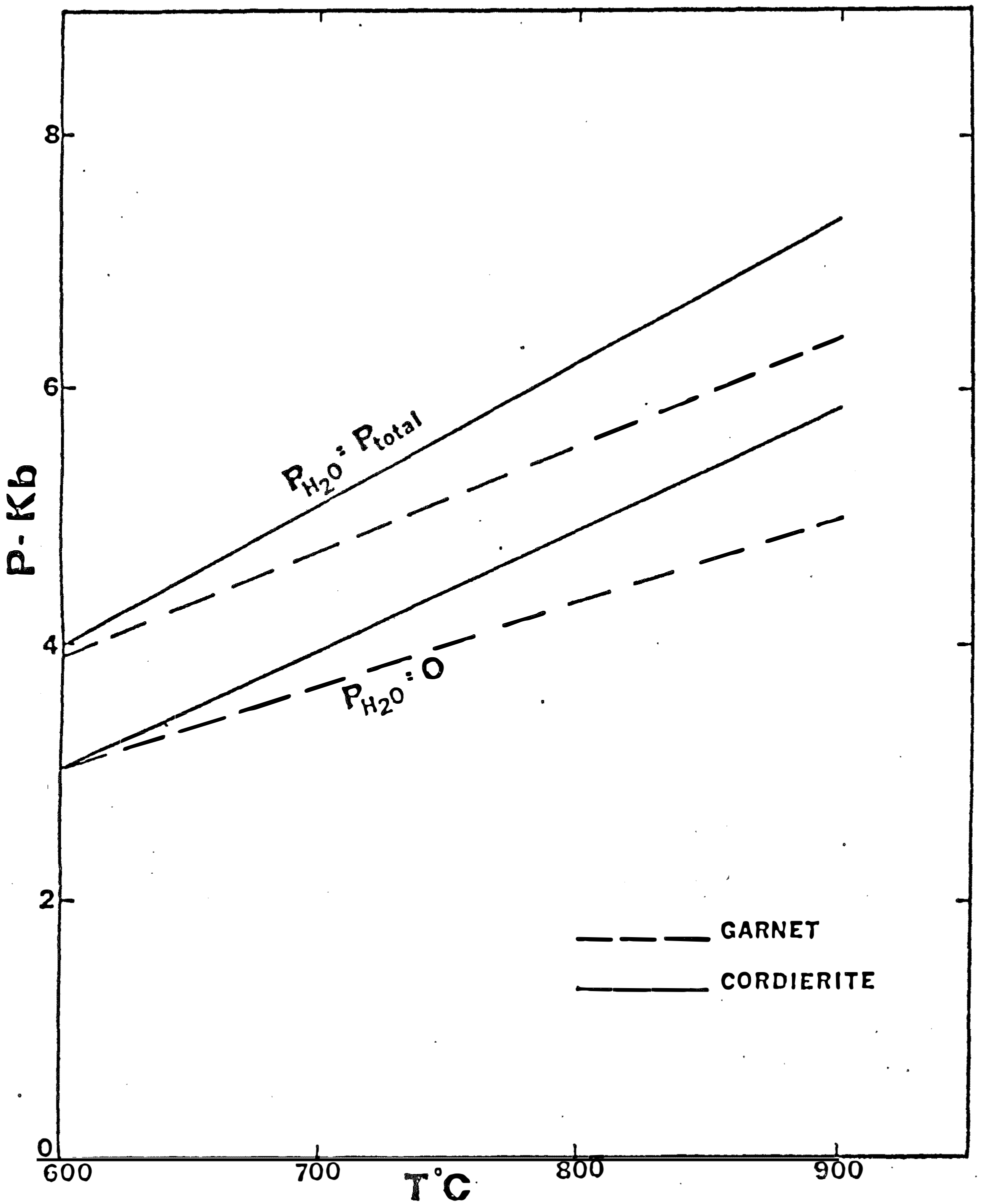

Fig. 8: Garnet and cordierite isopleths for sample RF 8-14 based on model by Martingnole and Sisi (1981). Sillimanite not present.

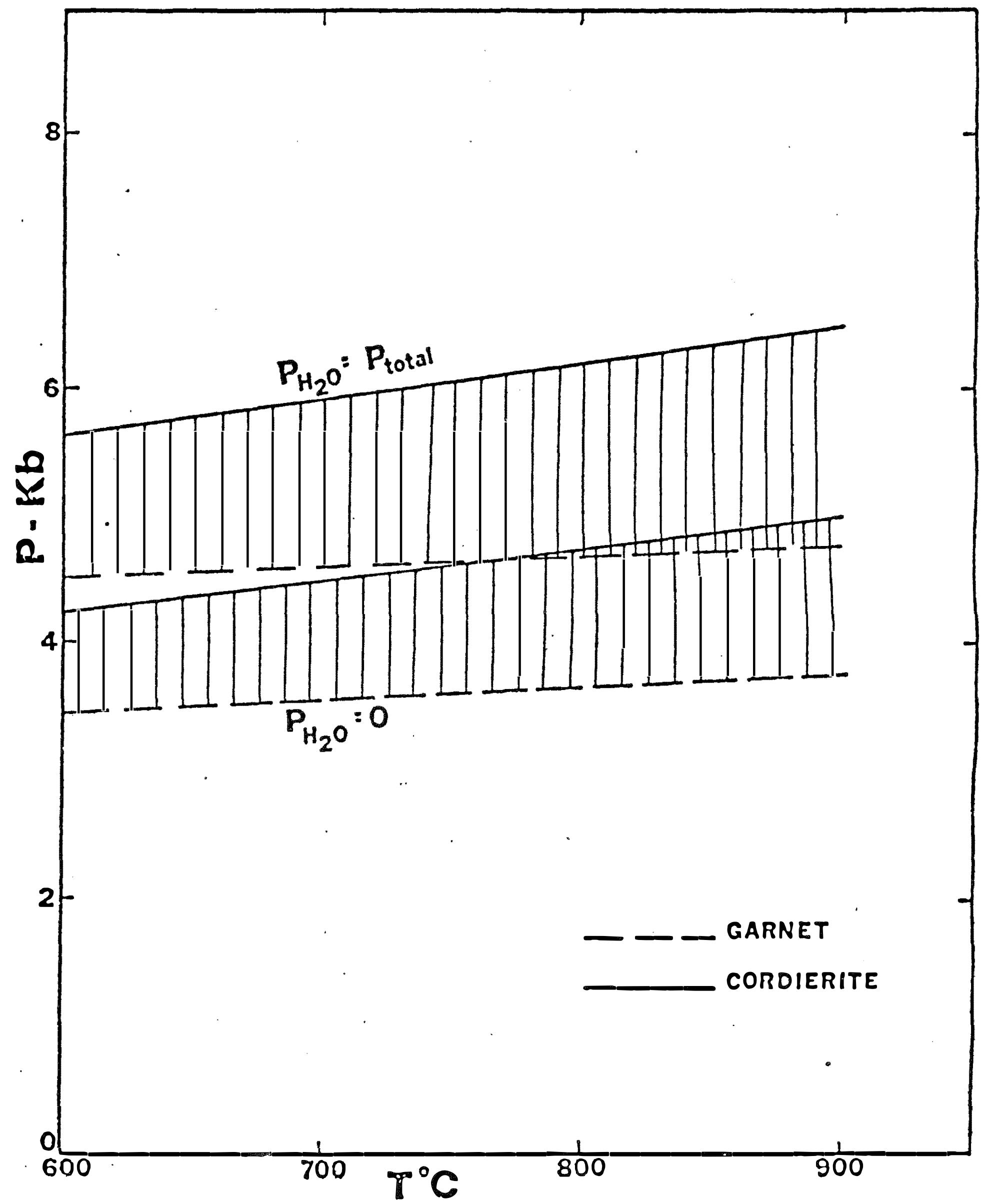

Fig. 9: Garnet and cordierite isopleths for sample RF 8-14 based on model by Newton and Wood (1979). Sillimanite not present.

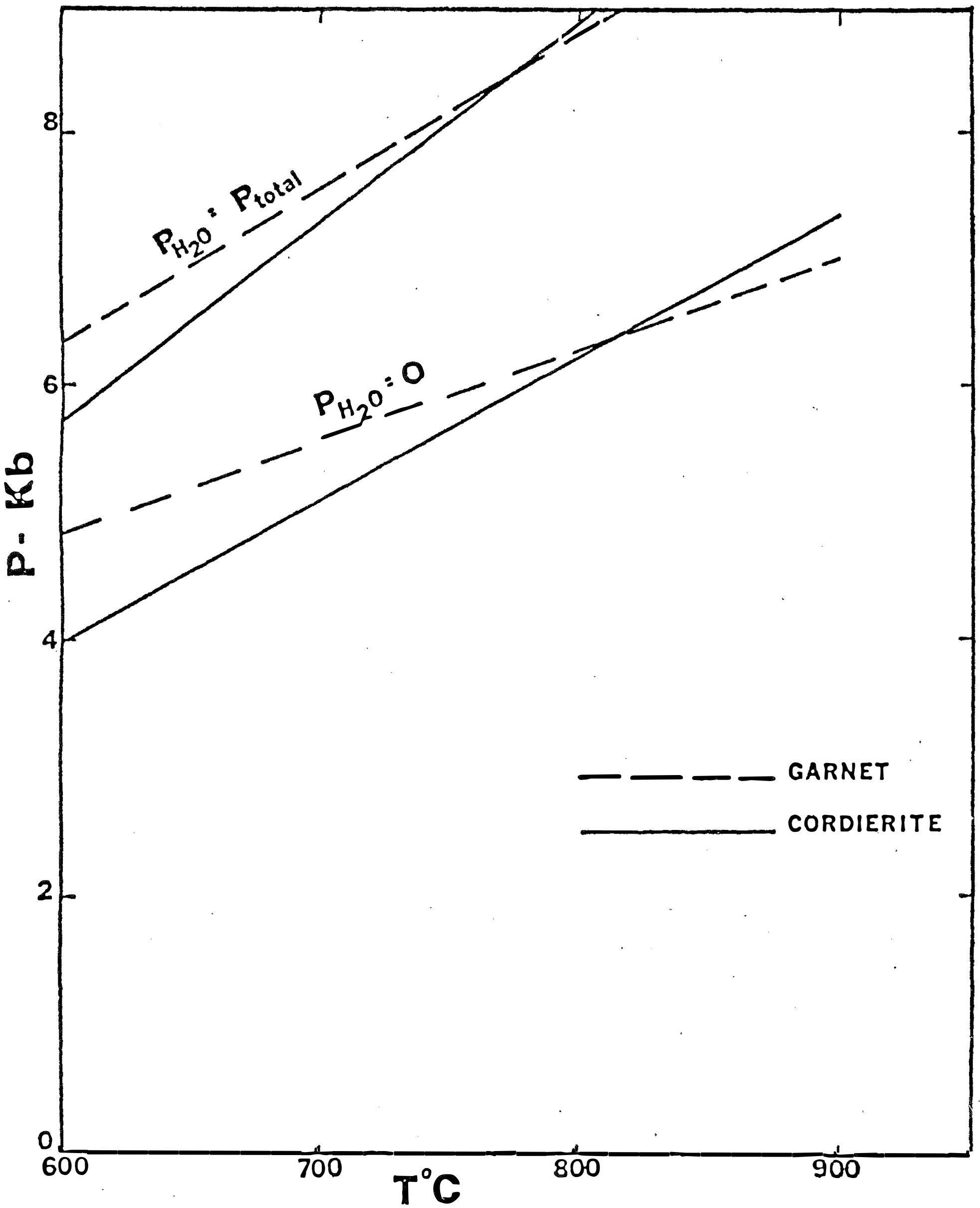

Fig. 10: Garnet and cordierite isopleths for sample RF 8-26 based on model by Martingnole and Sisi (1981). Sillimanite not present.

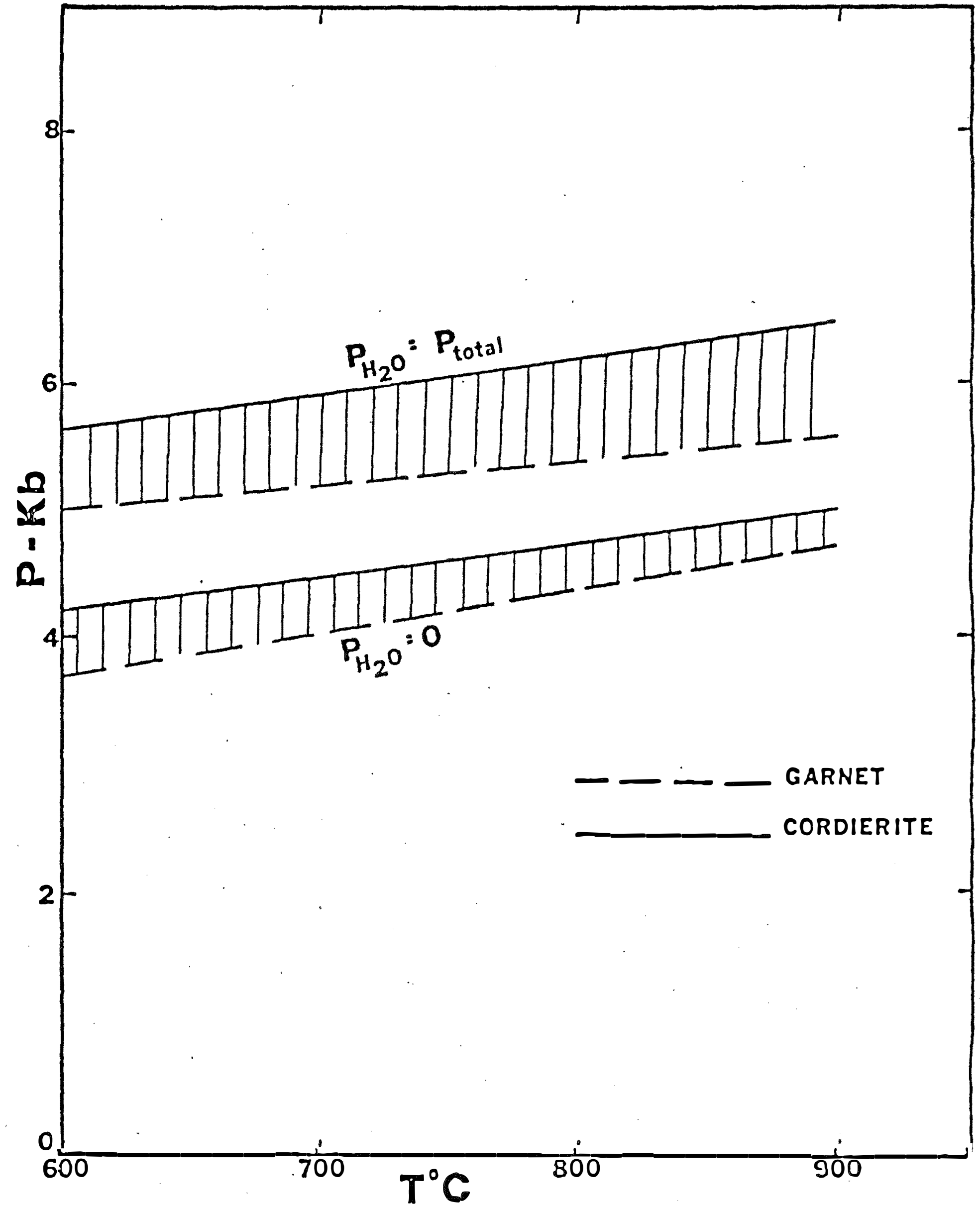

Fig. 11: Garnet and cordierite isopleths for sample RF 8-26 based on model by Newton and Wood (1979). Sillimanite not present.

CONCLUSIONS

The temperature of metamorphism indicated by the geothermometry conducted in this study is approximately 600°C. Barometry indicates pressures between 4 and 6 Kbars. This suggests a metamorphic event, upper amphibolite to granulite facies at approximately 600°C and 4-6 Kbars, which affected most of the Minnesota River Valley.

The scattered presence of orthopyroxene throughout the valley (indicating granulite facies metamorphism) may be the result of the Mortonian event, dated at 3550 m.y. ago (Figure 3). The basement complexes at Montevideo, Granite Falls and Morton all have either reported or positively identified orthopyroxene present, and all were involved in this event.

Orthopyroxene is also found, or reported to have been found, in rocks not involved in the Mortonian event, specificly the quartz monzonite in the Ortonville-Odessa area and the metasediments of locality RF 8.

The rocks in the Ortonville-Odessa area have been dated at 2650 m.y. and their emplacement is essentially contemporaneous with the Algoman orogeny (Goldich, Hedge and Stern, 1970).

The Rb-Sr isotope data on the metasediments of location RF 8 suggest the last major period of metamorphism to affect these rocks occurred 2700 m.y. ago (Wooden, Grant and Nyquist, 1977) but the actual age of the metasediments are thought to be closer to 3000 m.y. or older (Goldich and Wooden, 1980b). This last major metamorphic event was likely the Algoman orogeny.

Based on the thermometry and barometry, plus the presence of orthopyroxene, it may be concluded the Algoman orogeny dated at 2600 m.y. ago was least upper amphibolite facies and probably marginal to granulite facies, while the basement complexes had indeed undergone granulite facies metamorphism.

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APPENDIX 1

Sample Localities and Mineral Assemblages

Sample	T-R-Sec. Location	QUARTZ	PLAGIOCLASE	MICROCLINE	PERTHITE	BIOTITE	AMPHIBOLE	GARNET	SILLIMANITE	CLINOPYROXENE	ORTHOPYROXENE	CORDIERITE	SPHENE	ZIRCON	MAGNITITE/IL	WHITE MICA	CHLORITE	HEMATITE	Rock
GF 11-1	116-39-31	X	X	X	X	X										X			granitic gneiss
GF 11-2	116-39-31	X	X	X		X							X			X			granitic gneiss
MV 3-1	117-40-29	X	X	X		X		X							X	X		X	tonalitic gneiss
MV 3-2	117-40-29	X	X			X		X						X				X	tonalitic gneiss
MV 3-3	117-40-29	X	X		X	X		X										X	granitic gneiss
MV 3-4	117-40-29	X	X		X	X									X			X	granitic gneiss
MV 3-8	117-40-29	X	X		X	X										X		X	granitic gneiss
MV 5-1	117-40-20	X	X			X		X						X	X				tonalitic gneiss
MV 5-2	117-40-20	X	X		X	X		X							X				granitic gneiss
MV 6-1	117-40-19	X	X	X									X	X		X	X		granitic gneiss
MV 6-2	117-40-19		X			X	X			X	X				X				charnokitic amphibolite
MV 6-4	117-40-19	X	X	X			X			X	X								charnokitic gneiss

APPENDIX 1 (continued)

Sample	T-R-Sec. Location	QUARTZ	PLAGIOCLASE	MICROCLINE	PERTHITE	BIOTITE	AMPHIBOLE	GARNET	SILLIMANITE	CLINOPYROXENE	ORTHOPYROXENE	CORDIERITE	SPHENE	ZIRCON	MAGNITITE/IL.	WHITE MICA	CHLORITE	HEMATITE	Rock
OV 5-1	120-44-M12	X	X	X		X								X	X	X			quartz monzonite
OV 5-2	120-44-M12	X	X	X		X								X	X	X	X		quartz monzonite
OV 5-3	120-44-M12	X	X	X		X								X	X	X			quartz monzonite
OV 6-4	120-45-16	X	X	X		X		X						X	X	X			quartz monzonite
OV 6-5	120-45-16	X	X	X		X							X	X		X			quartz monzonite
OV 7-1	120-45-4	X	X	X	X	X		X					X	X		X	X		quartz monzonite
RF 6-9	113-34-31	X	X	X		X	X								X	X	X		granite migmatite
RF 6-12	113-34-31	X	X	X		X									X	X	X		tonalite migmatite
RF 7-1	113-35-20	X	X	X		X									X	X	X		granitic gneiss
RF 8-1	114-36-C28,29,32,33	X	X			X	X									X			amphibolite
RF 8-2	114-36-C28,29,32,33	X	X			X		X							X	X			gt.-bi. schist
RF 8-4	114-36-C28,29,32,33	X	X			X		X							X	X			gt.-bi. schist
RF 8-5	114-36-C28,29,32,33	X	X				X				X				X	X			charnockitic schist

APPENDIX 1 (continued)

Sample	T-R-Sec. Location	QUARTZ	PLAGIOCLASE	MICROCLINE	PERTHITE	BIOTITE	AMPHIBOLE	GARNET	SILLIMANITE	CLINOPYROXENE	ORTHOPYROXENE	CORDIERITE	SPHENE	ZIRCON	MAGNITITE/IL.	WHITE MICA	CHLORITE	HEMATITE	Rock
RF 8-14	114-36-C28,29,32,33	X	X			X		X				X		X		X			cr.-gt.-bi. schist
RF 8-24	114-36-C28,29,32,33	X	X			X	X	X	X			X	X		X				cr.-gt.-bi. schist
RF 8-26	114-36-C28,29,32,33	X	X			X	X	X				X			X				cr.-gt.-bi. schist
RF 8-34	114-36-C28,29,32,33	X	X			X		X						X					gt.-bi.schist
VB 5-1	114-38-13	X	X	X		X							X			X	X		quartz monzonite
VB 5-3	114-38-13	X	X	X		X	X			X			X		X	X			charnokitic gneiss
VB 7-3	114-37-7	X	X	X		X									X	X		X	quartz monzonite

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Appendix 2

Analysis of Feldspar, Biotite, Garnet and Cordierite

oxide/ion	GF 11-1 plag	GF 11-1 Kspar	GF 11-1 Kspar	GF 11-1 plag	GF 11-2 plag	GF 11-2 Kspar	GF 11-2 Kspar	MV 3-3 plag	MV 3-3 Kspar
SiO_2	63.55	61.87	60.93	59.73	57.71	59.95	61.3	63.43	63.95
Al_2O_3	18.03	17.53	16.96	21.84	21.06	17.02	17.51	22.09	17.82
MgO	-	-	-	-	-	-	-	-	-
FeO	-	-	-	-	-	-	-	0.12	-
MnO	-	-	0.10	0.09	-	-	-	-	-
TiO_2	0.16	0.28	0.25	-	-	0.31	0.36	0.11	0.10
CaO	0.43	0.52	0.49	4.54	3.86	0.72	0.75	3.50	0.86
Na_2O	8.05	0.54	1.05	7.75	7.62	0.69	1.16	8.88	3.56
K_2O	4.71	15.63	15.57	0.21	0.11	15.40	15.46	0.23	10.37
total	94.93	96.37	95.34	94.15	90.36	93.88	96.53	98.37	96.66
Si	8.9470	8.9342	8.9397	8.4001	8.4321	8.8892	8.8693	8.5196	8.9997
Al	2.9907	2.9832	2.9289	3.6198	3.6273	2.9841	2.9851	3.4968	2.9557
Mg	-	-	-	-	-	-	-	-	-
Fe	-	-	-	-	-	-	-	0.0131	-
Mn	-	-	0.0118	0.0103	-	-	-	-	-
Ti	0.0164	0.0303	0.0271	-	-	0.0350	0.0389	0.0111	0.0106
Ca	0.649	0.0807	0.0768	0.6847	0.6042	0.1140	0.1162	0.5034	0.1298
Na	2.1977	0.1508	0.2971	2.1123	2.1599	0.2000	0.3255	2.3131	0.9707
K	0.8463	2.8794	2.9112	0.0374	0.0198	2.9219	2.8531	0.0400	1.8610

Appendix 2 (continued)

oxide/ion	MV 3-3 Kspar	MV 3-3 plag	MV 3-4 kspar	MV 3-4 plag	MV 3-4 plag	MV 3-8 plag	MV 3-8 plag	MV 3-8 plag	MV 3-8 Kspar	MV 5-2 plag
SiO_2	63.57	61.36	60.15	60.77	61.37	62.14	65.17	163.78	59.47	62.50
Al_2O_3	17.82	21.45	16.81	20.85	20.99	20.45	19.14	20.35	16.79	22.24
MgO	-	-	-	-	-	-	-	-	-	-
FeO	-	0.32	0	0.17	0.15	0.27	-	-	-	0.12
MnO	0.13	-	-	-	-	-	-	-	-	-
TiO_2	-	-	0.15	-	-	-	0.13	0.08	-	-
CaO	0.50	3.17	0.50	3.19	3.08	2.95	0.86	2.50	0.49	3.68
Na_2O	5.63	9.06	2.35	8.51	8.27	9.53	9.25	9.95	1.04	8.82
K_2O	5.96	0.12	13.10	0.14	0.43	0.49	1.68	0.41	14.67	0.38
total	93.61	95.48	93.05	93.63	94.29	95.83	96.73	97.07	92.46	97.74
Si	9.0517	8.5050	8.9440	8.5640	8.5847	8.6026	8.9379	8.6852	8.9477	8.4669
Al	2.9906	3.5028	2.9466	3.4627	3.4609	3.3362	3.0701	3.2665	2.9774	3.5514
Mg	-	-	-	-	-	-	-	-	-	-
Fe	-	0.0365	-	0.0199	0.0171	0.0318	-	-	-	0.0139
Mn	0.0156	-	-	-	-	-	-	-	-	-
Ti	-	-	0.0162	-	-	-	0.0135	0.0079	-	-
Ca	0.0765	0.4709	0.0789	0.4822	0.4621	0.4369	0.1256	0.3647	0.0788	0.5346
Na	1.5539	2.4353	0.6765	2.3253	2.2425	2.5568	2.4399	2.6267	0.3037	2.3158
K	1.0825	0.0207	2.4845	0.0255	0.0773	0.0863	0.2922	0.0712	2.8151	0.0649

Appendix 2 (continued)

oxide/ion	MV 5-2 plag	MV 5-2 Kspar	MV 5-2 Kspar	MV 6-1 plag	MV 6-1 plag	MV 6-1 Kspar	MV 6-4 plag	MV 6-4 Kspar	MV 6-4 Kspar	MV 6-4 plag
SiO_2	61.44	64.51	63.77	58.51	58.86	59.70	54.99	57.35	56.82	58.03
Al_2O_3	21.39	18.27	17.91	21.55	21.78	16.87	22.73	15.85	16.09	23.44
MgO	-	-	-	-	-	-	-	-	0.13	-
FeO	-	0.15	-	-	-	-	-	0.16	-	0.11
MnO	0.15	-	-	-	-	-	-	-	-	0.12
TiO_2	-	0.14	0.28	0.07	-	0.48	-	0.38	0.45	0.08
CaO	3.72	0.62	0.69	4.20	4.38	0.69	6.49	0.73	0.86	6.08
Na_2O	8.91	3.37	1.05	8.02	7.38	0.29	6.45	0.44	0.46	6.62
K_2O	0.28	12.03	16.18	-	-	16.41	0.39	15.78	16.05	0.63
total	95.90	99.08	99.89	92.35	92.40	94.45	91.15	90.69	90.85	95.11
Si	8.4929	8.9360	8.9131	8.3838	8.4049	8.8750	8.0607	8.8971	8.8243	8.1378
Al	3.4839	2.9828	2.9510	3.6393	3.6658	2.9559	3.9274	2.8980	2.9439	3.8742
Mg	-	-	-	-	-	-	-	-	0.0296	-
Fe	-	0.0169	-	-	-	-	-	0.0212	-	0.0130
Mn	0.0177	-	-	-	-	-	-	-	-	0.0138
Ti	-	0.0150	0.0294	0.0071	-	0.0538	-	0.0444	0.0523	0.0081
Ca	0.5515	0.0920	0.1034	0.6445	0.6693	0.1102	1.0345	0.1213	0.1423	0.9133
Na	2.3882	0.9037	0.2849	2.2284	2.0440	0.0843	1.8325	0.1322	0.1386	1.7996
K	0.0493	2.1253	2.8850	-	-	3.1121	0.0728	3.1221	3.1788	0.1129

Appendix 2 (continued)

oxide/ion	OV 5-1 plag	OV 5-1 plag	OV 5-1 Kspar	OV 5-1 Kspar	OV 5-2 Kspar	OV 5-2 Kspar	OV 5-2 plag	OV 5-2 plag	OV 5-3 plag	OV 5-3 plag
SiO_2	58.75	60.04	60.96	59.88	59.12	59.81	60.31	59.09	62.50	59.51
Al_2O_3	21.31	21.22	16.95	16.98	16.38	17.00	21.13	20.80	22.64	21.24
MgO	-	-	0.22	0.14	-	0.10	-	-	-	-
FeO	-	-	-	-	9.15	-	-	9.27	-	0.14
MnO	-	-	0.10	0.11	-	-	-	-	-	-
TiO_2	-	0.11	-	-	-	0.11	-	-	-	-
CaO	3.83	3.81	0.82	0.69	0.81	0.87	3.54	3.56	4.30	3.89
Na_2O	7.62	8.40	0.58	0.31	0.29	0.41	3.04	7.99	8.76	8.15
K_2O	0.05	-	16.11	16.23	15.89	15.68	0.04	0.21	0.09	0.11
total	91.56	93.58	95.75	94.35	92.64	93.99	93.07	91.92	98.29	93.03
Si	8.4581	8.4772	8.9195	8.8996	8.9463	8.8971	8.5352	8.4987	8.4186	8.4601
Al	3.6166	3.5312	2.9234	2.9745	2.9205	2.9807	3.5239	3.5252	3.5935	3.5581
Mg	-	-	0.0487	0.0315	-	0.0231	-	-	-	-
Fe	-	-	-	-	0.0192	-	-	0.0323	-	0.0166
Mn	-	-	0.0128	0.0141	-	-	-	-	-	-
Ti	-	0.0117	-	-	-	0.0125	-	-	-	-
Ca	0.5913	0.5757	0.1284	0.1093	0.1311	0.1392	0.5359	0.5486	0.6205	0.5936
Na	2.1256	2.2989	0.1651	0.0903	0.0850	0.1189	2.2073	2.2284	2.2886	2.2463
K	0.0090	-	3.0059	3.0774	3.0672	2.9754	0.0081	0.0388	0.0151	0.0199

Appendix 2 (continued)

oxide/ion	OV 5-3 Kspar	OV 5-3 plag	OV 5-3 Kspar	OV 6-4 plag	OV 6-4 Kspar	OV 6-5 Kspar	OV 6-5 plag	OV 6-5 plag	OV 7-1 Kspar	OV 7-1 Kspar
SiO_2	60.48	59.33	58.51	64.67	61.87	63.77	57.52	59.58	65.12	60.15
Al_2O_3	17.02	21.55	16.56	23.83	17.65	18.10	15.85	21.39	18.25	16.72
MgO	-	-	0.18	-	-	0.24	-	-	-	-
FeO	-	-	-	-	-	0.15	0.19	-	0.12	-
MnO	-	0.09	-	-	-	-	-	-	-	-
TiO_2	0.30	0.12	0.27	-	0.30	0.11	-	-	0.27	0.09
CaO	0.77	4.05	0.65	4.38	0.68	0.54	0.36	4.05	0.61	0.61
Na_2O	0.18	8.04	0.31	9.80	0.44	0.62	8.38	7.71	0.61	0.62
K_2O	16.40	-	15.71	-	16.26	16.80	0.10	0.14	16.09	16.28
total	95.15	83.18	92.19	102.67	97.21	100.33	82.40	92.86	101.08	94.46
Si	8.9073	8.4185	8.887	8.3602	8.8957	8.8942	9.0943	8.4676	8.9554	8.9317
Al	2.9540	3.6036	2.9650	3.6303	2.9912	2.9744	2.9535	3.5821	2.9574	2.9263
Mg	-	-	0.0413	-	-	0.0491	-	-	-	-
Fe	-	-	-	-	-	0.0177	0.247	-	0.0141	-
Mn	-	0.0104	-	-	-	-	-	-	-	-
Ti	0.0334	0.0129	0.0307	-	0.0326	0.0117	-	-	0.0277	0.0100
Ca	0.1207	0.6158	0.1050	0.6064	0.1039	0.0805	0.0611	0.6170	0.0900	0.0962
Na	0.0518	2.2102	0.0904	2.4553	0.1216	0.1683	2.5701	2.1232	0.1632	0.1773
K	3.0809	-	3.0433	-	2.9826	2.9892	0.0200	0.0257	2.8230	3.0839

Appendix 2 (continued)

oxide/ion	OV 7-1 plag	OV 7-1 Kspar	RF 6-9 Kspar	RF 6-9 Kspar	RF 6-9 Kspar	RF 6-9 plag	RF 6-12 Kspar	RF 6-12 Kspar	RF 6-12 plag	RF 6-12 plag
SiO_2	61.97	60.53	69.18	61.48	60.26	58.78	60.60	58.23	57.99	58.95
Al_2O_3	17.43	17.01	16.76	17.06	17.04	21.73	17.35	19.68	21.27	21.96
MgO	-	-	0.12	-	-	-	0.20	-	-	-
FeO	0.10	-	0.48	-	-	0.14	-	0.12	0.15	0.11
MnO	-	-	-	-	-	-	-	-	-	-
TiO_2	-	0.19	0.15	-	-	-	0.21	0.23	-	-
CaO	0.47	0.61	0.51	0.56	0.61	4.79	0.63	3.31	4.16	4.82
Na_2O	3.62	0.47	0.34	0.44	1.11	8.05	0.26	1.92	7.63	7.75
K_2O	10.55	16.14	16.29	16.62	15.05	0.26	16.67	10.51	0.25	0.19
total	94.15	94.94	94.83	96.16	94.07	93.75	95.93	94.02	91.44	93.78
Si	8.9821	8.9228	8.9125	8.9559	8.9290	8.3376	8.8657	8.5309	8.3992	8.3413
Al	2.9771	2.9543	2.9257	2.9290	2.9757	2.6324	2.9917	3.3977	3.6292	3.6628
Mg	-	-	0.0271	-	-	-	-	-	-	-
Fe	0.0120	-	0.0592	-	-	0.0166	-	0.0143	0.0176	0.0131
Mn	-	-	-	-	-	-	-	-	-	-
Ti	-	0.0211	0.0162	-	-	-	0.0234	0.0258	-	-
Ca	0.0736	0.0967	0.0803	0.0880	0.0971	0.7283	0.0991	0.5199	0.6449	0.7300
Na	1.0815	0.1329	0.0962	0.1246	0.3125	2.2142	0.0738	0.5465	2.1431	2.1262
K	1.9501	3.0346	3.0776	3.0882	2.8448	0.0477	3.1109	1.9646	0.0453	0.0334

Appendix 2 (continued)

oxide/ion	RF 7-1 plag	RF 7-1 Kspar	RF 7-1 plag	RF 7-1 Kspar	RF 7-1 Kspar	RF 7-1 plag	VB 5-1 plag	VB 5-1 Kspar	VB 5-1 Kspar	VB 5-1 plag
SiO_2	58.78	55.97	58.96	60.99	62.65	59.14	62.26	59.60	60.48	59.92
Al_2O_3	21.72	15.72	21.47	17.51	17.28	22.20	21.98	17.03	16.93	20.05
Mg	-	-	-	-	0.19	-	-	0.27	-	-
FeO	0.18	-	-	-	-	-	-	-	-	0.13
MnO	-	-	0.15	-	0.21	-	-	-	-	0.15
TiO_2	-	0.28	-	0.20	0.12	-	0.19	0.39	0.39	-
CaO	4.48	0.84	4.13	0.76	0.75	4.71	3.81	0.85	0.81	2.89
Na_2O	7.74	0.56	8.15	1.20	0.44	7.27	8.40	0.34	1.17	8.34
K_2O	0.05	15.55	-	15.28	16.05	0.09	0.19	15.95	15.44	0.10
total	92.95	88.91	92.86	95.94	97.69	93.41	96.84	94.43	95.22	91.58
Si	8.3750	8.8663	8.4067	8.8733	8.9523	8.3651	8.4894	8.8465	8.8866	8.6238
Al	3.6475	2.9350	3.6072	3.0028	2.9104	3.7001	3.5326	2.9779	2.9326	3.4003
Mg	-	-	-	-	0.0397	-	-	0.0586	-	-
Fe	0.028	-	-	-	-	-	-	-	-	0.0161
Mn	-	-	0.0182	-	0.0257	-	-	-	-	0.0184
Ti	-	0.0333	-	0.0220	0.0132	-	0.0192	0.0437	0.0432	-
Ca	0.6837	0.1419	0.6305	0.118	0.1141	0.7143	0.5562	0.1354	0.1275	0.4450
Na	2.1382	0.1706	2.2536	0.3379	0.1210	1.9930	2.2211	0.0967	0.3330	2.3255
K	0.0098	3.1414	-	2.8357	2.9259	0.0170	0.0336	3.0198	2.8940	0.0184

Appendix 2 (continued)

oxide/ion	VB 5-3 plag	VB 5-3 plag	VB 5-3 Kspar	VG 5-3 Kspar	VB 7-3 Kspar	VB 7-3 Kspar	VB 7-3 Kspar	VB 7-3 plag	MV 3-1 biotite	MV 3-1 biotite
SiO_2	60.78	59.46	59.43	60.70	61.60	58.77	60.03	66.67	34.74	34.86
Al_2O_3	20.61	20.42	17.18	17.40	17.70	16.64	17.24	19.49	16.91	16.58
MgO	-	-	-	-	0.20	0.14	-	-	0.29	9.44
FeO	0.19	0.15	0.10	-	-	-.12	-	-	16.29	16.47
MnO	-	0.10	-	0.13	0.18	-	-	-	0.41	0.32
TiO_2	-	-	0.30	0.20	0.19	0.27	0.39	-	2.45	2.19
CaO	2.77	3.10	0.84	0.91	0.75	0.64	0.84	0.50	0.37	0.46
Na_2O	8.37	8.28	0.15	0.32	0.16	0.39	0.16	9.84	0.22	-
K_2O	0.13	0.16	16.21	16.59	17.30	15.67	15.94	0.09	9.85	9.94
total	92.84	91.67	94.22	96.25	98.16	92.64	94.60	96.60	90.54	90.27
Si	8.6159	8.5616	8.8504	8.8589	8.8333	8.8856	8.8741	8.9927	6.0515	6.0938
Al	3.4423	3.4652	3.0155	2.9936	3.0042	2.9648	3.0042	3.0979	3.4715	3.4162
Mg	-	-	-	-	0.0437	0.0326	-	-	2.4126	2.4607
Fe	0.0221	0.0183	0.0123	-	-	0.0155	-	-	2.3723	2.4074
Mn	-	0.0116	-	0.0155	0.0215	-	-	-	0.0608	0.0479
Ti	-	-	0.0338	0.0221	0.0205	0.0305	0.0435	-	0.3211	0.2884
Ca	0.4201	0.4789	0.1342	0.1418	0.115	0.1032	0.1327	0.0723	0.0695	0.0866
Na	2.3010	2.3104	0.0437	0.0909	0.0456	0.1156	0.0447	2.5738	0.0747	-
K	0.0232	0.0295	3.0791	3.0888	3.1641	3.0223	3.0059	0.0163	2.1895	2.2166

Appendix 2 (continued)

oxide/ion	MV 3-1 biotite	MV 3-1 biotite	MV 3-3 biotite	MV 3-3 biotite	MV 3-3 biotite	MV 5-1 biotite	MV 5-1 biotite	MV 5-2 biotite	MV 5-2 biotite	MV 5-2 biotite
SiO_2	34.63	35.02	32.84	32.36	34.66	35.32	34.76	34.99	35.75	35.21
Al_2O_3	15.46	16.08	14.11	14.20	14.95	13.69	13.64	14.33	14.31	14.07
MgO	7.63	7.64	7.63	7.98	8.23	9.89	11.43	8.75	8.70	8.95
FeO	21.82	20.60	18.49	18.68	19.47	19.10	17.16	20.65	20.72	19.94
MnO	0.20	0.66	0.23	0.14	-	0.19	0.15	0.31	0.33	0.41
TiO_2	3.39	3.39	3.26	3.33	3.22	4.10	1.63	3.57	3.36	3.36
CaO	0.48	0.56	0.44	0.52	0.41	0.42	0.43	0.61	0.55	0.59
Na_2O	-	0.52	0.51	0.61	0.26	0.18	0.46	0.62	0.64	0.20
K_2O	9.92	9.85	8.99	9.16	9.62	9.82	9.41	9.48	9.44	9.81
total	93.52	94.15	89.40	86.99	90.82	92.69	100.00	93.31	93.80	92.54
Si	6.0095	6.0091	5.6004	5.9985	6.1178	6.1089	4.7529	6.0604	6.1438	6.1321
Al	3.1613	3.2524	2.8436	3.1022	3.1094	2.7904	2.1977	2.9252	2.8988	2.8875
Mg	0.9727	1.9079	1.9452	2.2061	2.1665	2.5492	2.3287	2.2604	2.2279	2.3240
Fe	3.1655	3.9565	2.6450	2.8959	2.8744	2.7624	1.9616	2.9906	2.9769	2.9037
Mn	0.0300	0.0954	0.0327	0.0216	-	0.0282	0.0170	0.0460	0.0487	0.0611
Ti	0.4417	0.4374	0.4188	0.4644	0.4269	0.5326	0.1678	0.4652	0.4340	0.4405
Ca	0.0890	0.1033	0.0806	0.1040	0.0780	0.0769	0.0632	0.1128	0.2030	0.1108
Na	-	0.1727	0.1693	0.2190	0.0876	0.0619	0.1215	0.2083	0.2117	0.0677
K	1.1962	2.1570	1.9612	2.1663	2.1663	2.1663	1.6417	2.0934	2.0688	2.1794

Appendix 2 (continued)

oxide/ion	OV 6-4 biotite	OV 7-1 biotite	OV 7-1 biotite	RF 8-2 biotite	RF 8-2 biotite	RF 8-14 biotite	RF 8-14 biotite	RF 8-34 biotite	RF 8-34 biotite
SiO_2	34.39	32.42	31.87	31.59	32.63	36.29	35.81	37.25	37.38
Al_2O_3	16.42	15.235	15.83	14.40	16.42	17.45	17.50	16.40	16.14
MgO	6.83	6.49	6.76	10.99	13.41	11.49	11.17	14.08	14.09
FeO	22.62	22.34	21.48	14.42	18.44	17.82	18.08	15.06	15.39
MnO	0.44	0.14	0.18	-	0.13	0.10	0.10	-	0.18
TiO_2	2.34	2.66	2.55	2.05	2.25	2.34	2.23	1.51	1.62
CaO	0.47	0.48	0.39	0.11	0.27	-	-	0.13	0.14
Na_2O	0.18	0.37	-	0.23	0.45	0.23	0.40	-	-
K_2O	10.03	9.90	9.50	7.72	5.81	9.35	9.56	8.52	8.95
total	93.72	90.15	91.55	100.00	100.00	95.08	94.86	92.94	93.38
Si	5.9872	5.9110	5.4058	3.8903	4.4533	5.9953	5.9577	6.1696	6.1612
Al	3.3684	3.2981	3.1641	2.0899	2.6410	3.3984	3.4310	3.2002	3.1350
Mg	1.7717	1.7640	1.7087	2.0178	2.7285	2.8313	2.7711	3.4765	3.4623
Fe	3.2921	3.4051	3.0465	1.4846	2.1045	2.4614	2.5156	2.0852	2.1212
Mn	0.0645	0.0218	0.0251	-	0.0155	0.0141	0.0136	-	0.0247
Ti	0.3062	0.3642	0.3256	0.1901	0.2312	0.2908	0.2792	0.1882	0.2006
Ca	0.0883	0.0944	0.0714	0.0150	0.0425	-	-	0.0223	0.0240
Na	0.0610	0.1302	-	0.0540	0.1190	0.0752	0.1284	-	-
K	2.2260	2.3032	2.0561	1.2124	1.0112	1.9708	2.0295	1.7996	1.8822

Appendix 2 (continued)

oxide/ion	MV 3-1 garnet	MV 3-1 garnet	MV 3-1 garnet	MV 3-2 garnet	MV 3-2 garnet	MV 3-3 garnet	MV 3-3 garnet	MV 3-3 garnet	MV 5-1 garnet	MV 5-1 garnet
SiO_2	36.01	35.96	36.60	36.03	36.15	36.59	35.25	35.02	36.88	36.23
Al_2O_3	20.35	20.12	20.19	20.56	20.08	20.54	19.82	19.93	20.84	19.69
MgO	2.19	2.12	2.54	2.47	1.97	2.44	2.87	2.63	3.36	2.69
FeO	30.54	31.40	31.28	31.38	29.46	29.28	27.40	27.71	29.75	38.55
MnO	6.40	5.65	5.45	6.01	7.55	4.85	3.94	4.02	4.41	4.24
TiO_2	-	-	-	-	-	-	-	0.13	-	-
CaO	1.37	1.49	1.33	1.31	1.81	1.40	1.21	1.42	1.43	1.56
Na_2O	-	-	-	0.36	0.24	-	-	0.37	-	-
K_2O	-	-	-	-	-	-	0.09	-	-	-
total	96.85	96.73	97.39	98.10	96.63	95.10	90.58	91.23	96.67	92.95
Si	6.0147	6.0235	6.0633	5.9570	6.0564	6.1318	6.1555	6.0966	6.0724	6.1929
Al	4.0068	3.9711	3.9419	4.0057	3.9643	4.0566	4.0801	4.0897	4.0449	3.9668
Mg	0.5451	0.5297	0.6281	0.6083	0.4926	0.6096	0.7485	0.6823	0.8240	0.6843
Fe	4.2654	4.3976	4.3329	4.3383	4.1263	4.1021	4.0010	4.0347	4.0961	4.0799
Mn	0.9051	0.8013	0.7639	0.8421	1.0715	0.6889	0.5827	0.5928	0.6146	0.6132
Ti	-	-	-	-	-	-	-	0.0176	-	-
Ca	0.2445	0.2674	0.2351	0.2314	0.2116	0.2506	0.2262	0.2650	0.2527	0.2861
Na	-	-	-	0.1139	0.0767	-	-	0.1233	-	-
K	-	-	-	-	-	-	-	-	-	-

Appendix 2 (continued)

oxide/ion	MV 5-1 garnet	MV 5-1 garnet	MV 5-2 garnet	MV 5-2 garnet	OV 6-4 garnet	OV 7-1 garnet	OV 7-1 garnet	RF 8-2 garnet	RF 8-14 garnet	RF 8-14 garnet
SiO_2	36.06	36.88	36.77	36.56	36.71	34.87	35.40	38.23	38.23	37.97
Al_2O_3	20.15	20.57	20.12	21.14	20.76	19.71	19.78	21.54	21.17	20.96
MgO	3.26	3.19	1.97	2.29	1.12	2.70	2.98	5.60	3.76	4.12
FeO	29.11	30.06	29.21	30.72	24.09	32.94	32.80	33.18	33.74	32.60
MnO	4.05	4.19	7.91	6.45	13.92	1.77	1.62	2.29	3.55	2.53
TiO_2	-	-	-	-	-	-	-	-	-	-
CaO	1.45	1.41	1.50	1.56	1.38	1.66	1.63	1.61	1.13	1.12
Na_2O	0.24	-	0.30	0.30	-	0.19	-	-	-	0.20
K_2O	-	-	-	-	-	-	-	-	-	0.14
total	94.32	96.30	97.78	99.02	97.98	93.84	94.20	102.45	101.59	99.65
Si	6.0884	6.1014	6.0834	5.9683	6.0681	5.9946	6.0365	5.9464	6.0397	6.0741
Al	4.0086	4.0100	3.9229	4.0673	4.0433	3.9924	3.9742	3.9484	3.9408	3.9514
Mg	0.8203	0.7877	0.4847	0.5581	0.2755	0.6907	0.7580	1.2991	0.8857	0.9828
Fe	4.1088	4.1580	4.0407	4.1926	3.3303	4.7356	4.6763	4.3155	4.4573	4.3601
Mn	0.5787	0.5868	1.1082	0.8914	1.9483	0.2582	0.2333	0.3010	0.4755	0.3431
Ti	-	-	-	-	-	-	-	-	-	-
Ca	0.2623	0.2494	0.2655	0.2730	0.2444	0.3050	0.2978	0.2687	0.1905	0.1926
Na	0.0795	-	0.0988	0.0940	-	0.0644	-	-	-	0.0626
K	-	-	-	-	-	-	-	-	-	0.0288

Appendix 2 (continued)

oxide/ion	RF 8-24 garnet	RF 8-24 garnet	RF 8-24 garnet	RF 8-24 garnet	RF 8-24 garnet	RF 8-26 garnet	RF 8-34 garnet	RF 8-34 garnet	RF 8-14 cord.
SiO_2	38.79	38.01	39.32	38.36	38.43	37.49	38.25	39.34	48.55
Al_2O_3	21.11	21.08	21.78	21.19	21.79	19.88	21.45	21.80	31.75
MgO	5.23	3.92	6.27	4.93	3.31	6.23	4.92	4.11	8.45
FeO	32.34	33.24	31.41	31.90	35.30	30.24	30.16	30.53	7.32
MnO	1.73	2.62	1.68	1.87	2.68	2.15	4.60	3.61	0.12
TiO_2	-	-	-	-	-	-	-	-	-
CaO	1.61	1.59	1.61	1.76	1.00	1.73	1.76	1.92	-
Na_2O	-	-	-	-	-	-	-	0.19	0.26
K_2O	0.08	0.08	-	-	-	-	-	-	-
total	100.89	100.53	102.06	100.01	102.51	97.71	101.14	103.52	96.46
Si	6.0852	6.0454	6.0533	6.0702	6.0209	6.0640	6.0094	6.0086	6.7622
Al	3.9032	9.9513	3.9512	3.9520	4.0231	3.7892	3.9710	3.9231	5.2121
Mg	1.2240	0.9304	1.4382	1.1618	0.7738	1.5025	1.1530	1.3906	1.7552
Fe	4.2426	4.4211	4.0436	4.2211	4.6256	4.0901	3.9627	3.8987	0.8519
Mn	0.2293	0.3526	0.2195	0.2505	0.3557	0.2947	0.6115	0.4672	0.0146
Ti	-	-	-	-	-	-	-	-	-
Ca	0.2702	0.2701	0.2648	0.2979	0.1679	0.3005	0.3971	0.3148	-
Na	-	-	-	-	-	-	-	-	-
K	0.0168	0.0152	-	-	-	-	-	-	-

Appendix 2 (continued)

oxide/ion	RF 8-14 cord.	RF 8-24 cord.	RF 8-24 cord.	RF 8-24 cord.	RF 8-24 cord.	RF 3-24 cord.	RF 8-26 cord.	RF 8-26 cord.
SiO_2	48.14	49.99	50.10	49.91	49.23	42.79	49.47	49.83
Al_2O_3	31.87	33.32	33.26	33.36	32.08	47.88	32.31	32.62
MgO	8.93	9.62	9.50	9.39	9.09	3.84	9.66	9.71
FeO	7.44	6.89	7.37	7.18	6.72	4.63	6.15	7.97
MnO	-	-	0.21	-	0.15	-	0.36	0.48
TiO_2	-	-	0.10	-	-	-	0.19	0.27
CaO	-	-	-	-	0.08	-	-	-
Na_2O	-	-	-	0.47	0.34	-	-	-
K_2O	0.32	0.35	0.44	-	0.05	0.18	-	-
total	96.70	100.23	100.97	100.30	97.74	99.31	98.13	100.89
Si	6.6995	6.6888	6.6778	6.6831	6.7551	5.7078	6.7388	6.6709
Al	5.2270	5.2546	5.2237	5.2635	5.1874	7.5272	5.1871	5.1459
Mg	1.8518	1.9196	1.8870	1.8737	1.8603	0.7626	1.9625	1.9382
Fe	0.8659	0.7714	0.8211	0.8040	0.7704	0.5158	0.7000	0.8916
Mn	-	-	0.0241	-	0.0169	-	0.0409	0.0546
Ti	-	-	0.0098	-	-	-	0.0189	0.0273
Ca	-	-	-	-	0.0107	-	-	-
Na	0.0851	0.0910	0.1133	0.1211	0.0912	-	-	-
K	-	0.0073	-	-	0.0091	0.0298	-	-