

A Geochemical and Stable Isotope Study

of some

Rocks from the Bandelierkop Formation,

Southern Marginal Zone of the Limpopo Belt,

South Africa

by

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Volume 2

Appendix

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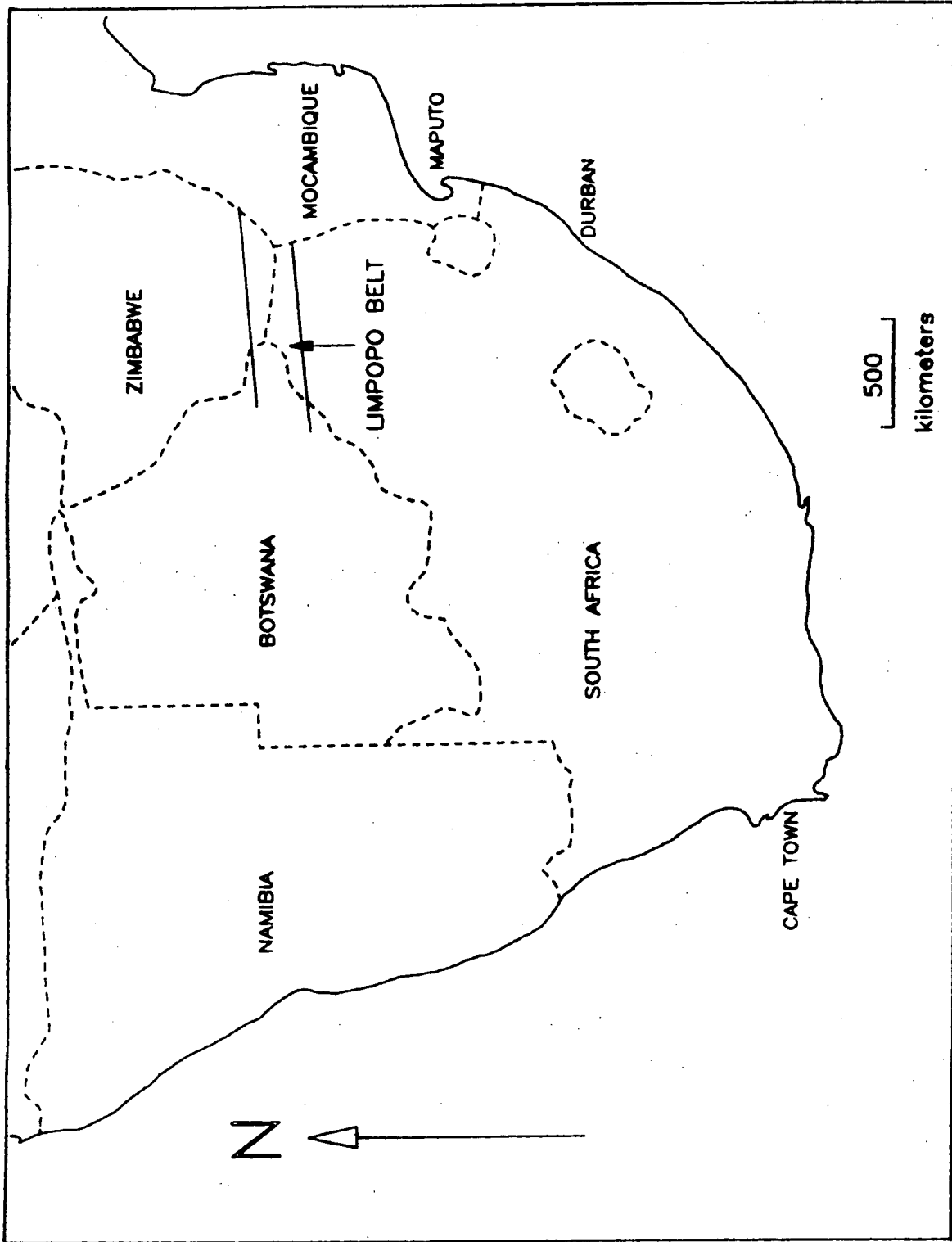


Figure 1.1: Sketch locality map of the Limpopo Belt.

DOMAIN	STRUCTURAL ZONE	STRATIGRAPHIC ZONE
1	Northern Marginal	Northern Marginal
2	Northern Marginal	Central
3	Central	Central
4	Central	Central
5	Southern Marginal	Central
6	Southern Marginal	Central
7	Southern Marginal	Southern Marginal

	Gradational Contact
	Orthopyroxene Isograd
	Fault Zone
	Shear Zone
	Thrust Zone
	Cover

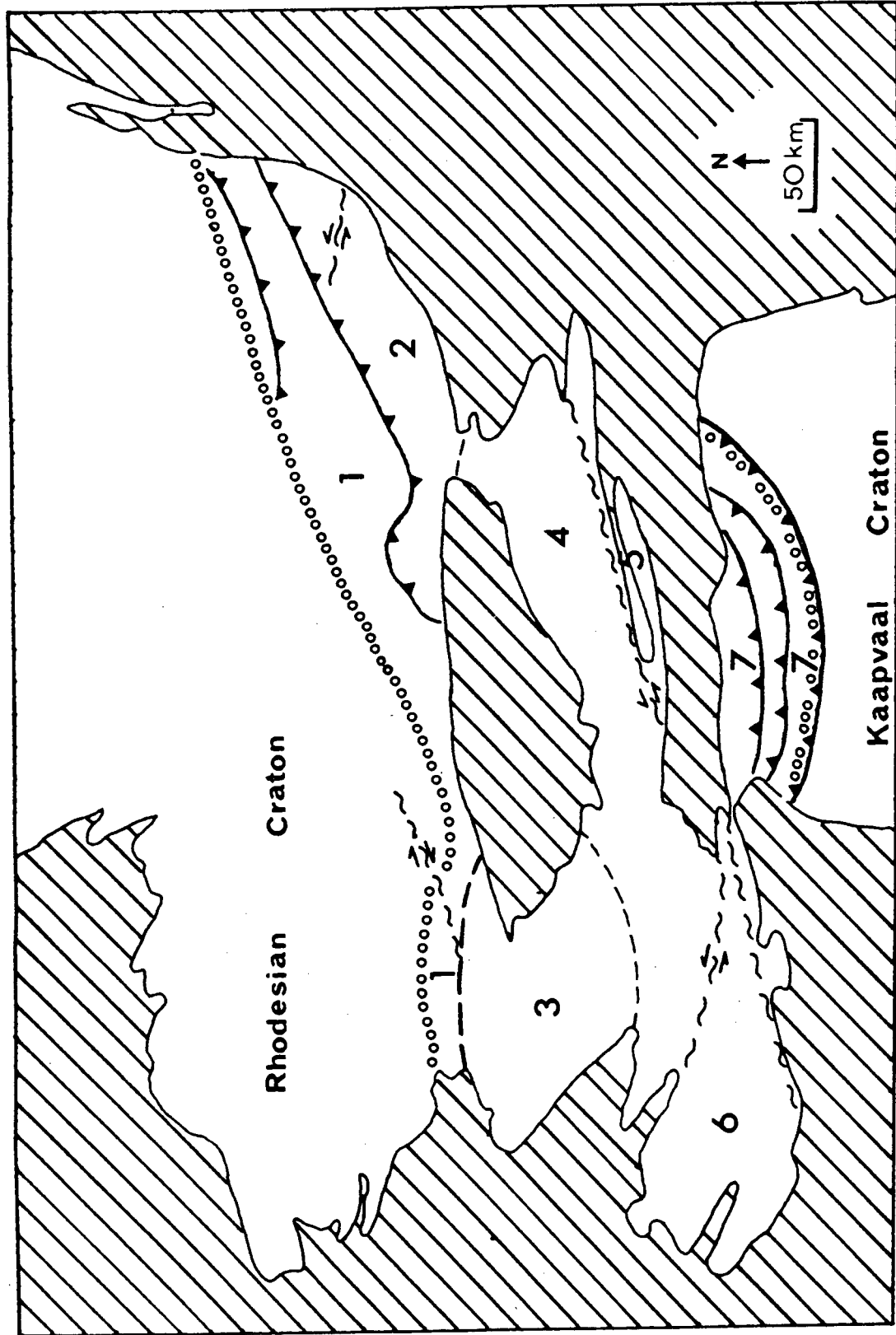


Figure 1.2: Division of the Limpopo Belt into structural and stratigraphic domains (after Watkeys, 1983).

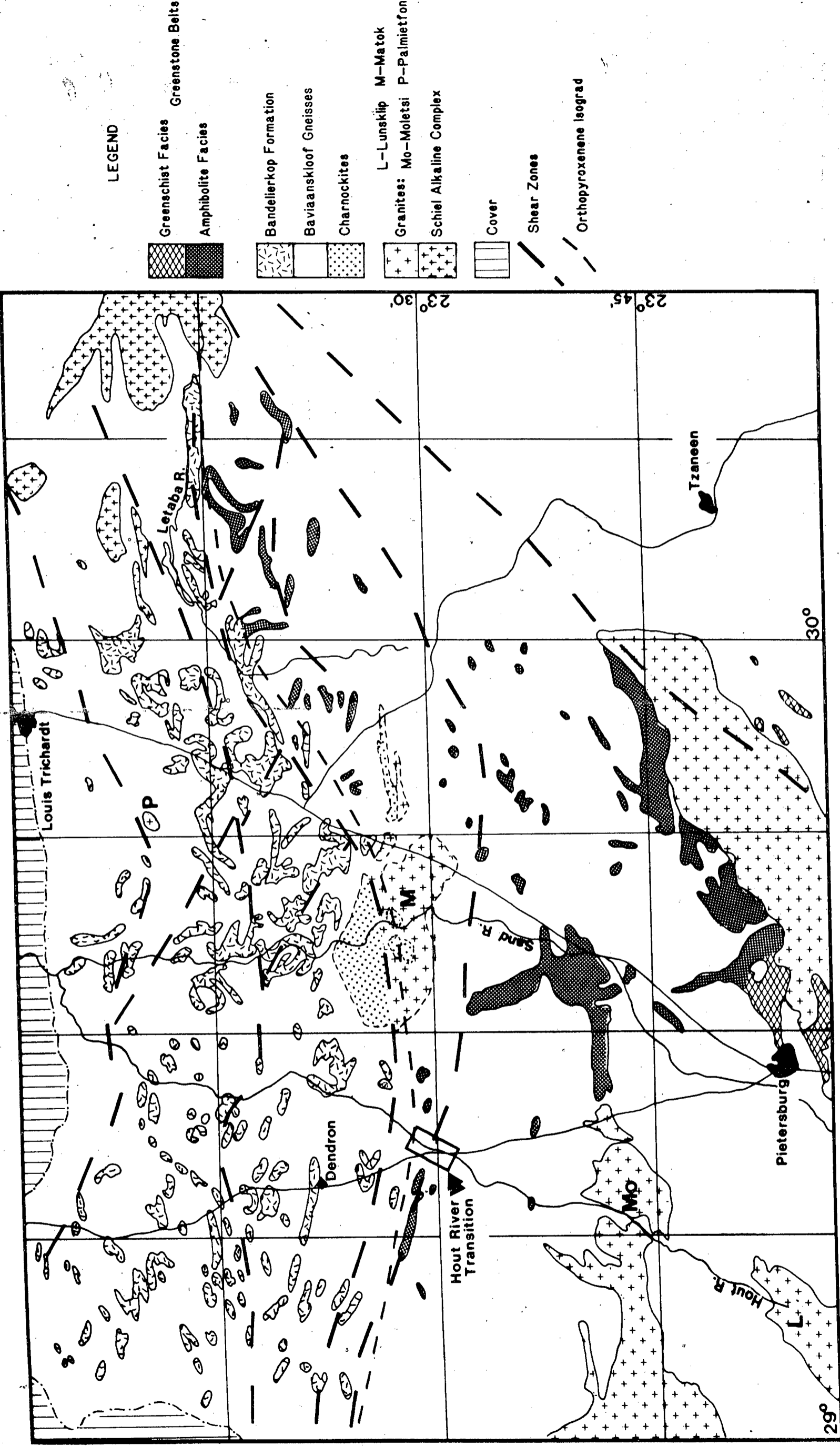


Figure 1.3: Sketch map of the general geology of the Southern Marginal Zone of the Limpopo Belt and the adjacent Kaapvaal craton.

Figure 2.1: Sample localities of the rocks collected for this study. For orientation purposes the shear zones and the orthopyroxene isograd are also shown. Symbols:  $\blacktriangle$  - ultramafic rocks,  $\bullet$  mafic rocks,  $\blacksquare$  - pelitic rocks,  $\nabla$  - pegmatites,  $+$  - banded iron formation,  $\square$  - gneiss,  $\circ$  - charnockite,  $\diamond$  - granodiorite.

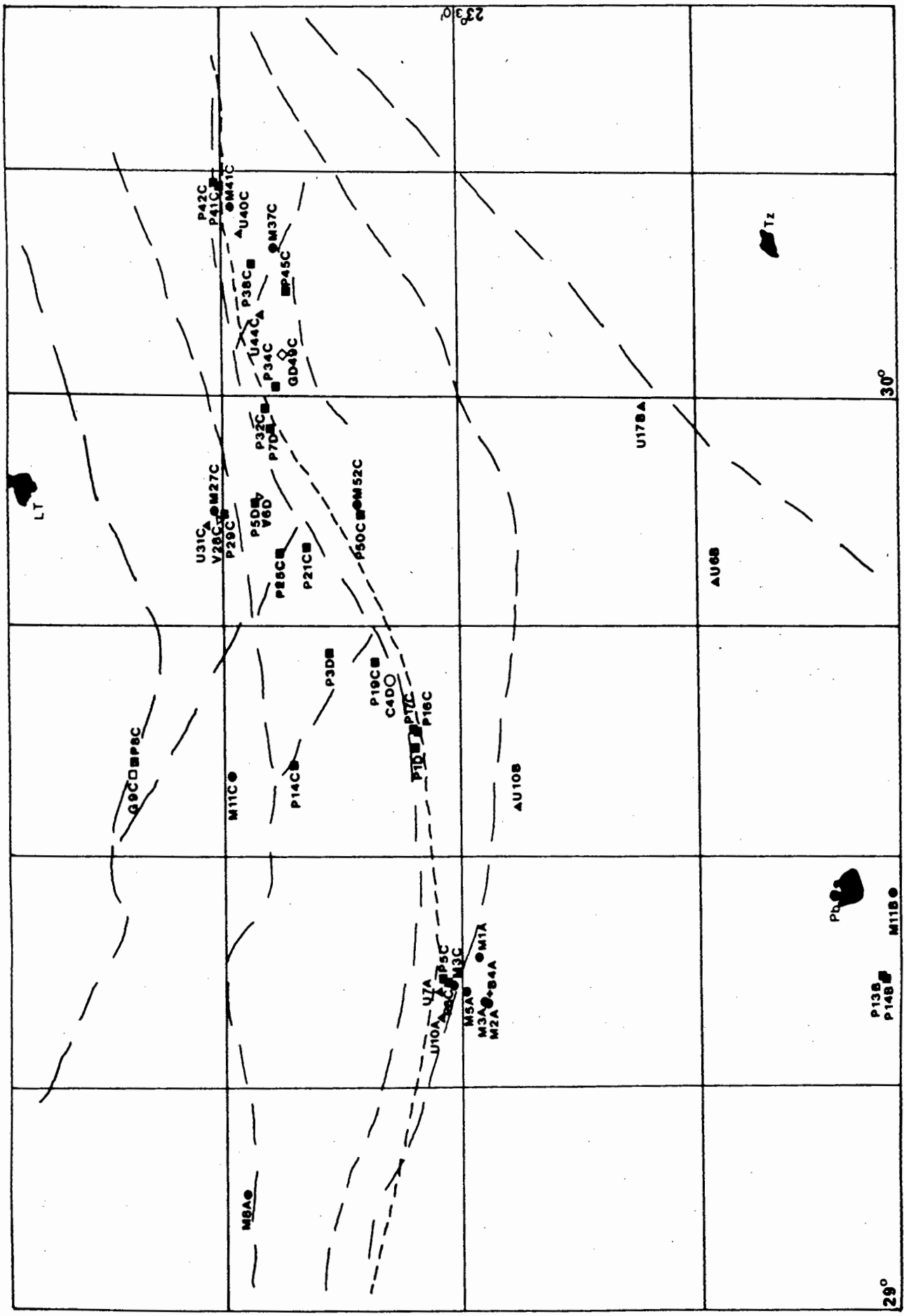


Table 2.1

X-Ray Fluorescence Analysis - Average Absolute Errors and  
Detection Limits (LLD; 95% confidence limits)

Oxide	Avg. Abs. Error	LLD	Element	Avg. Abs. Error	LLD
SiO <sub>2</sub>	0.13	0.013	Ba	3.0	5.5
TiO <sub>2</sub>	0.02	0.004	Sc	0.5	1.2
Al <sub>2</sub> O <sub>3</sub>	0.10	0.017	Co	1.3	3.5
FeO	0.12	0.015	Mn	2.8	3.0
MgO	0.15	0.056	Cr	2.8	2.9
CaO	0.06	0.004	V	1.7	2.8
Na <sub>2</sub> O	0.10	0.020	Zn	1.0	2.5
K <sub>2</sub> O	0.03	0.003	Cu	1.1	3.0
P <sub>2</sub> O <sub>5</sub>	0.01	0.011	Ni	2.5	4.0
			Nb	0.5	1.6
			Zr	0.7	1.8
			Y	0.6	2.2
			Sr	0.8	1.7
			Rb	0.7	1.9
			Th	1.3	3.9
			Pb	1.5	4.8

Table 2.2

Electron Microprobe Analysis  
Standards, Errors (2 standard deviations) and Detection limits (LLD)

----- Olivine -----					----- Pyroxene -----			
Oxide	Std	wt%	LLD	2s.d.	Std	wt%	LLD	2s.d.
SiO <sub>2</sub>	M-O	40.57	0.04	0.25	Dio	50.43	0.04	0.28
TiO <sub>2</sub>	Rut	0.03	0.04	0.03	Rut	0.08	0.04	0.03
Al <sub>2</sub> O <sub>3</sub>	K-P	0.00	0.03	0.00	K-P	6.02	0.04	0.10
Cr <sub>2</sub> O <sub>3</sub>	Chr	0.00	0.04	0.00	Chr	0.18	0.05	0.04
FeO	M-O	9.86	0.07	0.26	K-P	18.69	0.08	0.36
MnO	Rho	0.13	0.07	0.06	Rho	0.01	0.07	0.05
MgO	M-O	48.69	0.03	0.24	Dio	24.78	0.03	0.18
CaO	K-P	0.01	0.03	0.02	Dio	0.07	0.03	0.02
Na <sub>2</sub> O	---	---	---	---	K-H	0.01	0.03	0.02
K <sub>2</sub> O	---	---	---	---	K-H	0.01	0.02	0.02
NiO	NIS	0.41	0.08	0.08	---	---	---	---
Total		99.71				100.24		

----- Amphibole -----					----- Mica -----			
Oxide	Std	wt%	LLD	2s.d.	Std	wt%	LLD	2s.d.
SiO <sub>2</sub>	K-H	44.88	0.05	0.27	K-H	36.67	0.06	0.31
TiO <sub>2</sub>	Rut	2.04	0.05	0.07	Rut	5.29	0.05	0.14
Al <sub>2</sub> O <sub>3</sub>	K-H	10.43	0.04	0.13	K-H	14.61	0.05	0.20
Cr <sub>2</sub> O <sub>3</sub>	Chr	0.16	0.05	0.04	Chr	0.01	0.06	0.04
FeO	K-H	13.60	0.08	0.32	K-H	16.73	0.11	0.45
MnO	Rho	0.16	0.07	0.06	Rho	0.01	0.09	0.06
MgO	K-H	13.19	0.03	0.14	K-H	13.23	0.04	0.18
CaO	K-H	12.14	0.03	0.16	K-H	0.01	0.04	0.03
Na <sub>2</sub> O	K-H	1.40	0.03	0.06	K-H	0.01	0.04	0.03
K <sub>2</sub> O	K-H	0.64	0.02	0.04	K-H	9.44	0.03	0.17
(F) *	---	---	---	---	Flu	1.08	0.08	0.09
(Cl) *	---	---	---	---	Sca	0.08	0.01	0.01
Total		98.64				97.12		

\* F, Cl counted for 100 seconds on peak.

Table 2.3

Electron Microprobe Analysis  
Standards, Errors (2 standard deviations) and Detection limits (LLD)

----- Garnet -----					----- Cordierite -----			
Oxide	Std	wt%	LLD	2s.d.	Std	wt%	LLD	2s.d.
-----	---	-----	----	----	---	-----	----	----
SiO <sub>2</sub>	K-P	39.23	0.05	0.26	Dio	49.58	0.04	0.27
TiO <sub>2</sub>	Rut	0.01	0.04	0.03	Rut	0.00	0.04	0.00
Al <sub>2</sub> O <sub>3</sub>	K-P	22.72	0.04	0.20	MGA	33.73	0.03	0.21
Cr <sub>2</sub> O <sub>3</sub>	Chr	0.21	0.05	0.04	---	-----	---- <td>---- </td>	----
FeO	K-P	26.63	0.08	0.44	K-P	3.55	0.07	0.16
MnO	Rho	0.67	0.07	0.08	Rho	0.03	0.06	0.04
MgO	K-P	10.29	0.03	0.12	Dio	11.35	0.03	0.11
CaO	K-P	1.14	0.03	0.05	Dio	0.01	0.03	0.02
Na <sub>2</sub> O	K-H	0.01	0.03	0.02	---	-----	---- <td>---- </td>	----
Total		100.89				98.25		

----- Plagioclase -----				
Oxide	Std	wt%	LLD	2s.d.
-----	---	-----	----	----
SiO <sub>2</sub>	Nun	60.52	0.06	0.41
Al <sub>2</sub> O <sub>3</sub>	Nun	24.98	0.05	0.25
FeO	K-H	0.02	0.09	0.07
MgO	K-H	0.00	0.03	0.00
CaO	Lac	7.05	0.04	0.16
Na <sub>2</sub> O	Nun	7.56	0.04	0.16
K <sub>2</sub> O	Or1	0.11	0.03	0.03
Total		100.24		

Table 2.4

Average Yields and  $\delta^{18}\text{O}$  Errors

Sample (n)	Reaction Temp. in °C	Avg. Yield %	s.d.	Avg. $\delta^{18}\text{O}$ error ‰
NBS-28 (72)	550	100.0	1.76	0.07 (9.64)
Quartz (54)	550	98.4	1.91	0.06
Plagioclase (44)	550	98.0	2.77	0.09
K-feldspar (2)	550	98.8	0.57	0.07
Biotite (36)	600	99.8	2.06	0.06
Garnet (32)	625	98.1	1.78	0.09
Orthopyroxene (22)	600	97.3	2.10	0.08
Clinopyroxene (12)	600	100.3	3.60	0.05
Hornblende (20)	600	100.2	2.27	0.05
Orthoamphibole (8)	600	103.0	3.02	0.06
Cordierite (8)	550	96.1	1.58	0.06
magnetite (2)	600	101.9	1.63	0.10
Whole rocks (26)	600	-	-	0.04

(n) = number of extractions

Table 2.5

## Reaction Time and Temperature Experiments

## Quartz

A (NBS-28; 720min; 80#*)				B (Murch-Q; 550 °C; 80#)			
Temp C	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰	Time min	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰
200 <sup>a</sup>	11.10	-	-	10	10.32	-	-
250 <sup>b</sup>	10.26	~0.2	-	20	10.30	19.0	9.98
300 <sup>c</sup>	10.51	4.7	-4.29	30	10.09	94.5	9.43
350	10.55	76.6	8.71	40	10.51	99.6	10.05
400	11.27	93.1	7.34	50	11.08	99.6	10.04
450	11.25	99.9	9.63	65	10.41	103.0	10.20
500	10.30	100.2	9.63	105	10.44	100.0	9.98
550	11.94	100.1	9.65	150	10.47	100.5	9.92
550	8.13	99.4	9.65	330	11.47	98.8	10.24
a rerun at 550, 720min			9.63	450	10.35	100.9	10.21
b	"	"	9.81				
c	"	"	10.32				

## Plagioclase

A (An <sub>38</sub> ; 720min; 120#; etch)				B (An <sub>70</sub> ; 550; 200#; no etch)			
Temp C	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰	Time min	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰
100	10.36	1.7	-	10	11.37	-	-
150	10.17	2.9	6.62	20	10.94	82.4	5.67
200	9.88	6.1	2.70	30	10.57	94.7	6.17
250	10.34	13.7	1.45	40	11.66	96.1	6.56
300	10.18	28.4	2.89	120	11.73	99.5	6.79
350	11.00	51.4	1.07	720	11.18	101.0	6.80
400	10.11	92.5	6.46				
450	11.60	97.1	9.14				
550	9.96	97.4	9.33				
550	10.69	96.3	9.41				

\* grain size in mesh units

Table 2.6

## Reaction Time and Temperature Experiments

## Biotite (NBS-30)

A (780min; 60#*)				B (600 °C; 60#)			
Temp C	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰	Time min	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰
100	9.97	-	-	15	10.01	3.5	-
200	10.29	-	-	30	10.11	93.5	4.63
300	9.59	65.9	3.29	45	10.04	98.0	4.87
350	9.85	48.7	2.71	60	10.30	98.0	4.98
400	10.27	94.6	4.40	90	10.14	99.5	4.99
450	9.85	96.7	4.73	120	9.90	96.8	5.03
500	10.00	101.6	4.86	150	9.97	98.7	5.17
550	9.94	100.3	4.84	240	10.21	99.5	5.11
550	9.97	98.2	-				
600	10.06	100.3	5.11				

Garnet (Alm<sub>60</sub> PY<sub>35</sub> Sp<sub>1.5</sub> Gr<sub>2.5</sub>)

A (720min; 300#)				B (625 °C; 300#)			
Temp C	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰	Time min	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰
250	9.94	~1.0	-	15	9.71	5.5	(61.3)
350	9.78	12.0	13.21	30	9.42	33.2	-
400	9.62	12.4	12.43	40	10.01	27.9	-
450	9.97	23.3	-	60	9.66	39.5	7.77
500	9.89	44.1	7.85	90	9.74	58.8	8.14
550	9.71	81.0	7.72	150	9.80	84.4	7.69
600	9.78	99.7	8.04	270	9.82	91.6	8.05
625	9.61	98.8	8.22	480	9.84	100.4	8.42
650	10.00	101.3	8.08				

\* grain size in mesh units

Table 2.7

## Reaction Time and Temperature Experiments

Pyroxene (Di<sub>82</sub> Hd<sub>18</sub>)

A (780min; 200#*)				B (550 °C; 200#)			
Temp C	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰	Time min	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰
150	10.13	-	-	15	10.19	33.7	4.91
250	10.18	~1.0	-	30	10.03	92.9	5.58
350	10.21	66.7	3.28	45	10.06	96.2	6.22
400	10.03	93.5	5.69	90	9.97	97.1	6.16
450	10.17	100.8	5.87	120	10.13	98.0	6.41
500	10.13	99.9	5.97	180	10.23	99.6	6.24
550	10.73	99.7	5.97				
600	10.16	100.9	6.16				
625	10.20	99.2	6.31				

Olivine (Fo<sub>90</sub> Fa<sub>10</sub>)

A (870min; 300#)				B (650 °C; 300#)			
Temp C	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰	Time min	Weight mg	Yield %	$\delta^{18}\text{O}$ ‰
250	9.83	~1.2	-	240	9.88	13.9	2.12
350	9.91	9.3	-				
450	9.66	13.4	2.15				
500	9.96	14.0	-				
550	10.21	14.0	-				
600	9.73	23.6	4.87				
625	10.40	34.9	-				
650	9.82	28.4	6.06				

\* grain size in mesh units

Figure 2.2a: Yield versus temperature plot summarizing the reaction-temperature experiments.

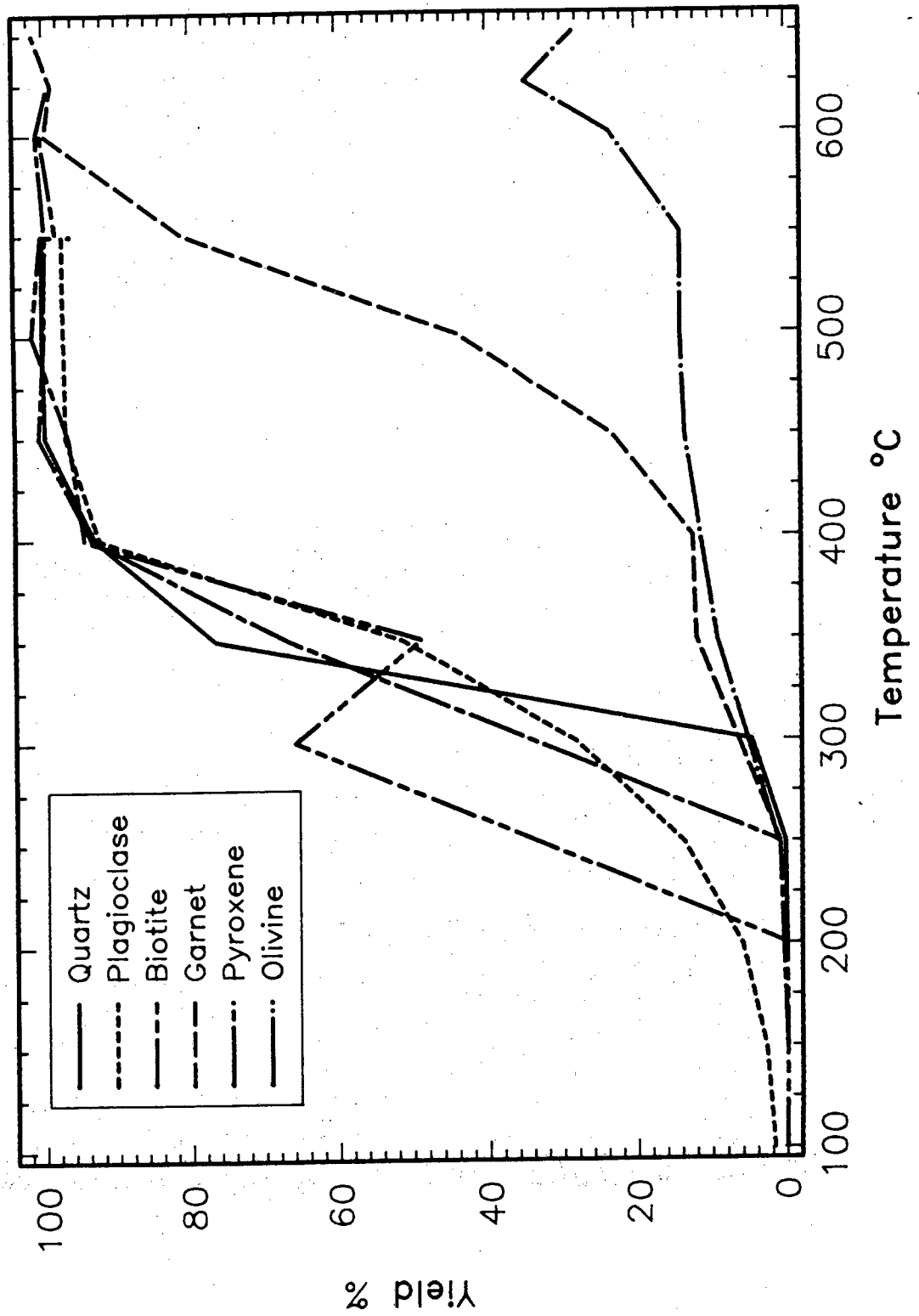
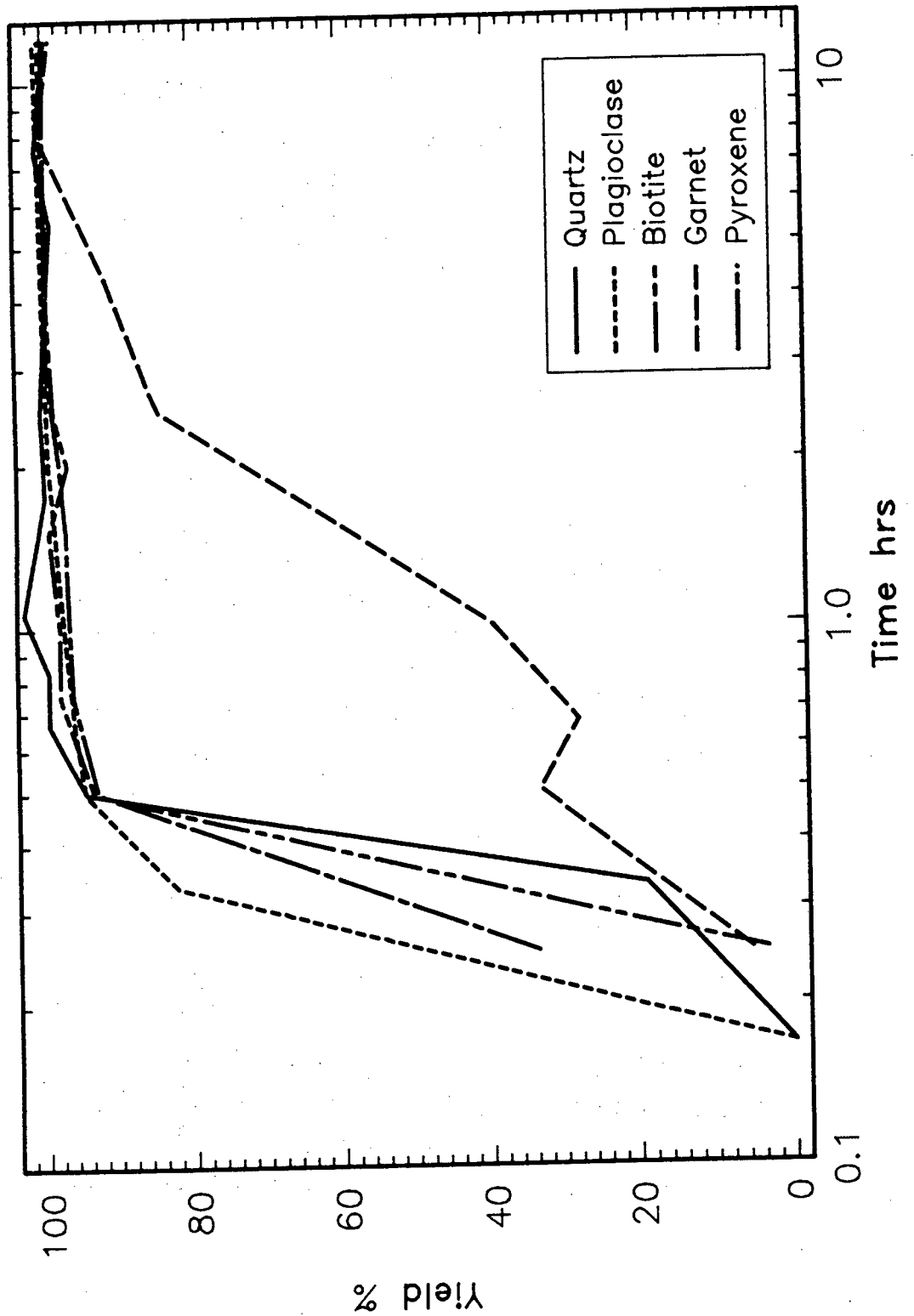


Figure 2.2b: Yield versus time plot summarizing the reaction-time experiments.



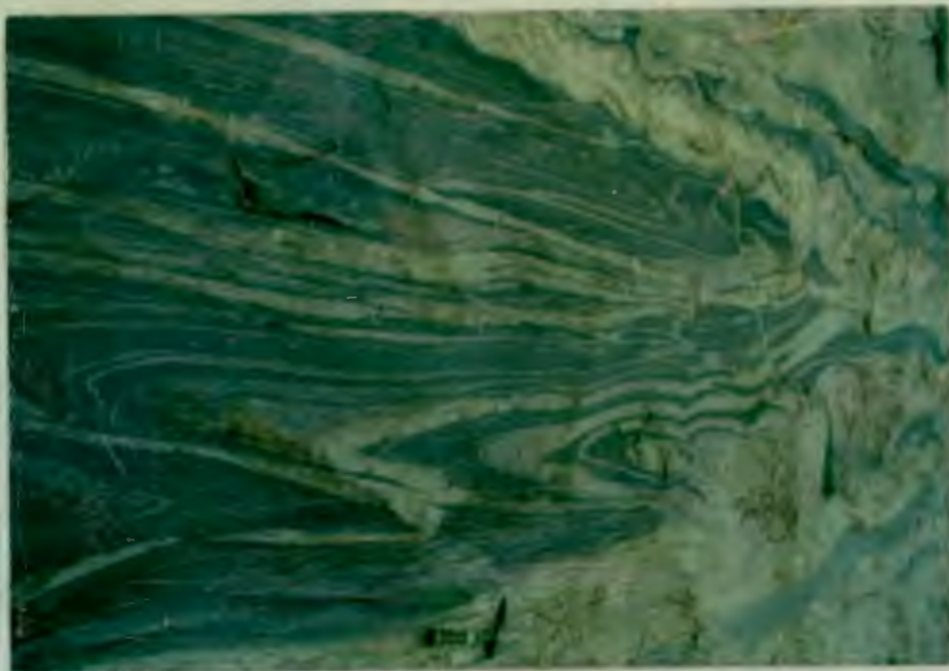


Figure 3.1: Migmatitic Baviaanskloof gneiss on the farm Goudplaats 340 LT.



Figure 3.2: Contact relationship between grey gneiss and amphibolite lens in the Hout River transition.

Table 3.1

Mineralogy and whole rock oxygen isotope values (‰) of ultramafic rocks. Modal proportions are estimated from thin section examination, mineral separates, and bulk rock composition.

Abbreviations: opx=orthopyroxene, cpx=clinopyroxene, olv=olivine, ser=serpentine, chl=chlorite, trm=tremolite, ant=anthophyllite, spn=spinel, car=carbonate, opa=opagues, t=trace (<1%).

Sample	opx	cpx	olv	ser	chl	trm	ant	spn	opa	car	$\delta^{18}O$
U10A	70	-	-	-	7	18	2	3	-	-	8.87
U7A	60	t	8	5	5	16	-	4	-	t	4.20
U6B	-	-	t	81	13	-	-	-	5	1	3.89
U10B	4	t	4	25	25	34	-	-	8	-	7.07
U17B	52	t	32	-	10	4	-	1	1	t	5.90
U31C	30	t	20	38	4	4	-	1	4	t	3.69
U40C	44	t	25	6	12	8	-	3	2	t	4.91
U44C	31	t	12	6	4	35	-	10	2	-	6.15

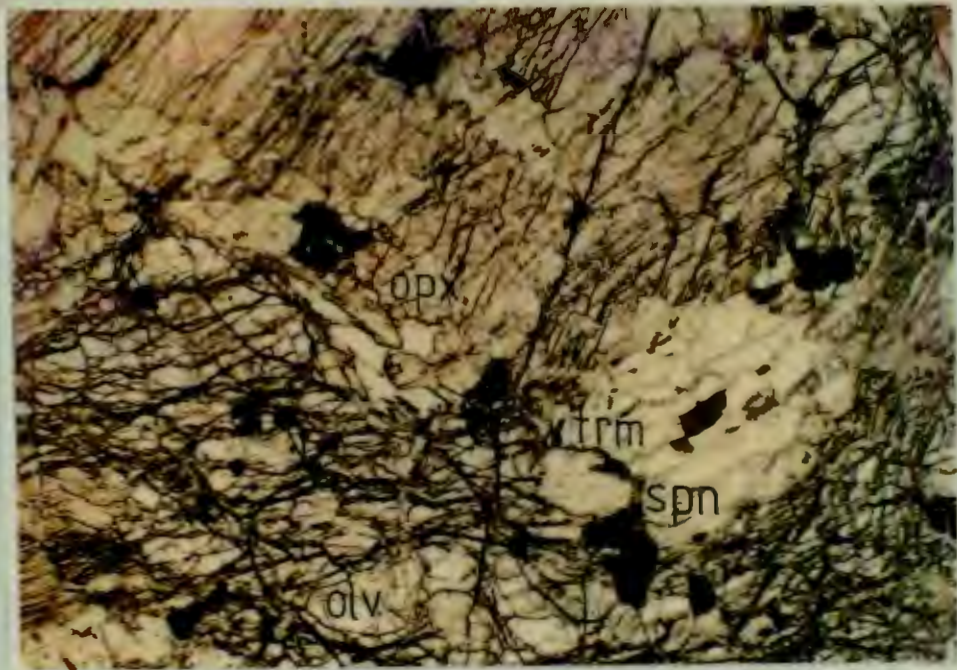


Figure 3.3: Coexistence of forsterite (olv), enstatite (opx), tremolite (trm) and spinel (spn) in sample U44C.  
Horizontal field of view: 9mm; nicols parallel.

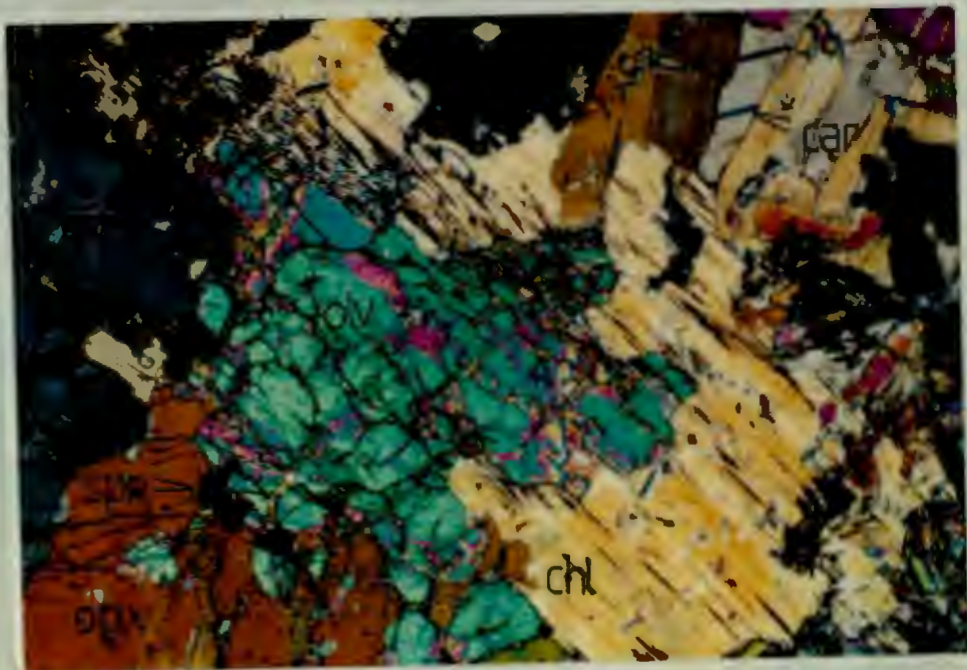


Figure 3.4: Chlorite (chl) breakdown to enstatite (opx), olivine (olv) and spinel (spn). Also note the presence of carbonate (car) and tremolite (trm). Sample U17B.  
Horizontal field of view: 4.5mm; nicols crossed.

Table 3.2

Mineralogy and whole rock oxygen isotope values ( $^{\circ}/_{\infty}$ ) of mafic rocks. Modal proportions are estimated from thin section examination, mineral separates, and bulk rock composition.

Abbreviations: opx=orthopyroxene, cpx=clinopyroxene, amp=amphibole, plg=plagioclase, qtz=quartz, sct=sericite, chl=chlorite, sph=sphene. An=anorthite contents, opa=opagues, t=trace (<1%).

Sample	opx	cpx	amp	plg(An)	qtz	sct	opa	chl	sph	$\delta^{18}O$
M1A	-	-	60	15 (43)	5	20	-	-	-	6.38
M2A	-	5	41	49 (42)	t	5	t	-	-	8.34
M3A	-	8	44	48 (38)	-	-	-	-	-	8.39
M5A	-	3	55	30 (38)	-	12	-	-	-	6.41
M8A	-	28	32	38 (47)	-	-	3	-	-	6.43
M11B	-	-	70	10 (?)	10	-	-	10	-	6.33
M11C	-	28	29	40 (46)	-	-	3	-	-	7.03
M27C	22	27	10	40 (59)	-	-	6	-	-	7.82
M37C	-	15	64	15 (?)	6	-	t	-	-	8.16
M41C	-	-	65	35 (30)	-	-	-	-	-	6.63
M52C	-	10	37	18 (?)	25	7	t	-	1	8.56

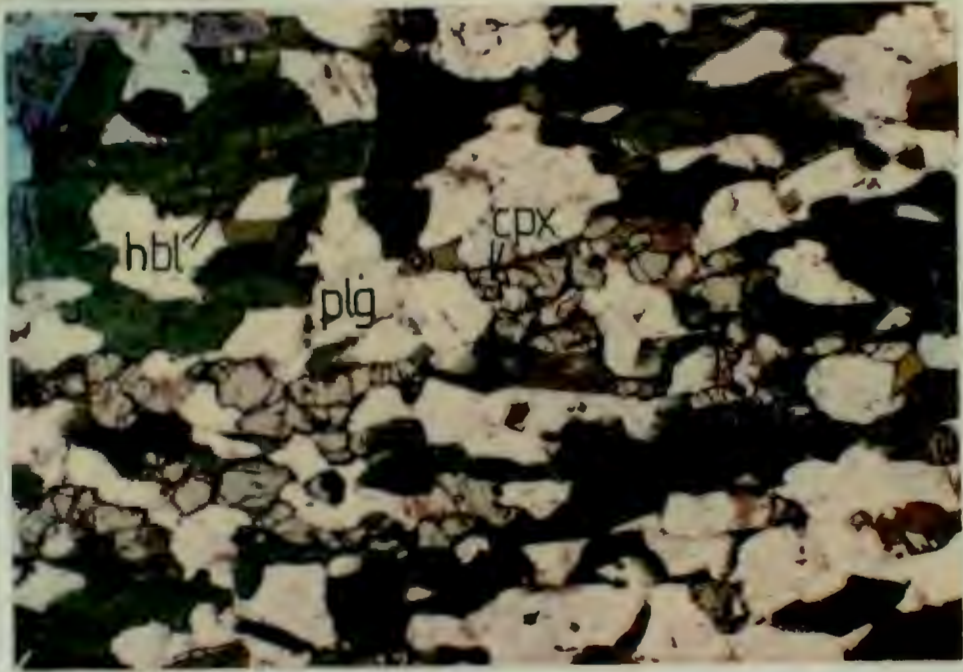


Figure 3.5: Coexistence of hornblende (hbl), andesine (plg) and clinopyroxene (cpx) in an amphibolite sampled from the Hout River transition (M3A). Horizontal field of view: 9mm; nicols parallel.

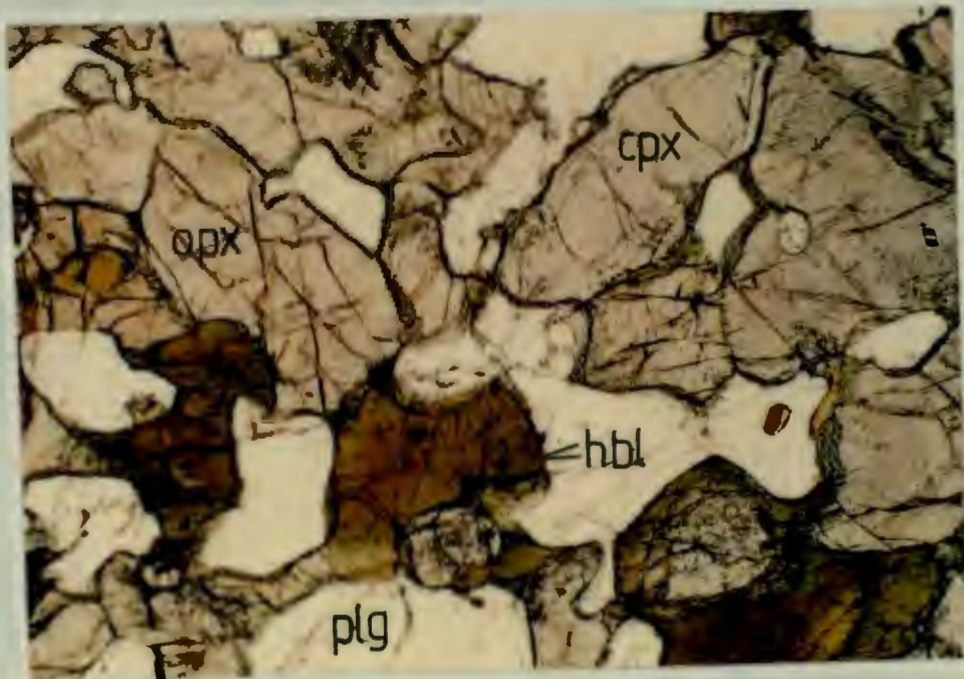


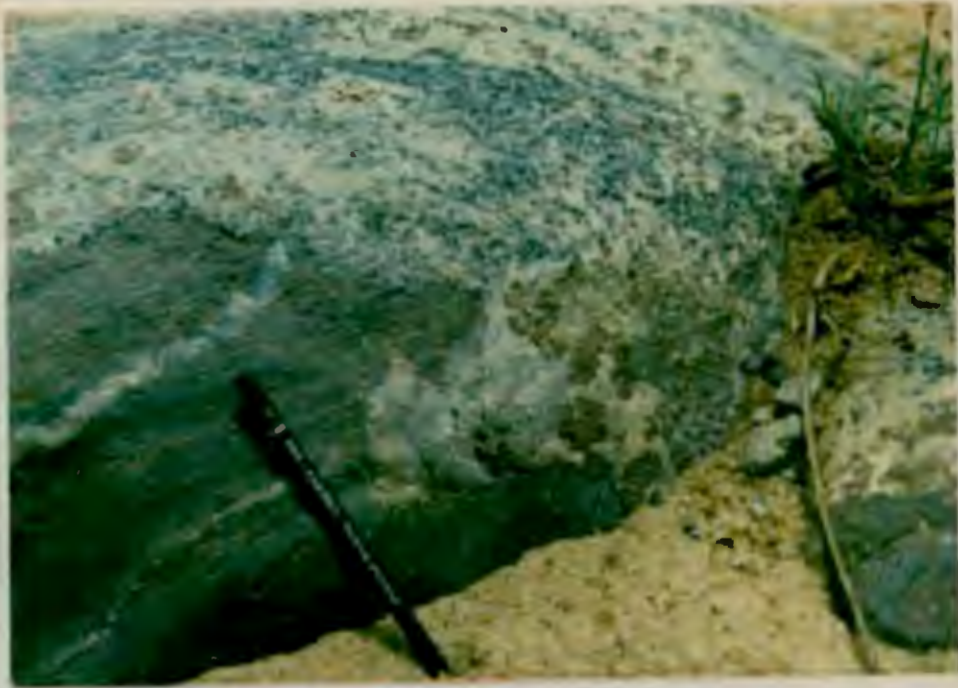
Figure 3.6: Typical texture of the orthopyroxene (opx), diopside (cpx), hornblende (hbl), labradorite (plg) mafic rock M27C.. Horizontal field of view: 4.5mm; nicols parallel.

Table 3.3

Mineralogy and whole rock oxygen isotope values ( $^{\circ}/_{\infty}$ ) of pelitic rocks. Modal proportions are estimated from thin section examination, mineral separates, and bulk rock composition.

Abbreviations: cor=cordierite, gar=garnet, opx=orthopyroxene, amp=amphibole, bio=biotite, qtz=quartz, plg=plagioclase, An=anorthite contents, ksp=K-feldspar, alu= $Al_2SiO_5$  polymorphs, spn=spinel, opa=opagues, grp=graphite, t=trace (<1%), X=present but exact amount not determinable.

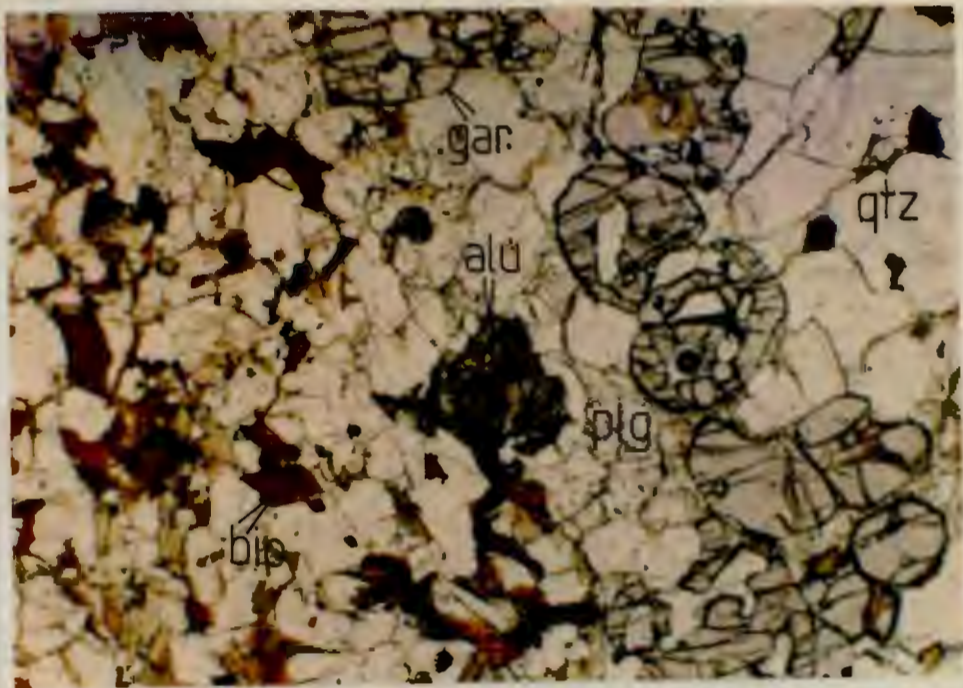
Sample	cor	gar	opx	amp	bio	qtz	plg(An)	ksp	alu	spn	ore	grp	$\delta^{18}O$
Group 1:													
P17C	-	8	-	-	19	40	33 (24)	-	t	-	t	-	10.05
P41C	-	11	-	-	16	38	35 (21)	-	-	-	t	-	9.34
Group 2:													
P5C	-	22	-	20	-	42	15 (?)	-	-	-	1	t	10.48
P6C	-	45	-	20	-	30	3 (?)	-	-	-	2	-	9.80
P32C	t	X	-	X	X	X	X (28)	-	X	-	X	-	8.09
P34C	2	10	-	10	26	25	25 (27)	t	2	-	t	t	11.28
P38C	-	3	-	10	15	56	14 (30)	-	2	-	t	-	9.34
P42C	-	22	-	12	5	40	20 (41)	-	-	-	1	t	9.15
P45C	-	3	-	20	14	30	32 (26)	-	-	-	1	-	10.00
P50C	t	10	-	40	15	13	20 (37)	-	t	-	1	1	9.41
P7D	-	20	-	17	30	20	13 (30)	-	t	-	t	-	8.52
Group 3:													
P25C	-	12	16	-	8	34	30 (31)	-	t	-	t	-	9.05
Group 4:													
P14C	15	7	15	-	18	20	20 (32)	2	t	t	3	-	9.07
P19C	16	5	26	-	13	15	15 (34)	4	6	t	t	-	8.43
P21C	14	10	6	-	8	30	25 (27)	5	2	-	t	-	9.94
P29C	4	10	19	-	18	16	16 (?)	2	15	t	t	-	8.15
P1D	7	6	12	-	12	28	32 (29)	-	2	-	1	-	9.97
Group 5:													
P8C	12	t	8	-	12	35	30 (28)	t	t	t	t	-	11.43
P3D	22	-	20	-	15	16	26 (23)	-	1	-	-	-	9.26
P5D	12	-	18	-	10	34	23 (32)	-	3	-	t	t	11.14



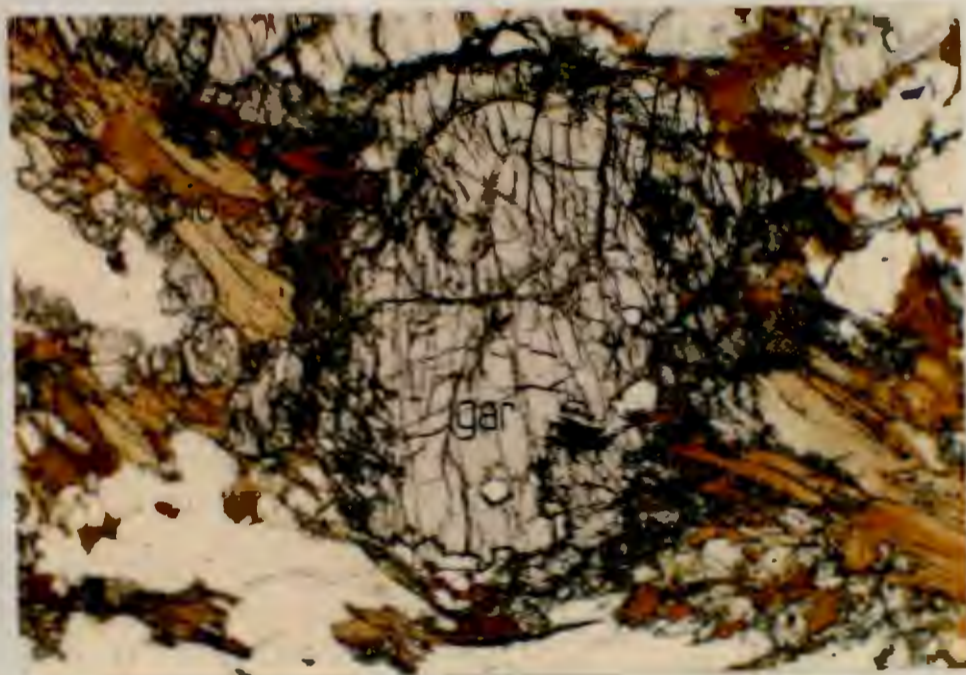
**Figure 3.7: Pelite with concordant and discordant felsic segregations containing large garnets (from Sand River traverse).**



**Figure 3.8: Pelitic rock with large cordierite grains but no leucocratic segregations; -20 meters from the rocks shown in Fig. 3.7 above. (Sand River traverse).**



**Figure 3.9:** Skeletal growth of garnet (gar) after biotite (bio). In this sample (P17C) the garnet is confined to the coarse grained quartz (qtz) and plagioclase (plg) zones, suggesting the involvement of partial melting processes. Also note the fine needles of aluminosilicate (?; alu) in biotites close to the segregation containing garnet.  
Horizontal field of view: 9mm; nicols parallel.



**Figure 3.10:** Garnet (gar) - biotite (bio) disequilibrium in the orthoamphibole gneisses (P7D). Also note the syn- to post-tectonic growth of the garnet.  
Horizontal field of view: 9mm; nicols parallel.

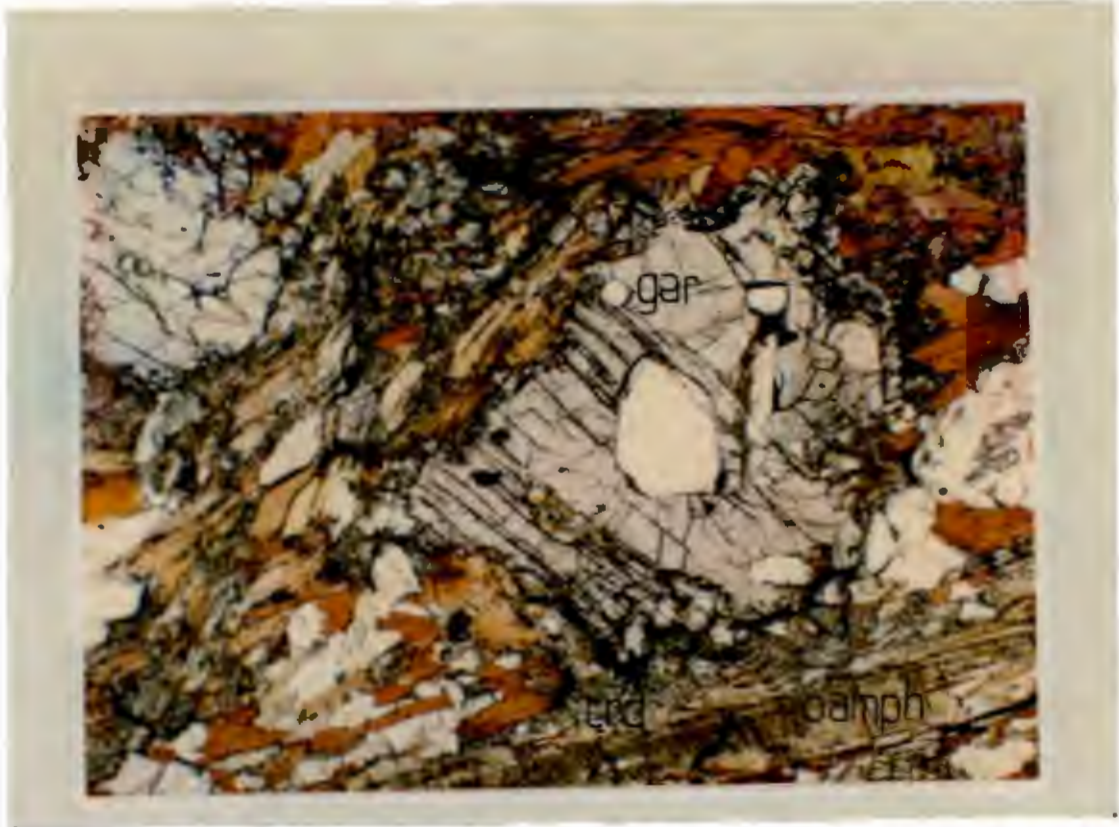


Figure 3.11: Garnet (gar) - gedrite (oamph) disequilibrium in the orthoamphibole gneisses (P50C). Also note the growth of cordierite adjacent to the garnet.  
Horizontal field of view: 9mm; nicols parallel.



Figure 3.12: Stable coexistence of the ferromagnesian phases of garnet (gar), orthopyroxene (opx) and biotite (bio) in the garnet granulite (P25C). Also note the presence of biotite and quartz inclusions in garnet and orthopyroxene, suggesting growth of garnet and orthopyroxene after biotite + quartz + plagioclase assemblages.  
Horizontal field of view: 9mm; nicols parallel.

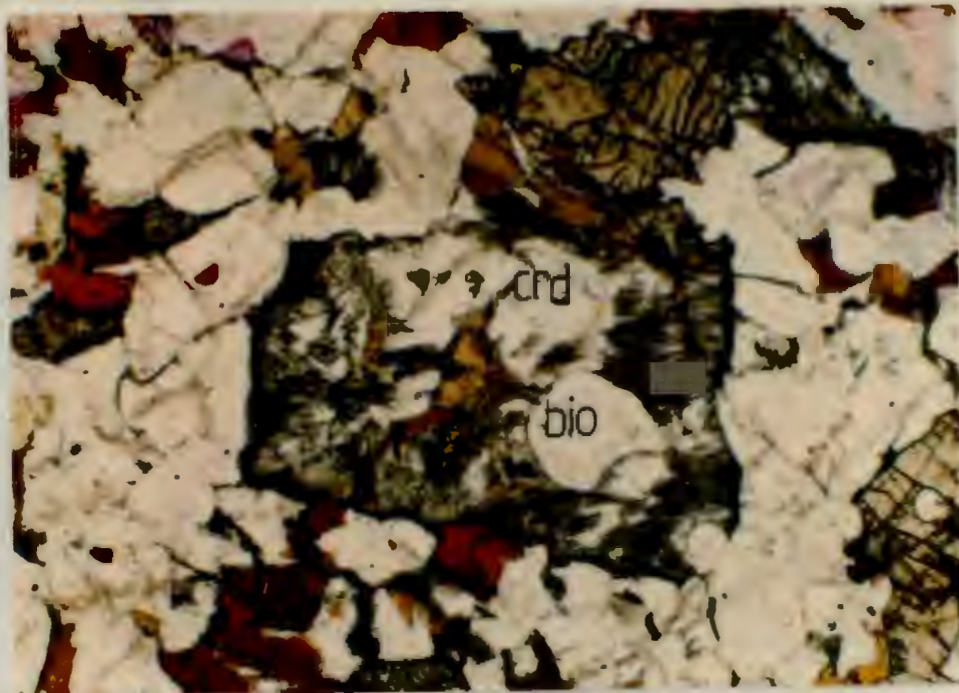


Figure 3.13: Cordierite (crd) replacing biotite (bio) laths, suggesting growth of cordierite after biotite. Biotite is intergrown with aluminosilicate needles; similarly these needles also tend to rim the cordierite crystals. Sample P1D. Horizontal field of view: 9mm; nicols parallel.

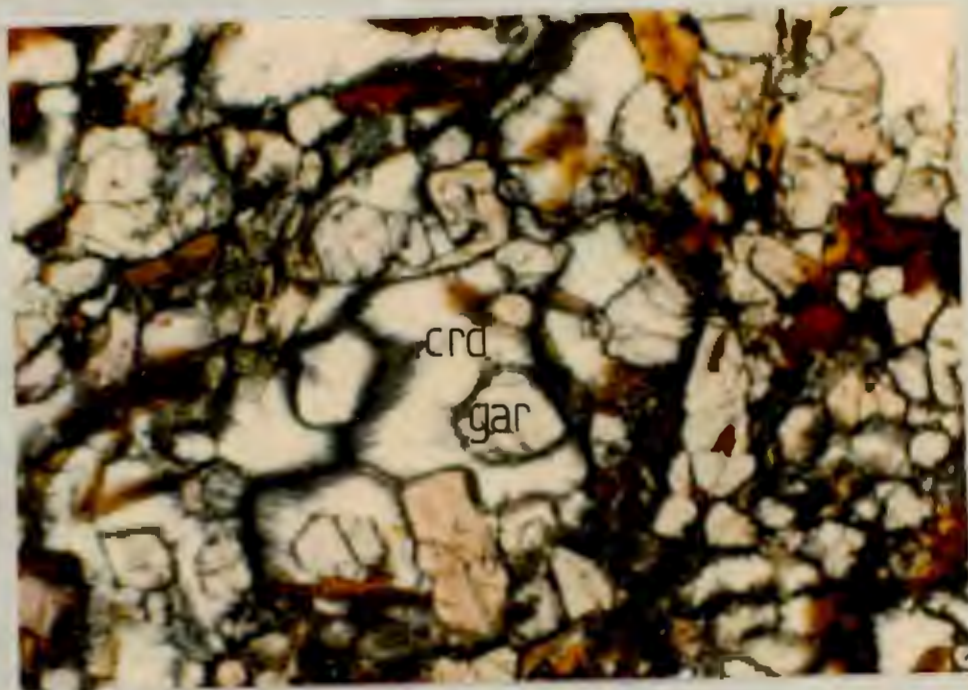


Figure 3.15: Small garnets (gar) occurring as inclusions within the cordierite (crd) crystals. In other parts of the same section, spinel occurs as inclusion in the cordierite indicating localized chemical gradients (see text). Sample P19C. Horizontal field of view: 4.5mm; nicols parallel.

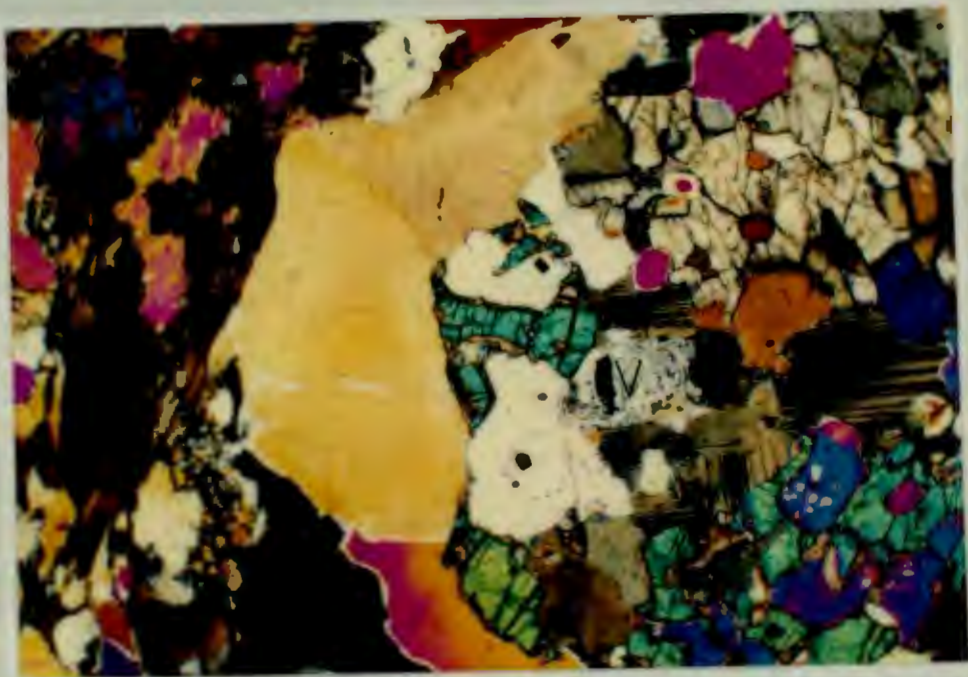
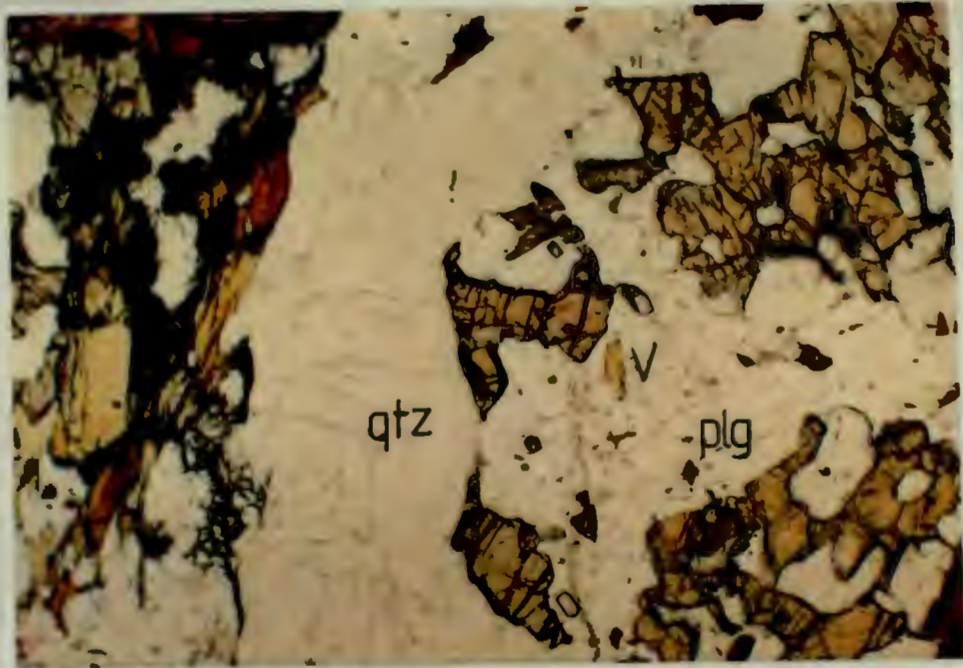


Figure 3.14: Vermicular (V) intergrowth of plagioclase (plg), K-feldspar and quartz (qtz) in sample Pl4C. The presence of large quartz plagioclase grains is taken to suggest the involvement of partial melting processes in the petrogenesis of the samples. Horizontal field of view: 9mm; nicols top parallel, bottom crossed.

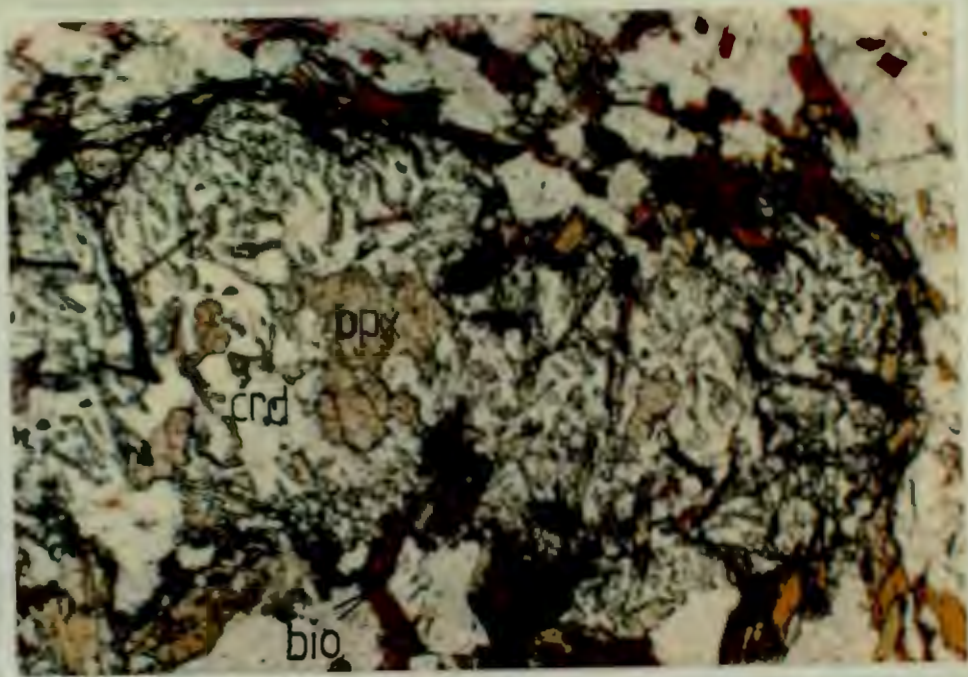


Figure 3.16: Cordierite (crd) - orthopyroxene (opx) intergrowths after garnet. Intergrowth is rimmed by somewhat coarser orthopyroxene and biotite (bio). Small biotite laths are also present within the cordierite - orthopyroxene intergrowths. Sample P8C. Horizontal field of view: 9mm; nicols parallel.

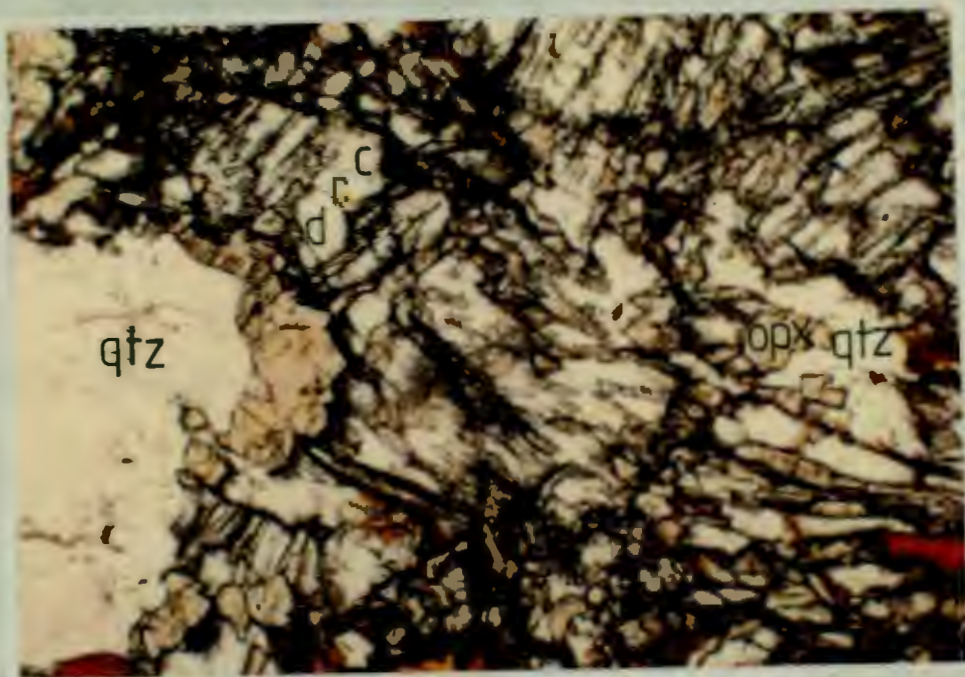
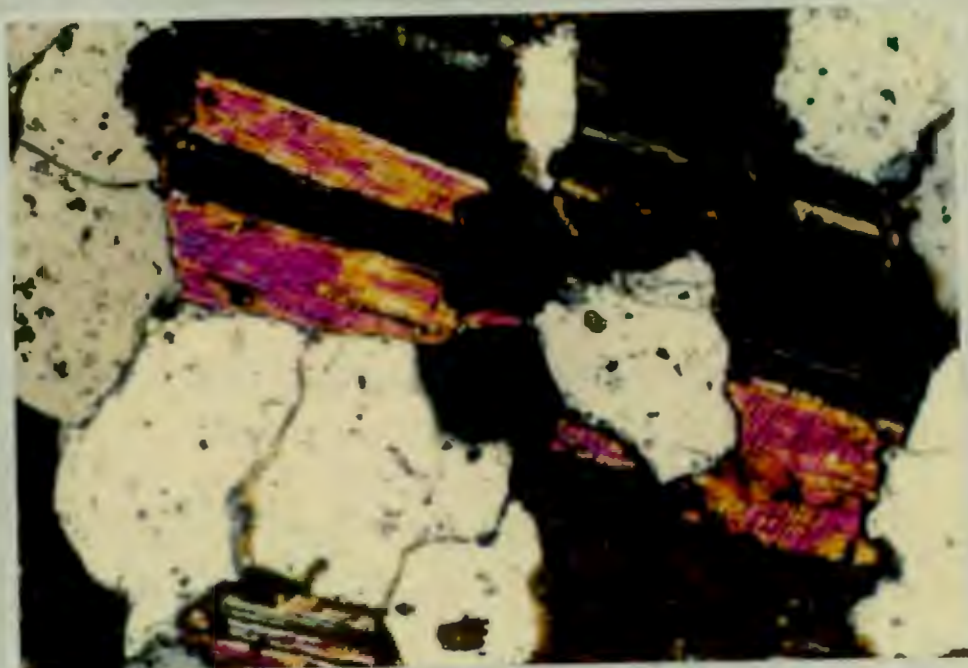
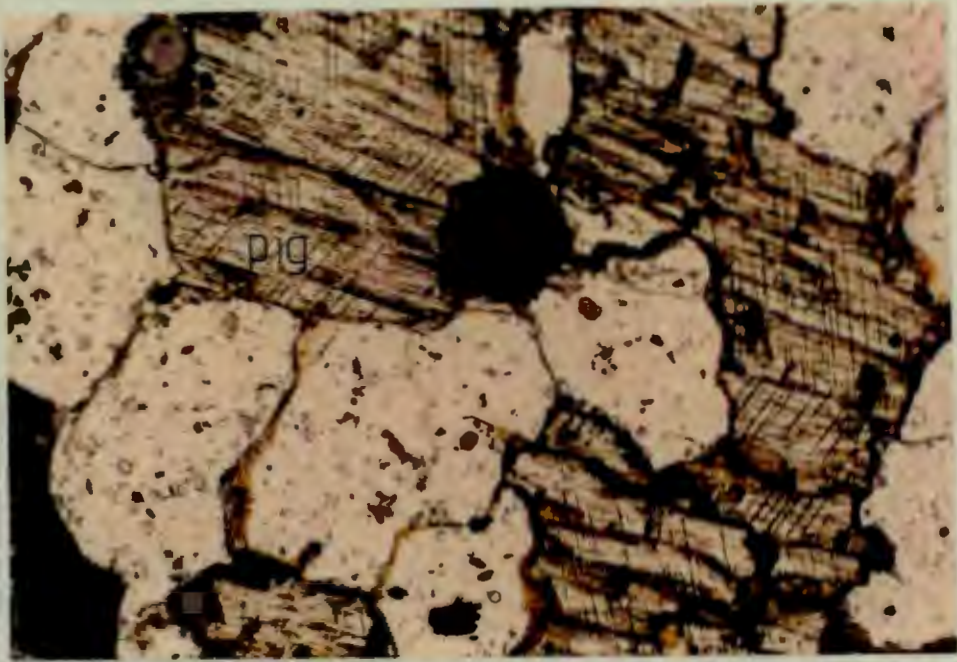


Figure 3.17: Cordierite (crd) - orthopyroxene (opx) symplectite illustrating both the occurrence quartz (qtz) within the symplectite and coarse-grained orthopyroxene adjacent to coarse-grained quartz rimming the symplectite. Sample P5D. Horizontal field of view: 9mm; nicols parallel.



**Figure 3.18:** Uninvited pigeonite (pig) from the banded iron formation B4A. Note the separate extinction of twin-crystals under crossed nicols. Horizontal field of view: 1.8mm; nicols top parallel, bottom crossed.

Figure 3.19: Pressure and temperature conditions as estimated from a comparison of texturally interpreted mineral reactions in the SMZ rocks to experimentally calibrated mineral reactions (shaded area). Sources: A - Yoder and Fawcett, 1966; B - Evans, 1977; C - Wells, 1979; D - Spear, 1981; E,F - Clemens and Wall, 1981; G - Martignole and Sisi, 1981; H - Luth et al., 1964. Diamond enclosed in the square indicates peak P-T conditions as predicted from the cation geothermometry (Chapter 6).

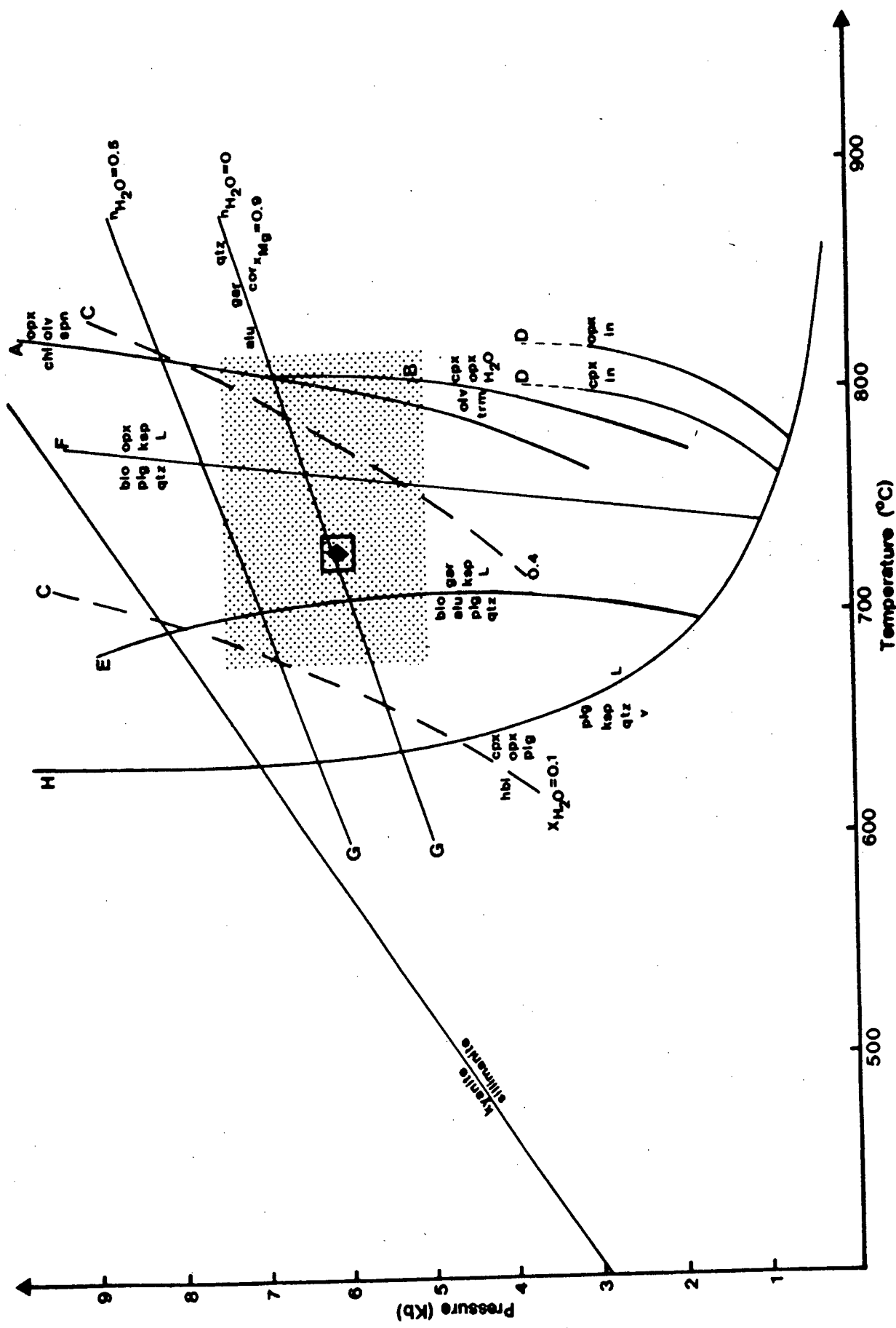


Table 4.1

Major and trace element composition of the ultramafic rocks.  
 Majors in weight % oxide and traces in ppm.

	U10A	U6B	U10B	U17B	U31C	U40C	U44C
SiO <sub>2</sub>	50.30	40.60	44.89	45.62	40.64	46.02	44.89
TiO <sub>2</sub>	.15	.14	.22	.11	.24	.14	.04
Al <sub>2</sub> O <sub>3</sub>	7.59	2.54	4.28	2.71	2.88	4.27	6.98
FeO	7.51	6.56	10.40	7.50	7.98	7.91	6.31
MnO	.13	.11	.15	.12	.12	.14	.14
MgO	30.80	36.83	26.74	39.74	33.73	33.75	32.02
CaO	1.97	1.40	7.23	1.16	2.87	2.85	4.21
Na <sub>2</sub> O	.32	.02	.16	.08	.10	.06	.25
K <sub>2</sub> O	.01	.00	.02	.01	.01	.00	.07
P <sub>2</sub> O <sub>5</sub>	.01	.01	.01	.01	.02	.01	.01
H <sub>2</sub> O-	.03	.78	.10	.09	.45	.22	.23
LOI	1.24	11.95	6.13	3.61	10.98	5.04	5.67
Total	100.05	100.91	100.32	100.74	100.02	100.40	100.78
Ba	43	11	4.8	11	42	4.5	2.3
Sc	33	14	23	15	13	19	26
Co	115	125	115	114	107	103	83
Cr	4265	2224	2475	4195	1822	2593	2930
V	115	61	83	51	62	91	83
Zn	53	16	61	45	53	47	36
Cu	4.5	3.3	27	2.0	13	19	4.4
Ni	1786	2898	1882	1794	1956	1723	1367
Nb	1.0	.9	1.1	1.0	1.0	1.0	1.0
Zr	7.0	4.8	11	6.4	12	6.7	1.8
Y	6.8	3.8	5.9	3.7	4.5	3.1	3.3
Sr	24	5.9	36	11	153	90	17
Rb	1.2	1.1	1.3	1.1	3.3	1.2	1.3
Th	2.7	2.4	3.0	2.6	2.7	2.7	2.6
Pb	3.1	2.8	3.4	3.0	5.5	4.9	3.0

\*\*\* All Fe calculated as FeO \*\*\*

Table 4.2

Comparison of major and selected trace element data between the high grade ultramafic rocks of this study (excluding U6B, U10B) and other Archaean komatiitic and intrusive ultramafic rocks. All data are compared on a recalculated volatile free basis. Oxides in weight percent, elements in ppm.

Belingwe - komatiitic rocks, Nisbet et al., (1977);  
 Barberton - komatiitic rocks, Smith and Erlank, (1982);  
 Intrusives - harzburgitic rocks, Viljoen and Viljoen, (1970)  
 and Anhaeusser (1979);  
 (n) = number of samples in the given range.

	SMZ (5)	Belingwe (23)	Barberton		Intrusives (4)
			Aphyric (11)	Phyric (11)	
SiO <sub>2</sub>	47.89	46.81-51.83	44.89-49.51	44.23-47.52	42.37-47.79
TiO <sub>2</sub>	0.14	0.22- 0.42	0.27- 0.41	0.21- 0.47	0.10- 0.21
Al <sub>2</sub> O <sub>3</sub>	5.11	5.08- 8.44	3.11- 4.92	2.30- 4.51	2.26- 3.78
FeO	7.86	10.62-12.10	10.69-13.61	8.52-12.14	8.86- 9.74
MnO	0.13	0.14- 0.20	0.17- 0.22	0.13- 0.19	0.11- 0.17
MgO	35.88	20.45-31.81	24.09-33.01	30.64-38.20	37.14-43.06
CaO	2.77	5.05- 9.71	3.76-10.07	3.14- 5.74	1.26- 1.84
Na <sub>2</sub> O	0.17	0.02- 0.64	0.01- 0.63	0.02- 0.39	0.10- 0.16
K <sub>2</sub> O	0.02	0.01- 0.68	0.01- 0.10	0.02- 0.26	0.03- 0.10
P <sub>2</sub> O <sub>5</sub>	0.01	0.01- 0.05	0.02- 0.04	0.01- 0.04	~ 0.03
Cr	3300	2478-3529	2258-4584	1437-4858	2383- 7530
Ni	1821	851-1627	1145-2095	1759-2704	~ 2315
Co	110	89- 135	109- 159	117- 151	-----

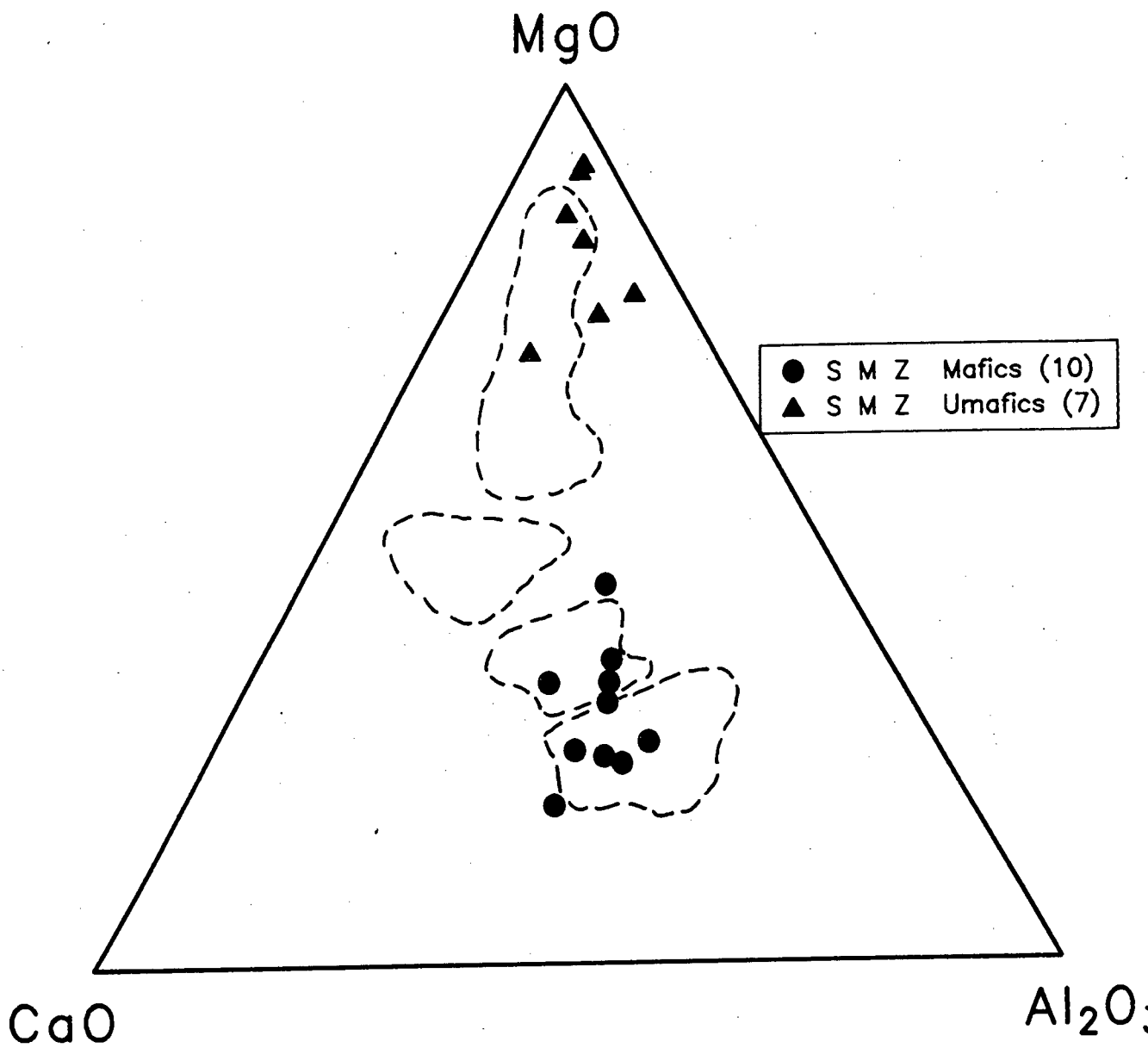


Figure 4.1: MgO - CaO - Al<sub>2</sub>O<sub>3</sub> diagram of ultramafic and mafic rocks. Fields outlined by dashed lines refer to compositional ranges of other South African ultramafic and mafic rocks after Viljoen et al., (1982).

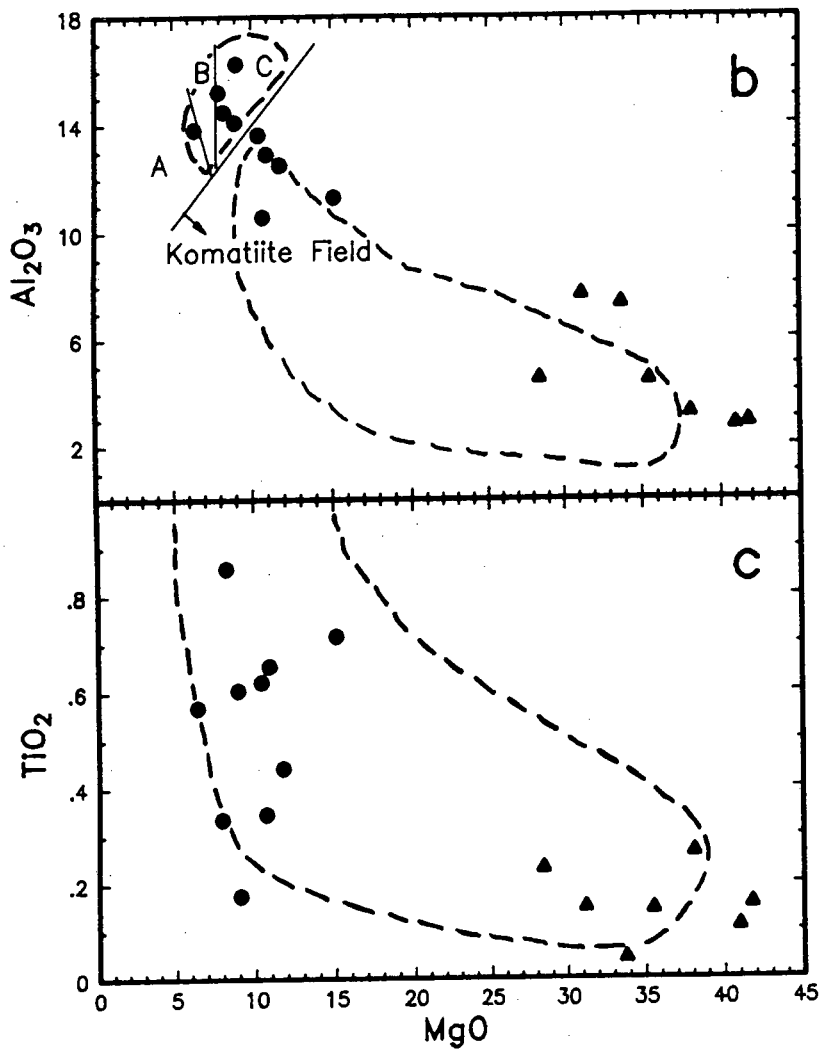
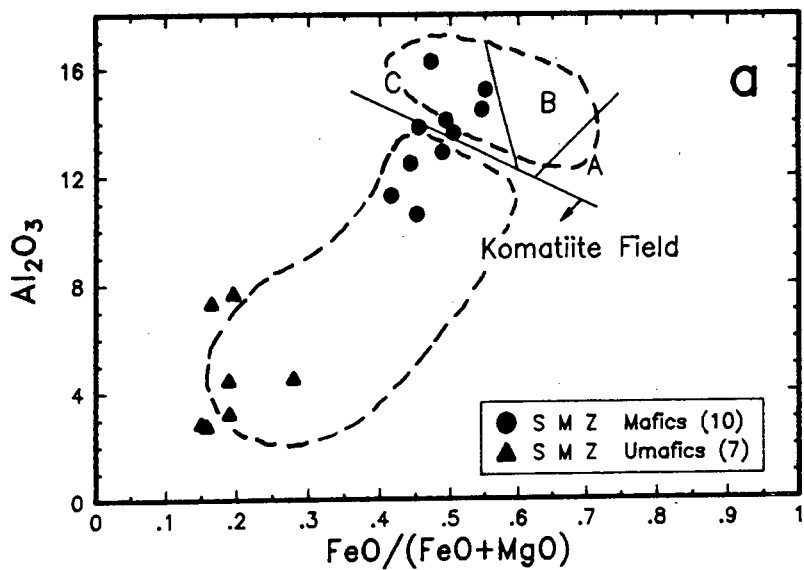


Figure 4.2a:  $\text{Al}_2\text{O}_3$  -  $\text{FeO}/(\text{FeO} + \text{MgO})$  diagram of ultramafic and mafic rocks. All Fe as FeO. Fields outlined by dashed lines refer to compositional ranges of other ultramafic and mafic volcanic rocks from South Africa (Viljoen et al., 1982). A - Fe-tholeiite field, B - normal tholeiite field, C - Mg-tholeiite field.

b:  $\text{Al}_2\text{O}_3$  - MgO diagram of ultramafic and mafic members, fields as in Figure 4.2a above.

c:  $\text{TiO}_2$  - MgO diagram of ultramafic and mafic members, fields as in Figure 4.2a above.

Table 4.3

Major and trace element composition of the mafic rocks.  
 Majors in weight % oxide and traces in ppm.

	M3A	M5A	M8A	M11C	M27C	M37C	M41C	M52C	M3C	M11B
SiO <sub>2</sub>	50.97	51.08	49.86	50.64	50.41	53.65	50.26	55.56	49.87	53.17
TiO <sub>2</sub>	.33	.17	.60	.85	.61	.34	.64	.55	.70	.43
Al <sub>2</sub> O <sub>3</sub>	15.02	16.05	13.84	14.39	13.35	10.37	12.62	13.35	10.99	12.23
FeO	9.59	8.01	8.59	9.86	10.44	8.67	10.22	5.14	10.50	9.18
MnO	.18	.18	.16	.19	.17	.24	.18	.24	.20	.17
MgO	7.83	8.96	8.81	8.20	10.24	10.50	10.69	6.17	14.75	11.50
CaO	11.43	10.40	13.58	12.12	10.83	11.89	10.04	14.64	8.45	9.45
Na <sub>2</sub> O	2.91	2.88	2.37	2.91	2.01	1.69	2.84	.49	.66	1.57
K <sub>2</sub> O	.46	.98	.44	.21	.05	.73	.36	.31	1.08	.20
P <sub>2</sub> O <sub>5</sub>	.05	.01	.09	.06	.04	.03	.06	.16	.23	.03
H <sub>2</sub> O-	.04	.09	.05	.04	.08	.17	.11	.10	.14	.06
LOI	1.51	1.86	1.98	1.14	2.23	2.07	2.15	3.48	2.88	2.74
Total	100.32	100.66	100.35	100.62	100.46	100.33	100.18	100.17	100.42	100.72
Ba	87	332	64	53	16	78	85	49	350	35
Sc	46	41	37	37	46	35	41	22	35	42
Co	53	50	49	63	61	58	58	47	71	60
Cr	132	465	376	575	663	1111	761	1324	1584	877
V	189	145	217	276	242	165	234	114	178	199
Zn	63	69	61	95	69	61	80	61	105	65
Cu	2.4	3.0	49	33	15	4.5	12	161	2.5	53
Ni	104	209	192	192	182	291	147	402	432	203
Nb	2.6	1.3	4.4	2.0	1.2	2.1	1.2	4.3	4.4	1.1
Zr	30	8.5	40	33	23	28	32	93	83	21
Y	20	7.3	18	21	18	13	15	29	28	11
Sr	103	225	91	132	112	132	267	150	91	200
Rb	5.8	32	3.3	1.4	1.6	24	6.5	9.5	45	5.1
Th	3.1	3.0	3.1	3.2	3.2	3.1	3.1	3.8	3.9	3.0
Pb	3.6	5.4	8.1	3.7	3.7	7.7	13	19	4.0	3.5

\*\*\* All Fe calculated as FeO \*\*\*

Table 4.4

Comparison of major and selected trace element data between the high grade mafic rocks of this study (excluding M11B) and other Archaean mafic rocks. All data are compared on a recalculated volatile free basis. Oxides in weight percent, elements in ppm.

Krom. Thol. - Kromberg tholeiites, Vennemann, (1985);  
 Belingwe - Komatiitic basalt series, Nisbet et al., (1977);  
 B. Komat. - Basaltic komatiites, Viljoen and Viljoen, (1969);  
 Stolzburg - Gabbro's from a layered complex, Anhaeusser, (1979);  
 India - Mafic gabbro, Srikantappa et al., (1984).  
 (n) = number of samples in the given range.

	SMZ (9) Range	Ave.	Krom.Thol. (29)	Belingwe (23)	B. Komat. (10)
SiO <sub>2</sub>	50.71-57.52	(52.34)	49.60-62.31	48.79-58.66	48.68-60.53
TiO <sub>2</sub>	0.18- 0.86	( 0.54)	1.01- 3.21	0.50- 1.54	0.65- 1.52
Al <sub>2</sub> O <sub>3</sub>	10.57-16.26	(13.58)	12.59-16.41	6.63-15.72	8.12-11.70
FeO	5.32-10.78	( 9.17)	7.54-15.87	3.42-11.00	6.94-16.43
MnO	0.15- 0.23	( 0.19)	0.14- 0.25	0.08- 0.29	0.15- 0.29
MgO	6.39-15.15	( 9.76)	2.83- 9.77	7.92-17.80	9.49-11.74
CaO	8.68-15.16	(11.71)	2.83-12.48	6.55-12.76	8.90-14.19
Na <sub>2</sub> O	0.50- 2.95	( 2.12)	0.09- 4.81	0.07- 3.54	1.01- 3.40
K <sub>2</sub> O	0.05- 1.11	( 0.52)	0.05- 4.94	0.01- 0.78	0.06- 0.94
P <sub>2</sub> O <sub>5</sub>	0.01- 0.24	( 0.08)	0.07- 0.26	0.03- 0.21	0.04- 0.11
Cr	134- 1625	( 749)	10- 369	706- 1528	-----
Ni	105- 444	( 244)	28- 216	222- 567	-----
Co	49- 73	( 58)	39- 82	97- 106	-----
Zr	9- 96	( 42)	68- 175	-----	-----
Y	7- 30	( 19)	16- 48	-----	-----

	Stolzburg (4)	India (1)
SiO <sub>2</sub>	54.30-63.81	48.70
TiO <sub>2</sub>	0.31- 0.55	0.22
Al <sub>2</sub> O <sub>3</sub>	11.39-14.73	15.75
FeO	4.29-10.43	8.99
MnO	0.05- 0.15	0.15
MgO	4.86-12.91	13.43
CaO	4.67-10.67	10.84
Na <sub>2</sub> O	3.04- 6.76	1.82
K <sub>2</sub> O	0.15- 0.73	0.09
P <sub>2</sub> O <sub>5</sub>	0.04- 0.09	0.01
Cr	70- 703	531
Ni	-----	124
Co	-----	44
Zr	-----	80
Y	-----	14

Table 4.5

Major and trace element compositions of the pelitic and pegmatitic rocks. Majors in weight % oxide and traces in ppm.

	P17C	P41C	P5C	P6C	P16C	P32C	P34C	P38C	P42C	P45C
SiO <sub>2</sub>	68.39	68.73	60.95	51.05	62.98	56.96	61.71	68.48	60.92	66.54
TiO <sub>2</sub>	.58	.51	.63	.61	.64	.60	.62	.49	.47	.54
Al <sub>2</sub> O <sub>3</sub>	15.38	13.94	13.26	13.91	15.79	19.10	16.03	13.61	13.57	13.40
FeO	4.37	5.23	12.98	23.03	6.76	8.34	7.28	6.19	12.63	6.30
MnO	.03	.06	.12	.09	.07	.07	.08	.05	.11	.05
MgO	3.26	3.38	6.45	7.84	6.56	7.47	6.49	5.90	4.68	6.53
CaO	1.94	1.76	2.59	1.55	1.64	1.47	1.74	.98	3.86	1.58
Na <sub>2</sub> O	2.98	3.70	1.98	.60	2.27	1.83	2.14	1.16	1.48	2.12
K <sub>2</sub> O	1.77	1.77	.06	.08	1.71	2.26	2.38	1.51	.48	1.33
P <sub>2</sub> O <sub>5</sub>	.06	.11	.08	.20	.04	.09	.02	.13	.16	.05
H <sub>2</sub> O-	.13	.24	.19	.14	.19	.11	.17	.19	.09	.12
LOI	.98	.96	1.20	1.35	1.40	1.79	1.30	1.63	1.79	1.57
Total	99.83	100.38	100.51	100.46	100.03	100.08	99.95	100.34	100.24	100.08
Ba	535	341	153	333	464	535	559	422	133	305
Sc	9.0	13	19	22	19	28	22	15	17	18
Co	24	25	34	37	50	56	44	42	30	45
Cr	321	334	766	773	862	1002	837	566	457	756
V	88	91	141	152	150	163	153	97	121	132
Zn	57	59	99	107	92	87	98	72	74	97
Cu	66	39	45	58	87	27	43	39	115	65
Ni	88	94	170	245	409	381	348	292	212	327
Nb	6.0	6.1	5.3	4.6	7.0	7.9	7.5	5.3	5.1	6.9
Zr	168	126	100	85	129	110	118	135	98	118
Y	10	15	16	19	18	24	22	19	16	13
Sr	462	193	150	47	192	154	216	105	201	182
Rb	70	71	2.2	4.4	78	107	120	63	26	61
Th	6.3	5.0	3.1	3.8	5.8	5.3	5.9	4.6	6.8	4.0
Pb	13	13	4.9	4.3	12	10	11	7.8	9.5	7.8
K/Rb	210.1	206.3	243.1	159.3	183.1	174.9	165.0	198.1	153.2	182.1
K/Ba	27.5	43.1	3.5	2.1	30.7	35.0	35.4	29.7	29.8	36.2
Rb/Sr	.151	.369	.015	.095	.405	.694	.559	.605	.128	.333
Sr/Ba	.865	.567	.978	.140	.414	.289	.387	.248	1.510	.597

\*\*\* All Fe calculated as FeO \*\*\*

Table 4.5 (cont.)

	P50C	P7D	P25C	P14C	P19C	P21C	P29C	P1D	P8C	P3D
SiO <sub>2</sub>	56.36	55.83	65.11	56.82	53.99	64.61	52.12	62.45	57.78	53.70
TiO <sub>2</sub>	.76	.77	.62	.88	.95	.56	.84	.62	.67	.73
Al <sub>2</sub> O <sub>3</sub>	17.25	16.42	13.17	17.78	20.84	14.29	19.68	16.28	17.21	19.18
FeO	8.33	10.94	7.18	9.70	9.49	7.51	10.09	7.04	7.45	7.81
MnO	.10	.13	.10	.09	.09	.08	.09	.06	.10	.09
MgO	8.63	9.18	6.61	8.82	9.42	5.63	10.25	6.27	9.94	10.82
CaO	2.24	1.04	2.48	1.25	1.10	1.76	1.52	1.83	1.85	1.69
Na <sub>2</sub> O	2.45	1.08	2.79	1.44	1.06	2.40	1.63	2.52	2.24	2.77
K <sub>2</sub> O	1.74	2.42	1.28	1.76	1.77	1.84	2.12	1.52	1.31	1.71
P <sub>2</sub> O <sub>5</sub>	.04	.04	.04	.03	.01	.02	.04	.04	.04	.04
H <sub>2</sub> O-	.11	.19	.35	.19	.08	.09	.14	.13	.11	.16
LOI	2.18	2.01	.83	1.48	1.51	1.49	1.57	1.39	1.70	1.67
Total	100.17	100.08	100.56	100.23	100.30	100.29	100.12	100.16	100.40	100.39
Ba	410	618	343	469	498	499	613	492	268	310
Sc	30	32	20	28	36	20	32	18	29	34
Co	61	58	48	64	68	42	66	44	67	73
Cr	1414	1100	760	1132	1195	728	1228	667	1535	1670
V	178	206	128	211	233	140	239	150	162	189
Zn	109	118	85	117	131	80	132	86	87	106
Cu	39	82	40	90	64	66	62	58	42	30
Ni	556	525	414	487	590	319	609	324	647	785
Nb	6.4	7.1	3.7	7.1	8.6	5.9	7.3	5.8	6.1	5.9
Zr	130	136	100	165	126	134	120	129	108	103
Y	16	35	18	19	26	17	26	5.8	17	15
Sr	185	89	246	143	71	194	136	228	116	232
Rb	73	110	50	99	81	75	87	79	47	84
Th	3.3	7.0	3.5	5.9	5.2	2.8	4.4	6.0	2.7	2.8
Pb	9.2	6.6	8.3	6.6	3.3	9.8	6.6	9.8	4.1	8.9
K\Rb	198.1	181.6	212.2	148.5	180.2	202.3	202.0	159.5	232.2	169.5
K\Ba	35.3	32.5	30.9	31.2	29.4	30.5	28.8	25.7	40.6	45.8
Rb\Sr	.396	1.24	.203	.687	1.15	.388	.640	.348	.405	.362
Sr\Ba	.450	.144	.717	.306	.142	.388	.223	.464	.432	.747

\*\*\* All Fe calculated as FeO \*\*\*

Table 4.5 (cont.)

	P5D	V28C	V6D
SiO <sub>2</sub>	57.75	71.76	72.39
TiO <sub>2</sub>	.63	.01	.02
Al <sub>2</sub> O <sub>3</sub>	17.46	16.19	15.93
FeO	7.09	2.20	1.80
MnO	.08	.14	.03
MgO	10.63	.63	.75
CaO	1.97	3.23	2.00
Na <sub>2</sub> O	2.31	5.54	5.28
K <sub>2</sub> O	1.21	.45	1.08
P <sub>2</sub> O <sub>5</sub>	.04	.00	.05
H <sub>2</sub> O-	.13	.15	.15
LOI	1.31	.36	.99
Total	100.63	100.64	100.45
Ba	305	116	1009
Sc	28	3.9	6.5
Co	65	1.8	4.1
Cr	1553	12	4.6
V	160	3.8	2.0
Zn	93	7.5	9.0
Cu	34	4.3	17
Ni	670	17	10
Nb	4.6	.9	.8
Zr	109	81	37
Y	15	24	6.8
Sr	159	446	533
Rb	42	4.6	9.0
Th	4.1	2.4	2.3
Pb	5.5	11	24
K\Rb	239.1	815.7	999.3
K\Ba	32.8	32.3	8.9
Rb\Sr	.264	.010	.017
Sr\Ba	.520	3.840	.528

\*\*\* All Fe calculated as FeO \*\*\*

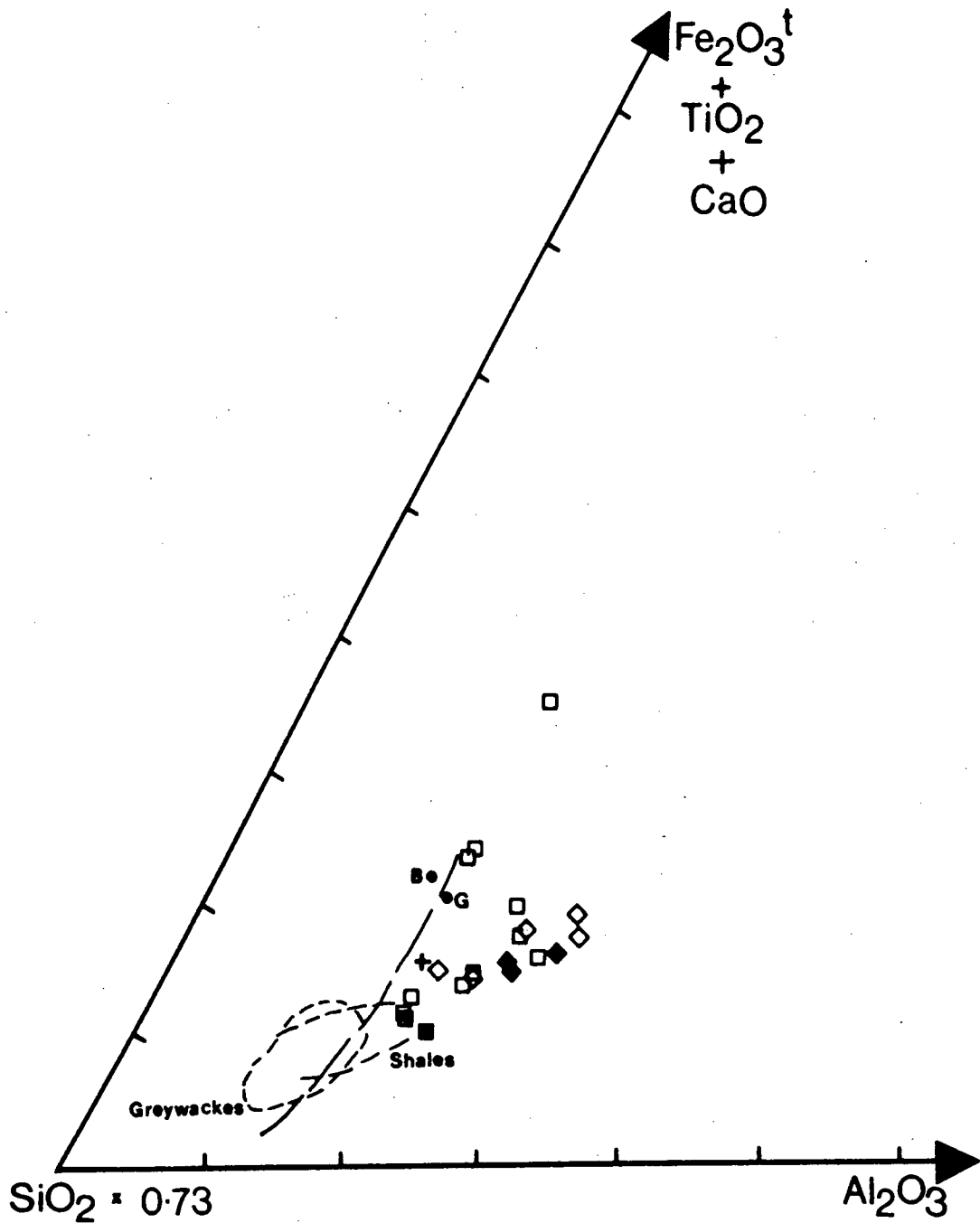


Figure 4.3: Ternary ( $\text{Fe}_2\text{O}_3 + \text{TiO}_2 + \text{CaO}$ ) - ( $\text{SiO}_2 \times 0.73$ ) -  $\text{Al}_2\text{O}_3$  diagram for the bulk analysis of pelitic rocks. All Fe is calculated as  $\text{Fe}_2\text{O}_3$ ; compositions as weight % oxides. After de la Roche (1966); B-basalt; G-gabbro.

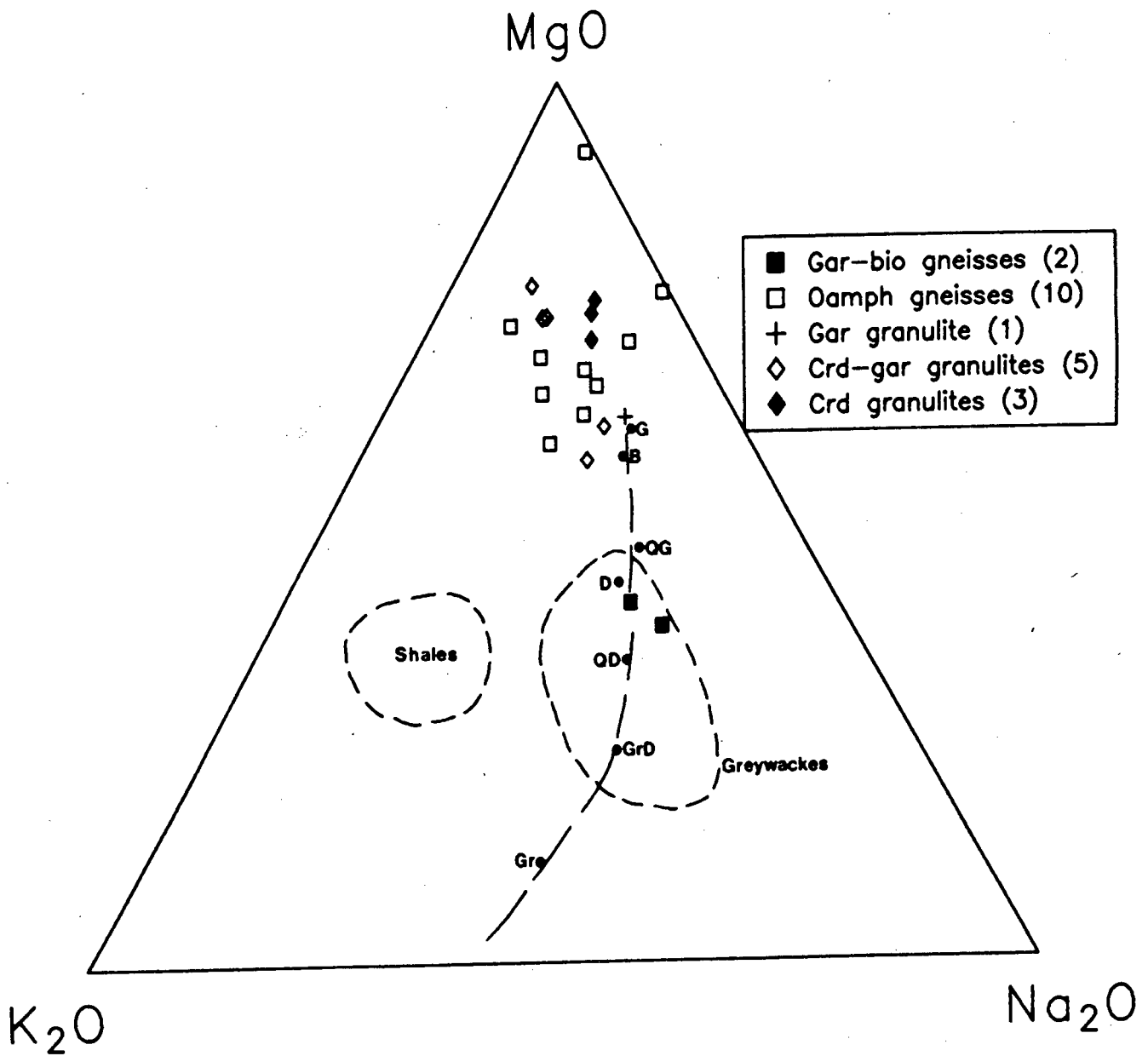


Figure 4.4: Ternary MgO - K<sub>2</sub>O - Na<sub>2</sub>O diagram for the bulk analysis of pelitic rocks. Shale and Greywacke compositional fields are adapted from de la Roche (1966). Compositions as weight % oxides. B-basalt, D-diorite, G-gabbro, Gr-granite, GrD-grano-diorite, QD-quartz-diorite, QG-quartz-gabbro.

Table 4.6

Major and trace element compositional comparison between the average of the SMZ pelitic rocks and other Archaean greywackes and shales. All data are compared on a recalculated volatile free basis, oxides in weight %, traces in ppm.

SMZ A - average of all high grade pelitic rocks of this study;  
 SMZ B - average of the biotite-garnet gneisses of this study;  
 Fig T Sh - composite Fig Tree shale from the Barberton greenstone belt, after Danchin (1970);  
 Bellv Gw - average of the greywackes from the Bellvue formation, Barberton greenstone belt, after Condie et al. (1970);  
 Murch Pel - average quartz-chlorite schist (magnesiopelites) from Pearton, (1982);  
 India Gw and India SH - average of greywackes and shales from Archaean greenstone terranes in India, after Naqvi et al. (1988);  
 Can Sh - average shale from the Canadian Archaean after Cameron and Garrels (1980);  
 (n) - number of samples;  
 nd - not determined.

	SMZ A	SMZ B	Fig T	Bellv	Murch	India	India	Can
	(21)	(2)	Sh	Gw	Pel	Gw	Sh	Sh
			(8)	(7)	(38)	(126)	(25)	(406)
SiO <sub>2</sub>	60.99	69.27	64.26	64.60	59.28	63.22	58.58	61.40
TiO <sub>2</sub>	0.66	0.55	0.56	0.59	1.03	0.57	0.60	0.77
Al <sub>2</sub> O <sub>3</sub>	16.30	14.82	13.20	13.93	14.81	13.91	16.46	17.89
FeO	8.97	4.85	11.64	7.09	10.80	7.62	9.35	7.22
MnO	0.08	0.05	0.09	0.09	0.06	0.13	0.14	nd
MgO	7.47	3.35	6.25	4.80	11.36	2.88	3.50	3.52
CaO	1.83	1.87	1.23	3.43	0.29	3.28	2.24	2.19
Na <sub>2</sub> O	2.07	3.38	1.31	3.06	0.16	2.76	1.92	2.66
K <sub>2</sub> O	1.55	1.79	1.33	2.41	0.76	1.97	3.47	2.88
P <sub>2</sub> O <sub>5</sub>	0.06	0.09	0.09	nd	0.11	0.11	0.12	nd
Ba	416	443	240	676	nd	352	662	558
Sc	24	11	nd	14	nd	12	15	16
Cr	950	330	nd	nd	nd	138	136	135
Zn	96	74	nd	nd	nd	nd	nd	328
Ni	410	91	nd	173	nd	74	79	129
Zr	123	148	nd	199	nd	160	179	nd
Y	18	12	nd	nd	nd	27	35	18
Sr	179	331	52	382	nd	288	204	202
Rb	69	71	48	97	nd	83	130	92
K/Rb	190	209	230	206	-	197	222	260
Rb/Sr	0.45	0.22	0.92	0.25	-	0.29	0.64	0.46
Ca/Sr	73.1	40.4	169.0	64.2	-	81.4	78.5	77.5
K <sub>2</sub> O/ Na <sub>2</sub> O	0.75	0.53	1.02	0.79	-	0.71	1.81	1.08

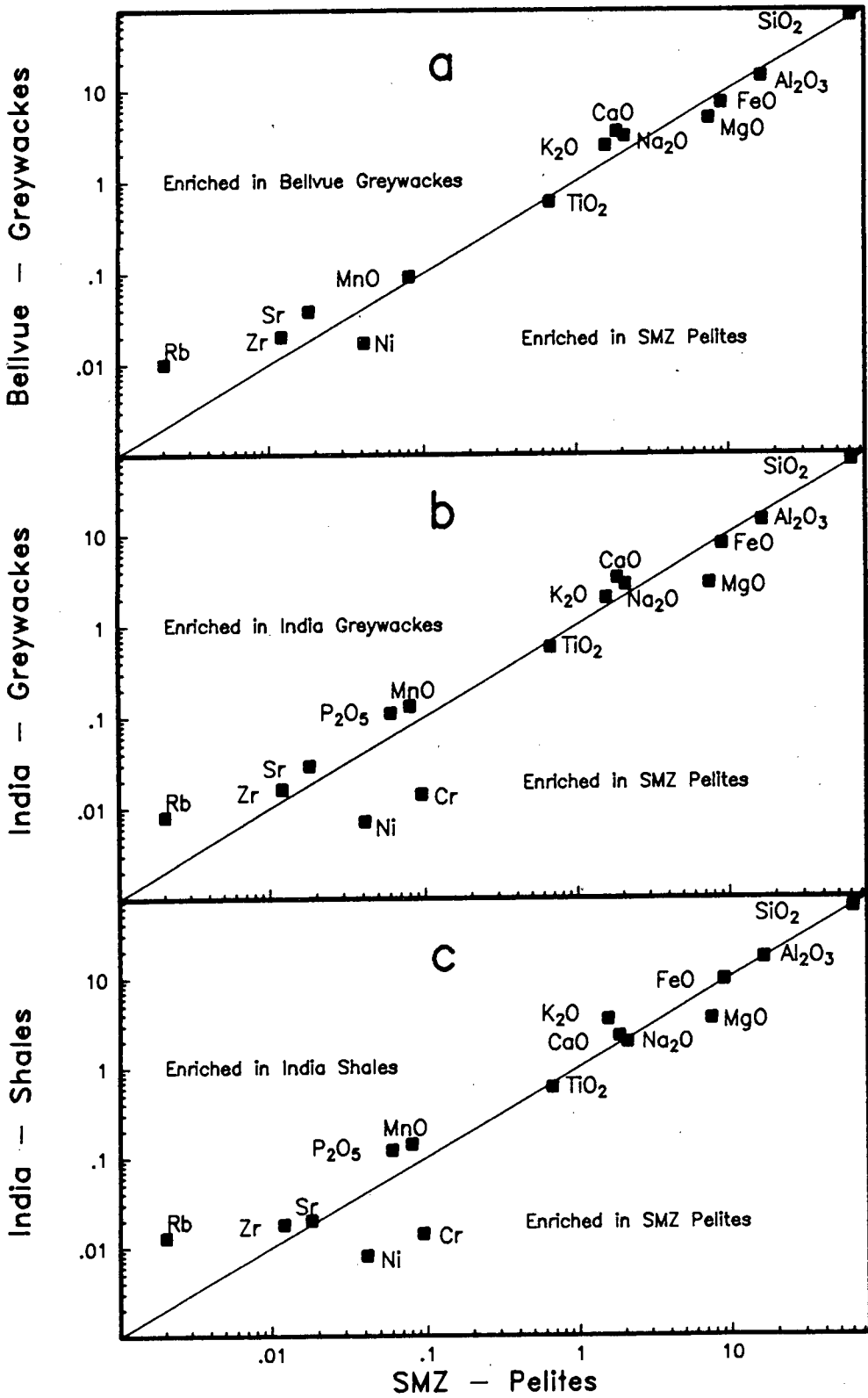


Figure 4.5: Comparison diagrams of the average of the pelitic rocks and the Bellvue greywacke average (a - Condie et al., 1970), the Indian greywacke average (b - Naqvi et al., 1988) and the Indian shale average (c - Naqvi et al., 1988).

Table 4.7

Least squares approximation to the source proportions of the average SMZ pelitic rock. All calculations on a volatile free basis.

Tonal - average tonalitic rock from du Toit et al. (1983),  
 Trond - average trondhjemitic rock from du Toit et al. (1983),  
 Musc, Chlor, Serp - muscovite, chlorite and serpentine analysis taken from Deer et al. (1966),  
 Pelite - average of all pelitic rocks of this study,  
 C<sub>obs</sub>, C<sub>cal</sub> - observed and calculated compositions,  
 Sum (C<sub>obs</sub>-C<sub>cal</sub>)<sup>2</sup> - sum of squares of differences between observed and calculated concentrations,  
 X<sub>S</sub> - amount of phase in source.

Phases used:	Tonal	Trond	Quartz	Musc	Chlor	Serp	Pelite
SiO <sub>2</sub>	64.48	72.63	100.0	47.75	28.82	48.44	60.99
TiO <sub>2</sub>	.69	.20	.0	.01	.99	.02	.66
Al <sub>2</sub> O <sub>3</sub>	15.33	14.97	.0	38.89	23.83	.63	16.30
FeO	6.26	1.44	.0	.10	28.16	1.48	8.97
MnO	.06	.02	.0	.12	.39	.08	.08
MgO	2.72	.69	.0	.08	17.19	49.14	7.47
CaO	5.07	2.14	.0	.01	.18	.02	1.83
Na <sub>2</sub> O	3.89	5.24	.0	.68	.01	.01	2.07
K <sub>2</sub> O	1.20	1.55	.0	10.64	.01	.01	1.55
P <sub>2</sub> O <sub>5</sub>	.24	.07	.0	.01	.01	.01	.06

	C <sub>obs</sub>	C <sub>cal</sub>	Phase	X <sub>S</sub>
SiO <sub>2</sub>	60.99	60.76	Tonal	.2803
TiO <sub>2</sub>	.66	.47	Trond	.1743
Al <sub>2</sub> O <sub>3</sub>	16.30	16.23	Quartz	.1640
FeO	8.97	8.95	Musc	.0897
MnO	.08	.13	Chlor	.2436
MgO	7.47	7.44	Serp	.0481
CaO	1.83	1.84		
Na <sub>2</sub> O	2.07	2.07	Total	1.0000
K <sub>2</sub> O	1.55	1.57		
P <sub>2</sub> O <sub>5</sub>	.06	.08		
Sum (C <sub>obs</sub> -C <sub>cal</sub> ) <sup>2</sup>		.10		

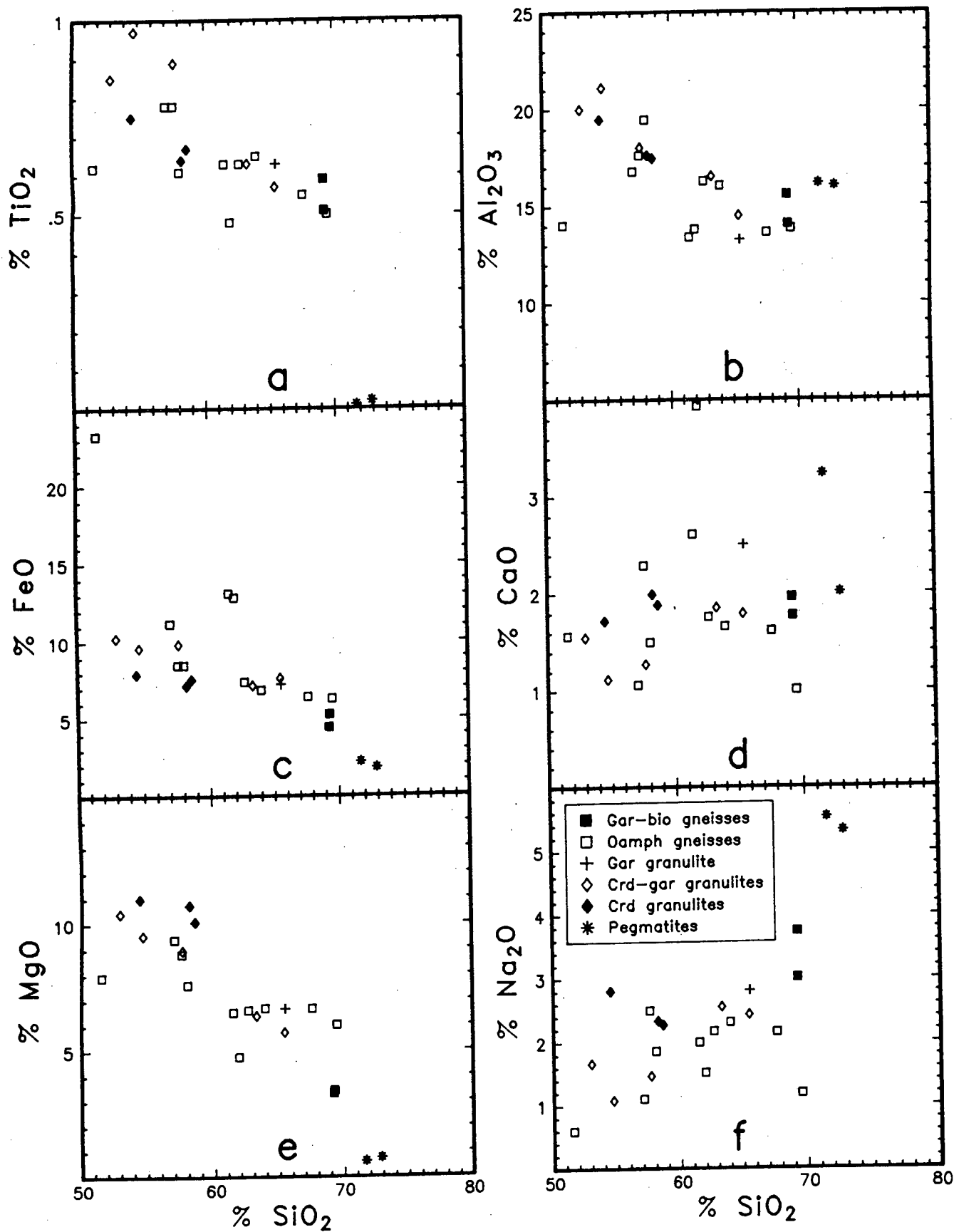
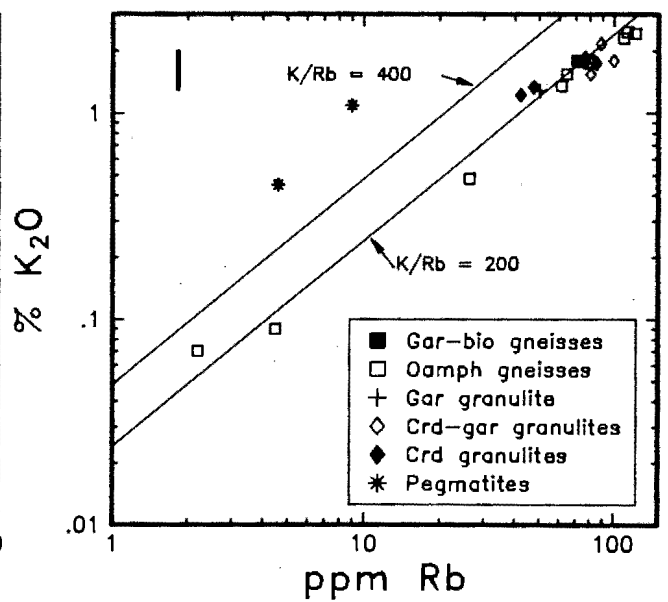
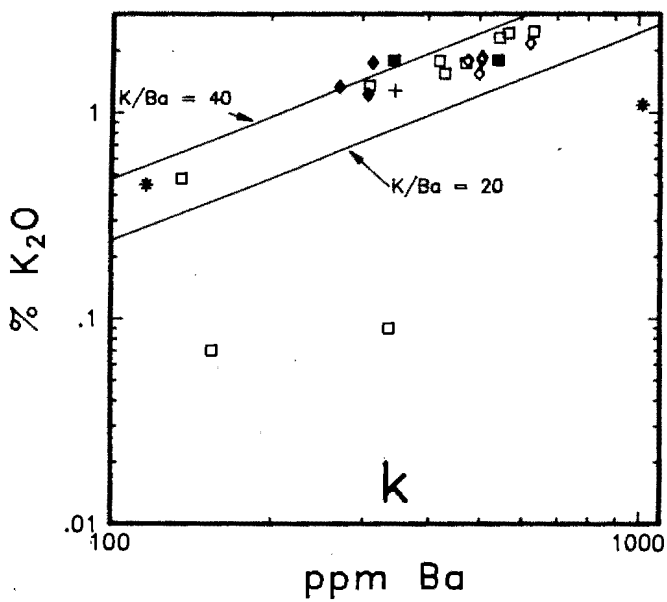
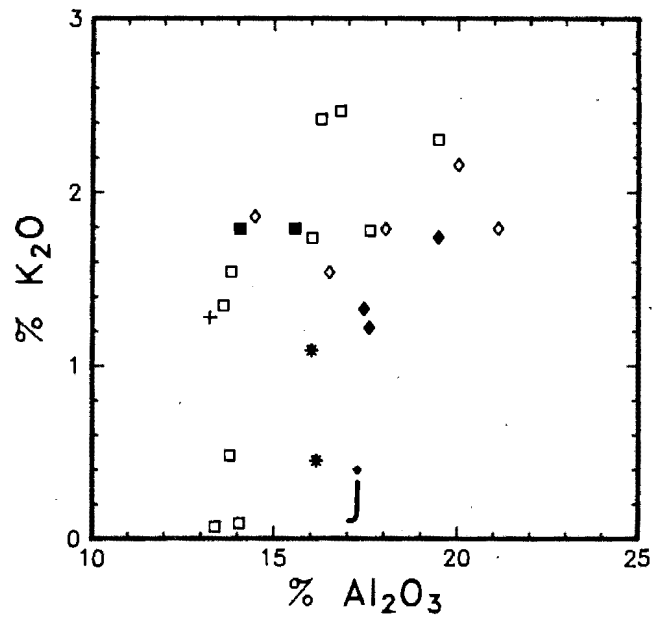
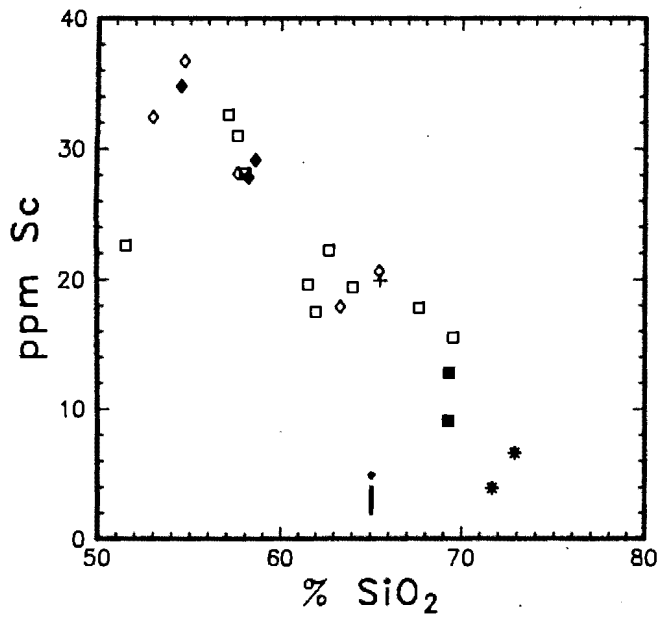
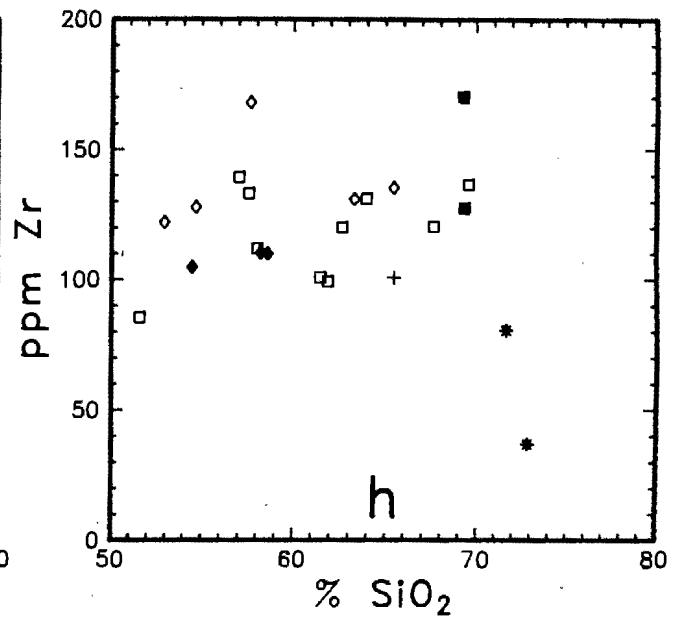
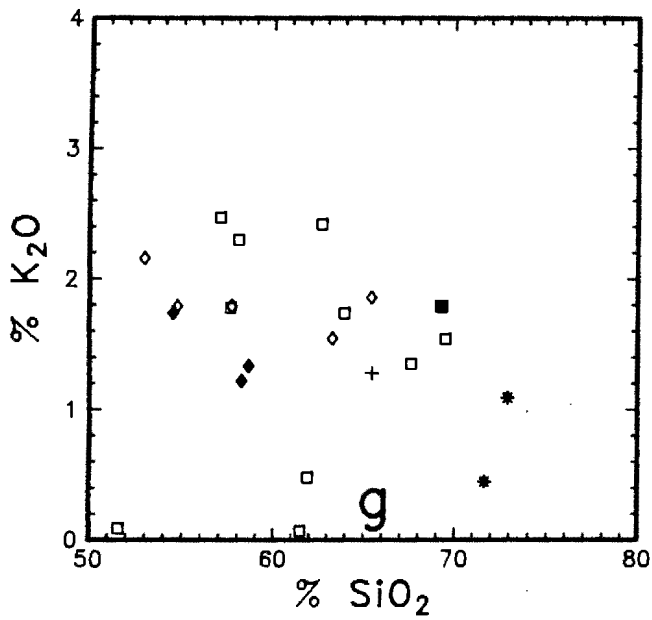


Figure 4.6a - 1: Major and trace element variation diagrams for the pelitic rocks and the pegmatitic rocks of this study. Major elements given in weight % oxide, trace elements in ppm. For diagrams g to 1 see following page.



- Gar-bio gneisses
- Oamph gneisses
- + Gar granulite
- ◇ Crd-gar granulites
- ◆ Crd granulites
- \* Pegmatites

Table 4.8

Partial melting modeling for the pelitic rocks. See text for details.

SMZ B - average of the biotite-garnet gneisses of this study;

SMZ C - average of P19C, P29C and P3D;

Min Melt - adapted from White and Chappel (1977);

Model Melt - model melt obtained from 70 % partial melting and using equation 4.3 (see text).

	SMZ B	Min Melt	Residue compositions			SMZ C	Model Melt
			25 %	50 %	75 %		
SiO <sub>2</sub>	69.27	75.73	67.12	62.81	54.20	54.05	75.79
TiO <sub>2</sub>	0.55	0.28	0.64	0.82	1.18	0.86	0.42
Al <sub>2</sub> O <sub>3</sub>	14.82	12.96	15.44	16.68	19.16	20.19	12.52
FeO	4.85	1.54	5.95	8.16	12.57	9.26	2.96
MnO	0.05	0.03	0.06	0.07	0.10	0.09	0.03
MgO	3.35	0.31	4.36	6.39	10.44	10.31	0.37
CaO	1.87	1.12	2.12	2.62	3.62	1.46	2.05
Na <sub>2</sub> O	3.38	3.11	3.47	3.65	4.01	1.85	4.04
K <sub>2</sub> O	1.79	4.85	0.77	(-1.27)	(-5.35)	1.90	1.74
P <sub>2</sub> O <sub>5</sub>	0.09	0.06	0.10	0.12	0.16	0.03	0.12

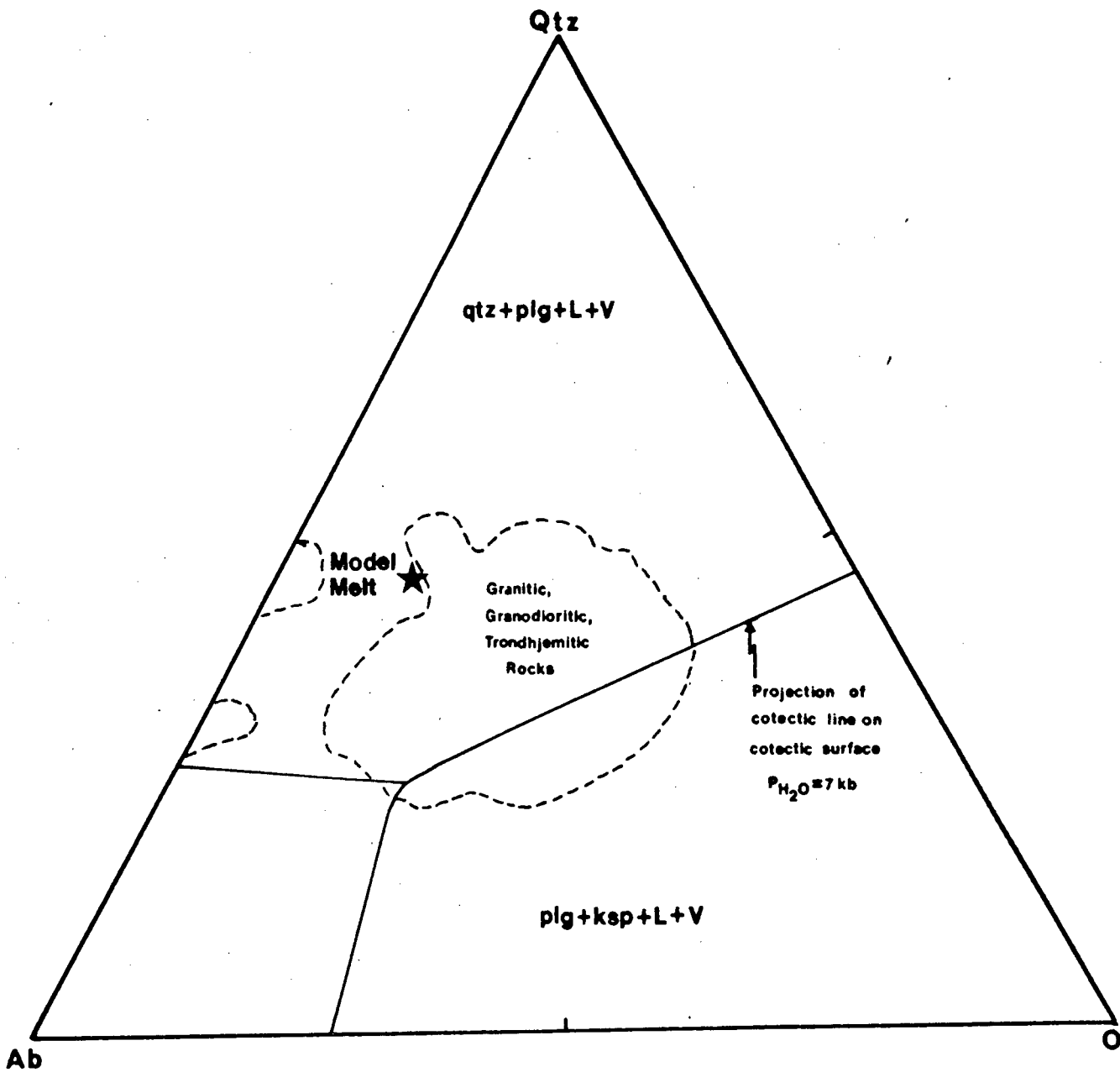


Figure 4.7: Normative quartz (Qtz) : albite (Ab) : orthoclase (Or) diagram illustrating the compositional field for granites as well as the projections of cotectic surfaces and cotectic lines for the system quartz-albite-orthoclase-anorthite-H<sub>2</sub>O after Winkler (1976). Shown as a cross is the model melt of Table 4.8 with a normative Qtz : Ab : Or ratio of 46 : 41 : 13. Mineral abbreviations as in Table 3.3.

Table 4.9

Major and trace element composition of several other lithologies.  
 Majors in weight % oxide and traces in ppm.

	P13B	P14B	G9C	GD49C	C4D	C8D
SiO <sub>2</sub>	70.43	66.13	69.86	75.94	57.39	58.28
TiO <sub>2</sub>	.60	.61	.34	.04	1.82	2.14
Al <sub>2</sub> O <sub>3</sub>	20.06	20.94	15.28	13.78	14.00	13.31
FeO	2.57	4.73	2.66	.80	9.17	9.55
MnO	.06	.18	.04	.04	.15	.13
MgO	.86	.85	1.44	.13	3.68	2.86
CaO	.35	.41	3.50	.86	6.16	5.98
Na <sub>2</sub> O	1.07	1.36	4.03	5.16	3.51	3.42
K <sub>2</sub> O	1.53	2.03	1.46	3.38	1.81	1.99
P <sub>2</sub> O <sub>5</sub>	.04	.07	.13	.02	1.01	1.11
H <sub>2</sub> O-	.17	.16	.13	.08	.11	.12
LOI	2.90	3.12	1.33	.39	1.29	1.24
Total	100.62	100.59	100.15	100.59	100.09	100.13
Ba	124	167	669	202	1455	1685
Sc	61	56	5.7	1.5	18	20
Co	12	18	6.4	1.5	27	25
Mn	428.6	1237.2	269.3	78.4	968.3	961.1
Cr	303	294	29	2.9	103	50
V	261	264	43	1.3	135	158
Zn	32	31	54	12	125	133
Cu	3.8	6.1	20	7.2	27	26
Ni	70	48	16	2.0	65	36
Nb	1.7	1.7	2.1	2.9	23	27
Zr	45	45	115	18	400	453
Y	16	15	5.9	2.6	61	73
Sr	49	71	603	104	774	723
Rb	39	53	41	75	41	42
Th	2.3	2.4	2.4	3.6	4.5	5.7
Pb	2.6	4.0	9.8	33	17	16
K\Rb	327.4	319.1	292.8	374.0	363.2	389.5
K\Ba	102.6	100.7	18.1	139.0	10.3	9.8
Rb\Sr	.786	.740	.069	.722	.053	.059
Sr\Ba	.399	.427	.901	.514	.532	.429

\*\*\* All Fe calculated as FeO \*\*\*

**Table 5.1: Microprobe analysis of olivine from U17B.**  
**Cation proportions on the basis of 4 oxygens.**  
**Fo, Fa - forsterite and fayalite contents (%).**

	U17B-1C	U17B-2C	U17B-3C	U17B-4C	U17B-5C	U17B-6C
SiO <sub>2</sub>	40.45	40.31	40.57	40.62	40.52	40.27
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	.00	.00	.00	.00	.00	.00
Cr <sub>2</sub> O <sub>3</sub>	.00	.00	.00	.00	.00	.00
FeO	10.12	9.45	9.66	9.87	9.73	9.82
MnO	.10	.15	.15	.13	.16	.11
MgO	48.26	49.20	49.20	48.78	48.79	48.77
CaO	.00	.00	.00	.00	.00	.00
NiO	.31	.39	.39	.42	.42	.42
Total	99.27	99.53	100.00	99.85	99.65	99.42
Si	1.001	.993	.995	.999	.998	.995
Ti						
Al						
Cr						
Fe <sup>2+</sup>	.209	.195	.198	.203	.200	.203
Mn	.002	.003	.003	.003	.003	.002
Mg	1.779	1.806	1.799	1.787	1.790	1.795
Ca						
Ni	.006	.008	.008	.008	.008	.008
Sum	2.999	3.007	3.005	3.001	3.002	3.005
Fo	89.47	90.27	90.07	89.80	89.93	89.85
Fa	10.53	9.73	9.92	10.20	10.07	10.15

\*\*\* All zero values below detection limit \*\*\*

**SAMPLE DESCRIPTIONS :**

U17B-1C : OLIVINE 623/201  
 U17B-2C : OLIVINE 387/300  
 U17B-3C : OLIVINE 586/73  
 U17B-4C : OLIVINE 431/93  
 U17B-5C : OLIVINE 473/178  
 U17B-6C : OLIVINE 563/177

Table 5.2: Microprobe analysis of orthopyroxene from U10A and U17B.  
 Cation proportions on the basis of 6 oxygens.  
 ca, mg, fe - cation proportions of Ca, Mg, Fe,  
 recalculated to 100;  
 M -  $Mg/(Mg+Fe) * 100$ ,  
 C -  $Ca/(Ca+Mg)$ .

	U10A-1C	U10A-2C	U10A-3C	U10A-4C	U10A-5C	U17B-1C	U17B-2C	U17B-3C	U17B-4C	U17B-5C	U17B-6C
SiO <sub>2</sub>	56.74	55.76	56.60	55.63	55.71	56.52	56.69	56.95	56.67	56.97	56.50
TiO <sub>2</sub>	.03	.05	.08	.06	.05	.05	.00	.07	.06	.07	.08
Al <sub>2</sub> O <sub>3</sub>	1.39	1.98	1.46	2.32	1.61	1.01	.63	.64	.66	1.14	1.54
Cr <sub>2</sub> O <sub>3</sub>	.13	.09	.14	.06	.20	.12	.10	.12	.09	.11	.11
FeO	8.18	8.16	8.16	8.46	8.22	6.34	6.45	6.36	6.38	6.75	7.07
MnO	.11	.19	.18	.11	.13	.20	.13	.14	.12	.12	.18
MgO	33.97	33.92	34.23	33.98	34.17	35.76	35.74	35.80	36.00	35.70	35.40
CaO	.10	.10	.11	.11	.16	.16	.17	.13	.13	.10	.12
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.69	100.30	101.01	100.78	100.29	100.20	99.96	100.25	100.15	101.00	101.04
Si	1.958	1.935	1.949	1.924	1.936	1.949	1.959	1.961	1.954	1.950	1.938
Ti	.001	.001	.002	.002	.001	.001		.002	.002	.002	.002
Al	.057	.081	.059	.095	.066	.041	.026	.026	.027	.046	.062
Cr	.004	.002	.004	.002	.005	.003	.003	.003	.002	.003	.003
Fe <sup>2+</sup>	.236	.237	.235	.245	.239	.183	.186	.183	.184	.193	.203
Mn	.003	.006	.005	.003	.004	.006	.004	.004	.004	.003	.005
Mg	1.747	1.754	1.757	1.751	1.769	1.838	1.841	1.837	1.850	1.821	1.809
Ca	.004	.004	.004	.004	.006	.006	.006	.005	.005	.004	.004
Na											
K											
Ni											
Sum	4.011	4.023	4.018	4.027	4.028	4.028	4.027	4.023	4.030	4.024	4.028
ca	.19	.19	.20	.20	.30	.29	.31	.24	.25	.18	.22
mg	87.93	87.94	88.02	87.56	87.85	90.69	90.52	90.72	90.74	90.24	89.73
fe	11.88	11.87	11.77	12.23	11.86	9.02	9.17	9.04	9.02	9.58	10.06
M	88.10	88.11	88.20	87.74	88.11	90.95	90.80	90.93	90.95	90.41	89.92
C	.21	.21	.23	.23	.34	.32	.34	.26	.26	.20	.24

\*\*\* All zero values below detection limits \*\*\*

SAMPLE DESCRIPTIONS :

U10A-1C : OPX  
 U10A-2C : OPX 441/115  
 U10A-3C : OPX 570/0  
 U10A-4C : OPX 447/23  
 U10A-5C : OPX 564/99  
 U17B-1C : OPX 580/200  
 U17B-2C : OPX 475/241  
 U17B-3C : OPX 617/55  
 U17B-4C : OPX 473/138  
 U17B-5C : OPX 586/201  
 U17B-6C : OPX 592/202

**Table 5.3: Microprobe analysis of chlorite and tremolite from U10A and U17B. Cation proportions of chlorite calculated relative to 28 oxygens and of hornblende relative to 23 oxygens.  
M - Mg/(Mg+Fe) \* 100.**

	U10A-1C	U17B-1C	U17B-2C	U17B-3C	U10A
SiO <sub>2</sub>	27.85	29.84	29.73	29.76	48.40
TiO <sub>2</sub>	.14	.09	.14	.14	.58
Al <sub>2</sub> O <sub>3</sub>	21.94	21.62	21.28	21.74	10.49
Cr <sub>2</sub> O <sub>3</sub>	.37	.98	1.02	.59	.79
FeO	4.34	3.10	3.06	3.08	3.53
MnO	.02	.00	.00	.00	.07
MgO	31.09	32.15	32.35	32.35	19.20
CaO	.05	.00	.00	.00	12.73
Na <sub>2</sub> O	.04	.00	.00	.00	1.23
K <sub>2</sub> O	.02	.00	.00	.00	.10
NiO	.33	.27	.15	.25	.06
F	.00	.00	.00	.00	.00
Cl	.43	.00	.00	.00	.00
Total	86.63	88.10	87.78	87.96	97.19
Si	5.360	5.573	5.572	5.561	6.799
Ti	.020	.013	.020	.020	.062
Al	4.977	4.759	4.701	4.788	1.736
Cr	.056	.145	.151	.087	.088
Fe <sup>2+</sup>	.699	.484	.480	.481	.415
Mn	.005	.001	.001	.001	.008
Mg	8.917	8.948	9.036	9.008	4.020
Ca	.010	.002	.002	.002	1.916
Na	.015	.003	.003	.003	.335
K	.005	.002	.002	.002	.018
Ni	.051	.041	.023	.038	.006
Sum	20.113	19.963	19.982	19.982	15.404
M	92.74	94.87	94.96	94.93	90.65

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

U10A-1C : CHLORITE 459/133  
 U17B-1C : CHLORITE 612/94  
 U17B-2C : CHLORITE 637/220  
 U17B-3C : CHLORITE 521/192  
 U10A : ACTINOLITE-TREMOLITE 437/8

Table 5.4: Microprobe analysis of plagioclase from the mafic rocks. cation proportions are calculated relative to 8 oxygens. An, Ab, Or - anorthite, albite and orthoclase proportions.

	M1A-1C	M1A-2C	M1A-3C	M1A-4C	M3A-1C	M3A-2C	M3A-3C	M3A-4C	M5A-1C	M5A-2C
SiO <sub>2</sub>	58.60	57.25	50.29	57.41	59.18	59.20	60.16	59.92	59.49	60.20
Al <sub>2</sub> O <sub>3</sub>	25.57	26.39	31.31	26.57	25.44	25.50	25.06	25.21	25.49	25.13
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	7.98	9.16	14.69	8.95	7.55	7.89	7.23	7.37	7.87	7.40
Na <sub>2</sub> O	6.88	6.08	2.89	6.22	6.75	6.52	6.74	6.80	6.55	6.79
K <sub>2</sub> O	.08	.07	.00	.08	.19	.12	.21	.19	.20	.25
Total	99.11	98.95	99.18	99.23	99.18	99.30	99.47	99.56	99.67	99.84
Si	2.638	2.589	2.306	2.588	2.657	2.654	2.687	2.676	2.658	2.682
Al	1.357	1.407	1.692	1.412	1.346	1.348	1.319	1.327	1.343	1.320
Fe <sup>2+</sup>										
Mg					.001					
Ca	.385	.444	.722	.432	.363	.379	.346	.353	.377	.353
Na	.601	.533	.257	.544	.588	.567	.584	.589	.568	.587
K	.005	.004		.005	.011	.007	.012	.011	.011	.014
Sum	4.986	4.976	4.977	4.980	4.968	4.958	4.951	4.959	4.959	4.958
An	38.88	45.24	73.75	44.09	37.77	39.79	36.74	37.03	39.43	37.03
Ab	60.66	54.34	26.25	55.44	61.10	59.49	61.99	61.83	59.38	61.48
Or	.46	.41		.47	1.13	.72	1.27	1.14	1.19	1.49

\*\*\* All zero values below detection limits \*\*\*

SAMPLE DESCRIPTIONS :

M1A-1C : PLAGIOCLASE 536/146  
M1A-2C : PLAGIOCLASE 498/200  
M1A-3C : PLAGIOCLASE 518/212  
M1A-4C : PLAGIOCLASE 518/40  
M3A-1C : PLAG 394/123  
M3A-2C : PLAG 470/145  
M3A-3C : PLAG 348/169  
M3A-4C : PLAG 324/187  
M5A-1C : PLAG  
M5A-2C : PLAG 512/202

Table 5.4: continued

	MSA-3C	MSA-4C	MSA-5C	MSA-6C	MSA-7C	M8A-1C	M8A-1R	M8A-2C	M8A-3C	M8A-3R
SiO <sub>2</sub>	60.44	60.19	59.87	59.90	58.80	56.01	57.13	57.13	56.30	58.10
Al <sub>2</sub> O <sub>3</sub>	25.50	25.40	25.30	25.24	25.72	27.77	27.49	26.94	28.09	26.43
FeO	.10	.11	.00	.14	.00	.00	.00	.19	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	7.54	7.63	7.54	7.61	8.18	10.43	10.02	9.37	10.78	8.91
Na <sub>2</sub> O	6.80	6.80	6.67	6.79	6.58	5.30	5.63	5.89	5.15	6.03
K <sub>2</sub> O	.20	.20	.21	.20	.18	.19	.18	.26	.19	.27
Total	100.64	100.39	99.66	99.94	99.53	99.70	100.45	99.78	100.51	99.74
Si	2.673	2.670	2.672	2.670	2.637	2.524	2.551	2.568	2.517	2.604
Al	1.329	1.328	1.331	1.326	1.359	1.475	1.447	1.427	1.480	1.396
Fe <sup>2+</sup>	.004	.004		.005				.007		
Mg										
Ca	.357	.363	.361	.363	.393	.504	.479	.451	.516	.428
Na	.583	.585	.577	.587	.572	.463	.487	.513	.446	.524
K	.011	.011	.012	.011	.010	.011	.010	.015	.011	.015
Sum	4.959	4.963	4.956	4.965	4.974	4.976	4.975	4.982	4.971	4.968
An	37.54	37.82	37.96	37.79	40.29	51.51	49.06	46.07	53.04	44.23
Ab	61.27	61.00	60.78	61.02	58.65	47.37	49.89	52.41	45.85	54.17
Or	1.19	1.18	1.26	1.18	1.06	1.12	1.05	1.52	1.11	1.60

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

MSA-3C : PLAG 466/144  
MSA-4C : PLAG 626/94  
MSA-5C : PLAG 601/94  
MSA-6C : PLAG 459/64  
MSA-7C : PLAG 610/67  
M8A-1C : PLAGIOCLASE 591/165 CORE  
M8A-1R : PLAGIOCLASE 591/165 RIM  
M8A-2C : PLAGIOCLASE 597/253  
M8A-3C : PLAGIOCLASE 581/111 CORE  
M8A-3R : PLAGIOCLASE 581/111 RIM TO C,H

Table 5.4: continued

	M8A-4C	M8A-4R	M8A-5C	M11C-1C	M11C-2C	M11C-3C	M11C-4C	M27C-1C	M27C-2C	M27C-3C
SiO <sub>2</sub>	58.37	58.32	57.54	57.17	58.28	57.36	56.99	55.22	54.92	54.82
Al <sub>2</sub> O <sub>3</sub>	26.25	26.13	26.79	27.17	26.44	27.16	26.94	28.38	28.41	28.05
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	8.47	8.56	9.39	9.38	8.59	9.78	9.37	11.23	11.35	11.48
Na <sub>2</sub> O	5.95	6.15	5.89	5.76	6.20	5.83	5.72	5.40	5.14	5.37
K <sub>2</sub> O	.72	.32	.32	.22	.28	.20	.19	.00	.00	.00
Total	99.76	99.48	99.93	99.70	99.79	100.33	99.21	100.23	99.82	99.72
Si	2.617	2.619	2.580	2.567	2.609	2.564	2.571	2.483	2.479	2.481
Al	1.387	1.383	1.416	1.438	1.395	1.431	1.433	1.504	1.512	1.497
Fe <sup>2+</sup>										
Mg										
Ca	.407	.412	.451	.451	.412	.468	.453	.541	.549	.557
Na	.517	.535	.512	.502	.538	.505	.500	.471	.450	.471
K	.041	.018	.018	.013	.016	.011	.011			
Sum	4.969	4.967	4.977	4.971	4.970	4.979	4.968	5.000	4.990	5.006
An	42.15	42.65	45.96	46.75	42.64	47.55	46.97	53.47	54.96	54.16
Ab	53.58	55.45	52.17	51.95	55.70	51.29	51.89	46.53	45.04	45.84
Or	4.27	1.90	1.87	1.31	1.65	1.16	1.13			

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

M8A-4C : PLAGIOCLASE 498/55  
M8A-4R : PLAGIOCLASE 498/55 RIM  
M8A-5C : PLAGIOCLASE 470/48  
M11C-1C : PLAGIOCLASE 609/111  
M11C-2C : PLAGIOCLASE 589/141  
M11C-3C : PLAGIOCLASE 575/218  
M11C-4C : PLAGIOCLASE 452/199  
M27C-1C : PLAGIOCLASE 423/43  
M27C-2C : PLAG 393/389  
M27C-3C : PLAG 416/393

Table 5.4: continued

	M27C-4C	M27C-5C	M27C-6C	M27C-7C	M27C-8C	M27C-9C	M41C-1C	M41C-2C	M41C-3C	M41C-4C	M41C-5C
SiO <sub>2</sub>	55.42	55.06	53.84	52.82	53.19	54.04	61.72	62.61	61.88	61.84	62.46
Al <sub>2</sub> O <sub>3</sub>	27.95	28.08	28.76	29.49	29.15	28.83	24.60	24.19	24.36	24.42	24.35
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	11.10	10.88	12.18	12.51	12.06	11.59	6.45	5.95	6.22	6.28	5.84
Na <sub>2</sub> O	5.25	5.35	4.50	4.30	4.32	4.51	7.93	8.08	7.84	7.95	8.14
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.13	.16	.12	.13	.14
Total	99.72	99.37	99.28	99.12	98.72	98.97	100.83	100.99	100.42	100.62	100.93
Si	2.501	2.494	2.448	2.410	2.431	2.459	2.719	2.748	2.732	2.728	2.742
Al	1.487	1.499	1.541	1.586	1.570	1.546	1.277	1.251	1.268	1.270	1.260
Fe <sup>2+</sup>											
Mg											
Ca	.537	.528	.593	.612	.591	.565	.304	.280	.294	.297	.275
Na	.459	.470	.397	.380	.383	.398	.677	.688	.671	.680	.693
K							.007	.009	.007	.007	.008
Sum	4.985	4.991	4.980	4.988	4.975	4.967	4.985	4.975	4.973	4.981	4.978
An	53.88	52.92	59.93	61.65	60.67	58.68	30.78	28.66	30.27	30.16	28.16
Ab	46.12	47.08	40.07	38.35	39.33	41.32	68.48	70.43	69.04	69.10	71.03
Or							.74	.92	.70	.74	.80

\*\*\* All zero values below detection limits \*\*\*

SAMPLE DESCRIPTIONS :

M27C-4C : PLAG 328/77  
M27C-5C : PLAG 345/60  
M27C-6C : PLAGIOCLASE 469/10  
M27C-7C : PLAGIOCLASE 471/184  
M27C-8C : PLAGIOCLASE 605/190  
M27C-9C : PLAGIOCLASE 590/141  
M41C-1C : PLAGIOCLASE 595/18  
M41C-2C : PLAGIOCLASE 566/63  
M41C-3C : PLAGIOCLASE 560/164  
M41C-4C : PLAGIOCLASE 497/158  
M41C-5C : PLAGIOCLASE 513/190

Table 5.5: Microprobe analysis of amphibole from the mafic rocks.  
 Cation proportions are calculated relative to 23 oxygens.  
 $M = \text{Mg}/(\text{Mg}+\text{Fe}) * 100$ .

	M1A-1C	M3A-1C	M3A-2C	M3A-3C	M3A-4C	M3A-5C	M3A-6C	M3A-7C	M5A-1C	M5A-2C
SiO <sub>2</sub>	46.67	45.41	45.72	45.52	45.86	44.69	44.77	45.20	45.28	44.53
TiO <sub>2</sub>	.48	.62	.48	.63	.58	.69	.61	.60	.31	.32
Al <sub>2</sub> O <sub>3</sub>	10.07	10.00	9.76	10.46	9.97	10.51	10.76	9.93	11.23	11.45
Cr <sub>2</sub> O <sub>3</sub>	.26	.00	.00	.00	.00	.05	.00	.00	.07	.13
FeO	12.63	16.95	15.93	16.27	15.96	16.93	16.82	16.79	13.84	13.66
MnO	.21	.25	.29	.28	.27	.27	.27	.25	.24	.25
MgO	14.97	11.81	12.34	11.92	12.13	11.63	11.69	11.80	13.79	13.46
CaO	11.56	11.91	11.81	11.52	11.86	11.79	11.77	11.77	12.39	12.41
Na <sub>2</sub> O	1.58	1.61	1.50	1.48	1.40	1.57	1.58	1.44	1.56	1.63
K <sub>2</sub> O	.22	.55	.51	.57	.54	.62	.60	.57	.72	.76
Total	98.65	99.14	98.37	98.68	98.60	98.77	98.90	98.38	99.45	98.62
Si	7.045	6.690	6.747	6.700	6.747	6.617	6.611	6.702	6.568	6.523
Ti	.054	.069	.053	.070	.064	.076	.068	.067	.033	.036
Al	1.792	1.736	1.698	1.815	1.729	1.834	1.872	1.735	1.920	1.977
Cr	.031					.006			.008	.015
Fe <sup>2+</sup>	1.594	2.089	1.966	2.003	1.964	2.096	2.077	2.083	1.679	1.674
Mn	.027	.031	.037	.034	.033	.033	.033	.031	.029	.031
Mg	3.368	2.593	2.714	2.615	2.660	2.567	2.573	2.607	2.981	2.939
Ca	1.870	1.880	1.867	1.817	1.870	1.870	1.862	1.870	1.926	1.948
Na	.462	.460	.430	.422	.399	.451	.453	.414	.439	.463
K	.043	.103	.096	.107	.101	.117	.113	.108	.133	.142
Sum	16.287	15.654	15.612	15.587	15.573	15.670	15.666	15.622	15.719	15.748
M	67.87	55.39	57.99	56.63	57.53	55.04	55.33	55.60	63.97	63.71

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

M1A-1C : HORNBLLENDE 542/210  
 M3A-1C : HORNBLLENDE 316/280  
 M3A-2C : HORNBLLENDE 589/173  
 M3A-3C : HORNBLLENDE 487/235  
 M3A-4C : HORNBLLENDE 400/216  
 M3A-5C : HORNBLLENDE 453/117  
 M3A-6C : HORNBLLENDE 580/120  
 M3A-7C : HORNBLLENDE  
 M5A-1C : HORNBLLENDE 502/38  
 M5A-2C : HORNBLLENDE 616/38

Table 5.5: continued

	M5A-3C	M5A-4C	M5A-5C	M5A-6C	M5A-7C	M5A-8C	M8A-1C	M8A-2C	M8A-3C	M8A-4C
SiO <sub>2</sub>	44.80	44.74	44.99	45.38	44.96	44.86	43.46	43.98	43.68	43.66
TiO <sub>2</sub>	.29	.28	.33	.32	.34	.28	2.41	2.31	1.83	2.20
Al <sub>2</sub> O <sub>3</sub>	11.57	11.48	11.52	10.94	11.47	10.99	11.23	10.93	11.46	11.21
Cr <sub>2</sub> O <sub>3</sub>	.14	.12	.00	.08	.00	.14	.14	.16	.08	.13
FeO	13.98	13.39	13.75	13.14	13.53	13.53	14.95	14.19	14.52	14.97
MnO	.28	.26	.26	.32	.28	.22	.21	.14	.16	.18
MgO	13.44	13.68	13.58	13.69	13.45	13.55	11.79	12.06	12.29	11.95
CaO	12.45	12.26	12.64	12.50	12.32	12.56	11.72	12.12	11.82	11.81
Na <sub>2</sub> O	1.52	1.56	1.50	1.54	1.65	1.50	1.63	1.41	1.62	1.60
K <sub>2</sub> O	.72	.70	.77	.65	.70	.71	1.14	1.26	1.01	1.04
Total	99.21	98.49	99.37	98.58	98.73	98.36	98.68	98.56	98.47	98.75
Si	6.526	6.543	6.536	6.620	6.562	6.579	6.420	6.482	6.442	6.439
Ti	.031	.030	.036	.036	.038	.031	.268	.256	.203	.244
Al	1.986	1.979	1.973	1.881	1.973	1.900	1.956	1.899	1.993	1.949
Cr	.016	.014	.009	.009	.017	.017	.017	.019	.009	.015
Fe <sup>2+</sup>	1.703	1.638	1.671	1.603	1.652	1.659	1.847	1.749	1.791	1.846
Mn	.034	.032	.032	.040	.034	.027	.026	.018	.020	.023
Mg	2.918	2.982	2.940	2.976	2.925	2.962	2.596	2.649	2.701	2.626
Ca	1.943	1.922	1.968	1.954	1.927	1.974	1.856	1.914	1.868	1.866
Na	.430	.442	.422	.436	.467	.427	.467	.402	.463	.458
K	.134	.131	.143	.121	.131	.133	.215	.237	.190	.195
Sum	15.723	15.715	15.724	15.678	15.712	15.711	15.666	15.623	15.681	15.662
M	63.14	64.55	63.77	64.99	63.92	64.09	58.43	60.23	60.13	58.72

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

M5A-3C : HORNBLLENDE 450/220  
M5A-4C : HORNBLLENDE 498/198  
M5A-5C : HORNBLLENDE 516/224  
M5A-6C : HORNBLLENDE 545/81  
M5A-7C : HORNBLLENDE 519/126  
M5A-8C : HORNBLLENDE  
M8A-1C : HORNBLLENDE 551/42 CORE  
M8A-2C : HORNBLLENDE 551/42 RIM  
M8A-3C : HORNBLLENDE 496/245  
M8A-4C : HORNBLLENDE 547/86

Table 5.5: continued

	M11C-1C	M11C-2C	M27C-1C	M27C-2C	M27C-3C	M41C-1C	M41C-1R	M41C-2C	M41C-3C
SiO <sub>2</sub>	44.54	44.88	46.94	45.68	45.08	46.67	46.16	46.86	46.32
TiO <sub>2</sub>	2.14	2.04	1.28	1.09	1.61	.80	.91	.84	.82
Al <sub>2</sub> O <sub>3</sub>	10.61	10.43	9.94	10.52	10.87	9.29	9.73	9.12	9.48
Cr <sub>2</sub> O <sub>3</sub>	.16	.16	.39	.25	.35	.16	.11	.12	.14
FeO	14.05	13.60	12.38	12.86	12.89	14.00	13.91	13.67	13.87
MnO	.16	.16	.11	.14	.10	.22	.19	.19	.17
MgO	13.17	13.19	14.04	13.28	13.05	13.60	13.34	13.75	13.60
CaO	11.93	12.14	11.87	11.87	11.86	11.78	11.89	11.78	11.93
Na <sub>2</sub> O	1.60	1.40	1.54	1.59	1.82	1.69	1.81	1.66	1.69
K <sub>2</sub> O	.63	.64	.10	.08	.09	.35	.37	.33	.36
Total	98.99	98.64	98.59	97.36	97.72	98.56	98.42	98.32	98.38
Si	6.505	6.558	7.077	7.001	6.902	6.802	6.744	6.831	6.766
Ti	.235	.224	.145	.125	.185	.088	.100	.092	.090
Al	1.826	1.796	1.767	1.901	1.961	1.596	1.676	1.567	1.632
Cr	.019	.019	.046	.030	.043	.019	.013	.014	.016
Fe <sup>2+</sup>	1.716	1.662	1.561	1.649	1.651	1.706	1.700	1.666	1.695
Mn	.020	.020	.014	.018	.013	.027	.023	.023	.021
Mg	2.867	2.873	3.154	3.034	2.977	2.954	2.904	2.987	2.961
Ca	1.867	1.901	1.917	1.950	1.946	1.840	1.861	1.840	1.867
Na	.453	.396	.451	.473	.540	.478	.512	.469	.479
K	.117	.119	.019	.016	.018	.065	.069	.062	.067
Sum	15.623	15.568	16.151	16.196	16.235	15.574	15.602	15.552	15.593
M	62.55	63.35	66.90	64.79	64.33	63.38	63.09	64.19	63.60

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

M11C-1C : HORNBLENDE 602/220  
M11C-2C : HORNBLENDE 526/133  
M27C-1C : HORNBLENDE 457/54  
M27C-2C : HORNBLENDE 447/64  
M27C-3C : HORNBLENDE 527/214  
M41C-1C : HORNBLENDE 584/158 CORE  
M41C-1R : HORNBLENDE 584/158 RIM  
M41C-2C : HORNBLENDE 561/199 CORE  
M41C-3C : HORNBLENDE 463/189 CORE

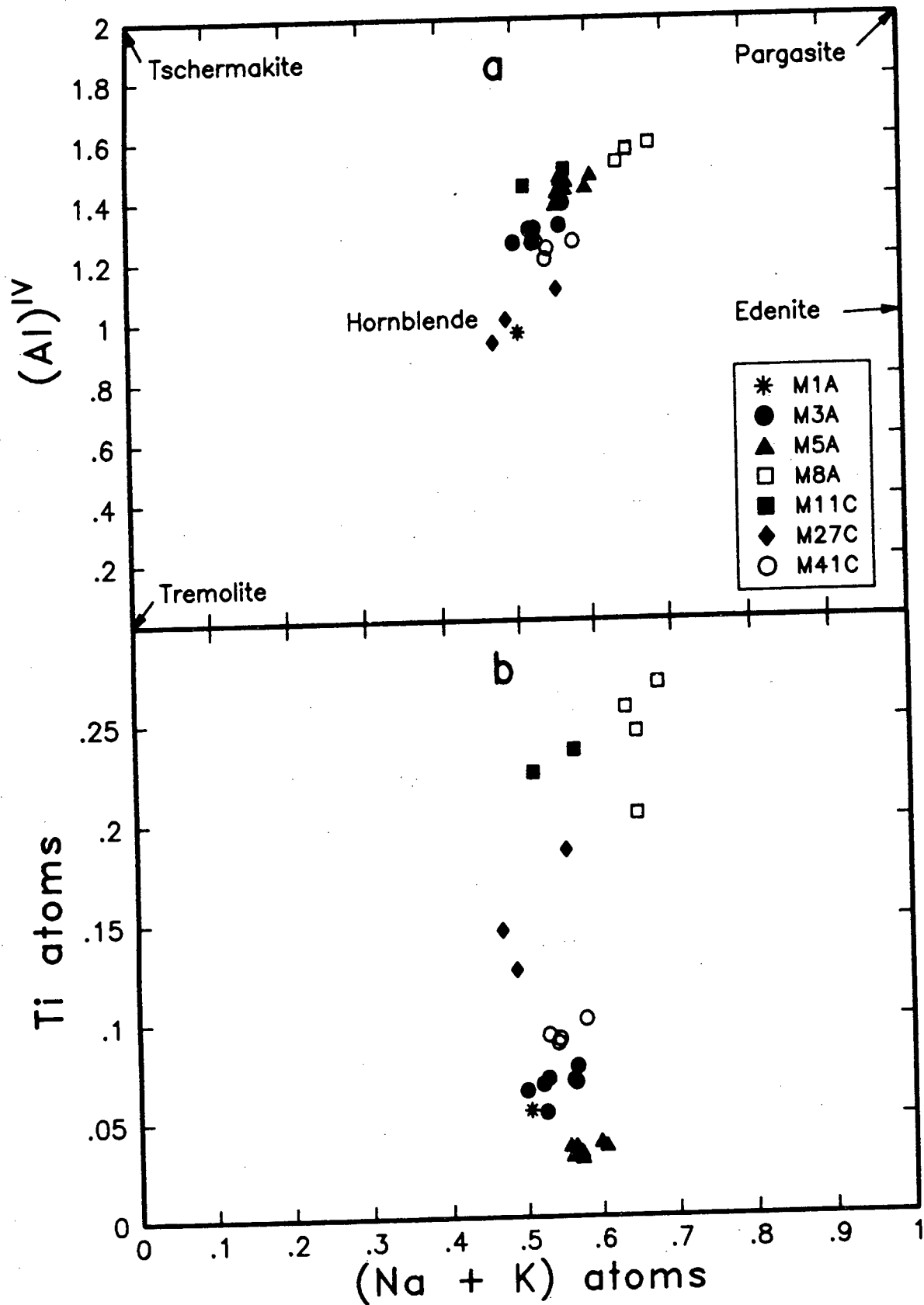


Figure 5.1a: Chemical variation of the amphiboles from the mafic rocks expressed as the number of (Na+K) and Al<sup>IV</sup> atoms per formula unit (based on 23 oxygens).

Figure 5.1b: Ti and (Na+K) atomic variation of amphiboles from the mafic rocks.

Table 5.6: Microprobe analysis of pyroxene from the mafic rocks.  
 Cation proportions are calculated relative to 6 oxygens.  
 ca, mg, fe - cation proportions of Ca, Mg, Fe  
 recalculated to 100;  
 M -  $Mg/(Mg+Fe) * 100$ ,  
 C -  $Ca/(Ca+Mg) * 100$ ,  
 T1 - geothermometry sample number for diopside-enstatite  
 thermometry.

	M3A-1C	M3A-2C	M3A-3C	M3A-4C	M3A-5C	M3A-6C	M8A-1C	M8A-2C	M8A-3C	M8A-3R
SiO <sub>2</sub>	51.64	51.94	52.06	52.11	52.61	52.43	51.50	51.55	52.28	52.10
TiO <sub>2</sub>	.09	.08	.06	.07	.00	.00	.20	.19	.21	.18
Al <sub>2</sub> O <sub>3</sub>	2.82	1.99	1.53	1.70	1.13	1.61	2.23	2.31	1.90	1.77
Cr <sub>2</sub> O <sub>3</sub>	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00
FeO	10.72	9.90	9.96	9.98	9.59	9.83	9.71	8.73	8.35	9.29
MnO	.40	.35	.39	.41	.39	.44	.33	.31	.32	.28
MgO	12.30	12.27	12.46	12.43	12.78	12.45	13.69	13.33	13.54	13.99
CaO	21.82	22.45	22.72	22.67	22.88	22.65	21.29	22.94	22.74	21.99
Na <sub>2</sub> O	.65	.48	.48	.51	.42	.50	.54	.51	.50	.48
K <sub>2</sub> O	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.51	99.54	99.70	99.92	99.85	99.96	99.49	99.87	99.84	100.08
Si	1.935	1.960	1.965	1.962	1.978	1.970	1.939	1.933	1.954	1.948
Ti	.003	.002	.002	.002			.006	.005	.006	.005
Al	.125	.089	.068	.075	.050	.071	.099	.102	.084	.078
Cr		.001								
Fe <sup>2+</sup>	.336	.312	.314	.314	.302	.309	.306	.274	.261	.290
Mn	.013	.011	.012	.013	.012	.014	.011	.010	.010	.009
Mg	.687	.690	.701	.697	.716	.697	.768	.745	.754	.780
Ca	.876	.908	.919	.914	.922	.912	.859	.922	.911	.881
Na	.047	.035	.035	.037	.031	.036	.039	.037	.036	.035
K	.002									
Sum	4.024	4.010	4.017	4.017	4.012	4.012	4.026	4.029	4.016	4.025
ca	46.14	47.52	47.51	47.48	47.53	47.54	44.44	47.50	47.29	45.15
mg	36.17	36.12	36.24	36.21	36.92	36.35	39.74	38.39	39.16	39.96
fe	17.69	16.36	16.26	16.31	15.55	16.10	15.82	14.11	13.55	14.89
M	67.15	68.83	69.03	68.94	70.37	69.30	71.53	73.13	74.29	72.85
C	56.05	56.81	56.73	56.73	56.28	56.67	52.79	55.30	54.70	53.05

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

M3A-1C : CPX 493/144  
 M3A-2C : CPX 565/118  
 M3A-3C : CPX 479/61  
 M3A-4C : CPX 494/51  
 M3A-5C : CPX 577/14  
 M3A-6C : CPX 502/87  
 M8A-1C : PYROXENE 497/161  
 M8A-2C : PYROXENE 495/160  
 M8A-3C : PYROXENE 550/40  
 M8A-3R : PYROXENE 550/40 RIM

Table 5.6: continued

	M8A-4C	M8A-5C	M11C-1C	M11C-2C	M11C-3C	M11C-4C	M27C-1C	M27C-2C	M27C-3C	M27C-3R
SiO <sub>2</sub>	51.56	51.64	50.91	50.84	51.28	51.47	51.67	52.17	51.42	51.85
TiO <sub>2</sub>	.19	.15	.29	.23	.28	.25	.37	.27	.30	.20
Al <sub>2</sub> O <sub>3</sub>	2.13	2.50	1.92	2.11	2.15	2.31	2.38	1.98	2.15	1.64
Cr <sub>2</sub> O <sub>3</sub>	.00	.00	.00	.00	.00	.10	.13	.12	.09	.09
FeO	8.65	9.41	8.79	8.86	8.71	8.97	8.14	8.22	8.55	8.24
MnO	.31	.32	.36	.28	.32	.26	.17	.14	.20	.18
MgO	13.53	13.55	14.22	13.59	13.62	13.58	13.35	13.52	13.12	13.80
CaO	22.66	22.14	22.33	22.89	22.77	22.70	22.92	22.93	22.86	23.24
Na <sub>2</sub> O	.49	.55	.45	.52	.51	.50	.47	.42	.40	.34
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	99.52	100.26	99.27	99.32	99.64	100.14	99.60	99.77	99.09	99.58
Si	1.938	1.930	1.923	1.922	1.929	1.927	1.936	1.950	1.941	1.946
Ti	.005	.004	.008	.007	.008	.007	.010	.008	.009	.006
Al	.094	.110	.085	.094	.095	.102	.105	.087	.096	.073
Cr						.003	.004	.004	.003	.003
Fe <sup>2+</sup>	.272	.294	.278	.280	.274	.281	.255	.257	.270	.259
Mn	.010	.010	.012	.009	.010	.008	.005	.004	.006	.006
Mg	.758	.755	.800	.766	.763	.758	.746	.753	.738	.772
Ca	.913	.887	.904	.927	.918	.910	.920	.918	.925	.935
Na	.036	.040	.033	.038	.037	.036	.034	.030	.029	.025
K										
Sum	4.027	4.030	4.043	4.043	4.034	4.032	4.016	4.012	4.016	4.023
ca	46.98	45.81	45.60	47.00	46.94	46.72	47.91	47.62	47.84	47.56
mg	39.02	38.99	40.39	38.81	39.05	38.87	38.81	39.05	38.19	39.28
fe	14.00	15.20	14.01	14.20	14.01	14.41	13.28	13.33	13.97	13.16
M	73.60	71.96	74.24	73.21	73.59	72.96	74.51	74.56	73.22	74.90
C	54.63	54.02	53.03	54.77	54.59	54.58	55.25	54.94	55.61	54.77

\*\*\* All zero values below detection limit \*\*\*

**SAMPLE DESCRIPTION :**

M8A-4C : PYROXENE 437/37  
M8A-5C : PYROXENE 589/162  
M11C-1C : PYROXENE 443/190  
M11C-2C : PYROXENE 444/191  
M11C-3C : PYROXENE 436/142  
M11C-4C : PYROXENE 615/28  
M27C-1C : DIOPSIDE 422/48  
M27C-2C : DIOPSIDE 493/74 T5  
M27C-3C : DIOPSIDE 450/61 CORE T1  
M27C-3R : DIOPSIDE 450/61 RIM T1

Table 5.6: continued

	M27C-4C	M27C-5C	M27C-5R	M27C-6C	M27C-7C	M27C-8C	M27C-8R	M27C-9C	M27C-10C	M27C-10R	M27C-11C
SiO <sub>2</sub>	51.86	51.69	52.12	51.64	52.71	52.10	51.63	52.06	52.46	52.21	52.57
TiO <sub>2</sub>	.30	.26	.21	.35	.16	.00	.00	.00	.08	.29	.00
Al <sub>2</sub> O <sub>3</sub>	1.98	2.09	1.76	2.24	.94	1.08	.90	.98	1.03	1.09	.95
Cr <sub>2</sub> O <sub>3</sub>	.09	.08	.13	.12	.08	.00	.00	.08	.00	.00	.00
FeO	8.24	8.46	7.77	8.68	24.22	25.77	25.25	26.21	25.47	24.90	24.99
MnO	.18	.19	.17	.16	.38	.49	.45	.53	.48	.45	.39
MgO	13.74	13.52	14.05	13.46	21.49	21.18	21.22	21.21	21.56	21.52	21.48
CaO	23.02	22.97	22.94	22.46	.57	.32	.64	.36	.31	.34	.34
Na <sub>2</sub> O	.44	.47	.43	.42	.00	.00	.00	.00	.00	.00	.00
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	99.85	99.73	99.58	99.53	100.55	100.94	100.09	101.43	101.39	100.80	100.72
Si	1.940	1.938	1.950	1.938	1.969	1.954	1.952	1.948	1.955	1.953	1.966
Ti	.008	.007	.006	.010	.004				.002	.008	
Al	.087	.092	.078	.099	.041	.048	.040	.043	.045	.048	.042
Cr	.003	.002	.004	.004	.002			.002			
Fe <sup>2+</sup>	.258	.265	.243	.273	.757	.808	.799	.820	.794	.779	.782
Mn	.006	.006	.005	.005	.012	.016	.014	.017	.015	.014	.012
Mg	.766	.756	.783	.753	1.196	1.184	1.196	1.183	1.197	1.200	1.197
Ca	.923	.923	.919	.903	.023	.013	.026	.014	.012	.014	.014
Na	.032	.034	.031	.031							
K											
Sum	4.023	4.024	4.019	4.016	4.005	4.022	4.027	4.029	4.021	4.015	4.013
ca	47.40	47.48	47.25	46.83	1.15	.64	1.28	.72	.62	.68	.68
mg	39.35	38.87	40.25	39.04	60.55	59.04	59.19	58.63	59.76	60.22	60.09
fe	13.24	13.65	12.49	14.13	38.29	40.31	39.53	40.66	39.62	39.10	39.23
M	74.82	74.01	76.32	73.43	61.26	59.43	59.96	59.05	60.13	60.63	60.50
C	54.64	54.99	54.00	54.54	1.87	1.08	2.12	1.21	1.02	1.12	1.13

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTION :

M27C-4C : DIOPSIDE 466/7 T2  
M27C-5C : DIOPSIDE 485/160 CORE T3  
M27C-5R : DIOPSIDE 485/160 RIM T3  
M27C-6C : DIOPSIDE 620/119 T4  
M27C-7C : ENSTATITE 490/64 T5  
M27C-8C : ENSTATITE 450/62 CORE T1  
M27C-8R : ENSTATITE 450/62 RIM T1  
M27C-9C : ENSTATITE 466/8 CORE T2  
M27C-10C : ENSTATITE 484/160 CORE T3  
M27C-10R : ENSTATITE 484/160 RIM T3  
M27C-11C : ENSTATITE 620/120 CORE T4

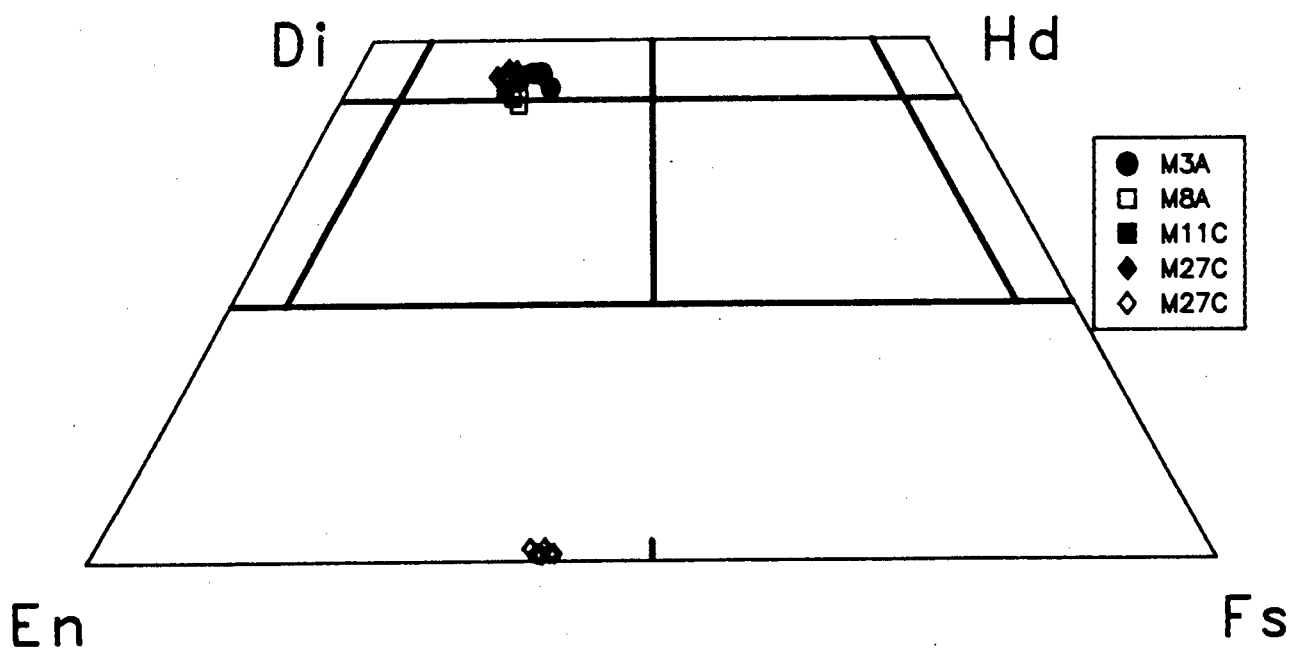


Figure 5.2: Compositions of the pyroxenes from the mafic rocks in the system  $\text{MgSiO}_3$  (En-enstatite) -  $\text{FeSiO}_3$  (Fs-ferrosilite) -  $\text{CaSiO}_3$ ; Di-diopside, Hd-hedenbergite.

Table 5.7: Microprobe analysis of plagioclase from the pelitic rocks. Cation proportions are calculated relative to 8 oxygens. An, Ab, Or - anorthite, albite, orthoclase proportions.

	P41C-1C	P41C-2C	P41C-2R	P41C-3C	P41C-4C	P41C-4R	P41C-5C	P5C-1C	P5C-2C	P5C-3C
SiO <sub>2</sub>	64.53	64.50	63.59	63.62	64.32	64.09	64.01	59.28	59.19	58.95
Al <sub>2</sub> O <sub>3</sub>	22.82	22.89	23.00	22.89	22.64	22.88	22.95	26.20	25.34	26.14
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.17	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	4.22	4.22	4.32	4.42	4.23	4.29	4.31	8.43	8.00	8.44
Na <sub>2</sub> O	9.02	8.98	8.87	8.87	8.97	8.93	9.08	6.64	6.82	6.49
K <sub>2</sub> O	.17	.15	.11	.11	.18	.12	.17	.06	.05	.08
Total	100.76	100.74	99.89	99.91	100.34	100.31	100.52	100.68	99.63	100.17
Si	2.824	2.823	2.808	2.810	2.827	2.818	2.812	2.628	2.651	2.626
Al	1.177	1.181	1.197	1.192	1.173	1.186	1.188	1.369	1.338	1.373
Fe <sup>2+</sup>									.006	
Mg										
Ca	.198	.198	.204	.209	.199	.202	.203	.400	.384	.403
Na	.765	.762	.760	.760	.764	.761	.773	.571	.592	.561
K	.009	.008	.006	.006	.010	.007	.010	.003	.003	.005
Sum	4.975	4.972	4.976	4.977	4.974	4.973	4.986	4.974	4.977	4.969
An	20.34	20.44	21.07	21.45	20.46	20.83	20.58	41.09	39.21	41.62
Ab	78.68	78.70	78.29	77.91	78.51	78.47	78.46	58.57	60.50	57.91
Or	.98	.87	.64	.64	1.04	.69	.97	.35	.29	.47

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P41C-1C	: PLAG 549/213
P41C-2C	: PLAG 467/210
P41C-2R	: PLAG 467/210 RIM
P41C-3C	: PLAG 545/165
P41C-4C	: PLAG 602/88
P41C-4R	: PLAG 602/88 RIM
P41C-5C	: PLAG 496/30
P5C-1C	: PLAG 601/208
P5C-2C	: PLAG 602/215
P5C-3C	: PLAG 570/224

Table 5.7: continued

	P5C-3R	P5C-4C	P5C-5C	P32C-1C	P32C-1R	P32C-2C	P32C-3C	P32-4C	P32-5C	P32C-5R
SiO <sub>2</sub>	59.24	59.08	58.86	62.10	62.18	62.52	62.57	62.51	62.45	61.60
Al <sub>2</sub> O <sub>3</sub>	25.48	26.05	26.19	24.16	24.20	23.92	24.12	24.07	24.10	24.22
FeO	.00	.00	.10	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	7.91	8.41	8.50	5.72	5.56	5.46	5.48	5.79	5.70	5.96
Na <sub>2</sub> O	6.86	6.39	6.66	8.16	8.20	8.37	8.35	8.16	8.14	7.99
K <sub>2</sub> O	.06	.06	.06	.10	.00	.07	.00	.09	.07	.00
Total	99.62	100.06	100.43	100.24	100.14	100.34	100.52	100.62	100.46	99.77
Si	2.651	2.632	2.619	2.744	2.747	2.758	2.754	2.751	2.752	2.735
Al	1.344	1.368	1.374	1.259	1.260	1.244	1.251	1.249	1.252	1.268
Fe <sup>2+</sup>			.004							
Mg										
Ca	.379	.402	.405	.271	.263	.258	.258	.273	.269	.284
Na	.595	.552	.575	.699	.703	.716	.713	.696	.695	.688
K	.003	.003	.003	.006		.004		.005	.004	
Sum	4.976	4.960	4.982	4.979	4.974	4.980	4.977	4.975	4.972	4.975
An	38.78	41.96	41.21	27.76	27.26	26.39	26.61	28.02	27.79	29.19
Ab	60.87	57.69	58.44	71.66	72.74	73.21	73.39	71.46	71.81	70.81
Or	.35	.36	.35	.58		.40		.52	.41	

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

- P5C-3R : PLAG 572/226 RIM
- P5C-4C : PLAG 562/185
- P5C-5C : PLAG 482/150
- P32C-1C : PLAG 534/58 CORE
- P32C-1R : PLAG 534/58 RIM
- P32C-2C : PLAG 487/49
- P32C-3C : PLAG 540/236
- P32-4C : PLAG 468/129
- P32-5C : PLAG 467/154
- P32C-5R : PLAG 467/154 RIM

Table 5.7: continued

	P34C-1C	P34C-2C	P34C-3C	P34C-4C	P38C-1C	P38C-2C	P38C-2R	P38C-3C	P38C-4C	P38C-5C
SiO <sub>2</sub>	62.27	62.47	62.71	62.48	61.88	61.73	61.48	61.63	61.74	61.20
Al <sub>2</sub> O <sub>3</sub>	23.74	23.62	23.68	23.63	24.43	24.64	24.49	24.74	24.05	24.36
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	5.56	5.68	5.70	5.63	6.26	6.36	6.24	6.21	5.58	6.01
Na <sub>2</sub> O	8.32	8.44	8.40	8.68	8.15	8.00	8.19	8.06	8.08	7.97
K <sub>2</sub> O	.11	.17	.16	.13	.08	.10	.00	.00	.57	.10
Total	100.00	100.38	100.65	100.55	100.80	100.83	100.40	100.64	100.02	99.64
Si	2.758	2.760	2.762	2.757	2.726	2.718	2.719	2.717	2.741	2.725
Al	1.239	1.230	1.229	1.229	1.268	1.279	1.277	1.286	1.259	1.278
Fe <sup>2+</sup>										
Mg										
Ca	.264	.269	.269	.266	.295	.300	.296	.293	.265	.287
Na	.715	.723	.717	.743	.696	.683	.702	.689	.696	.688
K	.006	.010	.009	.007	.004	.006			.032	.006
Sum	4.982	4.991	4.987	5.003	4.990	4.986	4.994	4.985	4.993	4.983
An	26.80	26.85	27.03	26.19	29.66	30.35	29.63	29.86	26.72	29.24
Ab	72.57	72.20	72.07	73.08	69.88	69.08	70.37	70.14	70.03	70.18
Or	.63	.96	.90	.72	.45	.57			3.25	.58

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P34C-1C : PLAGIOCLASE 455/13  
P34C-2C : PLAGIOCLASE 492/232  
P34C-3C : PLAGIOCLASE 529/162  
P34C-4C : PLAGIOCLASE 571/27  
P38C-1C : PLAGIOCLASE 525/154  
P38C-2C : PLAGIOCLASE 553/245  
P38C-2R : PLAGIOCLASE 553/245 RIM  
P38C-3C : PLAGIOCLASE 443/139  
P38C-4C : PLAGIOCLASE 510/86  
P38C-5C : PLAGIOCLASE 582/53 CORE

Table 5.7: continued

	P38C-5R	P42C-1C	P42C-2C	P42C-3C	P42C-3R	P42C-4C	P42C-5C	P45C-1C	P45C-2C	P45C-3C
SiO <sub>2</sub>	61.42	58.33	58.62	58.44	58.60	58.96	58.91	62.56	62.61	62.49
Al <sub>2</sub> O <sub>3</sub>	24.46	25.76	25.70	25.73	25.87	25.54	25.65	23.61	23.99	23.93
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	6.18	8.59	8.59	8.43	8.36	8.30	8.07	5.24	5.70	5.12
Na <sub>2</sub> O	8.04	6.49	6.44	6.57	6.53	6.70	6.82	8.27	8.23	8.28
K <sub>2</sub> O	.06	.15	.12	.15	.12	.13	.15	.11	.12	.16
Total	100.16	99.32	99.47	99.32	99.48	99.63	99.60	99.79	100.65	99.98
Si	2.722	2.625	2.632	2.628	2.629	2.642	2.640	2.772	2.755	2.763
Al	1.278	1.366	1.360	1.364	1.368	1.349	1.355	1.233	1.244	1.247
Fe <sup>2+</sup>										
Mg										
Ca	.293	.414	.413	.406	.402	.398	.387	.249	.269	.243
Na	.691	.566	.561	.573	.568	.582	.593	.710	.702	.710
K	.003	.009	.007	.009	.007	.007	.009	.006	.007	.009
Sum	4.987	4.980	4.972	4.980	4.974	4.979	4.983	4.970	4.977	4.972
An	29.71	41.88	42.14	41.13	41.14	40.33	39.19	25.77	27.49	25.23
Ab	69.95	57.25	57.16	58.00	58.15	58.92	59.94	73.59	71.82	73.83
Or	.34	.87	.70	.87	.70	.75	.87	.64	.69	.94

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P38C-5R : PLAGIOCLASE 582/53 RIM  
P42C-1C : PLAGIOCLASE 573/229  
P42C-2C : PLAG 508/190  
P42C-3C : PLAG 438/184  
P42C-3R : PLAG 438/184 RIM  
P42C-4C : PLAG 454/130  
P42C-5C : PLAG 62/64  
P45C-1C : PLAG 493/247  
P45C-2C : PLAG 515/200  
P45C-3C : PLAG 523/169

Table 5.7: continued

	P45C-4C	P45C-5C	P45C-5R	P50C-1C	P50C-1R	P50C-2C	P50C-3C	P50C-4C	P50C-5C	P50C-5R
SiO <sub>2</sub>	62.74	62.42	63.01	60.35	59.30	59.63	60.91	60.78	60.90	59.70
Al <sub>2</sub> O <sub>3</sub>	23.78	23.72	24.01	25.30	25.87	25.85	25.02	24.99	24.81	25.63
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.19
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	5.36	5.46	5.54	7.19	8.04	7.65	6.96	6.88	6.72	7.51
Na <sub>2</sub> O	8.26	8.43	8.21	7.24	6.79	7.02	7.39	7.33	7.42	6.96
K <sub>2</sub> O	.13	.10	.11	.07	.08	.06	.11	.09	.16	.10
Total	100.27	100.13	100.88	100.15	100.08	100.21	100.39	100.07	100.01	100.09
Si	2.768	2.761	2.763	2.679	2.642	2.650	2.696	2.697	2.704	2.657
Al	1.236	1.237	1.241	1.324	1.358	1.354	1.305	1.307	1.299	1.345
Fe <sup>2+</sup>										.007
Mg				.342	.384	.364	.330	.327	.320	.358
Ca	.253	.259	.260	.623	.586	.605	.634	.631	.639	.601
Na	.707	.723	.698	.004	.005	.003	.006	.005	.009	.006
K	.007	.006	.006							
Sum	4.971	4.985	4.969	4.972	4.975	4.977	4.972	4.967	4.970	4.974
An	26.19	26.21	26.99	35.29	39.37	37.45	34.01	33.97	33.04	37.13
Ab	73.05	73.22	72.37	64.30	60.17	62.20	65.35	65.50	66.02	62.28
Or	.76	.57	.64	.41	.47	.35	.64	.53	.94	.59

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P45C-4C : PLAG 578/78  
P45C-5C : PLAG 590/23 CORE  
P45C-5R : PLAG 590/23 RIM  
P50C-1C : PLAGIOCLASE 570/143 CORE  
P50C-1R : PLAGIOCLASE 570/143 RIM  
P50C-2C : PLAGIOCLASE 553/107 CORE  
P50C-3C : PLAGIOCLASE 497/58 CORE  
P50C-4C : PLAGIOCLASE 443/127 CORE  
P50C-5C : PLAGIOCLASE 481/103 INCL  
P50C-5R : PLAGIOCLASE 481/106 RIM

Table 5.7: continued

	P50C-6C	P7D-1C	P7D-2C	P7D-3C	P7D-4C	P7D-5C	P7D-6C	P25C-1C	P25C-2C	P25C-3C
SiO <sub>2</sub>	59.09	61.23	60.62	61.56	62.07	61.85	62.25	60.62	61.23	60.57
Al <sub>2</sub> O <sub>3</sub>	26.32	24.56	24.60	24.12	23.88	24.14	24.19	24.43	24.60	24.63
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	8.62	6.75	6.57	5.94	5.86	6.25	5.89	6.18	6.42	6.35
Na <sub>2</sub> O	6.66	7.80	7.48	7.92	8.09	7.88	7.97	7.37	7.47	7.62
K <sub>2</sub> O	.07	.07	.07	.09	.09	.11	.08	.55	.42	.45
Total	100.76	100.41	99.34	99.63	99.99	100.23	100.38	99.15	100.14	99.62
Si	2.620	2.710	2.708	2.738	2.750	2.737	2.746	2.716	2.716	2.705
Al	1.375	1.281	1.295	1.265	1.247	1.259	1.258	1.290	1.286	1.296
Fe <sup>2+</sup>										
Mg										
Ca	.409	.320	.315	.283	.278	.296	.278	.297	.305	.304
Na	.573	.670	.648	.683	.695	.676	.682	.640	.643	.660
K	.004	.004	.004	.005	.005	.006	.005	.031	.024	.026
Sum	4.981	4.986	4.970	4.974	4.976	4.975	4.968	4.975	4.974	4.990
An	41.53	32.22	32.54	29.15	28.44	30.28	28.86	30.64	31.41	30.71
Ab	58.07	67.38	67.04	70.33	71.04	69.09	70.67	66.12	66.14	66.70
Or	.40	.40	.41	.53	.52	.63	.47	3.25	2.45	2.59

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P50C-6C : PLAGIOCLASE 509/158  
P7D-1C : PLAGIOCLASE 593/278  
P7D-2C : PLAGIOCLASE 601/102  
P7D-3C : PLAGIOCLASE 460/160  
P7D-4C : PLAGIOCLASE 430/181  
P7D-5C : PLAGIOCLASE 579/124  
P7D-6C : PLAGIOCLASE 595/82  
P25C-1C : PLAGIOCLASE 533/116  
P25C-2C : PLAGIOCLASE 516/58  
P25C-3C : PLAGIOCLASE 611/248

Table 5.7: continued

	P25C-4C	P25C-4R	P25C-5C	P14C-1C	P14C-2C	P14C-3C	P14C-4C	P14C-4R	P14C-5C	P19C-1C
SiO <sub>2</sub>	63.00	60.49	61.51	61.04	61.23	61.23	61.17	59.96	60.82	60.52
Al <sub>2</sub> O <sub>3</sub>	24.39	25.10	24.37	24.09	24.43	24.39	24.31	24.78	24.35	24.98
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	6.22	6.28	6.31	6.12	6.48	6.53	6.44	6.85	6.27	7.05
Na <sub>2</sub> O	7.39	7.18	7.50	7.57	7.39	7.40	7.29	7.16	7.47	7.56
K <sub>2</sub> O	.47	.73	.48	.16	.23	.19	.31	.15	.12	.11
Total	101.47	99.78	100.17	99.05	99.83	99.81	99.59	98.97	99.10	100.29
Si	2.750	2.696	2.727	2.732	2.722	2.722	2.725	2.692	2.721	2.686
Al	1.255	1.318	1.274	1.271	1.280	1.278	1.277	1.311	1.284	1.307
Fe <sup>2+</sup>										
Mg										
Ca	.291	.300	.300	.293	.309	.311	.307	.330	.301	.335
Na	.626	.620	.645	.657	.637	.638	.630	.623	.648	.651
K	.026	.042	.027	.009	.013	.011	.018	.009	.007	.006
Sum	4.948	4.976	4.972	4.965	4.963	4.963	4.959	4.968	4.964	4.988
An	30.86	31.18	30.85	30.59	32.20	32.41	32.20	34.28	31.46	33.79
Ab	66.36	64.51	66.36	68.46	66.44	66.47	65.96	64.83	67.82	65.58
Or	2.78	4.31	2.79	.95	1.36	1.12	1.85	.89	.72	.63

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

- P25C-4C : PLAGIOCLASE 608/25 CORE
- P25C-4R : PLAGIOCLASE 608/25 RIM
- P25C-5C : PLAGIOCLASE 497/74
- P14C-1C : PLAG 464/208
- P14C-2C : PLAG 539/176
- P14C-3C : PLAG 579/152
- P14C-4C : PLAG 514/54
- P14C-4R : PLAG 514/54 RIM
- P14C-5C : PLAG 464/187
- P19C-1C : PLAGIOCLASE 438/68

Table 5.7: continued

	P19C-2C	P19C-3C	P19C-3R	P19C-4C	P21C-1C	P21C-2C	P21C-3C	P21C-3R	P21C-4C	P21C-4R
SiO <sub>2</sub>	60.66	60.05	60.60	60.57	62.13	61.70	62.16	62.19	62.50	62.17
Al <sub>2</sub> O <sub>3</sub>	25.05	24.91	24.98	25.13	23.85	23.92	23.68	24.25	23.58	23.92
FeO	.00	.00	.10	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.06
CaO	6.90	6.82	7.12	7.00	5.95	6.03	5.85	5.96	5.73	5.80
Na <sub>2</sub> O	7.42	7.53	7.47	7.32	8.10	8.08	8.17	8.19	8.32	8.26
K <sub>2</sub> O	.08	.15	.10	.12	.45	.36	.46	.37	.38	.42
Total	100.18	99.53	100.43	100.21	100.48	100.09	100.32	100.96	100.51	100.63
Si	2.691	2.685	2.687	2.687	2.747	2.739	2.752	2.736	2.760	2.745
Al	1.310	1.313	1.305	1.314	1.243	1.252	1.236	1.258	1.228	1.245
Fe <sup>2+</sup>			.004							.004
Mg										
Ca	.328	.327	.338	.333	.282	.287	.278	.281	.271	.274
Na	.638	.653	.642	.630	.694	.695	.701	.699	.712	.707
K	.005	.009	.006	.007	.025	.020	.026	.021	.021	.024
Sum	4.975	4.989	4.984	4.973	4.992	4.993	4.993	4.995	4.993	4.998
An	33.79	33.07	34.30	34.33	28.14	28.60	27.62	28.08	26.98	27.30
Ab	65.75	66.07	65.13	64.97	69.32	69.36	69.80	69.84	70.89	70.35
Or	.47	.87	.57	.70	2.53	2.03	2.59	2.08	2.13	2.35

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P19C-2C : PLAGIOCLASE 577/68  
P19C-3C : PLAGIOCLASE 600/81  
P19C-3R : PLAGIOCLASE 600/81 RIM  
P19C-4C : PLAGIOCLASE 580/229  
P21C-1C : PLAGIOCLASE 451/125  
P21C-2C : PLAGIOCLASE 433/146  
P21C-3C : PLAGIOCLASE 493/112 CORE  
P21C-3R : PLAGIOCLASE 493/112 RIM TO QTZ  
P21C-4C : PLAGIOCLASE 483/170 CORE  
P21C-4R : PLAGIOCLASE 483/170 RIM

Table 5.7: continued

	P21C-5C	P21C-5R	P1D-1C	P1D-2C	P1D-3C	P1D-4C	P8C-1C	P8C-2C	P8C-3C	P8C-4C
SiO <sub>2</sub>	62.49	62.44	62.22	60.92	61.44	61.70	61.90	61.91	62.13	62.08
Al <sub>2</sub> O <sub>3</sub>	23.64	23.55	23.50	24.19	23.91	23.87	23.58	23.46	23.75	23.28
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	5.47	5.66	5.73	6.29	5.96	5.86	5.79	5.51	5.82	5.50
Na <sub>2</sub> O	8.44	8.25	7.99	7.68	7.90	7.98	7.89	7.75	7.78	7.86
K <sub>2</sub> O	.41	.32	.19	.12	.11	.11	.25	.34	.25	.31
Total	100.45	100.22	99.63	99.20	99.32	99.52	99.48	99.05	99.81	99.10
Si	2.761	2.763	2.765	2.725	2.742	2.747	2.758	2.767	2.757	2.773
Al	1.231	1.228	1.231	1.275	1.258	1.253	1.238	1.236	1.242	1.226
Fe <sup>2+</sup>										
Mg										
Ca	.259	.268	.273	.301	.285	.280	.276	.264	.277	.263
Na	.723	.708	.689	.666	.684	.689	.682	.672	.669	.681
K	.023	.018	.011	.007	.006	.006	.014	.019	.014	.018
Sum	4.997	4.986	4.969	4.974	4.974	4.974	4.971	4.960	4.963	4.963
An	25.76	26.99	28.07	30.94	29.23	28.68	28.43	27.63	28.82	27.37
Ab	71.94	71.19	70.82	68.36	70.12	70.68	70.11	70.34	69.71	70.79
Or	2.30	1.82	1.11	.70	.64	.64	1.46	2.03	1.47	1.84

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P21C-5C : PLAGIOCLASE 468/200  
P21C-5R : PLAGIOCLASE 468/200 RIM TO GAR  
P1D-1C : PLAG 544/167  
P1D-2C : PLAG 487/241  
P1D-3C : PLAG 469/253  
P1D-4C : PLAG 544/103  
P8C-1C : PLAG 529/205  
P8C-2C : PLAG 586/206  
P8C-3C : PLAG 576/148  
P8C-4C : PLAG 448/32

Table 5.7: continued

	P8C-5C	P8C-6C	P3D-1C	P3D-2C	P3D-2R	P3D-3C	P3D-4C	P3D-4C	P5D-1C	P5D-1R
SiO <sub>2</sub>	62.02	61.62	63.00	62.89	62.54	63.13	62.67	62.26	60.73	60.13
Al <sub>2</sub> O <sub>3</sub>	23.71	23.43	22.86	22.84	22.97	22.93	22.98	23.32	24.56	24.80
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	5.82	5.63	4.73	4.62	4.90	4.82	4.80	5.14	6.55	7.12
Na <sub>2</sub> O	7.78	8.04	9.09	8.86	8.66	8.74	9.06	8.76	7.85	7.55
K <sub>2</sub> O	.29	.25	.18	.21	.16	.24	.14	.08	.17	.13
Total	99.69	99.06	99.86	99.42	99.23	99.86	99.65	99.56	99.86	99.73
Si	2.756	2.758	2.794	2.798	2.788	2.797	2.786	2.770	2.705	2.685
Al	1.242	1.236	1.195	1.198	1.207	1.197	1.204	1.223	1.289	1.305
Fe <sup>2+</sup>										
Mg	.001				.234	.229	.229	.245	.313	.341
Ca	.277	.270	.225	.220	.749	.751	.781	.756	.678	.654
Na	.670	.698	.782	.764	.009	.014	.008	.005	.010	.007
K	.016	.014	.010	.012						
Sum	4.965	4.979	5.005	4.992	4.987	4.987	5.007	4.998	4.994	4.993
An	28.75	27.49	22.11	22.10	23.60	23.04	22.47	24.38	31.25	34.01
Ab	69.54	71.05	76.89	76.70	75.48	75.60	76.75	75.17	67.78	65.26
Or	1.71	1.45	1.00	1.20	.92	1.37	.78	.45	.97	.74

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

- P8C-5C : PLAG 448/32 RIM
- P8C-6C : PLAG 473/34
- P3D-1C : PLAG 358/163
- P3D-2C : PLAG 547/167
- P3D-2R : PLAG 547/167 RIM
- P3D-3C : PLAG 618/115
- P3D-4C : PLAG 459/73
- P3D-4C : PLAG 429/51
- P5D-1C : PLAG 472/172 CORE
- P5D-1R : PLAG 472/172 RIM

Table 5.7: continued

	P5D-2C	P5D-2R	P5D-3C	P5D-4C	V6D-1C	V6D-2C	V6D-3C	V6D-4C	V6D-4R	V6D-5C	V6D-6C
SiO <sub>2</sub>	60.84	60.71	60.87	60.30	64.82	64.95	64.86	64.54	64.47	64.74	64.60
Al <sub>2</sub> O <sub>3</sub>	24.46	24.66	24.28	24.57	22.08	21.98	21.80	22.09	22.07	21.79	21.92
FeO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CaO	6.60	6.72	6.63	6.85	3.37	3.51	3.42	3.68	3.76	3.43	3.56
Na <sub>2</sub> O	7.89	7.97	8.02	7.81	9.27	9.05	9.25	8.97	8.99	9.14	9.02
K <sub>2</sub> O	.19	.14	.16	.18	.37	.50	.46	.41	.27	.38	.43
Total	99.98	100.20	99.96	99.71	99.91	99.99	99.79	99.69	99.56	99.48	99.53
Si	2.707	2.698	2.711	2.694	2.857	2.861	2.864	2.852	2.851	2.865	2.859
Al	1.283	1.292	1.274	1.294	1.147	1.141	1.135	1.151	1.151	1.137	1.143
Fe <sup>2+</sup>											
Mg											
Ca	.315	.320	.316	.328	.159	.166	.162	.174	.178	.163	.169
Na	.681	.687	.692	.677	.792	.773	.792	.769	.771	.784	.774
K	.011	.008	.009	.010	.021	.028	.026	.023	.015	.021	.024
Sum	4.997	5.004	5.003	5.003	4.976	4.969	4.978	4.969	4.966	4.970	4.969
An	31.27	31.53	31.08	32.32	16.37	17.14	16.52	18.04	18.48	16.79	17.46
Ab	67.65	67.68	68.03	66.67	81.49	79.96	80.84	79.57	79.94	80.99	80.03
Or	1.07	.78	.89	1.01	2.14	2.91	2.64	2.39	1.58	2.22	2.51

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P5D-2C : PLAG 566/43 CORE  
P5D-2R : PLAG 566/43 RIM  
P5D-3C : PLAG 580/190  
P5D-4C : PLAG 511/177  
V6D-1C : PLAG 578/251  
V6D-2C : PLAG 626/27  
V6D-3C : PLAG 497/117  
V6D-4C : PLAG 544/53 CORE  
V6D-4R : PLAG 544/53 RIM  
V6D-5C : PLAG 511/70  
V6D-6C : PLAG 482/80

Table 5.8: Microprobe analysis of biotite from the pelitic rocks.  
 Cation proportions are calculated relative to 22 oxygens.  
 M - Mg/(Mg+Fe) \* 100,  
 T1,G (H,C,A,MX) - geothermobarometry sample number with  
 biotite in contact with garnet (hypersthene,  
 cordierite, orthoamphibole, matrix).

	P17C-1C	P17C-1R	P17C-2C	P17C-3C	P17C-4C	P17C-5C	P17C-6C	P17C-6R	P41C-1C	P41C-2C
SiO <sub>2</sub>	38.73	37.91	37.29	37.28	36.65	36.53	37.17	35.70	36.42	37.78
TiO <sub>2</sub>	2.60	2.29	3.21	3.41	3.41	3.99	4.14	4.11	2.81	2.78
Al <sub>2</sub> O <sub>3</sub>	19.50	18.82	18.50	18.83	18.33	18.37	18.84	17.43	18.85	19.16
Cr <sub>2</sub> O <sub>3</sub>	.21	.16	.23	.24	.21	.20	.23	.21	.24	.24
FeO	11.33	10.93	12.32	12.37	13.82	14.36	15.91	16.05	13.57	12.68
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	16.25	16.54	15.32	14.91	13.95	13.12	12.00	12.92	14.49	15.59
CaO	.06	.10	.00	.00	.00	.00	.04	.00	.09	.17
Na <sub>2</sub> O	.06	.09	.08	.17	.00	.07	.07	.04	.20	.29
K <sub>2</sub> O	7.97	7.94	8.73	8.62	8.86	8.90	8.97	9.18	7.99	7.77
NiO	.00	.00	.00	.00	.00	.12	.00	.00		
F	.00	.00	.30	.00	.00	.28	.00	.00	1.55	1.06
Cl	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	96.71	94.78	95.98	95.83	95.23	95.94	97.37	95.64	96.21	97.52
Si	5.496	5.494	5.425	5.412	5.407	5.386	5.408	5.333	5.377	5.427
Ti	.277	.250	.351	.372	.378	.442	.453	.462	.312	.300
Al <sup>IV</sup>	2.504	2.506	2.575	2.588	2.593	2.614	2.592	2.667	2.623	2.573
Al <sup>VI</sup>	.758	.709	.598	.634	.594	.578	.639	.402	.657	.671
Cr	.024	.018	.026	.028	.024	.023	.026	.025	.028	.027
Fe <sup>2+</sup>	1.345	1.325	1.499	1.502	1.705	1.771	1.936	2.005	1.676	1.523
Mn										
Mg	3.437	3.572	3.322	3.226	3.067	2.883	2.602	2.877	3.188	3.337
Ca	.009	.016					.006		.014	.026
Na	.017	.025	.023	.048		.020	.020	.012	.057	.081
K	1.443	1.468	1.620	1.597	1.667	1.674	1.665	1.750	1.505	1.424
Ni						.014				
Sum	15.313	15.386	15.445	15.412	15.444	15.410	15.352	15.538	15.438	15.390
M	71.88	72.95	68.90	68.23	64.27	61.95	57.34	58.92	65.55	68.66

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P17C-1C : BIOTITE 462/148 T1,G  
 P17C-1R : BIOTITE 462/148 T1,G  
 P17C-2C : BIOTITE 489/160 T2,G  
 P17C-3C : BIOTITE 517/182 T3,G  
 P17C-4C : BIOTITE 572/180 T4,G  
 P17C-5C : BIOTITE 442/175 T5,MX  
 P17C-6C : BIOTITE 604/90 T6,MX  
 P17C-6R : BIOTITE 604/90 T6,MX  
 P41C-1C : BIOTITE 534/110 T3,MX  
 P41C-2C : BIOTITE 497/246 T1,G

Table 5.8: continued

	P41C-2R	P41C-3C	P41C-4C	P32C-1C	P34C-1C	P34C-2C	P34C-2R	P38C-1C	P38C-2C	P38C-3C
SiO <sub>2</sub>	36.71	37.23	37.42	38.46	37.48	37.72	37.68	37.40	37.18	37.85
TiO <sub>2</sub>	2.62	2.84	2.95	2.28	2.40	2.48	2.35	2.52	1.93	2.53
Al <sub>2</sub> O <sub>3</sub>	19.05	19.24	18.98	18.64	18.01	18.36	18.15	18.07	17.93	18.19
Cr <sub>2</sub> O <sub>3</sub>	.21	.18	.26	.40	.35	.34	.31	.28	.17	.39
FeO	12.99	14.07	13.31	11.73	12.01	11.94	11.64	13.65	14.25	14.30
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	15.64	14.97	14.61	17.14	16.02	16.45	16.48	14.70	14.85	14.93
CaO	.35	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.36	.43	.32	.38	.28	.32	.24	.61	.44	.51
K <sub>2</sub> O	8.19	7.99	8.37	8.06	8.37	8.74	8.76	7.89	7.63	7.68
NiO										
F	1.27	.61	.38	.00	.00	.15	.15	.00	.00	.00
Cl	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	97.39	97.56	96.60	97.09	94.92	96.50	95.76	95.12	94.38	96.38
Si	5.334	5.369	5.427	5.471	5.484	5.444	5.473	5.492	5.508	5.488
Ti	.286	.308	.322	.244	.264	.269	.257	.278	.215	.276
Al4	2.666	2.631	2.573	2.529	2.516	2.556	2.523	2.508	2.492	2.512
Al6	.597	.639	.671	.597	.590	.568	.580	.620	.639	.597
Cr	.024	.021	.030	.045	.040	.039	.036	.033	.020	.045
Fe2+	1.579	1.697	1.614	1.396	1.470	1.441	1.414	1.676	1.765	1.734
Mn										
Mg	3.387	3.217	3.158	3.634	3.493	3.539	3.567	3.217	3.279	3.226
Ca	.054									
Na	.101	.120	.090	.105	.079	.090	.068	.174	.126	.143
K	1.518	1.470	1.549	1.463	1.562	1.609	1.623	1.478	1.442	1.421
Ni										
Sum	15.546	15.473	15.434	15.483	15.500	15.555	15.544	15.476	15.486	15.441
M	68.21	65.47	66.17	72.25	70.39	71.06	71.62	65.74	65.00	65.04

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P41C-2R : BIOTITE 497/246 T1,G  
P41C-3C : BIOTITE 566/58 T2,G  
P41C-4C : BIOTITE 512/243 T4,MX  
P32C-1C : BIOTITE 516/64 MX  
P34C-1C : BIOTITE 438/98 T1,MX  
P34C-2C : BIOTITE 447/195 T2,MX  
P34C-2R : BIOTITE 447/195 T2,MX  
P38C-1C : BIOTITE 553/170 MX  
P38C-2C : BIOTITE 476/173 MX  
P38C-3C : BIOTITE 562/55 G

Table 5.8: continued

	P38C-4C	P38C-4R	P42C-1C	P42C-1R	P42C-2C	P42C-3C	P50C-1C	P50C-1R	P50C-2C	P50C-3C
SiO <sub>2</sub>	37.55	37.56	36.87	36.56	36.09	36.23	38.12	37.83	37.79	38.37
TiO <sub>2</sub>	2.30	2.24	3.79	3.78	3.88	4.17	3.04	3.18	2.88	3.07
Al <sub>2</sub> O <sub>3</sub>	18.26	18.46	16.66	16.76	16.96	16.44	18.34	18.31	18.65	18.10
Cr <sub>2</sub> O <sub>3</sub>	.32	.28	.33	.33	.51	.26	.60	.71	.39	.36
FeO	14.04	12.85	14.86	14.69	14.22	15.38	10.15	10.54	10.10	10.05
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	15.01	15.17	14.55	14.49	14.94	13.98	17.15	17.01	17.56	17.73
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.54	.50	.26	.20	.50	.16	.24	.29	.25	.34
K <sub>2</sub> O	8.02	7.90	8.34	8.37	7.56	8.88	8.52	8.56	8.38	8.31
NiO										
F	.00	.00	.30	.32	.16	.21	.31	.22	.30	.13
Cl	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	96.04	94.96	95.96	95.50	94.66	95.71	96.47	96.65	96.30	96.46
Si	5.472	5.496	5.445	5.426	5.362	5.399	5.458	5.420	5.414	5.473
Ti	.252	.247	.421	.422	.434	.467	.327	.343	.310	.329
Al <sub>4</sub>	2.528	2.504	2.555	2.574	2.638	2.601	2.542	2.580	2.586	2.527
Al <sub>6</sub>	.608	.680	.345	.358	.332	.287	.553	.512	.564	.516
Cr	.037	.032	.039	.039	.060	.031	.068	.080	.044	.041
Fe <sub>2+</sub>	1.711	1.573	1.835	1.823	1.767	1.917	1.215	1.263	1.210	1.199
Mn										
Mg	3.260	3.308	3.202	3.205	3.308	3.105	3.659	3.632	3.749	3.769
Ca										
Na	.153	.142	.074	.058	.144	.046	.067	.081	.069	.094
K	1.491	1.475	1.571	1.585	1.433	1.688	1.556	1.565	1.532	1.512
Ni										
Sum	15.511	15.457	15.488	15.488	15.478	15.541	15.445	15.474	15.479	15.459
M	65.58	67.78	63.57	63.74	65.18	61.83	75.07	74.20	75.60	75.87

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P38C-4C : BIOTITE 557/52 G  
P38C-4R : BIOTITE 557/52 G  
P42C-1C : BIOTITE 453/0 T1,G  
P42C-1R : BIOTITE 453/0 T1,G  
P42C-2C : BIOTITE 539/B T2,G  
P42C-3C : BIOTITE 489/42 T3,MX  
P50C-1C : BIOTITE 436/132 T1,G  
P50C-1R : BIOTITE 436/132 T1,G  
P50C-2C : BIOTITE 462/132 T2,G  
P50C-3C : BIOTITE 605/112 T3,INCL G

Table 5.8: continued

	P50C-4C	P50C-4R	P50C-5C	P50C-6C	P50C-7C	P50C-7R	P50C-8C	P7D-1C	P7D-1R	P7D-2C
SiO <sub>2</sub>	38.22	38.10	37.91	37.62	37.30	37.17	37.33	38.00	37.54	37.86
TiO <sub>2</sub>	3.02	3.20	3.20	2.27	3.09	3.34	3.16	2.00	1.52	2.19
Al <sub>2</sub> O <sub>3</sub>	18.21	18.45	18.12	18.32	18.45	18.40	18.17	17.82	19.07	17.91
Cr <sub>2</sub> O <sub>3</sub>	.47	.61	.38	.30	.55	.61	.63	.63	.34	.39
FeO	10.79	10.87	11.35	12.42	13.65	13.28	12.57	11.79	11.97	11.14
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	16.93	16.76	16.57	16.66	14.97	14.86	15.83	16.90	17.05	17.19
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.21	.14	.24	.21	.22	.16	.25	.51	.52	.46
K <sub>2</sub> O	8.86	8.94	9.02	8.89	8.82	8.87	8.76	7.95	7.84	8.07
NiO								.17	.19	.19
F	.22	.00	.16	.21	.18	.14	.13	.00	.00	.11
Cl	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	96.93	97.07	96.95	96.90	97.05	96.83	96.83	95.77	96.04	95.51
Si	5.465	5.434	5.441	5.427	5.396	5.391	5.395	5.505	5.419	5.492
Ti	.325	.343	.345	.246	.336	.364	.343	.218	.165	.239
Al	2.535	2.566	2.559	2.573	2.604	2.609	2.605	2.495	2.581	2.508
Al <sub>6</sub>	.534	.535	.506	.542	.542	.537	.490	.548	.664	.554
Cr	.053	.069	.043	.034	.063	.070	.072	.072	.039	.045
Fe <sub>2+</sub>	1.290	1.296	1.362	1.499	1.651	1.611	1.519	1.428	1.445	1.351
Mn										
Mg	3.608	3.562	3.544	3.582	3.227	3.212	3.410	3.648	3.668	3.716
Ca										
Na	.058	.039	.067	.059	.062	.045	.070	.143	.146	.129
K	1.616	1.627	1.652	1.636	1.628	1.641	1.615	1.469	1.444	1.493
Ni										
Sum	15.486	15.471	15.519	15.599	15.509	15.480	15.520	15.526	15.569	15.527
M	73.66	73.32	72.23	70.50	66.15	66.60	69.18	71.87	71.74	73.33

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P50C-4C : BIOTITE 536/118 T4,G  
P50C-4R : BIOTITE 536/118 T4,G  
P50C-5C : BIOTITE 568/106 T5,MX  
P50C-6C : BIOTITE 438/173 T6,MX  
P50C-7C : BIOTITE 481/230 A  
P50C-7R : BIOTITE 481/230 A  
P50C-8C : BIOTITE 591/232 INCL A  
P7D-1C : BIOTITE 508/174 T1,G  
P7D-1R : BIOTITE 509/174 T1,G  
P7D-2C : BIOTITE 570/278 T2,G

Table 5.8: continued

	P7D-3C	P7D-3R	P7D-4C	P7D-5C	P25C-5C	P25C-5R	P25C-6C	P25C-7C	P25C-7R	P25C-8C
SiO <sub>2</sub>	37.89	38.03	37.38	37.60	37.19	37.53	37.49	36.76	37.34	37.12
TiO <sub>2</sub>	2.29	2.13	2.38	2.35	5.11	5.25	5.25	5.36	5.30	5.76
Al <sub>2</sub> O <sub>3</sub>	18.06	18.55	17.96	18.45	17.45	17.04	17.16	17.31	17.31	17.40
Cr <sub>2</sub> O <sub>3</sub>	.62	.45	.43	.43	.73	.71	.61	.57	.59	.60
FeO	11.61	11.33	12.05	12.01	10.52	10.31	10.13	10.47	10.81	12.11
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	17.19	16.93	16.87	16.86	15.59	15.93	15.55	15.21	15.39	15.00
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.47	.47	.43	.41	.00	.00	.00	.00	.00	.00
K <sub>2</sub> O	7.90	7.99	8.07	7.96	9.30	9.09	9.29	9.58	9.19	9.12
NiO										
F	.14	.00	.19	.18	.30	.35	.48	.41	.35	.35
Cl	.00	.00	.03	.00						
Total	96.17	95.88	95.79	96.25	96.19	96.21	95.96	95.67	96.28	97.46
Si	5.458	5.474	5.432	5.424	5.391	5.428	5.443	5.377	5.411	5.348
Ti	.248	.231	.260	.255	.557	.571	.573	.590	.578	.624
Al4	2.542	2.526	2.568	2.576	2.609	2.572	2.557	2.623	2.589	2.652
Al6	.525	.621	.508	.561	.373	.333	.380	.361	.368	.303
Cr	.071	.051	.049	.049	.084	.081	.070	.066	.068	.068
Fe2+	1.399	1.364	1.465	1.449	1.275	1.247	1.230	1.281	1.310	1.459
Mn										
Mg	3.691	3.631	3.654	3.625	3.368	3.434	3.365	3.316	3.324	3.221
Ca										
Na	.131	.131	.121	.115						
K	1.452	1.467	1.496	1.465	1.720	1.677	1.721	1.788	1.699	1.676
Ni										
Sum	15.516	15.496	15.554	15.518	15.378	15.345	15.340	15.402	15.348	15.354
M	72.52	72.70	71.39	71.44	72.53	73.36	73.23	72.13	71.73	68.82

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P7D-3C : BIOTITE 530/123 T3,G  
P7D-3R : BIOTITE 530/123 T3,G  
P7D-4C : BIOTITE 439/175 T4(T6),MX  
P7D-5C : BIOTITE 569/123 T5,MX  
P25C-5C : BIOTITE 460/110 T5,G  
P25C-5R : BIOTITE 460/110 T5,G  
P25C-6C : BIOTITE 436/225 T6,G  
P25C-7C : BIOTITE 452/220 T7,G  
P25C-7R : BIOTITE 452/220 T7,G  
P25C-8C : BIOTITE 483/193 T8,MX

Table 5.8: continued

	P25C-8R	P25C-9C	P25C-10C	P25C-10R	P14C-1C	P14C-5C	P14C-6C	P14C-7C	P14C-9C	P14C-10C
SiO <sub>2</sub>	37.19	36.46	36.59	36.77	36.51	37.47	37.16	36.41	36.96	37.01
TiO <sub>2</sub>	5.70	5.58	5.53	5.74	4.76	4.20	3.74	4.50	4.45	4.52
Al <sub>2</sub> O <sub>3</sub>	17.31	16.85	17.17	16.62	17.17	17.38	18.40	17.54	17.63	17.75
Cr <sub>2</sub> O <sub>3</sub>	.51	.56	.61	.58	.71	.77	.49	.48	.61	.73
FeO	11.37	11.43	11.53	11.60	12.91	9.99	9.22	12.48	12.67	13.03
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	15.30	14.97	14.66	14.99	14.47	16.96	17.73	14.41	14.41	14.69
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.00	.00	.09	.00	.17	.22	.17	.14	.13	.15
K <sub>2</sub> O	9.35	9.61	9.53	9.49	8.98	9.02	8.70	8.61	8.66	8.89
NiO					.00	.00	.00	.00	.14	.00
F	.34	.28	.34	.33	.30	.35	.40	.53	.00	.31
Cl					.00	.00	.00	.00	.00	.00
Total	97.07	95.74	95.72	96.12	95.98	96.36	96.01	95.10	95.66	97.08
Si	5.367	5.355	5.358	5.380	5.367	5.404	5.345	5.385	5.407	5.367
Ti	.619	.616	.609	.632	.526	.456	.405	.501	.490	.493
Al4	2.645	2.645	2.642	2.620	2.593	2.596	2.655	2.615	2.593	2.633
Al6	.299	.272	.321	.246	.382	.359	.465	.443	.447	.401
Cr	.058	.065	.071	.067	.083	.088	.056	.056	.071	.084
Fe2+	1.372	1.404	1.412	1.420	1.587	1.205	1.109	1.544	1.550	1.580
Mn										
Mg	3.291	3.277	3.199	3.269	3.170	3.646	3.801	3.176	3.142	3.175
Ca										
Na			.026		.048	.062	.047	.040	.037	.042
K	1.721	1.801	1.780	1.772	1.684	1.660	1.597	1.625	1.616	1.645
Ni									.016	
Sum	15.373	15.437	15.419	15.407	15.444	15.479	15.484	15.389	15.374	15.424
M	70.57	70.01	69.38	69.72	66.64	75.16	77.41	67.29	66.96	66.77

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P25C-8R : BIOTITE 483/193 T8,MX  
P25C-9C : BIOTITE 442/86 T9,MX  
P25C-10C : BIOTITE 560/102 T10,MX  
P25C-10R : BIOTITE 560/102 T10,MX  
P14C-1C : BIOTITE 437/199 T11,H  
P14C-5C : BIOTITE 444/65 T5,G  
P14C-6C : BIOTITE 443/82 T6,G,C,H  
P14C-7C : BIOTITE 503/188 T7,C  
P14C-9C : BIOTITE 521/200 T9,H  
P14C-10C : BIOTITE 504/80 T10,H

Table 5.8: continued

	P19C-1C	P19C-3C	P19C-4C	P21C-1C	P21C-1R	P21C-2C	P21C-2R	P21C-3C	P21C-4C	P21C-5C
SiO <sub>2</sub>	36.68	36.29	37.36	36.89	37.25	36.96	37.31	37.43	37.96	36.79
TiO <sub>2</sub>	3.73	3.78	3.32	5.65	5.54	5.20	5.20	5.05	3.50	5.65
Al <sub>2</sub> O <sub>3</sub>	17.24	17.80	17.75	17.15	17.27	17.57	17.49	17.32	17.90	16.86
Cr <sub>2</sub> O <sub>3</sub>	.47	.42	.30	.60	.59	.64	.61	.61	.42	.61
FeO	11.61	10.25	9.48	11.59	10.82	10.81	11.15	10.07	9.94	14.05
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
HgO	15.85	16.73	17.82	15.24	15.73	15.79	16.11	16.72	17.48	14.15
CaO	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.22	.19	.22	.11	.00	.09	.09	.09	.09	.08
K <sub>2</sub> O	9.48	9.53	9.66	9.54	9.71	9.64	9.49	9.65	9.30	9.67
NiO	.00	.00	.00							
F	.31	.29	.29	.31	.33	.29	.28	.34	.35	.24
Cl				.00	.00	.00	.00	.00	.00	.00
Total	95.63	95.28	96.35	97.08	97.24	96.99	97.73	97.28	96.94	98.10
Si	5.392	5.321	5.395	5.343	5.365	5.336	5.345	5.369	5.433	5.336
Ti	.412	.417	.361	.615	.600	.565	.560	.545	.377	.616
Al	2.608	2.679	2.605	2.657	2.635	2.664	2.655	2.631	2.567	2.664
Al <sub>6</sub>	.379	.397	.416	.271	.297	.326	.298	.297	.453	.218
Cr	.055	.049	.034	.069	.067	.073	.069	.069	.048	.070
Fe <sup>2+</sup>	1.427	1.257	1.145	1.404	1.303	1.305	1.336	1.208	1.190	1.704
Mn										
Mg	3.472	3.656	3.835	3.289	3.376	3.398	3.440	3.574	3.728	3.058
Ca	.006									
Na	.063	.054	.062	.031		.025	.025	.025	.025	.022
K	1.778	1.783	1.780	1.763	1.784	1.776	1.735	1.766	1.698	1.789
Ni										
Sum	15.595	15.617	15.637	15.441	15.428	15.468	15.463	15.483	15.518	15.478
M	70.87	74.41	77.01	70.09	72.15	72.24	72.03	74.74	75.81	64.22

\*\*\* All zero values below detection limit \*\*\*

## SAMPLE DESCRIPTIONS :

P19C-1C : BIOTITE 445/95 T7,T8,H  
P19C-3C : BIOTITE 481/253 T3,G  
P19C-4C : BIOTITE 460/163 T4,G  
P21C-1C : BIOTITE 439/225 T1,INCL G  
P21C-1R : BIOTITE 439/225 T1,INCL G  
P21C-2C : BIOTITE 462/224 T2,G  
P21C-2R : BIOTITE 462/224 T2,G  
P21C-3C : BIOTITE 607/160 T3,G  
P21C-4C : BIOTITE 553/33 T4,INCL G  
P21C-5C : BIOTITE 422/191 T5,MX

Table 5.8: continued

	P21C-5R	P1D-1C	P1D-1R	P1D-2C	P1D-2R	P1D-3C	P1D-3R	P8C-1C	P8C-2C	P8C-2R
SiO <sub>2</sub>	36.66	37.81	36.85	36.78	36.19	36.33	36.92	37.42	37.04	37.07
TiO <sub>2</sub>	5.87	3.42	3.30	3.50	3.31	3.48	3.44	5.06	4.72	4.97
Al <sub>2</sub> O <sub>3</sub>	16.64	18.21	18.08	17.60	18.04	17.58	18.01	17.11	16.61	17.07
Cr <sub>2</sub> O <sub>3</sub>	.64	.44	.42	.58	.66	.47	.46	.91	.91	.97
FeO	13.12	10.07	9.68	10.55	11.14	11.90	11.07	11.43	12.65	12.66
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	14.03	17.40	17.18	16.47	16.41	16.03	15.73	15.43	14.82	14.72
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.00	.22	.20	.16	.29	.16	.15	.10	.11	.15
K <sub>2</sub> O	9.80	9.17	9.02	8.95	8.50	9.23	9.13	8.92	8.60	8.95
NiO								.24	.00	.29
F	.31	.27	.24	.27	.26	.23	.20	.00	.29	.00
Cl	.00	.00	.00	.20	.19	.00	.00	.00	.00	.00
Total	97.07	97.01	94.97	94.88	94.99	95.41	95.11	96.62	95.75	96.85
Si	5.360	5.405	5.377	5.399	5.325	5.349	5.412	5.404	5.435	5.380
Ti	.645	.368	.362	.386	.366	.385	.379	.550	.521	.542
Al <sub>4</sub>	2.640	2.595	2.623	2.601	2.675	2.651	2.588	2.596	2.565	2.620
Al <sub>6</sub>	.228	.473	.487	.544	.454	.400	.524	.316	.308	.300
Cr	.074	.050	.048	.067	.077	.055	.053	.104	.106	.111
Fe <sup>2+</sup>	1.604	1.204	1.181	1.295	1.371	1.465	1.357	1.380	1.552	1.537
Mn										
Mg	3.057	3.707	3.736	3.603	3.599	3.517	3.437	3.321	3.241	3.184
Ca										
Na		.061	.057	.046	.083	.046	.043	.028	.031	.042
K	1.828	1.672	1.679	1.676	1.596	1.734	1.708	1.643	1.610	1.657
Ni								.028		.034
Sum	15.437	15.535	15.550	15.519	15.545	15.602	15.501	15.374	15.375	15.411
M	65.58	75.49	75.98	73.56	72.41	70.59	71.69	70.64	67.61	67.45

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P21C-5R : BIOTITE 422/191 T5,MX  
P1D-1C : BIOTITE 632/119 T1,INCL G  
P1D-1R : BIOTITE 632/119 T1,INCL G  
P1D-2C : BIOTITE 562/0 T2,G  
P1D-2R : BIOTITE 562/0 T2,G  
P1D-3C : BIOTITE 486/34 T3,MX  
P1D-3R : BIOTITE 486/34 T3,MX  
P8C-1C : BIOTITE 451/153 T1,H  
P8C-2C : BIOTITE 633/168 T2,H  
P8C-2R : BIOTITE 633/168 T2,H

Table 5.8: continued

	P8C-3C	P8C-4C	P8C-4R	P8C-5C	P8C-6C	P8C-7C	P8C-9C	P3D-1C	P3D-2C	P5D-1C	P5D-2C
SiO <sub>2</sub>	37.41	36.58	36.91	37.40	37.41	36.71	36.61	37.49	37.37	38.16	38.04
TiO <sub>2</sub>	5.16	5.06	4.97	4.87	4.13	4.99	5.12	4.81	4.82	3.76	3.69
Al <sub>2</sub> O <sub>3</sub>	17.19	17.05	17.26	16.98	17.65	16.93	16.94	17.05	17.53	17.86	17.77
Cr <sub>2</sub> O <sub>3</sub>	.87	.92	1.01	1.02	.51	1.14	.88	.99	.99	.76	.88
FeO	11.96	12.15	11.95	12.53	11.10	12.48	12.35	11.06	11.55	9.56	9.50
MnO	.00	.00	.00	.00	.00	.08	.00	.00	.00	.00	.00
MgO	14.34	15.28	15.44	15.81	16.68	15.12	14.74	16.28	15.81	17.30	17.32
CaO	.00	.00	.00	.00	.00	.07	.00	.00	.00	.00	.00
Na <sub>2</sub> O	.12	.11	.11	.12	.10	.11	.09	.21	.13	.16	.20
K <sub>2</sub> O	8.59	8.79	8.71	8.73	8.71	8.55	8.77	9.50	9.57	9.27	9.13
NiO	.17	.16	.20	.19	.18	.19	.21				
F	.28	.27	.20	.29	.25	.35	.00	.22	.26	.44	.27
Cl	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	96.09	96.41	96.80	98.03	96.78	96.74	95.93	97.61	98.03	97.27	96.80
Si	5.445	5.336	5.346	5.366	5.385	5.347	5.365	5.380	5.352	5.441	5.439
Ti	.565	.555	.541	.525	.447	.547	.564	.519	.519	.403	.397
Al4	2.555	2.664	2.654	2.634	2.615	2.653	2.635	2.620	2.648	2.559	2.561
Al6	.394	.267	.293	.237	.380	.253	.291	.264	.311	.443	.434
Cr	.100	.106	.116	.116	.058	.131	.102	.112	.112	.086	.099
Fe2+	1.456	1.482	1.448	1.503	1.336	1.520	1.514	1.327	1.383	1.140	1.136
Mn						.010					
Mg	3.111	3.322	3.333	3.380	3.578	3.282	3.219	3.482	3.375	3.676	3.691
Ca						.011					
Na	.034	.031	.031	.033	.028	.031	.026	.058	.036	.044	.055
K	1.595	1.636	1.609	1.598	1.600	1.589	1.640	1.739	1.749	1.686	1.665
Ni	.020	.019	.023	.022	.021	.022	.025				
Sum	15.279	15.423	15.401	15.430	15.455	15.397	15.389	15.502	15.485	15.478	15.478
H	68.12	69.15	69.72	69.22	72.81	68.34	68.02	72.40	70.92	76.33	76.46

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

- P8C-3C : BIOTITE 531/167 T3,H
- P8C-4C : BIOTITE 502/218 T4,H
- P8C-4R : BIOTITE 505/218 T4,H
- P8C-5C : BIOTITE 466/94 T5,H
- P8C-6C : BIOTITE 468/194 T6,H
- P8C-7C : BIOTITE 610/170 T7,H
- P8C-9C : BIOTITE 528/189 H
- P3D-1C : BIOTITE 621/130 INCL H
- P3D-2C : BIOTITE 452/58 MX
- P5D-1C : BIOTITE 476/248 MX
- P5D-2C : BIOTITE 474/178 MX

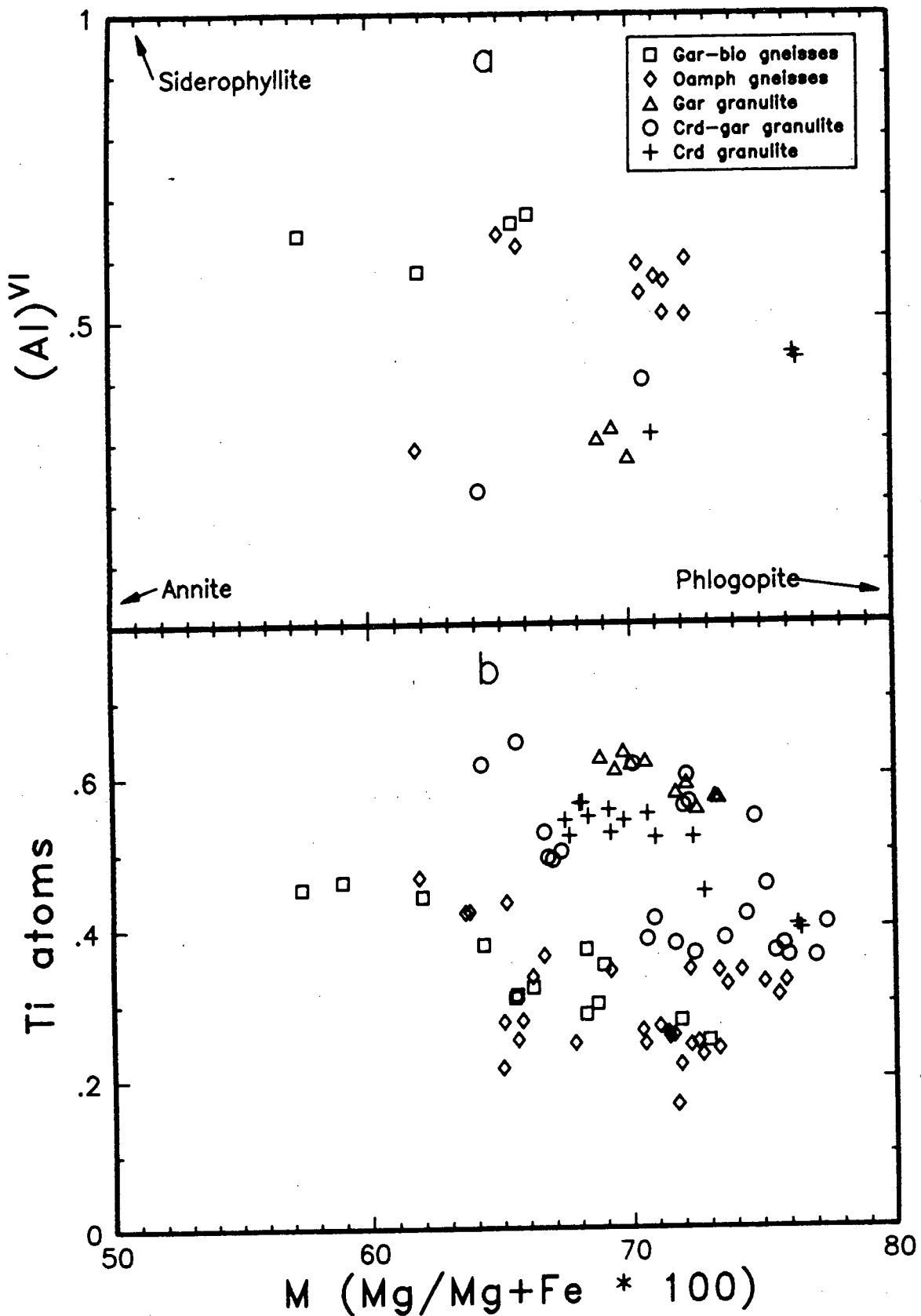


Figure 5.3a: Biotite compositions plotted in a section of the "ideal biotite plane" after Guidotti (1984), representing Fe/Mg exchange (M) relative to the tschermak exchange  $(\text{Mg}, \text{Fe}^{2+}) + \text{Si}^{\text{IV}} - \text{Al}^{\text{IV}} + \text{Al}^{\text{VI}}$  (plotted as  $\text{Al}^{\text{VI}}$ ); core analyses of matrix-biotites plotted only.

Figure 5.3b: Ti versus M ( $\text{Mg}/\text{Mg} + \text{Fe} * 100$ ) chemical variation of the biotites analyzed from the pelitic rocks.

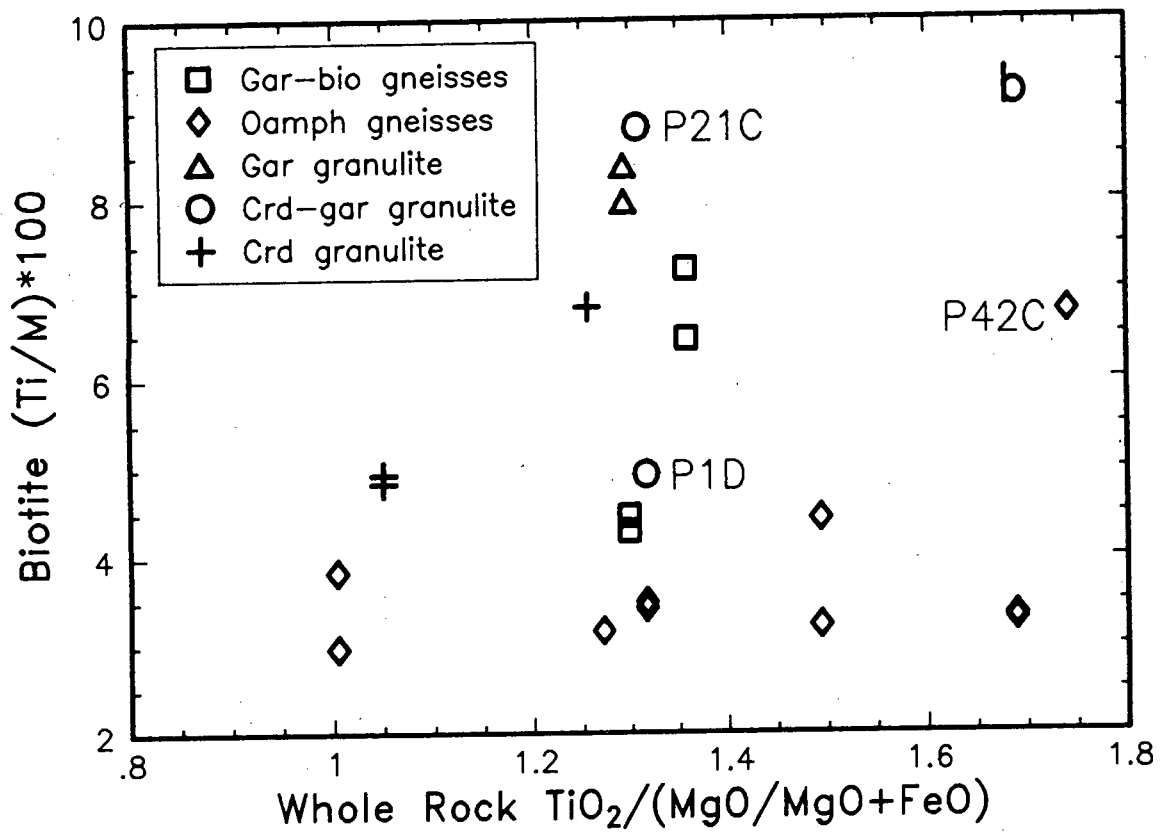
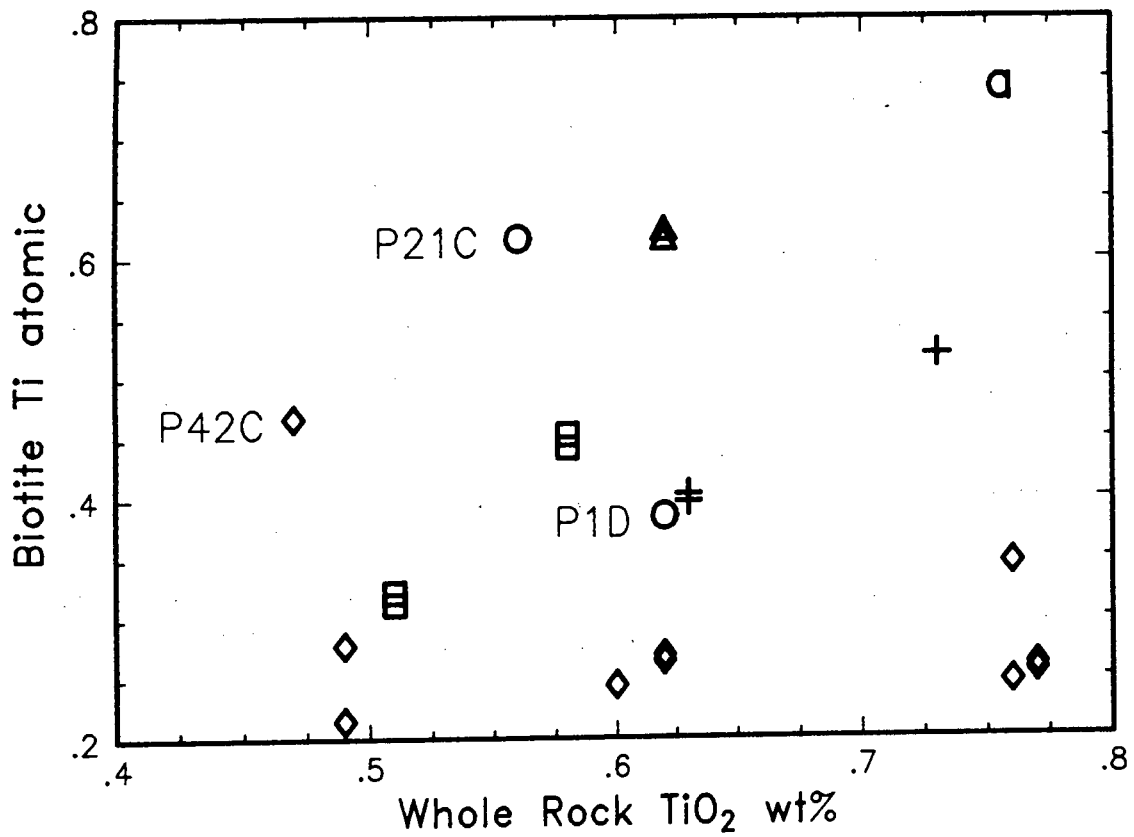


Figure 5.4a: Biotite Ti content plotted versus TiO<sub>2</sub> content of the bulk rock; core analyses of matrix-biotites plotted only (see text for discussion).

Figure 5.4b: Biotite (Ti/M)\*100 variation with TiO<sub>2</sub>/(MgO/MgO+FeO) variation in the bulk rock; core analyses of matrix biotites plotted only. (see text for discussion).

Table 5.9: Microprobe analysis of garnet from the pelitic rocks. Cation proportions are calculated relative to 12 oxygens. Alm, Py, Gr, Sp - almandine, pyrope, grossular and spessartine proportions, T1,B (H,C,A,MX) - geothermobarometry sample number of garnet in contact with biotite (hypersthene, cordierite, orthoamphibole, matrix).

	P17C-1C	P17C-1R	P17C-2C	P17C-3C	P17C-4C	P17C-5C	P17C-6C	P17C-6M	P17C-6R	P41C-1C
SiO <sub>2</sub>	38.52	38.43	38.31	38.68	38.09	38.20	38.10	38.21	38.44	38.32
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	21.27	21.07	21.05	21.15	21.16	21.12	21.08	20.98	21.24	22.53
Cr <sub>2</sub> O <sub>3</sub>	.11	.10	.08	.12	.10	.09	.09	.09	.06	.00
FeO	29.58	30.48	30.01	30.83	31.35	29.29	30.64	30.50	30.19	30.37
MnO	.68	.77	.74	.78	.92	.75	.79	.76	.78	.61
MgO	8.52	8.17	8.08	7.87	7.37	8.74	8.32	8.23	8.23	8.30
CaO	.87	.87	.92	.84	.84	.81	.69	.71	.91	1.26
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07
Total	99.60	99.94	99.24	100.32	99.88	99.05	99.76	99.53	99.90	101.46
Si	3.006	3.004	3.010	3.014	2.994	2.998	2.987	3.000	3.001	2.944
Ti										
Al	1.956	1.941	1.949	1.942	1.961	1.953	1.948	1.941	1.955	2.040
Cr	.007	.006	.005	.007	.006	.006	.006	.006	.004	
Fe <sup>2+</sup>	1.931	1.992	1.972	2.009	2.061	1.922	2.009	2.003	1.971	1.952
Mn	.045	.051	.049	.051	.061	.050	.052	.051	.052	.040
Mg	.991	.952	.946	.914	.863	1.022	.972	.963	.958	.950
Ca	.073	.073	.077	.070	.071	.068	.058	.060	.076	.104
Na										.010
Sum	8.013	8.023	8.013	8.012	8.022	8.023	8.037	8.027	8.020	8.041
Alm	63.52	64.93	64.78	66.00	67.44	62.77	64.99	65.10	64.48	64.08
Py	32.60	31.03	31.08	30.03	28.24	33.38	31.45	31.30	31.34	31.19
Gr	2.40	2.38	2.53	2.30	2.32	2.22	1.88	1.95	2.49	3.41
Sp	1.48	1.66	1.61	1.67	2.00	1.63	1.68	1.66	1.70	1.31

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P17C-1C	: GAR 464/146 T1,B
P17C-1R	: GAR 464/146 T1,8
P17C-2C	: GAR 487/160 T2,B
P17C-3C	: GAR 518/185 T3,B
P17C-4C	: GAR 571/183 T4,B
P17C-5C	: GAR 440/210 T5,MX
P17C-6C	: GAR 582/197 T6,MX
P17C-6M	: GAR 582/197 MX
P17C-6R	: GAR 582/197 T6,MX
P41C-1C	: GAR 498/246 T1,B

Table 5.9: continued

	P41C-1R	P41C-2C	P41C-2R	P41C-3C	P5C-1C	P5C-2C	P5C-2R	P5C-3C	P5C-4C	P34C-1C
SiO <sub>2</sub>	38.32	38.33	38.71	38.96	37.37	37.77	37.76	37.94	37.89	38.57
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.34	22.50	22.62	22.65	22.08	22.03	22.09	22.32	22.12	22.75
Cr <sub>2</sub> O <sub>3</sub>	.00	.00	.00	.00	.10	.15	.13	.07	.12	.12
FeO	32.21	30.54	32.36	30.12	31.82	31.70	32.38	31.25	31.92	28.57
MnO	.79	.68	.76	.72	.54	.56	.52	.53	.54	.67
MgO	6.88	8.24	7.20	8.08	6.10	6.20	5.93	6.56	6.02	9.29
CaO	1.21	1.16	.95	1.38	1.90	1.94	1.86	1.99	1.97	1.14
Na <sub>2</sub> O	.00	.00	.00	.06	.00	.00	.00	.00	.00	.00
Total	101.75	101.45	102.60	101.97	99.96	100.40	100.72	100.71	100.63	101.11
Si	2.961	2.947	2.961	2.971	2.947	2.962	2.959	2.957	2.966	2.947
Ti									.001	
Al	2.035	2.039	2.040	2.036	2.053	2.036	2.040	2.050	2.041	2.049
Cr					.006	.009	.008	.004	.007	.007
Fe <sup>2+</sup>	2.082	1.964	2.070	1.921	2.099	2.079	2.122	2.037	2.089	1.826
Mn	.052	.044	.049	.047	.036	.037	.035	.035	.036	.043
Mg	.792	.944	.821	.918	.717	.725	.693	.762	.702	1.058
Ca	.100	.096	.078	.113	.161	.163	.156	.166	.165	.093
Na				.009					.002	
Sum	8.022	8.034	8.019	8.015	8.023	8.016	8.017	8.016	8.011	8.024
Alm	68.80	64.44	68.59	64.05	69.66	69.21	70.59	67.90	69.82	60.46
Py	26.17	30.97	27.20	30.61	23.80	24.13	23.05	25.40	23.46	35.03
Gr	3.30	3.15	2.58	3.77	5.34	5.43	5.19	5.53	5.52	3.08
Sp	1.72	1.44	1.62	1.57	1.19	1.23	1.16	1.17	1.20	1.42

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P41C-1R : GAR 498/246 T1,B  
P41C-2C : GAR 563/58 T2,B  
P41C-2R : GAR 563/58 T2,B  
P41C-3C : GAR 540/99 T3,MX  
P5C-1C : GAR 567/207 MX  
P5C-2C : GAR 487/193 A  
P5C-2R : GAR 490/185 A  
P5C-3C : GAR 546/166 MX  
P5C-4C : GAR 582/163 MX  
P34C-1C : GARNET 431/159 T1,B

Table 5.9: continued

	P34C-2C	P34C-2M	P34C-2R	P42C-1C	P42C-1R	P42C-2C	P42C-2R	P42C-3C	P45C-1C	P45C-1R
SiO <sub>2</sub>	39.04	38.39	38.66	37.47	37.47	37.12	37.48	36.65	38.76	38.73
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.07	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.85	22.37	22.52	22.20	22.24	22.10	22.20	21.85	22.89	22.67
Cr <sub>2</sub> O <sub>3</sub>	.00	.10	.15	.00	.16	.00	.13	.10	.00	.00
FeO	27.07	27.67	28.10	31.30	31.09	31.20	31.71	31.04	29.24	29.75
MnO	.45	.54	.66	.48	.42	.46	.42	.45	.86	.72
MgO	10.23	9.40	9.46	6.65	5.74	6.26	6.29	5.77	8.72	8.31
CaO	1.36	1.28	1.38	2.82	4.50	3.54	3.39	4.12	1.19	1.23
Na <sub>2</sub> O	.17	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	101.17	99.75	100.93	100.92	101.62	100.68	101.69	99.98	101.66	101.41
Si	2.958	2.964	2.956	2.925	2.916	2.913	2.914	2.905	2.954	2.965
Ti							.004			
Al	2.041	2.036	2.029	2.043	2.040	2.044	2.034	2.041	2.056	2.046
Cr		.006	.009		.010		.008	.006		
Fe <sup>2+</sup>	1.715	1.787	1.797	2.044	2.024	2.048	2.062	2.057	1.864	1.905
Mn	.029	.035	.043	.032	.028	.031	.028	.030	.056	.047
Mg	1.155	1.082	1.078	.774	.666	.732	.729	.682	.990	.948
Ca	.110	.106	.113	.236	.375	.298	.282	.350	.097	.101
Na	.025									
Sum	8.034	8.015	8.025	8.053	8.059	8.065	8.061	8.071	8.018	8.012
Alm	57.00	59.37	59.29	66.24	65.44	65.87	66.49	65.95	61.99	63.48
Py	38.39	35.95	35.57	25.08	21.53	23.54	23.51	21.87	32.92	31.59
Gr	3.66	3.52	3.73	7.65	12.12	9.58	9.09	11.22	3.23	3.37
Sp	.96	1.16	1.42	1.04	.90	1.00	.90	.96	1.86	1.57

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P34C-2C : GARNET 490/174 ZONE 15X IN T2  
P34C-2M : GARNET 490/174 ZONE 4X IN  
P34C-2R : GARNET 490/174 ZONE RIM  
P42C-1C : GARNET 453/0 T1,B  
P42C-1R : GARNET 453/0 T1,B  
P42C-2C : GARNET 539/10 T2,B  
P42C-2R : GARNET 539/10 T2,B  
P42C-3C : GARNET 590/246 T3,MX  
P45C-1C : GAR 521/210 MX  
P45C-1R : GAR 521/210 MX

Table 5.9: continued

	P50C-1C	P50C-1R	P50C-2C	P50C-2R	P50C-3C	P50C-3R	P50C-4C	P50C-4R	P50C-5C	P7D-1C
SiO <sub>2</sub>	39.11	39.53	39.18	39.45	39.15	39.10	39.29	39.29	39.36	38.98
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	21.95	22.18	22.12	22.40	22.47	22.31	22.34	22.49	22.69	22.45
Cr <sub>2</sub> O <sub>3</sub>	.08	.00	.08	.09	.11	.11	.33	.00	.00	.22
FeO	29.21	28.26	29.24	29.35	28.94	29.27	29.08	28.88	28.63	28.14
MnO	.99	.63	1.07	.57	.97	.91	.89	.57	.43	.40
MgO	7.80	8.38	7.65	8.43	8.01	7.65	7.78	8.28	8.61	8.68
CaO	1.48	1.70	1.48	.96	1.48	1.60	1.56	1.65	1.55	1.76
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.62	100.68	100.82	101.25	101.13	100.95	101.27	101.16	101.27	100.63
Si	3.016	3.026	3.016	3.011	2.998	3.005	3.007	3.001	2.996	2.987
Ti										
Al	1.995	2.001	2.007	2.015	2.028	2.021	2.015	2.025	2.036	2.028
Cr	.005		.005	.005	.007	.007	.020			.013
Fe <sup>2+</sup>	1.884	1.809	1.882	1.873	1.853	1.881	1.861	1.845	1.823	1.803
Mn	.065	.041	.070	.037	.063	.059	.058	.037	.028	.026
Mg	.896	.956	.877	.959	.914	.876	.887	.943	.977	.991
Ca	.122	.139	.122	.079	.121	.132	.128	.135	.126	.145
Na										
Sum	7.984	7.973	7.979	7.979	7.985	7.981	7.976	7.986	7.986	7.993
Alm	63.50	61.43	63.78	63.54	62.79	63.81	63.43	62.33	61.71	60.81
Py	30.20	32.46	29.72	32.53	30.97	29.72	30.23	31.86	33.07	33.42
Gr	4.11	4.72	4.13	2.68	4.10	4.48	4.36	4.56	4.27	4.89
Sp	2.19	1.39	2.37	1.26	2.14	2.00	1.98	1.25	.95	.88

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P50C-1C : GARNET 436/136 T1,B  
P50C-1R : GARNET 436/136 T1,B  
P50C-2C : GARNET 462/130 T2,B  
P50C-2R : GARNET 462/130 T2,B  
P50C-3C : GARNET 604/114 T3(T6),B=INCL  
P50C-3R : GARNET 604/114 T3,B=INCL  
P50C-4C : GARNET 541/116 T4,B  
P50C-4R : GARNET 541/116 T4,B  
P50C-5C : GARNET 470/150 T5,SMALL G IN B  
P7D-1C : GARNET 511/174 T1,B

Table 5.9: continued

	P7D-1R	P7D-2C	P7D-2R	P7D-3C	P7D-3R	P7D-4C	P7D-5C	P25C-1C	P25C-1R	P25C-2C
SiO <sub>2</sub>	38.74	38.67	38.78	39.54	39.24	39.06	39.03	38.74	38.77	38.81
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.14	22.60	22.72	22.21	22.00	22.15	21.91	22.82	22.93	22.74
Cr <sub>2</sub> O <sub>3</sub>	.22	.10	.00	.24	.29	.10	.12	.14	.20	.22
FeO	30.09	29.51	28.61	28.21	29.59	30.07	29.10	26.85	26.44	26.29
MnO	.43	.96	.62	.44	.39	.52	1.05	.68	.70	.72
MgO	7.59	8.09	9.09	8.78	8.19	8.00	7.84	10.40	10.40	10.80
CaO	1.85	1.48	1.41	1.44	1.44	1.36	1.43	1.30	1.24	1.17
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	101.06	101.41	101.23	100.86	101.14	101.26	100.48	100.93	100.68	100.75
Si	2.986	2.964	2.960	3.018	3.008	2.998	3.014	2.944	2.947	2.947
Ti										
Al	2.011	2.042	2.044	1.998	1.988	2.004	1.994	2.044	2.055	2.035
Cr	.013	.006		.014	.018	.006	.007	.008	.012	.013
Fe <sup>2+</sup>	1.939	1.892	1.826	1.801	1.897	1.930	1.880	1.706	1.681	1.670
Mn	.028	.062	.040	.028	.025	.034	.069	.044	.045	.046
Mg	.872	.924	1.034	.999	.936	.915	.902	1.178	1.178	1.222
Ca	.153	.122	.115	.118	.118	.112	.118	.106	.101	.095
Na										
Sum	8.002	8.012	8.019	7.976	7.989	7.998	7.985	8.030	8.019	8.029
Alm	64.81	63.07	60.56	61.13	63.74	64.53	63.32	56.23	55.94	55.06
Py	29.14	30.80	34.29	33.91	31.45	30.59	30.38	38.83	39.20	40.29
Gr	5.11	4.07	3.81	4.01	3.97	3.74	3.97	3.49	3.36	3.13
Sp	.94	2.07	1.33	.95	.84	1.14	2.32	1.45	1.50	1.52

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P7D-1R : GARNET 511/174 T1,B  
P7D-2C : GARNET 577/284 T2,8  
P7D-2R : GARNET 577/284 T2,B  
P7D-3C : GARNET 528/123 T3,B  
P7D-3R : GARNET 528/123 T3,B  
P7D-4C : GARNET 562/210 T4,T5,SMALL G IN  
P7D-5C : GARNET 467/165 T6,MX  
P25C-1C : GARNET 520/245 T1,H  
P25C-1R : GARNET 520/245 T1,H  
P25C-2C : GARNET 490/132 T2,H

Table 5.9: continued

	P25C-3C	P25C-3R	P25C-4C	P25C-5C	P25C-5R	P25C-6C	P25C-6R	P25C-7C	P25C-7R	P25C-8C
SiO <sub>2</sub>	39.28	39.01	38.69	38.48	38.93	39.23	38.99	38.93	39.09	39.43
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.78	21.87	21.78	21.74	22.60	22.72	22.67	22.69	22.60	22.69
Cr <sub>2</sub> O <sub>3</sub>	.19	.18	.16	.18	.16	.21	.12	.23	.18	.18
FeO	25.76	25.78	26.74	26.20	26.05	26.63	27.02	27.13	27.90	25.86
MnO	.66	.67	.68	.72	.67	.67	.63	.64	.67	.66
MgO	10.92	10.89	10.42	10.45	10.30	10.29	9.33	10.21	9.85	10.82
CaO	1.10	1.21	1.31	1.52	1.41	1.14	2.35	1.17	1.12	1.29
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.69	99.61	99.78	99.29	100.12	100.89	101.11	101.00	101.41	100.93
Si	2.972	2.990	2.977	2.973	2.971	2.974	2.966	2.958	2.966	2.978
Ti										
Al	2.031	1.976	1.975	1.980	2.033	2.030	2.033	2.032	2.021	2.020
Cr	.011	.011	.010	.011	.010	.013	.007	.014	.011	.011
Fe <sub>2+</sub>	1.630	1.653	1.721	1.693	1.663	1.689	1.719	1.724	1.771	1.633
Mn	.042	.044	.044	.047	.043	.043	.041	.041	.043	.042
Mg	1.231	1.244	1.195	1.203	1.172	1.163	1.058	1.156	1.114	1.218
Ca	.089	.099	.108	.126	.115	.093	.192	.095	.091	.104
Na										
Sum	8.007	8.016	8.030	8.032	8.007	8.004	8.014	8.020	8.017	8.007
Alm	54.48	54.38	56.10	55.17	55.56	56.53	57.11	57.16	58.66	54.49
Py	41.14	40.92	38.95	39.20	39.16	38.92	35.15	38.33	36.90	40.64
Gr	2.97	3.26	3.52	4.11	3.84	3.11	6.38	3.15	3.01	3.47
Sp	1.40	1.45	1.43	1.53	1.44	1.44	1.36	1.36	1.42	1.40

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P25C-3C : GARNET 473/252 T3,H  
P25C-3R : GARNET 473/252 T3,H  
P25C-4C : GARNET 429/130 T4,H  
P25C-5C : GARNET 461/107 T5,B  
P25C-5R : GARNET 461/107 T5,B  
P25C-6C : GARNET 437/222 T6,B  
P25C-6R : GARNET 437/222 T6,B  
P25C-7C : GARNET 450/219 T7,B  
P25C-7R : GARNET 450/219 T7,B  
P25C-8C : GARNET 514/228 T8,MX

Table 5.9: continued

	P25C-9C	P25C-9R	P25C-10C	P14C-1C	P14C-1R	P14C-2C	P14C-3C	P14C-4C	P14C-5C	P14C-6C
SiO <sub>2</sub>	39.34	39.31	39.64	38.50	38.81	38.44	38.23	38.19	38.67	38.32
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.50	22.68	22.56	22.32	22.43	22.17	22.49	22.33	22.36	22.11
Cr <sub>2</sub> O <sub>3</sub>	.19	.18	.17	.15	.17	.22	.23	.22	.22	.24
FeO	26.26	26.30	25.84	27.54	27.51	28.45	27.90	28.71	28.30	27.94
MnO	.70	.77	.61	.71	.73	.71	.71	.74	.66	.62
MgO	10.28	10.42	10.88	9.60	9.40	9.04	9.56	8.80	9.39	9.14
CaO	1.42	1.14	1.25	1.15	1.14	1.15	1.18	1.11	1.13	1.14
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.03	.03	.00
Total	100.69	100.80	100.95	100.02	100.24	100.23	100.35	100.17	100.80	99.56
Si	2.986	2.979	2.991	2.964	2.978	2.967	2.941	2.954	2.963	2.971
Ti										
Al	2.013	2.026	2.006	2.025	2.029	2.017	2.039	2.036	2.019	2.020
Cr	.011	.011	.010	.009	.010	.013	.014	.013	.013	.015
Fe <sup>2+</sup>	1.667	1.667	1.630	1.773	1.765	1.836	1.795	1.857	1.813	1.811
Mn	.045	.049	.039	.046	.047	.046	.046	.048	.043	.041
Mg	1.163	1.177	1.223	1.102	1.075	1.040	1.096	1.014	1.072	1.056
Ca	.115	.093	.101	.095	.094	.095	.097	.092	.093	.095
Na								.004	.004	
Sum	8.001	8.002	8.001	8.019	8.003	8.019	8.033	8.023	8.023	8.012
Alm	55.75	55.83	54.46	58.79	59.21	60.86	59.16	61.67	60.01	60.31
Py	38.90	39.42	40.86	36.54	36.06	34.47	36.12	33.68	35.49	35.17
Gr	3.85	3.11	3.38	3.15	3.15	3.15	3.20	3.05	3.08	3.16
Sp	1.51	1.64	1.30	1.53	1.58	1.53	1.52	1.59	1.42	1.37

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P25C-9C : GARNET 452/84 T9,MX  
P25C-9R : GARNET 452/84 T9,MX  
P25C-10C : GARNET 554/93 T10,MX  
P14C-1C : GAR 584/105 T1,C  
P14C-1R : GAR 584/105 T1,C  
P14C-2C : GAR 543/6 T2,C,H  
P14C-3C : GAR 601/110 T3,C,H  
P14C-4C : GAR 513/19 T4,H  
P14C-5C : GAR 440/64 T5,B  
P14C-6C : GAR 449/78 T6,C,H,B

Table 5.9: continued

	P14C-7C	P19C-1C	P19C-1R	P19C-2C	P19C-3C	P19C-4C	P19C-5C	P19C-6C	P21C-1C	P21C-1R
SiO <sub>2</sub>	38.68	38.43	38.74	39.00	38.73	38.67	38.87	38.67	38.12	38.60
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.19	21.19	22.20	21.47	21.40	21.21	21.36	21.35	21.89	21.85
Cr <sub>2</sub> O <sub>3</sub>	.19	.12	.00	.11	.10	.13	.25	.13	.12	.19
FeO	28.38	28.23	27.66	27.34	27.21	27.69	26.86	27.20	28.80	28.74
MnO	.73	.88	.69	.84	.83	.78	.71	.69	.59	.62
MgO	9.01	9.06	9.54	9.56	9.65	9.42	10.10	9.77	8.36	8.50
CaO	1.12	1.73	1.40	1.39	1.63	1.64	1.28	1.35	1.58	1.32
Na <sub>2</sub> O	.03	.04	.03	.00	.03	.04	.00	.04	.00	.00
Total	100.37	99.72	100.31	99.76	99.62	99.62	99.48	99.24	99.46	99.82
Si	2.978	2.990	2.975	3.011	2.997	3.000	3.003	3.000	2.974	2.994
Ti										
Al	2.014	1.943	2.010	1.953	1.952	1.939	1.945	1.953	2.013	1.998
Cr	.012	.007		.007	.006	.008	.015	.008	.007	.012
Fe <sup>2+</sup>	1.827	1.837	1.777	1.765	1.761	1.796	1.735	1.765	1.879	1.864
Mn	.048	.058	.045	.055	.054	.051	.046	.045	.039	.041
Mg	1.034	1.050	1.092	1.100	1.113	1.089	1.163	1.130	.972	.983
Ca	.092	.144	.115	.115	.135	.136	.106	.112	.132	.110
Na	.004	.006	.004		.005	.006		.006		
Sum	8.011	8.038	8.021	8.010	8.026	8.029	8.018	8.022	8.016	8.001
Alm	60.88	59.47	58.67	58.15	57.49	58.46	56.89	57.83	62.18	62.18
Py	34.46	33.99	36.05	36.24	36.34	35.45	38.13	37.03	32.16	32.79
Gr	3.07	4.66	3.80	3.79	4.41	4.43	3.47	3.67	4.37	3.67
Sp	1.60	1.88	1.49	1.81	1.76	1.66	1.51	1.47	1.29	1.37

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P14C-7C : GAR 523/22 T11,C  
P19C-1C : GARNET 510/154 T1,H,C  
P19C-1R : GARNET 510/154 T1,H,C RIM TO C  
P19C-2C : GARNET 524/14 T2,T8,H  
P19C-3C : GARNET 481/251 T3,B  
P19C-4C : GARNET 461/161 T4,B  
P19C-5C : GARNET 609/213 T5,T7,C  
P19C-6C : GARNET 588/208 T6,C  
P21C-1C : GARNET 437/223 T1,B=INCL  
P21C-1R : GARNET 437/223 T1,B=INCL

Table 5.9: continued

	P21C-2C	P21C-2R	P21C-3C	P21C-4C	P21C-4R	P21C-5C	P21C-5R	P21C-6C	P21C-7C	P21C-7R
SiO <sub>2</sub>	39.20	38.98	39.29	38.80	38.35	38.71	38.40	38.97	38.78	38.80
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.16	22.20	22.28	22.38	21.87	21.92	21.65	22.18	21.93	21.82
Cr <sub>2</sub> O <sub>3</sub>	.23	.16	.19	.18	.17	.21	.21	.13	.18	
FeO	27.81	29.08	26.48	28.39	29.13	28.31	28.23	27.79	26.90	27.28
MnO	.33	.41	.41	.53	.56	.60	.63	.44	.44	.45
MgO	9.57	8.99	10.29	9.04	8.60	9.47	9.36	10.03	10.56	10.60
CaO	1.08	.91	1.05	1.63	1.42	1.10	1.19	1.07	1.07	.75
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.38	100.73	99.99	100.95	100.10	100.32	99.67	100.61	99.86	99.70
Si	3.000	2.990	3.000	2.970	2.974	2.980	2.979	2.978	2.977	2.985
Ti										
Al	1.999	2.007	2.005	2.019	1.999	1.989	1.980	1.998	1.985	1.979
Cr	.014	.010	.011	.011	.010	.013	.013	.008	.011	
Fe <sup>2+</sup>	1.780	1.866	1.691	1.817	1.889	1.822	1.831	1.776	1.727	1.755
Mn	.021	.027	.027	.034	.037	.039	.041	.028	.029	.029
Mg	1.091	1.028	1.171	1.031	.994	1.086	1.082	1.142	1.208	1.215
Ca	.089	.075	.086	.134	.118	.091	.099	.088	.088	.062
Na										
Sum	7.994	8.002	7.991	8.016	8.021	8.020	8.025	8.019	8.025	8.026
Alm	59.71	62.28	56.84	60.25	62.18	59.97	59.97	58.54	56.59	57.33
Py	36.60	34.31	39.36	34.18	32.72	35.75	35.44	37.64	39.58	39.69
Gr	2.99	2.50	2.89	4.44	3.88	2.99	3.24	2.90	2.88	2.03
Sp	.70	.90	.91	1.13	1.22	1.28	1.34	.92	.95	.95

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P21C-2C : GARNET 460/224 T2,B  
P21C-2R : GARNET 460/224 T2,B  
P21C-3C : GARNET 609/159 T3,(B)  
P21C-4C : GARNET 558/34 T4,B=INCL  
P21C-4R : GARNET 558/34 T4,B=INCL  
P21C-5C : GARNET 612/71 T5,H,C  
P21C-5R : GARNET 612/71 T5,H,C  
P21C-6C : GARNET 516/163 T6,C  
P21C-7C : GARNET 613/58 T7,INCL IN C  
P21C-7R : GARNET 613/58 T7,INCL IN C

Table 5.9: continued

	P21C-8R	P21C-8M3	P21C-8M6	P21C-8M1	P21C-8M1	P21C-8M1	P21C-8M2	P21C-8M2	P21C-8M3	P21C-8M3
SiO <sub>2</sub>	39.06	38.96	38.96	39.01	38.66	38.82	39.00	39.31	38.59	38.86
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	22.25	22.28	22.29	22.43	21.87	22.18	21.82	22.06	21.81	22.10
Cr <sub>2</sub> O <sub>3</sub>	.19	.19	.13	.12	.11	.15	.13	.14	.17	.17
FeO	27.60	28.26	28.22	28.33	28.20	28.21	28.39	28.52	28.67	29.24
MnO	.56	.55	.50	.54	.55	.55	.56	.56	.59	.48
MgO	9.20	9.41	9.33	9.32	9.21	9.19	9.28	9.14	9.16	9.03
CaO	1.41	1.15	1.37	1.36	1.48	1.56	1.60	1.42	1.15	1.10
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.27	100.80	100.80	101.11	100.08	100.66	100.78	101.15	100.14	100.98
Si	2.996	2.980	2.980	2.976	2.984	2.977	2.991	3.000	2.982	2.980
Ti										
Al	2.011	2.009	2.010	2.017	1.990	2.005	1.972	1.984	1.986	1.997
Cr	.012	.011	.008	.007	.007	.009	.008	.008	.010	.010
Fe <sup>2+</sup>	1.770	1.808	1.805	1.807	1.820	1.809	1.821	1.820	1.853	1.875
Mn	.036	.036	.032	.035	.036	.036	.036	.036	.039	.031
Mg	1.052	1.073	1.064	1.060	1.059	1.050	1.060	1.039	1.055	1.032
Ca	.116	.094	.112	.111	.122	.128	.131	.116	.095	.090
Na										
Sum	7.993	8.010	8.011	8.012	8.018	8.016	8.019	8.004	8.020	8.016
Alm	59.52	60.05	59.91	59.97	59.93	59.84	59.74	60.44	60.91	61.92
Py	35.37	35.64	35.31	35.18	34.87	34.73	34.78	34.51	34.68	34.08
Gr	3.90	3.12	3.72	3.68	4.02	4.23	4.30	3.85	3.12	2.97
Sp	1.21	1.20	1.06	1.16	1.18	1.19	1.18	1.20	1.28	1.02

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P21C-8R : GARNET ZONE 447/191 RIM TO QTZ  
P21C-8M3 : GARNET ZONE IN 3X  
P21C-8M6 : GARNET ZONE IN 6X  
P21C-8M10 : GARNET ZONE IN 10X  
P21C-8M13 : GARNET ZONE IN 13X  
P21C-8M16 : GARNET ZONE IN 16X, T5  
P21C-8M20 : GARNET ZONE IN 20X  
P21C-8M25 : GARNET ZONE IN 25X  
P21C-8M30 : GARNET ZONE IN 30X  
P21C-8M32 : GARNET ZONE IN 32X

Table 5.9: continued

	P21C-8M3	P1D-1C	P1D-1R	P1D-2C	P1D-2R	P1D-3C	V6D-1C	V6D-1R
SiO <sub>2</sub>	38.64	38.09	38.07	37.87	37.68	37.70	37.97	37.94
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	21.78	22.06	22.36	22.40	22.18	22.45	22.48	22.54
Cr <sub>2</sub> O <sub>3</sub>	.20	.19	.17	.17	.14	.16	.00	.00
FeO	29.87	29.57	30.66	30.50	31.38	29.59	32.37	32.94
MnO	.54	.77	.85	.71	.60	.84	.61	.70
MgO	8.82	8.52	7.85	8.23	7.39	8.70	7.11	6.91
CaO	1.08	1.00	1.13	1.09	1.27	1.02	.63	.67
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.93	100.20	101.09	100.97	100.64	100.46	101.17	101.70
Si	2.977	2.957	2.945	2.930	2.939	2.922	2.948	2.939
Ti								
Al	1.978	2.019	2.039	2.043	2.039	2.051	2.057	2.058
Cr	.012	.012	.010	.010	.009	.010		
Fe <sup>2+</sup>	1.925	1.920	1.983	1.974	2.047	1.918	2.102	2.134
Mn	.035	.051	.056	.047	.040	.055	.040	.046
Mg	1.013	.986	.905	.949	.859	1.005	.823	.798
Ca	.089	.083	.094	.090	.106	.085	.052	.056
Na								
Sum	8.028	8.027	8.031	8.043	8.038	8.047	8.023	8.031
Alm	62.87	63.16	65.27	64.51	67.07	62.62	69.67	70.34
Py	33.08	32.43	29.79	31.01	28.15	32.81	27.28	26.30
Gr	2.91	2.73	3.09	2.94	3.47	2.78	1.72	1.85
Sp	1.14	1.68	1.84	1.54	1.31	1.80	1.33	1.52

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P21C-8M35 : GARNET ZONE IN 35X RIM TO B10  
P1D-1C : GARNET 630/122 T1,B  
P1D-1R : GARNET 630/122 T1,B  
P1D-2C : GARNET 562/0 T2,B  
P1D-2R : GARNET 562/0 T2,B  
P1D-3C : GARNET 502/28 T3,MX  
V6D-1C : GARNET 563/0  
V6D-1R : GARNET 563/0

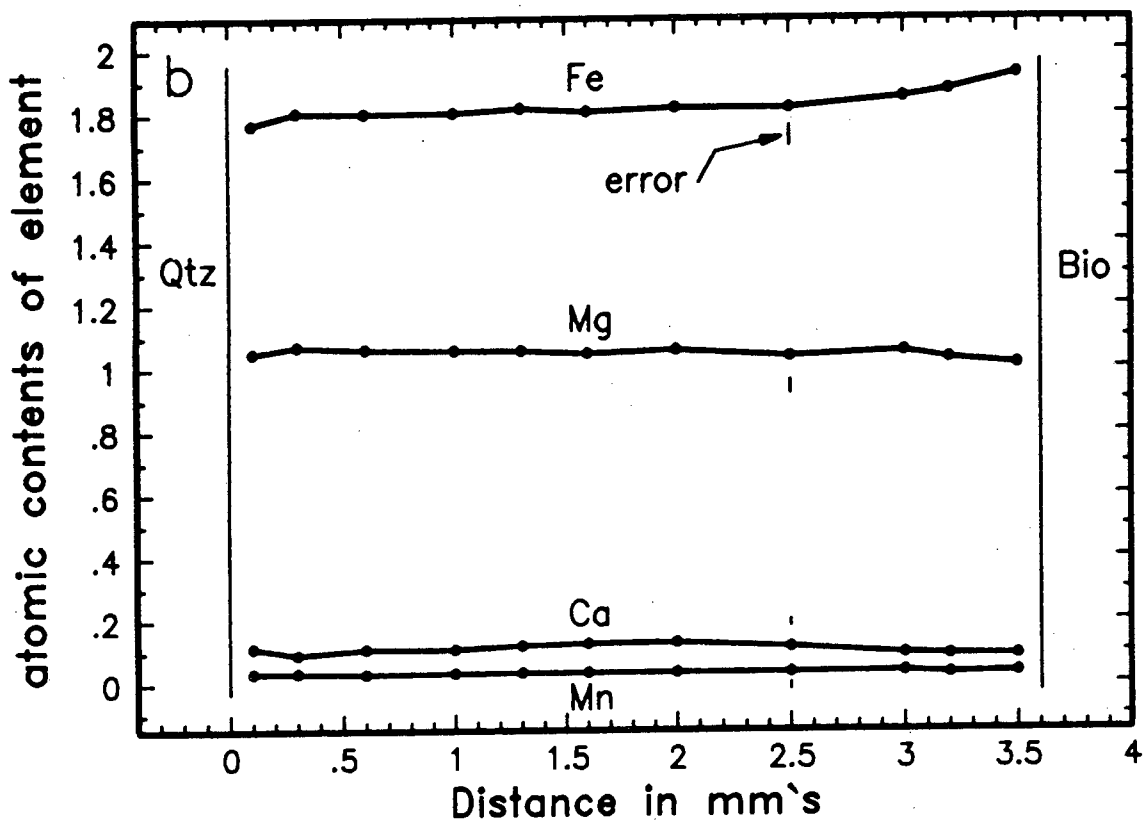
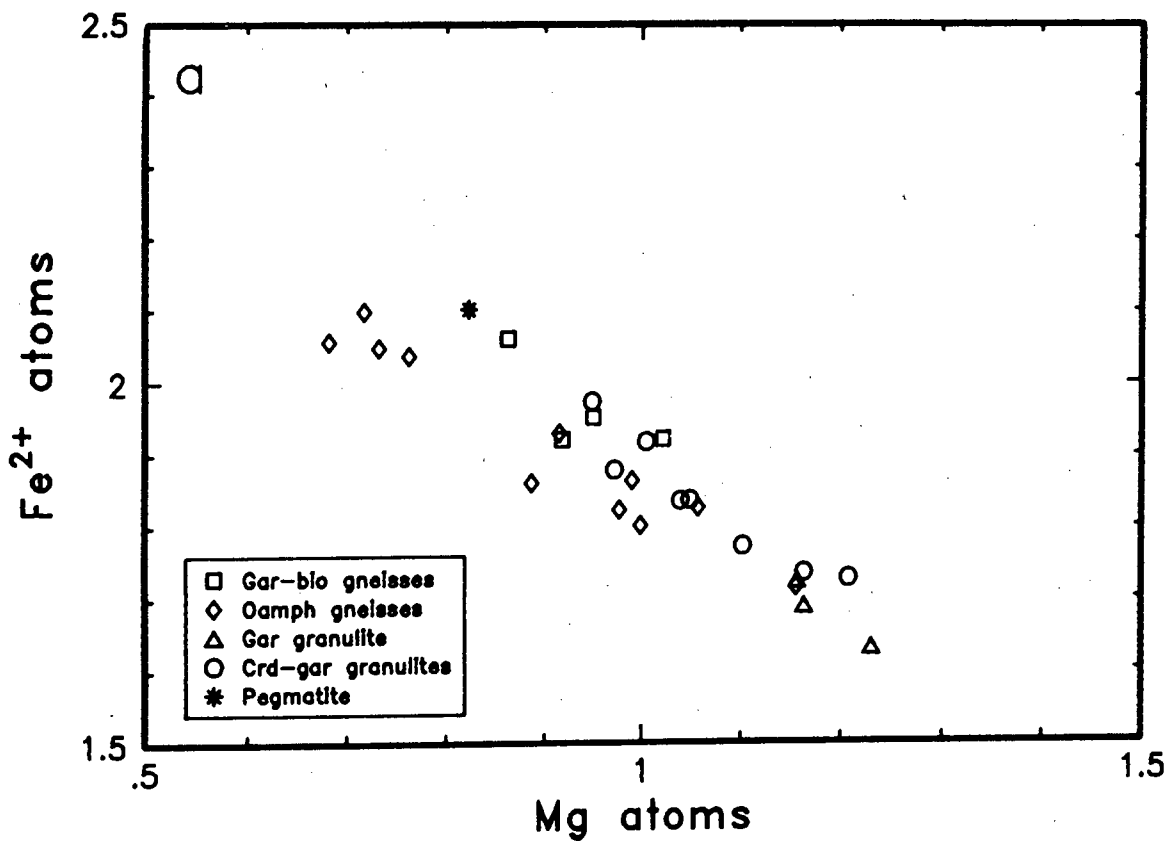


Figure 5.5a: Fe - Mg atomic relationships of selected garnets from the pelitic rocks. For clarity purposes only the core compositions of the most almandine- and pyrope-rich endmembers from each sample were plotted.

Figure 5.5b: An electron microprobe profile across a garnet from sample P21C (cordierite-garnet granulite) illustrating the typical zonation style observed in garnets.

Table 5.10: Microprobe analysis of orthoamphibole from the pelitic rocks. Cation proportions are calculated relative to 23 oxygens.

M -  $Mg/(Mg+Fe) * 100$ ,

B, G - sample in contact with biotite or garnet.

	P5C-1C	P5C-2C	P5C-3C	P5C-4C	P32C-1C	P38C-1C	P38C-1R	P38C-2C	P42C-1C	P50C-1C
SiO <sub>2</sub>	46.17	46.28	48.06	47.67	45.27	47.08	46.90	47.24	52.81	44.94
TiO <sub>2</sub>	.25	.34	.37	.27	.20	.19	.18	.22	.00	.41
Al <sub>2</sub> O <sub>3</sub>	12.18	13.07	9.28	10.10	16.54	13.38	13.57	12.20	1.45	16.20
Cr <sub>2</sub> O <sub>3</sub>	.39	.32	.19	.27	.00	.21	.23	.26	.11	.28
FeO	22.98	22.99	23.06	23.07	18.85	20.58	20.42	21.31	22.85	20.18
MnO	.11	.15	.14	.13	.00	.16	.17	.18	.00	.29
MgO	14.92	14.83	16.18	15.67	17.09	16.92	16.98	16.58	19.36	15.18
CaO	.42	.40	.36	.37	.39	.33	.28	.27	.61	.47
Na <sub>2</sub> O	1.04	1.02	.75	.79	1.71	1.13	1.15	1.07	.07	1.49
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	98.49	99.43	98.42	98.37	100.05	99.98	99.88	99.33	97.26	99.44
Si	6.732	6.675	6.998	6.945	6.372	6.669	6.647	6.761	7.737	6.414
Ti	.027	.037	.041	.030	.021	.020	.019	.024		.044
Al	2.093	2.222	1.593	1.734	2.744	2.234	2.267	2.058	.250	2.725
Cr	.045	.036	.022	.031		.023	.026	.029	.013	.031
Fe <sup>2+</sup>	2.802	2.773	2.808	2.811	2.219	2.438	2.420	2.551	2.800	2.409
Mn	.014	.018	.017	.016		.019	.021	.022		.036
Mg	3.242	3.188	3.511	3.402	3.585	3.572	3.587	3.537	4.227	3.228
Ca	.066	.062	.056	.058	.059	.050	.043	.042	.096	.072
Na	.294	.285	.212	.223	.466	.310	.316	.297	.020	.412
K										
Sum	15.319	15.301	15.261	15.255	15.467	15.337	15.345	15.320	15.142	15.370
M	53.64	53.49	55.57	54.77	61.77	59.43	59.71	58.10	60.16	57.27

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P5C-1C	: GEDRITE 437/247
P5C-2C	: GEDRITE 610/243
P5C-3C	: GEDRITE 621/164
P5C-4C	: GEDRITE 554/74
P32C-1C	: GEDRITE 558/234
P38C-1C	: GEDRITE 603/142
P38C-1R	: GEDRITE 603/142
P38C-2C	: GEDRITE 564/96
P42C-1C	: ANTHOPHYLITE 499/210
P50C-1C	: GEDRITE 594/235 B

Table 5.10: continued

	P50C-2C	P50C-2R	P50C-3C	P7D-1C	P7D-2C	P7D-3C
SiO <sub>2</sub>	44.16	45.45	51.81	53.16	54.08	53.16
TiO <sub>2</sub>	.46	.51	.12	.00	.08	.08
Al <sub>2</sub> O <sub>3</sub>	17.12	14.83	6.05	5.44	2.98	4.57
Cr <sub>2</sub> O <sub>3</sub>	.33	.42	.23	.14	.00	.12
FeO	20.61	20.50	18.72	17.84	18.29	18.13
MnO	.29	.28	.20	.13	.00	.00
MgO	14.69	15.52	19.90	21.26	21.70	21.03
CaO	.44	.43	.28	.24	.24	.22
Na <sub>2</sub> O	1.73	1.53	.48	.52	.19	.30
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00
Total	99.83	99.47	97.79	98.73	97.56	97.61
Si	6.301	6.500	7.401	7.475	7.696	7.562
Ti	.049	.054	.013		.008	.008
Al	2.879	2.500	1.018	.901	.450	.766
Cr	.038	.047	.026	.016		.014
Fe <sup>2+</sup>	2.459	2.452	2.236	2.098	2.086	2.157
Mn	.036	.033	.024	.016		
Mg	3.124	3.308	4.236	4.455	4.602	4.458
Ca	.067	.066	.043	.037	.037	.033
Na	.479	.424	.133	.142	.052	.083
K						
Sum	15.431	15.385	15.131	15.138	15.072	15.082
M	55.95	57.43	65.45	67.99	67.89	67.40

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P50C-2C : GEDRITE 477/230 B  
P50C-2R : GEDRITE 477/230 B  
P50C-3C : ANTHOPHYLLITE 553/144  
P7D-1C : ANTHOPHYLLITE 557/250  
P7D-2C : ANTHOPHYLLITE 570/223  
P7D-3C : ANTHOPHYLLITE 507/31

Figure 5.6: Orthoamphibole compositions plotted in terms of A-site occupancy (Na) versus Al<sup>IV</sup> for 23 oxygens.

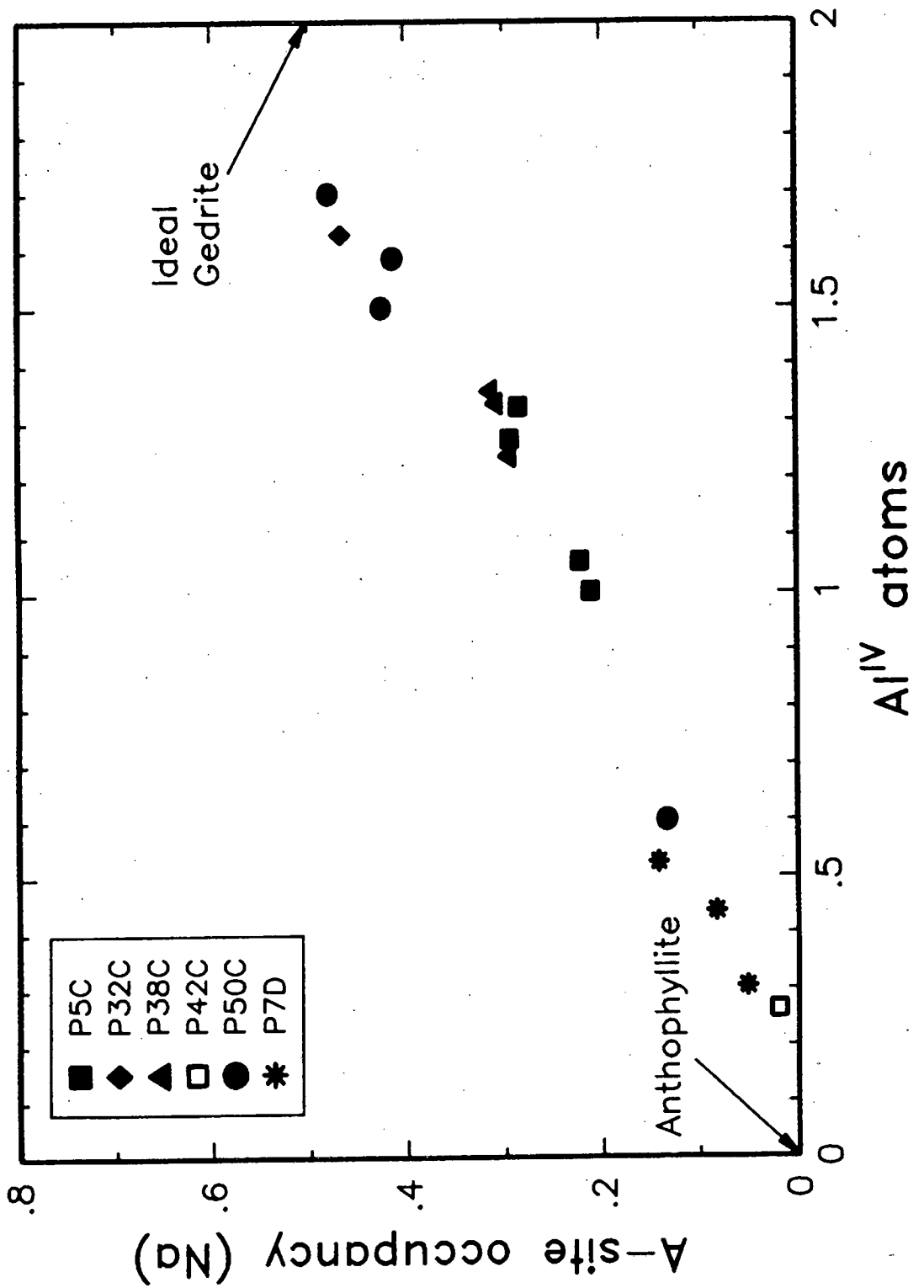


Table 5.11: Microprobe analysis of orthopyroxene from the pelitic rock. cation proportions are calculated relative to 6 oxygens. Wo, En, Fs - wollastonite, enstatite and ferrosalite proportions. T1,G (B,C,MX) - geothermobarometry sample number of orthopyroxene in contact with garnet (biotite, cordierite, matrix).

	P25C-1C	P25C-1R	P25C-2C	P25C-3C	P25C-3R	P25C-4C	P14C-2C	P14C-3C	P14C-4C	P14C-6C
SiO <sub>2</sub>	50.31	50.82	51.07	50.43	51.39	50.50	50.53	50.60	51.46	51.02
TiO <sub>2</sub>	.08	.00	.07	.08	.00	.15	.11	.08	.25	.07
Al <sub>2</sub> O <sub>3</sub>	5.76	6.04	5.54	6.02	5.23	5.99	4.74	4.51	3.65	4.09
Cr <sub>2</sub> O <sub>3</sub>	.19	.22	.20	.18	.21	.20	.26	.23	.17	.26
FeO	19.65	19.03	18.85	18.69	17.95	19.14	23.90	24.16	22.12	23.07
MnO	.20	.17	.16	.00	.15	.16	.20	.21	.20	.20
MgO	24.17	24.69	24.87	24.77	25.91	24.52	20.59	20.85	22.52	21.26
CaO	.06	.07	.06	.07	.06	.11	.06	.10	.06	.07
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.06	.00	.00	.00	.00
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.42	101.04	100.82	100.24	100.90	100.83	100.43	100.78	100.47	100.08
Si	1.842	1.842	1.854	1.840	1.856	1.837	1.885	1.884	1.903	1.902
Ti	.002		.002	.002		.004	.003	.002	.007	.002
Al	.249	.258	.237	.259	.223	.257	.208	.198	.159	.180
Cr	.006	.006	.006	.005	.006	.006	.008	.007	.005	.008
Fe <sup>2+</sup>	.602	.577	.572	.570	.542	.582	.746	.752	.684	.719
Mn	.006	.005	.005		.005	.005	.006	.007	.006	.006
Mg	1.319	1.334	1.345	1.347	1.395	1.330	1.145	1.157	1.241	1.181
Ca	.002	.003	.002	.003	.002	.004	.002	.004	.002	.003
Na						.004				
K										
Sum	4.028	4.026	4.023	4.026	4.029	4.029	4.005	4.012	4.009	4.003
Wo	.12	.14	.12	.14	.12	.22	.13	.21	.12	.15
En	68.59	69.71	70.07	70.15	71.92	69.38	60.48	60.47	64.39	62.06
Fs	31.29	30.15	29.81	29.71	27.96	30.39	39.39	39.32	35.49	37.79
M	68.67	69.81	70.16	70.25	72.01	69.54	60.56	60.60	64.47	62.15
C	.18	.20	.17	.20	.17	.32	.21	.34	.19	.24

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P25C-1C : HYP 519/248 T1,G  
P25C-1R : HYP 519/248 T1,G  
P25C-2C : HYP 491/130 T2,G  
P25C-3C : HYP 476/252 T3,G  
P25C-3R : HYP 476/252 T3,G  
P25C-4C : HYP 428/126 T4,G  
P14C-2C : HYP 547/8 T2,G,C  
P14C-3C : HYP 607/113 T3,G,C  
P14C-4C : HYP 510/17 T4,G  
P14C-6C : HYP 457/80 T6,G,C,B

Table 5.11: continued

	P14C-8C	P14C-9C	P14C-10C	P19C-1C	P19C-2C	P21C-5C	P21C-5R	P21C-6C	P1D-1C	P1D-2C
SiO <sub>2</sub>	49.93	50.19	50.25	49.75	49.26	49.56	49.76	49.53	50.47	50.27
TiO <sub>2</sub>	.09	.09	.08	.07	.07	.10	.08	.09	.53	.00
Al <sub>2</sub> O <sub>3</sub>	4.89	4.93	4.75	5.33	5.33	5.74	5.79	5.38	3.45	3.59
Cr <sub>2</sub> O <sub>3</sub>	.27	.25	.32	.29	.32	.31	.27	.32	.16	.16
FeO	23.93	24.20	24.21	22.52	21.67	23.19	21.01	23.20	25.14	25.85
MnO	.27	.19	.21	.24	.19	.13	.00	.15	.31	.31
MgO	20.34	19.91	20.29	21.96	22.24	21.27	22.96	21.51	20.69	20.60
CaO	.09	.06	.06	.08	.08	.06	.06	.06	.10	.09
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	99.85	99.86	100.21	100.28	99.20	100.36	99.93	100.24	100.85	100.87
Si	1.876	1.886	1.882	1.851	1.847	1.846	1.842	1.849	1.890	1.888
Ti	.003	.003	.002	.002	.002	.003	.002	.003	.015	
Al	.217	.218	.210	.234	.236	.252	.253	.237	.152	.159
Cr	.008	.007	.009	.009	.009	.009	.008	.009	.005	.005
Fe <sup>2+</sup>	.752	.760	.759	.701	.680	.723	.651	.724	.787	.812
Mn	.009	.006	.007	.008	.006	.004		.005	.010	.010
Mg	1.139	1.115	1.133	1.218	1.243	1.181	1.267	1.197	1.154	1.153
Ca	.004	.002	.002	.003	.003	.002	.002	.002	.004	.004
Na										
K										
Sum	4.009	3.999	4.006	4.026	4.028	4.020	4.025	4.026	4.017	4.030
Wo	.19	.13	.13	.17	.17	.13	.12	.13	.21	.18
En	60.12	59.37	59.82	63.37	64.54	61.96	65.99	62.22	59.33	58.57
Fs	39.69	40.50	40.05	36.47	35.29	37.91	33.89	37.66	40.46	41.25
M	60.23	59.45	59.89	63.47	64.65	62.04	66.07	62.29	59.46	58.68
C	.32	.22	.21	.26	.26	.20	.19	.20	.35	.31

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P14C-8C : HYP 507/160 T8,C  
P14C-9C : HYP 523/200 T9,B  
P14C-10C : HYP 502/82 T10,B  
P19C-1C : HYP 506/159 T1,C,G  
P19C-2C : HYP 522/13 T2,G  
P21C-5C : HYP 610/69 T5,FINGER,G,(C)  
P21C-5R : HYP 610/69 FINGER,G  
P21C-6C : HYP 447/170 MX  
P1D-1C : HYP 566/40 MX  
P1D-2C : HYP 452/117 MX

Table 5.11: continued

	P8C-1C	P8C-2C	P8C-3C	P8C-4C	P8C-4R	P8C-5C	P8C-6C	P8C-7C	P8C-8C	P8C-9C
SiO <sub>2</sub>	50.80	50.79	51.03	50.38	50.63	49.79	50.62	50.15	50.41	50.38
TiO <sub>2</sub>	.34	.06	.10	.05	.05	.07	.05	.07	.09	.06
Al <sub>2</sub> O <sub>3</sub>	5.27	4.91	5.26	5.01	5.01	4.75	5.13	5.25	5.46	5.46
Cr <sub>2</sub> O <sub>3</sub>	.44	.38	.05	.41	.44	.45	.43	.49	.57	.50
FeO	20.49	21.52	20.45	20.52	20.51	21.25	19.94	21.36	20.35	20.07
MnO	.39	.38	.30	.33	.35	.33	.42	.35	.43	.35
MgO	22.67	22.61	23.13	22.86	22.71	22.62	23.35	22.27	22.78	22.89
CaO	.07	.06	.07	.07	.07	.08	.05	.08	.07	.06
Na <sub>2</sub> O	.00	.00	.00	.00	.00	.03	.00	.02	.03	.00
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.51	100.75	100.43	99.67	99.81	99.40	100.03	100.07	100.22	99.81
Si	1.866	1.871	1.873	1.868	1.874	1.861	1.865	1.860	1.858	1.861
Ti	.009	.002	.003	.001	.001	.002	.001	.002	.002	.002
Al	.228	.213	.228	.219	.219	.209	.223	.230	.237	.238
Cr	.013	.011	.001	.012	.013	.013	.013	.014	.017	.015
Fe <sup>2+</sup>	.630	.663	.628	.636	.635	.664	.615	.663	.627	.620
Mn	.012	.012	.009	.010	.011	.010	.013	.011	.013	.011
Mg	1.241	1.241	1.265	1.263	1.253	1.260	1.282	1.231	1.252	1.260
Ca	.003	.002	.003	.003	.003	.003	.002	.003	.003	.002
Na						.002	.001	.001	.002	
K										
Sum	4.004	4.016	4.011	4.015	4.010	4.027	4.016	4.017	4.013	4.011
Wo	.15	.12	.15	.15	.15	.17	.10	.17	.15	.13
En	66.25	65.10	66.74	66.40	66.27	65.37	67.53	64.90	66.51	66.94
Fs	33.60	34.77	33.11	33.45	33.58	34.46	32.36	34.93	33.34	32.94
M	66.35	65.18	66.84	66.50	66.37	65.48	67.60	65.01	66.61	67.02
C	.22	.19	.22	.22	.22	.25	.15	.26	.22	.19

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P8C-1C : HYP 444/137 T1,B  
P8C-2C : HYP 631/171 T2,B  
P8C-3C : HYP 532/164 T3,B  
P8C-4C : HYP 505/218 T4,B  
P8C-4R : HYP 505/218 T4,B  
P8C-5C : HYP 467/96 T5,B  
P8C-6C : HYP 466/194 T6,B  
P8C-7C : HYP 610/173 T7,B-INCL  
P8C-8C : HYP 602/98 T8,C  
P8C-9C : HYP 477/192 T9,C

Table 5.11: continued

	P8C-10C	P8C-11C	P8C-12C	P8C-13C	P8C-13R	P8C-14C	P3D-1C	P3D-2C	P3D-3C	P5D-1C
SiO <sub>2</sub>	50.99	50.29	50.22	50.87	50.77	50.24	51.51	51.21	51.48	51.92
TiO <sub>2</sub>	.04	.06	.07	.17	.14	.06	.12	.00	.09	.30
Al <sub>2</sub> O <sub>3</sub>	4.71	5.04	5.19	5.01	5.14	5.50	4.35	4.35	4.28	5.29
Cr <sub>2</sub> O <sub>3</sub>	.53	.38	.57	.43	.38	.43	.31	.39	.31	.39
FeO	20.51	20.73	20.73	20.36	20.44	20.52	20.38	20.67	20.66	17.64
MnO	.32	.32	.38	.38	.39	.37	.23	.31	.29	.19
MgO	22.94	22.99	22.60	22.88	22.87	22.69	23.49	22.93	23.09	24.55
CaO	.05	.06	.05	.09	.10	.07	.07	.09	.07	.11
Na <sub>2</sub> O	.00	.03	.00	.36	.00	.00	.00	.00	.00	.00
K <sub>2</sub> O	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00
Total	100.13	99.93	99.85	100.62	100.27	99.92	100.46	99.95	100.27	100.39
Si	1.880	1.862	1.862	1.869	1.870	1.858	1.889	1.892	1.894	1.880
Ti	.001	.002	.002	.005	.004	.002	.003		.002	.008
Al	.205	.220	.227	.217	.223	.240	.188	.189	.186	.226
Cr	.015	.011	.017	.012	.011	.013	.009	.011	.009	.011
Fe <sup>2+</sup>	.633	.642	.643	.626	.629	.635	.625	.639	.636	.534
Mn	.010	.010	.012	.012	.012	.012	.007	.010	.009	.006
Mg	1.261	1.269	1.249	1.253	1.255	1.251	1.284	1.263	1.266	1.325
Ca	.002	.002	.002	.004	.004	.003	.003	.004	.003	.004
Na		.002		.026						
K				.002						
Sum	4.009	4.022	4.015	4.025	4.010	4.014	4.009	4.008	4.006	3.994
Wo	.10	.12	.11	.19	.21	.15	.14	.19	.15	.23
En	66.52	66.32	65.95	66.57	66.46	66.24	67.16	66.28	66.48	71.10
Fs	33.38	33.56	33.95	33.24	33.33	33.62	32.70	33.53	33.38	28.67
M	66.59	66.40	66.02	66.70	66.60	66.34	67.26	66.41	66.57	71.26
C	.16	.19	.16	.28	.31	.22	.21	.28	.22	.32

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P8C-10C : HYP 465/240 T10,C  
P8C-11C : HYP 442/230 T11,C  
P8C-12C : HYP 457/173 T12,C  
P8C-13C : HYP 548/148 C  
P8C-13R : HYP 550/156 C  
P8C-14C : HYP 549/182 MX  
P3D-1C : HYP 604/186 C  
P3D-2C : HYP 484/153 C  
P3D-3C : HYP 621/130 B-INCL  
P5D-1C : HYP 557/124 MX

Table 5.11: continued

	P5D-2C	P5D-3C
SiO <sub>2</sub>	51.86	52.00
TiO <sub>2</sub>	.11	.00
Al <sub>2</sub> O <sub>3</sub>	5.16	5.07
Cr <sub>2</sub> O <sub>3</sub>	.43	.51
FeO	18.47	16.72
MnO	.27	.25
MgO	24.39	25.16
CaO	.09	.08
Na <sub>2</sub> O	.00	.00
K <sub>2</sub> O	.00	.00
Total	100.78	99.79
Si	1.879	1.887
Ti	.003	
Al	.220	.217
Cr	.012	.015
Fe <sup>2+</sup>	.560	.507
Mn	.008	.008
Mg	1.317	1.361
Ca	.003	.003
Na		
K		
Sum	4.002	3.997
Wo	.19	.17
En	70.05	72.72
Fs	29.77	27.12
M	70.18	72.84
C	.26	.23

\*\*\* All zero values below detection limit.\*\*\*

SAMPLE DESCRIPTIONS :

P5D-2C : HYP 562/30 MX  
P5D-3C : HYP 474/54 FINGER,C

Table 5.12: Microprobe analysis of cordierite from the pelitic rocks. cation proportions are calculated relative to 18 oxygens. M - Mg/(Mg+Fe) \* 100. T1,G (H,B) - geothermobarometry sample number for cordierite in contact with garnet (hypersthene, biotite).

	P14C-1C	P14C-1R	P14C-2C	P14C-3C	P14C-6C	P14C-7C	P14C-7R	P14C-8C	P19C-1C	P19C-5C
SiO <sub>2</sub>	49.83	49.58	49.21	49.64	49.58	49.06	49.50	49.30	48.62	49.19
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	33.92	33.73	33.51	33.52	33.41	33.27	33.36	33.54	32.93	33.24
FeO	3.57	3.55	4.10	4.28	3.74	4.74	4.10	4.72	3.45	2.51
MnO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MgO	11.37	11.35	10.89	10.80	11.14	10.80	10.88	10.64	11.16	11.75
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	98.77	98.29	97.79	98.32	97.95	97.95	97.92	98.28	96.24	96.77
Si	4.993	4.992	4.993	5.011	5.013	4.987	5.014	4.991	4.999	5.007
Ti										
Al	4.006	4.003	4.008	3.989	3.981	3.986	3.983	4.003	3.991	3.988
Fe <sup>2+</sup>	.299	.299	.348	.361	.316	.403	.347	.406	.297	.214
Mn										
Mg	1.698	1.703	1.647	1.625	1.678	1.636	1.642	1.605	1.710	1.782
Ca										
K										
Sum	11.004	11.006	11.003	10.994	10.997	11.020	10.995	11.007	11.005	10.999
M	85.02	85.08	82.54	81.80	84.14	79.85	82.53	80.07	85.21	89.31

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P14C-1C : CORD 579/105 T1,G  
P14C-1R : CORD 579/105 T1,G  
P14C-2C : CORD 546/7 T2,G,H  
P14C-3C : CORD 604/112 T3,G,H  
P14C-6C : CORD 453/79 T6,G,H,B  
P14C-7C : CORD 498/190 T7,B  
P14C-7R : CORD 498/190 T7,B  
P14C-8C : CORD 505/165 T8,H  
P19C-1C : CORD 506/154 T1,G,H  
P19C-5C : CORD 612/213 T5,G

Table 5.12: continued

	P19C-6C	P21C-6C	P21C-7C	P21C-7R	P21C-8C	P1D-1C	P8C-8C	P8C-9C	P8C-9R	P8C-10C
SiO <sub>2</sub>	48.72	49.64	49.16	48.66	49.02	48.14	49.16	49.09	48.96	48.97
TiO <sub>2</sub>	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Al <sub>2</sub> O <sub>3</sub>	32.97	33.70	33.30	33.23	33.14	32.80	33.24	33.42	33.36	33.34
FeO	4.77	3.00	3.44	2.99	3.92	4.09	3.44	3.31	3.46	3.66
MnO	.09	.00	.00	.00	.00	.00	.08	.00	.10	.09
MgO	10.51	11.93	11.36	11.87	11.20	10.92	11.15	11.15	11.28	11.14
CaO	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
K <sub>2</sub> O	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	97.13	98.27	97.26	96.75	97.28	95.95	97.14	97.05	97.23	97.27
Si	4.996	4.988	4.999	4.969	4.996	4.981	5.007	5.000	4.986	4.988
Ti										
Al	3.985	3.991	3.992	4.000	3.981	4.000	3.991	4.012	4.004	4.003
Fe <sup>2+</sup>	.409	.252	.293	.255	.334	.354	.293	.282	.295	.312
Mn	.008						.007		.009	.008
Mg	1.606	1.786	1.722	1.807	1.701	1.684	1.693	1.692	1.712	1.691
Ca										
K										
Sum	11.012	11.017	11.005	11.031	11.013	11.019	10.998	10.994	11.012	11.010
M	79.69	87.64	85.48	87.61	83.58	82.64	85.25	85.71	85.32	84.45

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

- P19C-6C : CORD 585/206 T6,G
- P21C-6C : CORD 519/162 T6,G
- P21C-7C : CORD 611/55 T7,WITH G-INCL
- P21C-7R : CORD 611/55 T7,WITH G-INCL
- P21C-8C : CORD 610/69 G,H
- P1D-1C : CORD 599/48 MX
- P8C-8C : CORD 600/100 T8,H
- P8C-9C : CORD 474/193 T9,H,B
- P8C-9R : CORD 474/193 T9,H
- P8C-10C : CORD 462/240 T10,H

Table 5.12: continued

	P8C-11C	P8C-12C
SiO <sub>2</sub>	48.98	49.08
TiO <sub>2</sub>	.00	.00
Al <sub>2</sub> O <sub>3</sub>	33.39	33.39
FeO	3.32	3.59
MnO	.00	.11
MgO	11.13	11.09
CaO	.00	.03
K <sub>2</sub> O	.00	.00
Total	96.90	97.35
Si	4.997	4.994
Ti		
Al	4.015	4.004
Fe <sup>2+</sup>	.283	.305
Mn		.009
Mg	1.692	1.682
Ca		.003
K		
Sum	10.996	11.004
M	85.66	84.64

\*\*\* All zero values below detection limit \*\*\*

SAMPLE DESCRIPTIONS :

P8C-11C : CORD 442/229 T11,H  
P8C-12C : CORD 457/177 T12,H

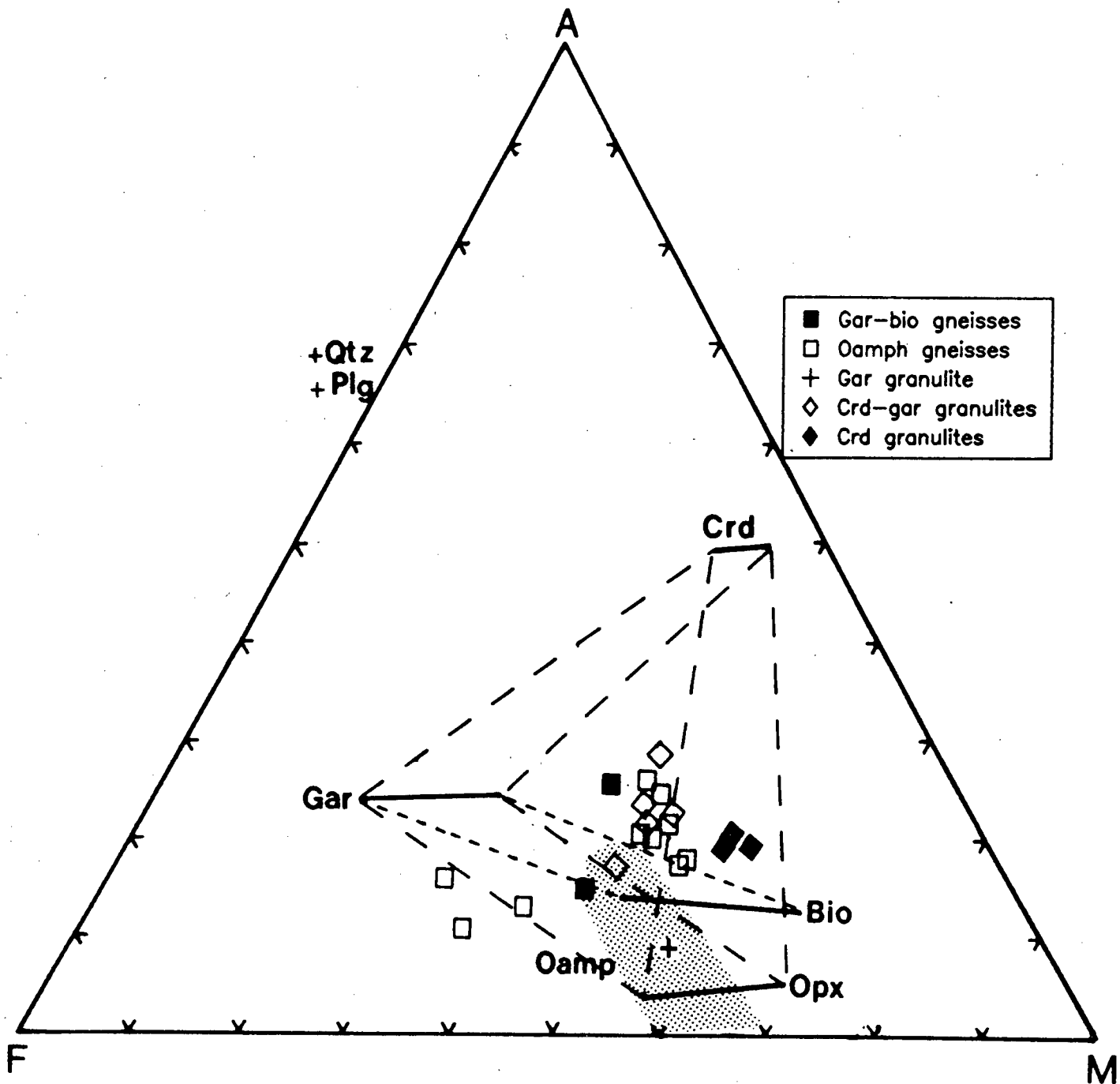


Figure 5.7: A - F - M diagram illustrating the bulk compositional control on phase relationships. Projection from K-feldspar:  
 A =  $[\text{Al}_2\text{O}_3] - [\text{CaO}] - [\text{Na}_2\text{O}] - [\text{K}_2\text{O}]$ ,  
 F =  $[\text{FeO}]$ ,  
 M =  $[\text{MgO}]$ , all in mole percent.  
 Representative mineral analyses are taken from Tables 5.8 to 5.12. Garnet compositions are corrected for grossular and spessartine components (Thompson, 1957).

Table 6.1

Summary of the results of cation geobarometry and geothermometry for the pelitic rocks. The values given represent the average of several mineral core compositions from one rock. Except if specified otherwise, the minerals were in contact with each other. All pressures calculated at 800°C while all temperatures calculated at 6kbars. See text for further discussion.

- A - Newton and Perkins (1982), Gar-Opx-Plg-Qtz;
- B - Harley and Green (1982), Gar-Opx;
- C - Sen and Bhattacharya (1984), Gar-Opx;
- D - Harley (1984), Gar-Opx;
- E - Perchuk and Lavrenteva (1983), Gar-BioMatrix;
- F - as E above but Gar and Bio in contact;
- G - Indares and Martignole (1985b), Gar-BioMatrix;
- H - Ferry and Spear (1978), Gar-BioMatrix;
- J - Perchuk and Lavrenteva (1983), Gar-Crd;
- K - Bhattacharya et al. (1988), Gar-Crd.

Abbreviations as in Table 3, pressures in kbars and temperatures in °C.

Sample	A	B	C	D	E	F	G	H	J	K
P17C	-	-	-	-	723	609	693	866	-	-
P41C	-	-	-	-	650	639	616	717	-	-
P34C	-	-	-	-	658	-	649	734	-	-
P42C	-	-	-	-	610	609	566	633	-	-
P50C	-	-	-	-	610	559	561	636	-	-
P7D	-	-	-	-	595	605	543	607	-	-
P25C	6.2	5.4	674	645	707	658	649	848	-	-
P14C	5.5	6.3	759	704	677	587	615	777	592	685
P19C	6.4	4.8	730	680	662	602	630	746	578	672
P21C	6.3	4.4	783	716	710	622	660	850	553	657
P1D	-	-	-	-	620	573	555	658	-	-

Figure 6.1: Average garnet and matrix-biotite core temperatures (in °C) are shown next to the sample positions (squares). Temperatures were calculated using the calibration of Perchuk and Lavrenteva (1983). Sample positions of all other samples are also shown (see Fig. 2.1 for details).

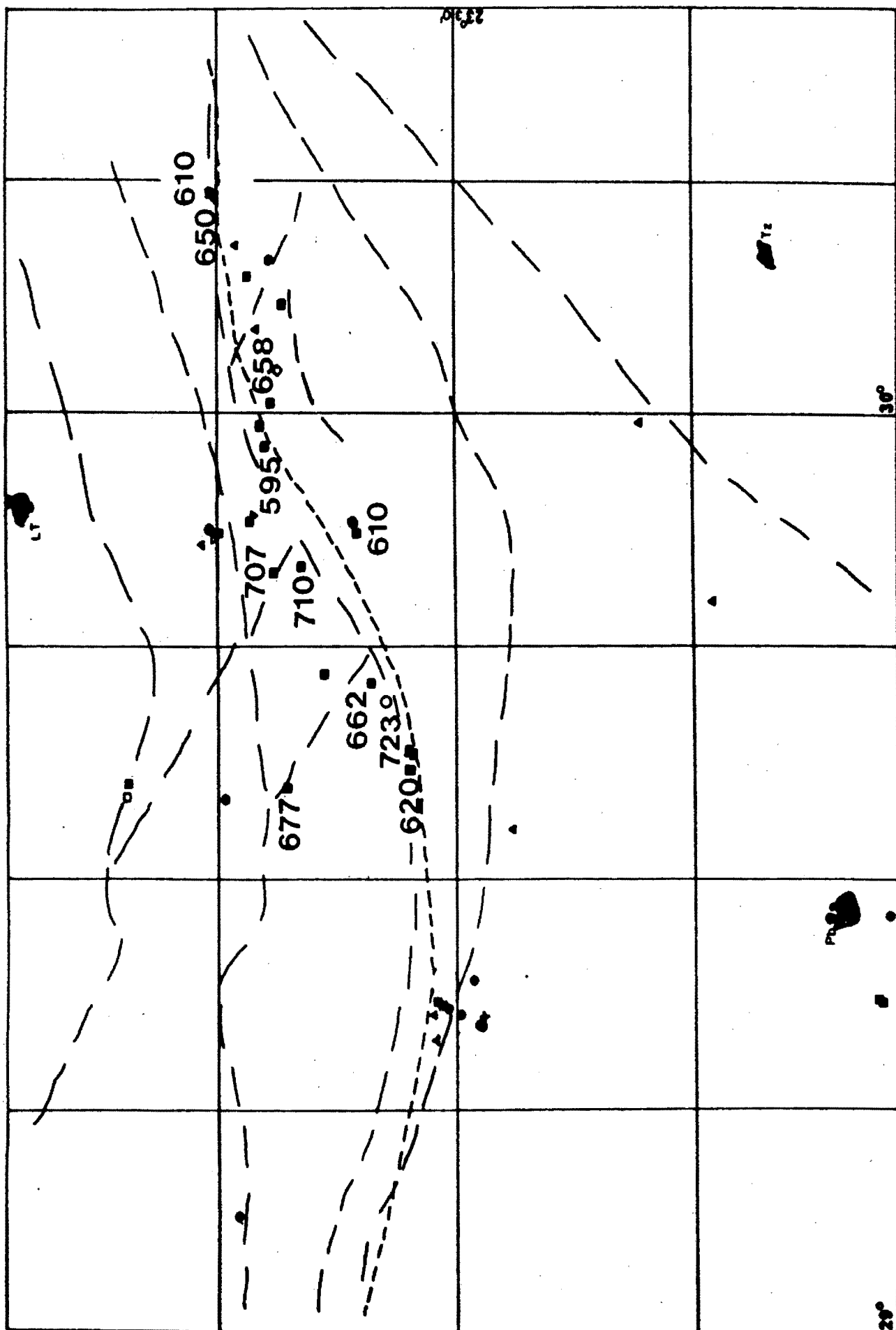


Table 7.1

Oxygen isotope data for the ultramafic rocks.  $\delta^{18}\text{O}$  values are reported as per mil (‰) relative to V-SMOW.

Abbreviations: opx=orthopyroxene, chl=chlorite, trm=tremolite, WR=whole rock.

Sample	opx	chl	trm	WR
U10A	8.86	8.92	9.04	8.88
U7A	--	--	5.07	4.20
U6B	--	--	--	3.89
U10B	--	--	--	7.07
U17B	6.51	--	6.24	5.90
U31C	--	--	--	3.71
U40C	5.52	--	5.73	4.92
U44C	6.75	--	6.66	6.15

Figure 7.1: Histogram illustrating the whole rock oxygen isotopic compositions of the ultramafic, mafic and pelitic rocks from this study and comparing the obtained ranges to those given for similar rocks in the literature. A - Margaritz and Taylor, 1976; B - Longstaffe and Schwarcz, 1977; C - Kyser, 1986; D - McNaughten and Wilson, 1983; E - Hoffman et al., 1985; F - Smith et al., 1984; GS - greenschist facies rocks from the Pietersburg greenstone belt.

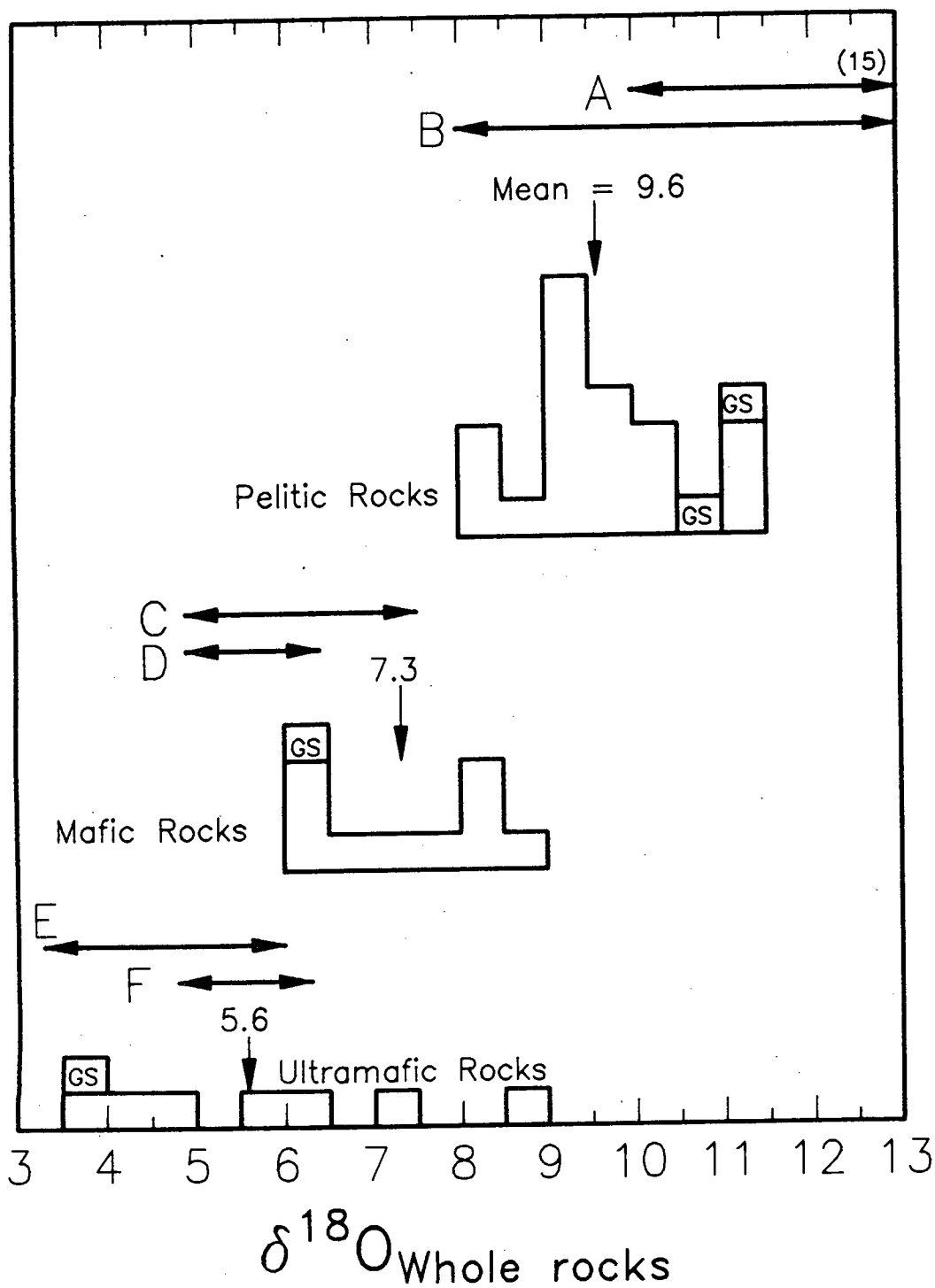


Table 7.2

Oxygen isotope data for the mafic rocks.  $\delta^{18}\text{O}$  values are reported as per mil (‰) relative to V-SMOW.

Abbreviations: pyx=pyroxene, amp=amphibole, plg=plagioclase, An=anorthite contents, qtz=quartz.

Sample	pyx	amp	plg (An)	qtz	WR
M1A	--	5.88	8.31 (43)	--	6.38
M2A	--	7.99	9.35 (42)	--	8.34
M3A	8.10	7.68	9.48 (38)	--	8.39
M5A	--	5.73	7.70 (38)	--	6.41
M8A	6.18	6.18	7.20 (47)	--	6.43
M11B	--	--	-- --	--	6.33
M3C	9.68	9.42	8.75 --	--	--
M11C	6.80	6.77	8.05 (46)	--	7.03
M27C	7.41	7.18	8.30 (54)	--	7.82
M37C	8.18	8.13	8.01 --	11.86	8.16
M41C	--	5.81	8.02 (30)	--	6.63
M52C	--	--	-- --	11.90	8.56

Figure 7.2:  $\delta^{18}\text{O}$  values (in ‰) of plagioclase from the mafic rocks are shown next to sample positions (dots). Sample positions of other samples are also shown for reference purposes (see Fig. 2.1 for details).

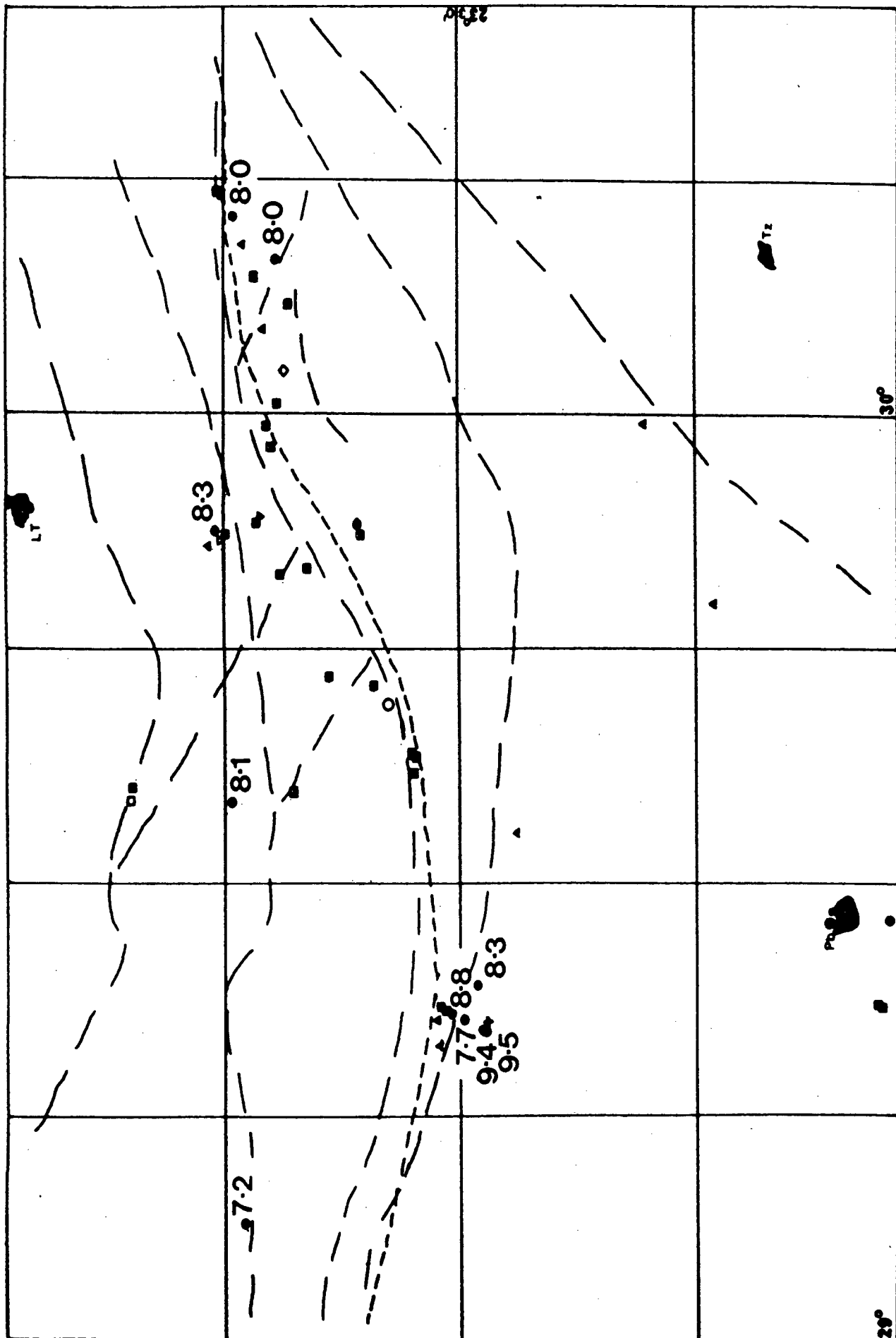


Table 7.3

Oxygen isotope data for the pelitic rocks.  $\delta^{18}\text{O}$  values are reported in per mil (‰) relative to V-SMOW.

Abbreviations: qtz=quartz, plg=plagioclase, An=anorthite content, bio=biotite, gar=garnet, oamp=orthoamphibole, opx=orthopyroxene, crd=cordierite, WR=whole rock, V=vein separate.

Sample	qtz	plg (An)	bio	gar	oamp	opx	crd	WR
P17C	11.54	-- --	6.63	8.83	--	--	--	10.05
P41C	11.21	9.15(21)	5.74	8.26	--	--	--	9.34
P5C	12.30	-- --	--	9.48	9.59	--	--	10.48
P6C	12.31	-- --	--	--	9.62	--	--	9.80
P16C	--	-- --	--	--	--	--	--	9.79
P32C	10.70	8.70(28)	5.34	7.67	--	--	--	8.09
P34C	13.26	11.35(27)	9.16	10.67	--	--	--	11.28
P38C	10.81	8.79(30)	5.88	7.65	7.78	--	--	9.34
P42C	11.14	8.96(41)	5.73	8.28	--	--	--	9.15
P45C	12.48	9.71(26)	--	9.87	--	--	--	10.00
P50C	11.67	9.83(37)	6.92	8.28	8.42	--	--	9.41
P7D	11.23	9.48(30)	6.46	8.16	--	--	--	8.52
V-P7D	11.14	9.52 --	6.23	8.15	--	--	--	--
P25C	10.81	8.99(31)	6.24	8.55	--	8.10	--	9.05
P14C	11.63	9.77(32)	7.20	8.38	--	8.45	9.38	9.07
P19C	10.77	9.08(34)	6.40	7.88	--	7.58	9.04	8.43
P21C	11.89	10.10(27)	7.29	9.17	--	8.83	--	9.94
P29C	--	--	--	--	--	--	--	8.15
P1D	11.72	9.85(29)	7.00	8.91	--	--	10.31	9.97
V-P1D	11.59	9.94 --	--	9.17	--	--	--	--
P8C	13.83	11.96(28)	8.85	--	--	10.97	11.54	11.43
P3D	11.67	9.89(23)	7.50	--	--	8.75	--	9.26
P5D	13.73	11.85(32)	9.29	--	--	10.67	--	11.14



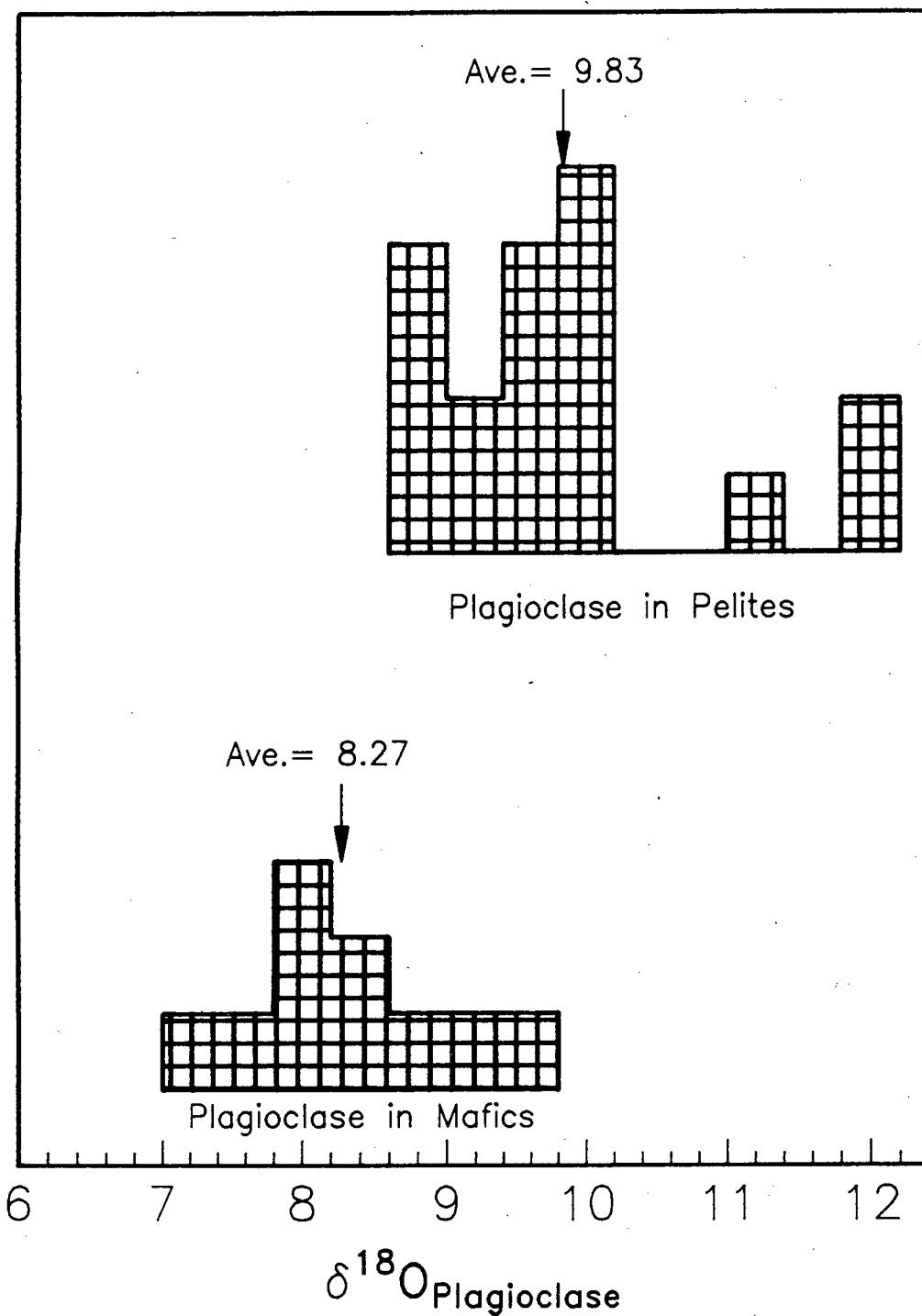


Figure 7.4: Histogram comparing the  $\delta^{18}\text{O}$  values of mafic and pelitic feldspars.

Table 7.4

Oxygen isotope data for various other rocks.  $\delta^{18}\text{O}$  values are reported as per mil (‰) relative to V-SMOW.

Abbreviations: qtz=quartz, plg=plagioclase, ksp=K-feldspar, bio=biotite, gar=garnet, mag=magnetite, WR=whole rock, Bif=banded iron formation, Charn=charnockite, Granod=granodiorite, Pegmat=pegmatite.

Sample	qtz	plg	ksp	bio	gar	mag	WR	Rock Type
B4A	19.70	--	--	--	--	9.72	--	Bif
C4D	9.68	--	--	5.05	--	--	7.75	Charn
C8D	--	--	--	--	--	--	7.78	Charn
G9C	12.27	--	--	7.13	--	--	10.71	Gneiss
GD49C	9.67	7.20	7.82	--	--	--	8.41	Granod
P13B	--	--	--	--	--	--	11.21	Pelite
P14B	--	--	--	--	--	--	10.92	Pelite
V6D	11.52	8.92	--	8.07	--	--	10.03	Pegmat
V28C	--	--	--	--	--	--	9.63	Pegmat

Table 7.5

Carbon isotope data for S M Z rocks.  $\delta^{13}\text{C}$  values are reported as per mil (‰) relative to PDB. Samples with prefix 'P' are from pelites, 'V' from pegmatites.  $\text{CO}_2$  calculated to be in equilibrium with the graphite.

Sample	$\delta^{13}\text{C}$ Graphite	$\delta^{13}\text{C}$ of $\text{CO}_2^*$ values at		
		730°C	650°C	600°C
P42C	-12.52	--	--	-3.7
P50C	-15.23	--	--	-6.4
P5D	-14.98	-7.6	--	--
P-A	-9.06	-1.7	--	--
P-B	-9.55	-2.2	--	--
V6D	-6.36	--	+1.89	--

\* using Friedman and O'Neil (1977)

Table 8.1

Anion temperature data for the pelitic rocks.

A = temperatures calculated using Bottinga and Javoy (1975),

B = temperatures calculated using Matthews et al. (1983).

Temperatures (T) in °C. Abbreviations as in Table 3.3.

s.d. = 1 standard deviation.

Sample	qtz-gar	qtz-amp	qtz-opx		qtz-plg		qtz-bio	plg-bio
	A	A	A	B	A	B	A	A
P17C	763	---	-----		-----		549	---
P41C	720	---	-----		489	325	510	520
P5C	744	756	-----		-----		---	---
P6C	---	758	-----		-----		---	---
P32C	706	---	-----		524	346	517	513
P34C	788	---	-----		540	376	617	666
P38C	686	703	-----		528	370	547	558
P42C	735	---	-----		531	389	513	503
P45C	783	---	-----		401	262	---	---
P50C	653	673	-----		588	431	561	546
P7D	700	---	-----		587	418	559	545
P25C	861	---	724	607	574	409	575	576
P14C	673	---	648	540	568	406	587	598
P19C	730	---	646	538	616	448	592	586
P21C	761	---	666	556	569	397	573	575
P1D	745	---	-----		557	391	563	567
P8C	---	---	699	585	554	387	544	540
P3D	---	---	688	575	556	380	610	641
P5D	---	---	667	556	565	403	587	600
Mean	736	722	677	-	547	-	563	569
s.d.	52	42	28		49		32	45

Table 8.2

Anion temperature data for the mafic rocks.  
 A = temperatures calculated using Bottinga and Javoy (1975),  
 B = temperatures calculated using Matthews et al. (1983).  
 Temperatures (T) in °C. Abbreviations as in Table 3.2,  
 s.d. = 1 standard deviation.

Sample	plg-pyx A	plg-pyx B	plg-amp A
M1A	---	---	526
M2A	---	---	755
M3A	704	650	652
M5A	---	---	616
M8A	820	753	832
M11C	719	659	767
M27C	835	757	779
M41C	---	---	592
Mean	769	705	690
s.d.	67	58	108

Table 8.3

Anion temperature data for various other rocks.  
 A = temperatures calculated using Bottinga and Javoy (1975),  
 B = temperatures calculated using Matthews et al. (1983).  
 Temperatures (T) in °C. Abbreviations as in Table 3.3.

Sample	qtz-gar	qtz-plg		qtz-ksp	qtz-bio	qtz-mgt	
	A	A	B	A	A	A	B
B4A	---	-----		---	---	479	515
G9C	---	-----		---	532	-----	
GD49C	---	451	308	454	---	-----	
C4D	---	-----		---	568	-----	
V6D	645	395	243	---	---	-----	

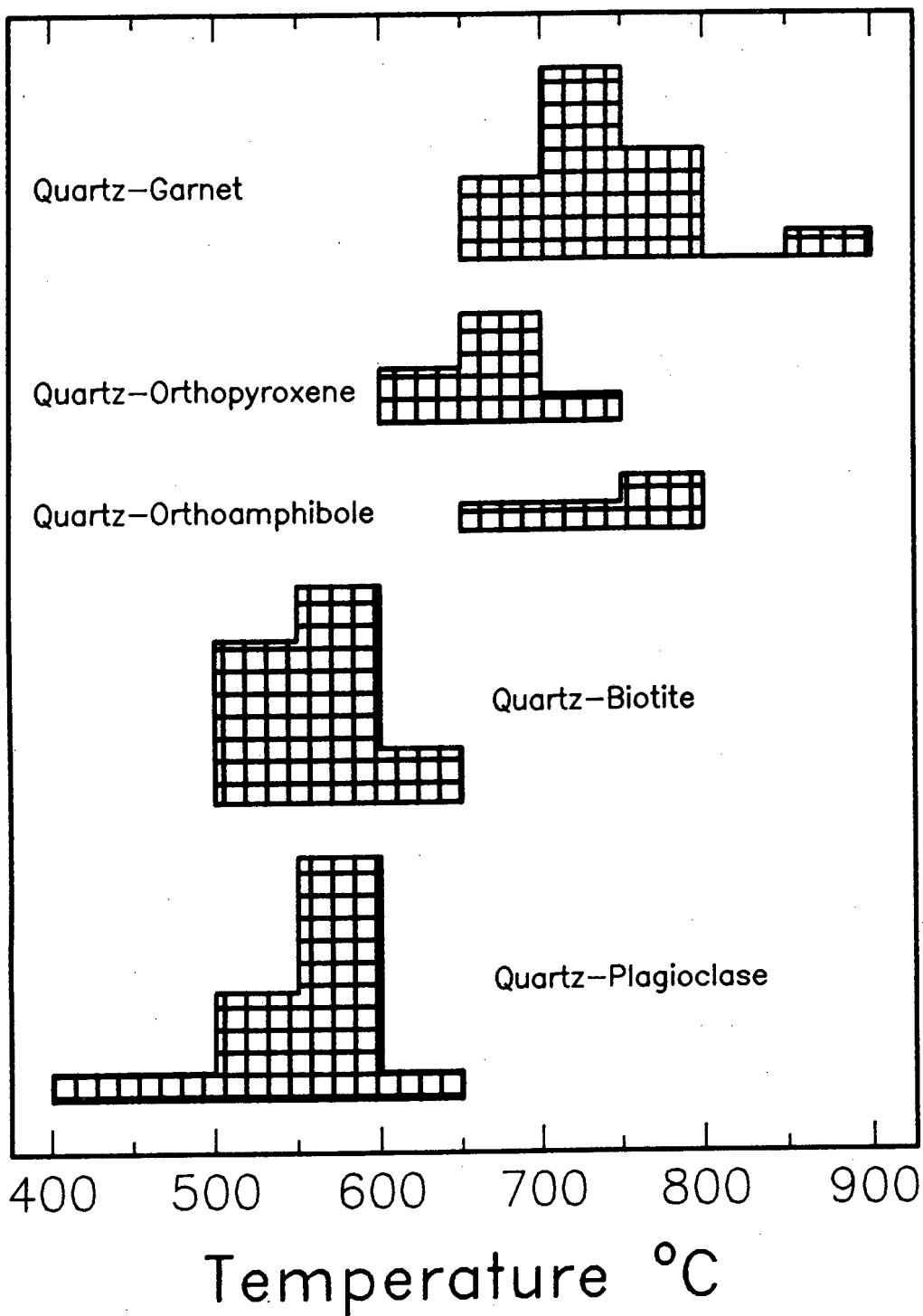
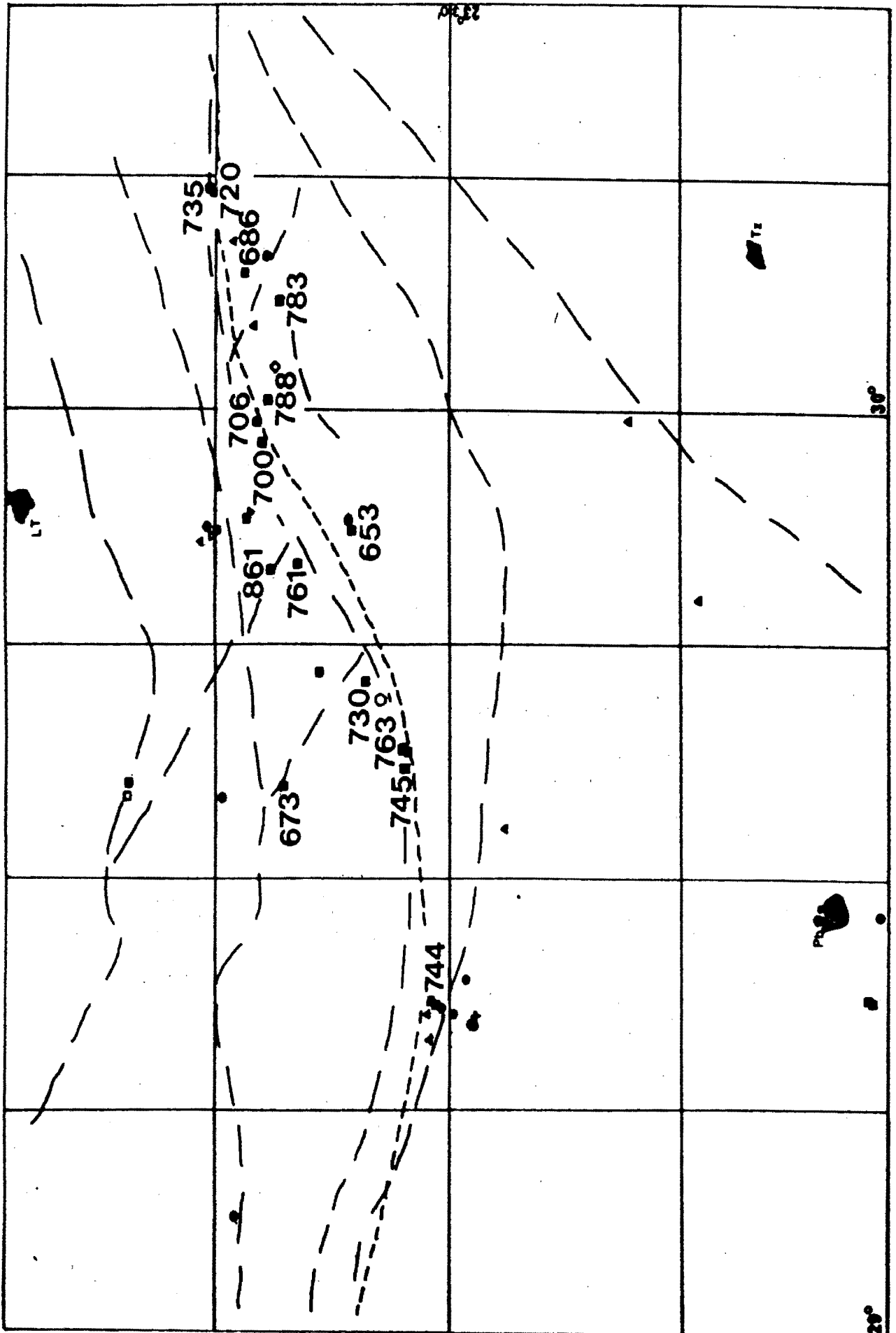


Figure 8.1: Histogram comparing the apparent oxygen isotope equilibration temperatures obtained for the quartz-mineral pairs in the pelitic rocks.

Figure 8.2: Quartz-garnet oxygen isotope temperatures (in °C) are shown next to the sample positions of the pelitic rocks (squares). Temperatures were calculated using the calibration of Bottinga and Javoy (1975). Sample positions of all other samples are also shown (see Fig. 2.1 for details).



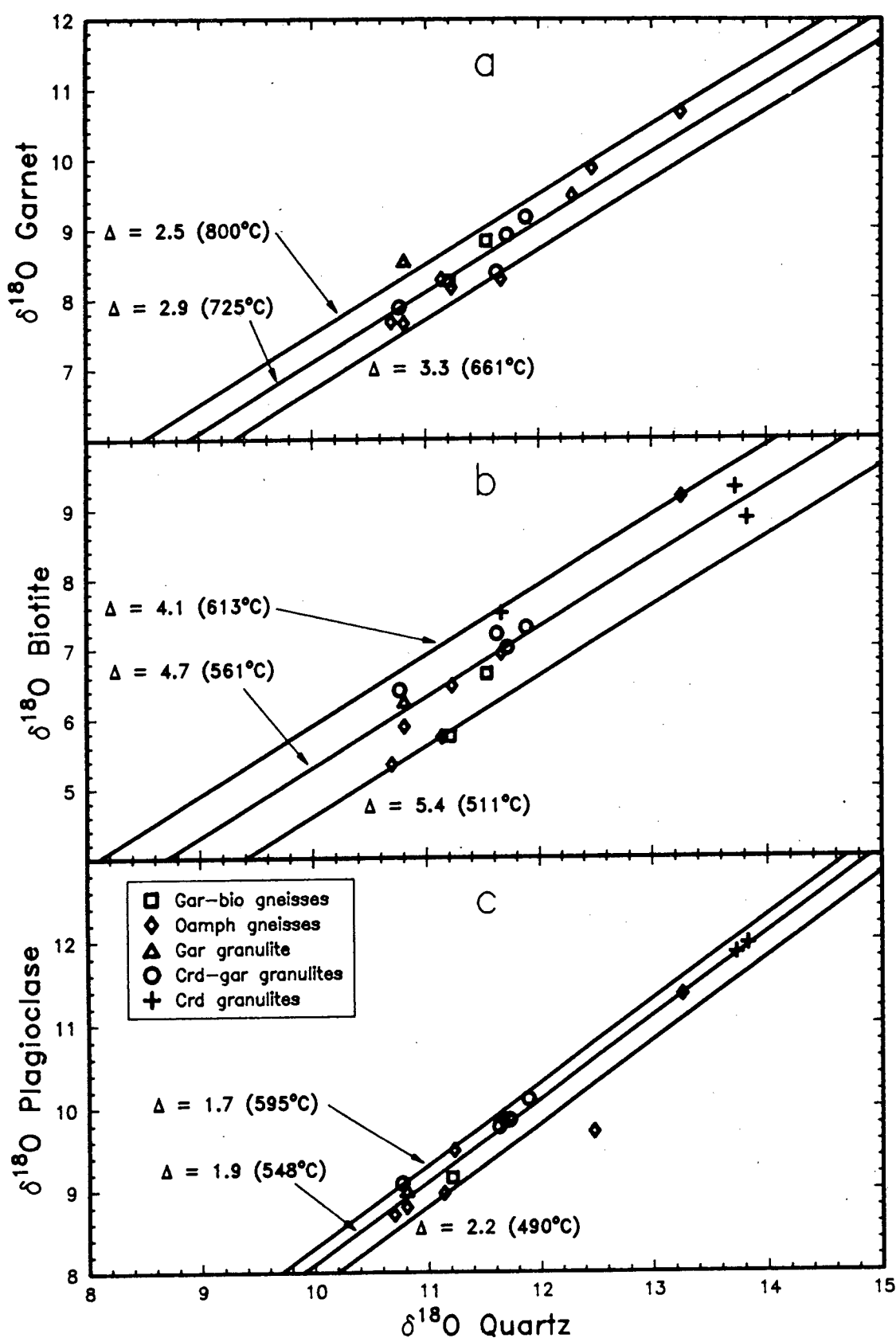


Figure 8.3a: Plot of  $\delta^{18}\text{O}_{\text{quartz}}$  versus  $\delta^{18}\text{O}_{\text{garnet}}$ ,  
 b: Plot of  $\delta^{18}\text{O}_{\text{quartz}}$  versus  $\delta^{18}\text{O}_{\text{biotite}}$ ,  
 c: Plot of  $\delta^{18}\text{O}_{\text{quartz}}$  versus  $\delta^{18}\text{O}_{\text{plagioclase}}$ ,  
 d: Plot of  $\delta^{18}\text{O}_{\text{quartz}}$  versus  $\delta^{18}\text{O}_{\text{orthopyroxene}}$ ,  
 e: Plot of  $\delta^{18}\text{O}_{\text{plagioclase}}$  versus  $\delta^{18}\text{O}_{\text{biotite}}$ ,  
 all above for the pelitic rocks,  
 f: Plot of  $\delta^{18}\text{O}_{\text{plagioclase}}$  versus  $\delta^{18}\text{O}_{\text{amphibole}}$  for  
 the mafic rocks.

Errors in  $\delta^{18}\text{O}_{\text{mineral}}$  are approximately as large as the symbol size. Also shown are lines of constant fractionation between the given mineral pairs. Temperatures for these lines were deduced from the calibrations of Bottinga and Javoy (1975); for c and e an average plagioclase of  $\text{An}_{30}$  was assumed, while for f  $\text{An}_{43}$  was assumed for the temperature calculations.

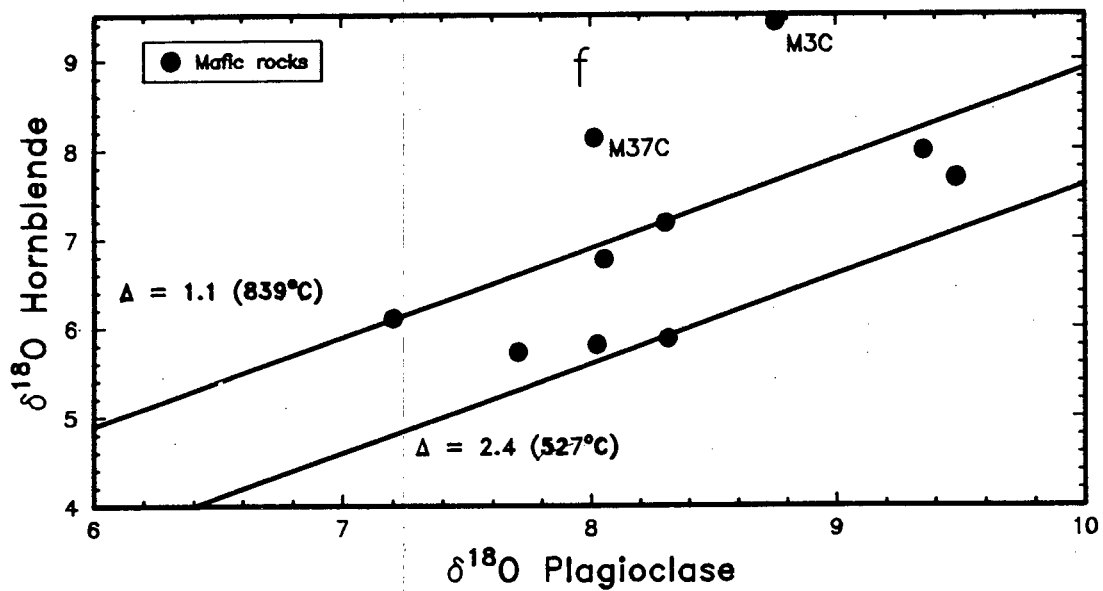
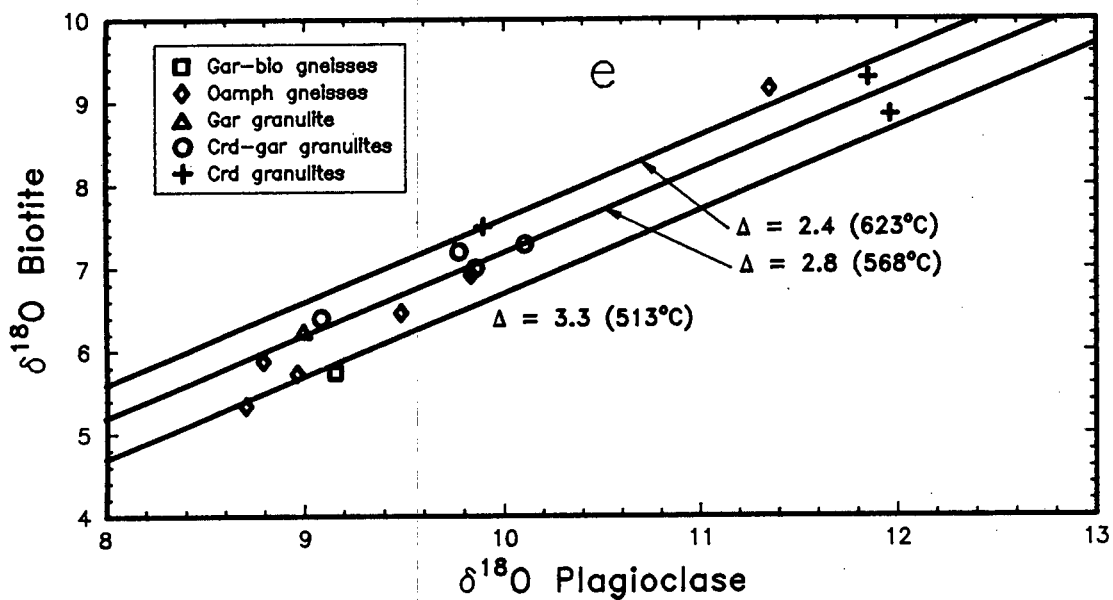
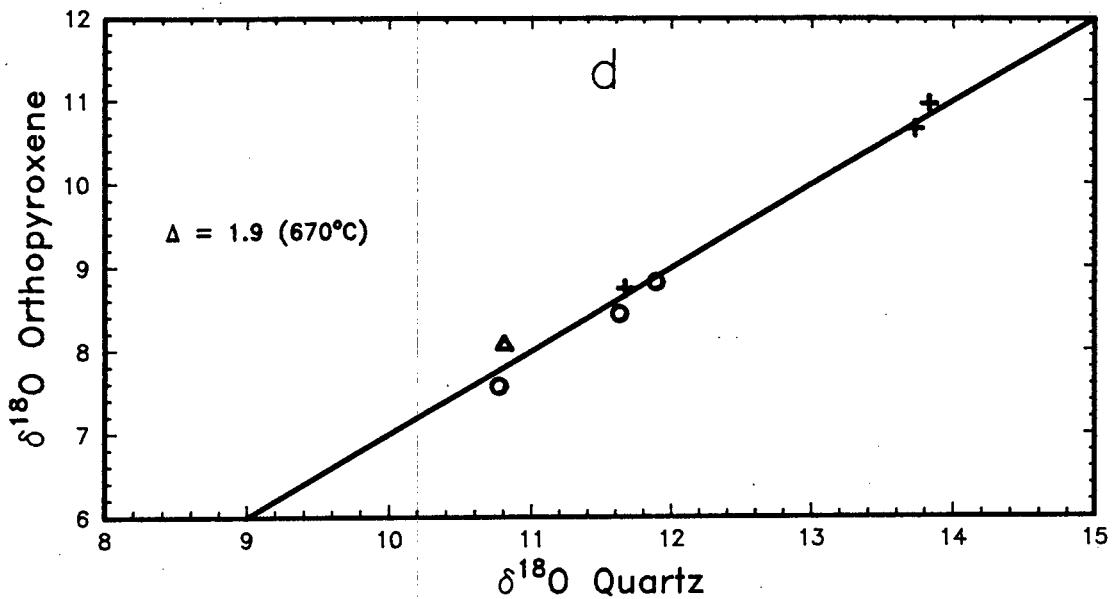


Figure 8.4: Arrhenius plot of selected oxygen diffusion coefficients for some minerals of relevance to this study. Minerals reacted with aqueous fluids except for 'dry' curves where minerals are reacted with  $O_2$  or  $CO_2$ . An = anorthite, Ab = albite, Qtz = quartz, Mgt = magnetite, Phl = phlogopite, Hbl = hornblende, Gar = garnet, Dio = diopside, para c, perp c = parallel or perpendicular to the c-axis of quartz; the quartz alpha-beta transition also shown. Sources: 1,2 - Giletti et al., 1978; 3,4,8 - Giletti and Yund, 1984; 5 - Giletti and Hess, 1988; 6 - Giletti and Anderson, 1977; 7 - Farver and Giletti, 1985; 9 - Elphick et al., 1988; 10 - Farver, 1989; 11 - Freer and Dennis, 1982; 12 - Haul and Dumbgen, 1962.

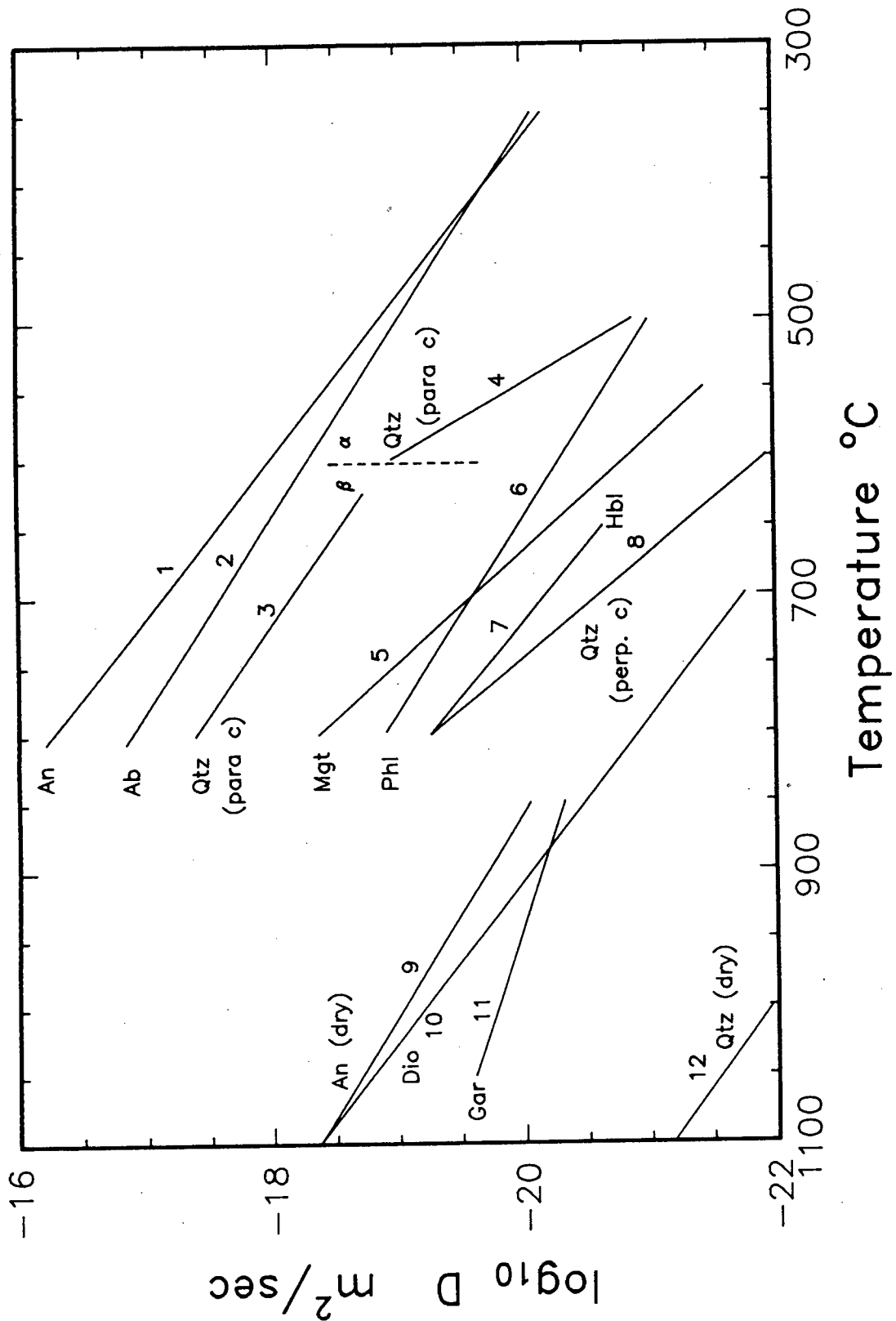


Figure 8.5: Closure temperatures of minerals versus cooling rates. Data for the minerals shown are from the same sources as in Fig. 8.4. Values given in brackets refer to the mineral size ( $-a$  in equation 8.2, see text).

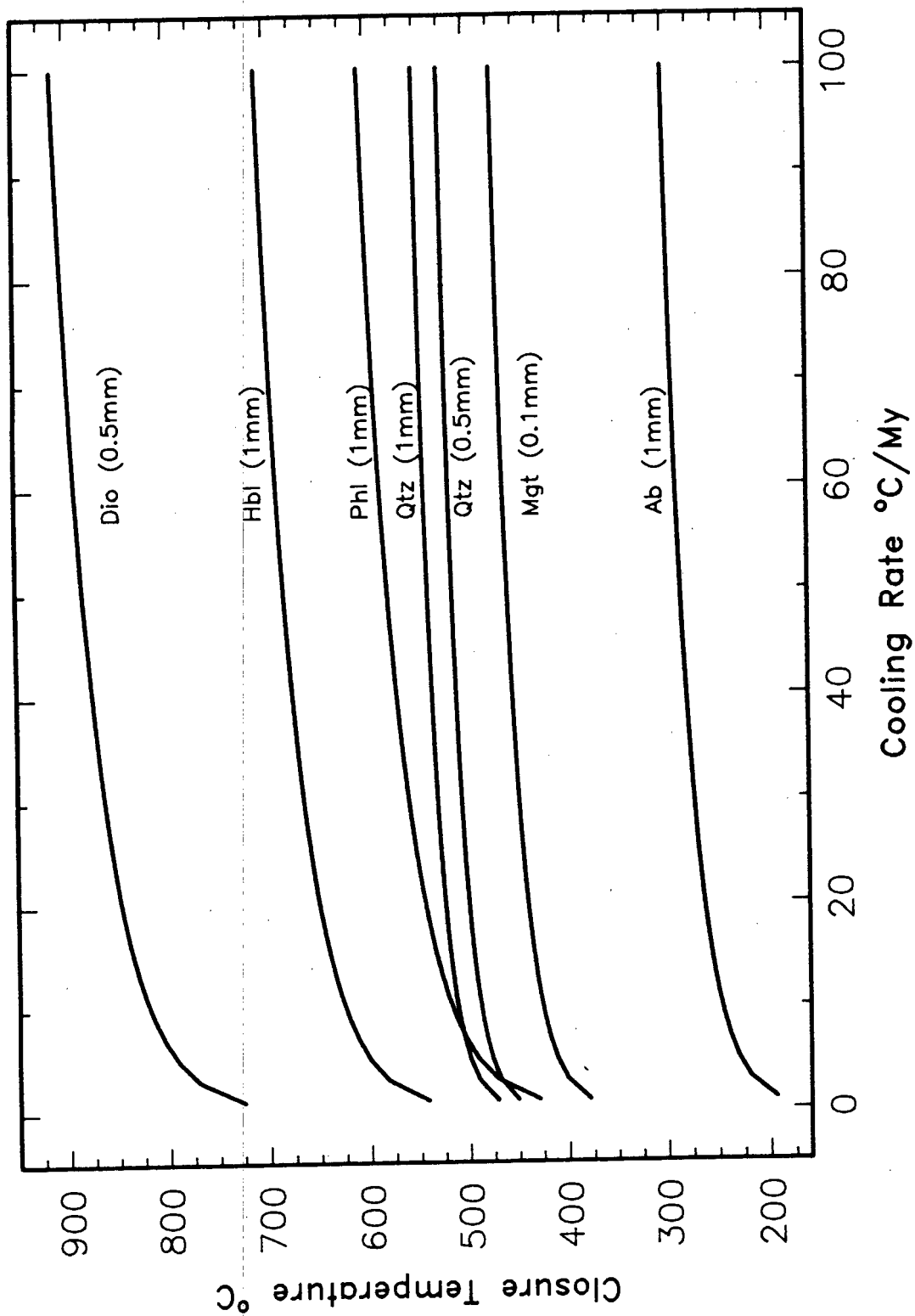


Table 8.4

Diffusion data for some minerals in selected rocks from the SMZ. Temperature (T) is the mineral-pair oxygen isotope temperature taken from Tables 8.2 and 8.3 and considered to represent the closure temperature of a given pair. Cooling rates are calculated using T. Temperatures  $T_{c10}$  are closure temperatures calculated for an assumed cooling rate of  $10^{\circ}\text{C}/\text{My}$ .  
 qtz = quartz, mgt = magnetite, gru = grunerite, pig = pigeonite, hbl = hornblende, cpx = diopside, plg = plagioclase.

Sample		2a	A	E	Do	T	dT/dt	$T_{c10}$	Ref.
		cm		kJ/mol	$\text{cm}^2/\text{sec}$	$^{\circ}\text{C}$	$^{\circ}\text{C}/\text{My}$	$^{\circ}\text{C}$	
B4A	qtz	0.05	8.7	285	190	479	24	465	1
	mgt	0.03	55	188	$3.5 \times 10^{-6}$	(515)	(208)	440	2
	gru+pig	0.04	-	-	-	-	-	-	-
M41C	hbl	0.12	8.7	172	$1 \times 10^{-7}$	592	12	585	3
	plg	0.08	55	89	$2.31 \times 10^{-9}$			205	4
M11C	cpx	0.1	8.7	226	$1.5 \times 10^{-7}$	767	618	814	5
	hbl	0.15	8.7	172	$1 \times 10^{-7}$			601	3
	plg	0.15	55	89	$2.31 \times 10^{-9}$			231	4

$R = 8.314 \text{ kJ/mol.K}$

References: 1 - Gilletti and Yund (1984); 2 - Gilletti and Hess (1988);  
 3 - Farver and Gilletti (1985); 4 - Gilletti et al. (1978);  
 5 - Farver (1989).

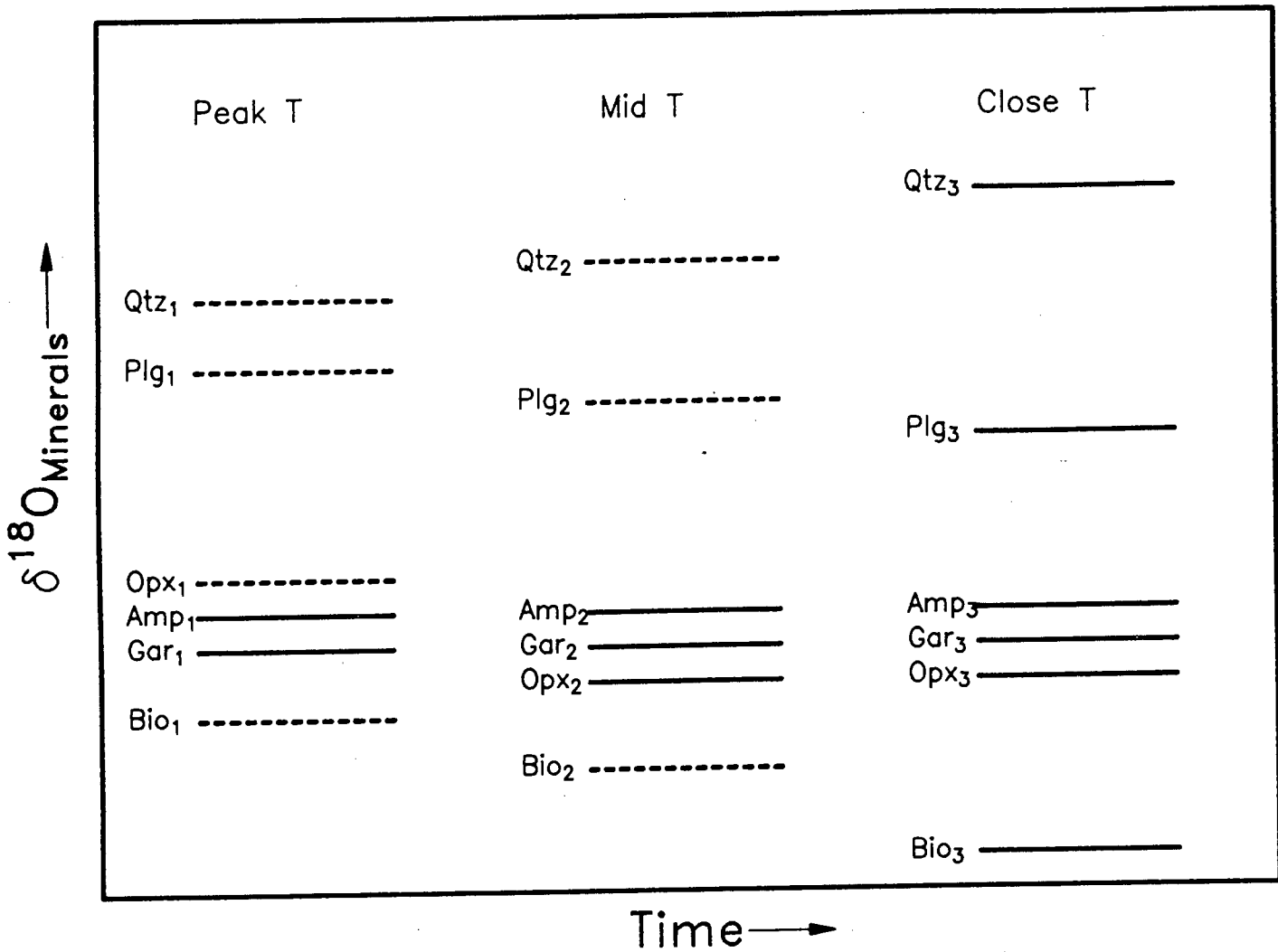


Figure 8.6: Schematic diagram illustrating oxygen isotope re-equilibration amongst minerals as a function of isotopic closure with time during retrogressive cooling. Dashed lines indicate open minerals while solid lines indicate minerals that are closed to further oxygen diffusion. Abbreviations as in Table 3.3.

Figure 9.1: Arrhenius plot of some cation and anion diffusion coefficients for several selected minerals. Bio = biotite, Dio = diopside, Gar = garnet, Ksp = K-feldspar, Phl = Phlogopite.  
 Sources: Bio,K - Hofmann et al., 1974; Phl,Ar - Giletti, 1974; Phl,O - Giletti and Anderson, 1977; Dio,Ca,Fe,Mg - Freer et al., 1982; Dio,O - Farver, 1989; Gar,Mn(Fe) - Freer, 1979; Gar,Mg - Cygan and Lasaga, 1985; Gar,O - Freer and Dennis, 1982; Ksp,Na,K,Rb,Ar - Foland, 1974 a,b; Ksp,O - Giletti et al., 1978.

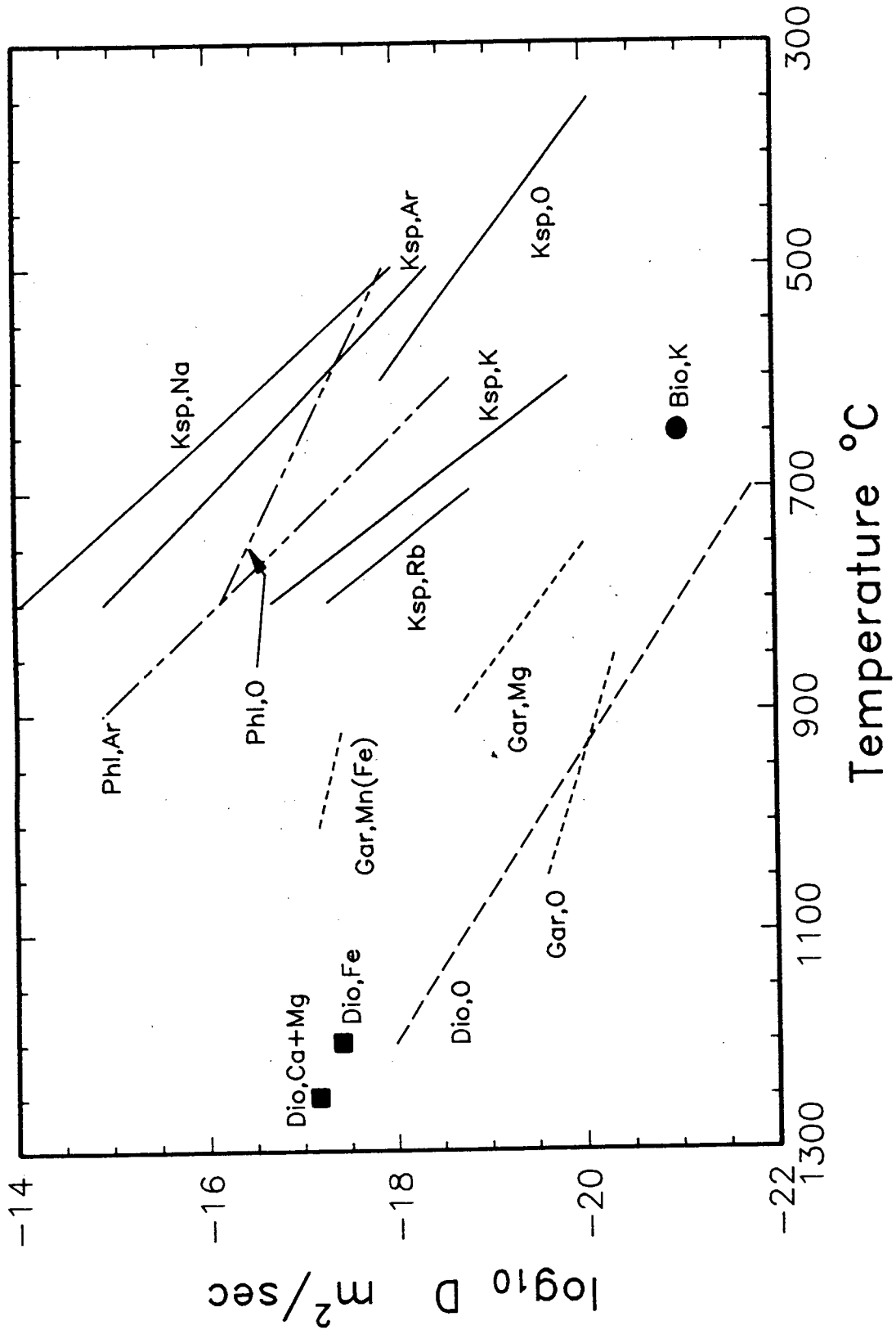
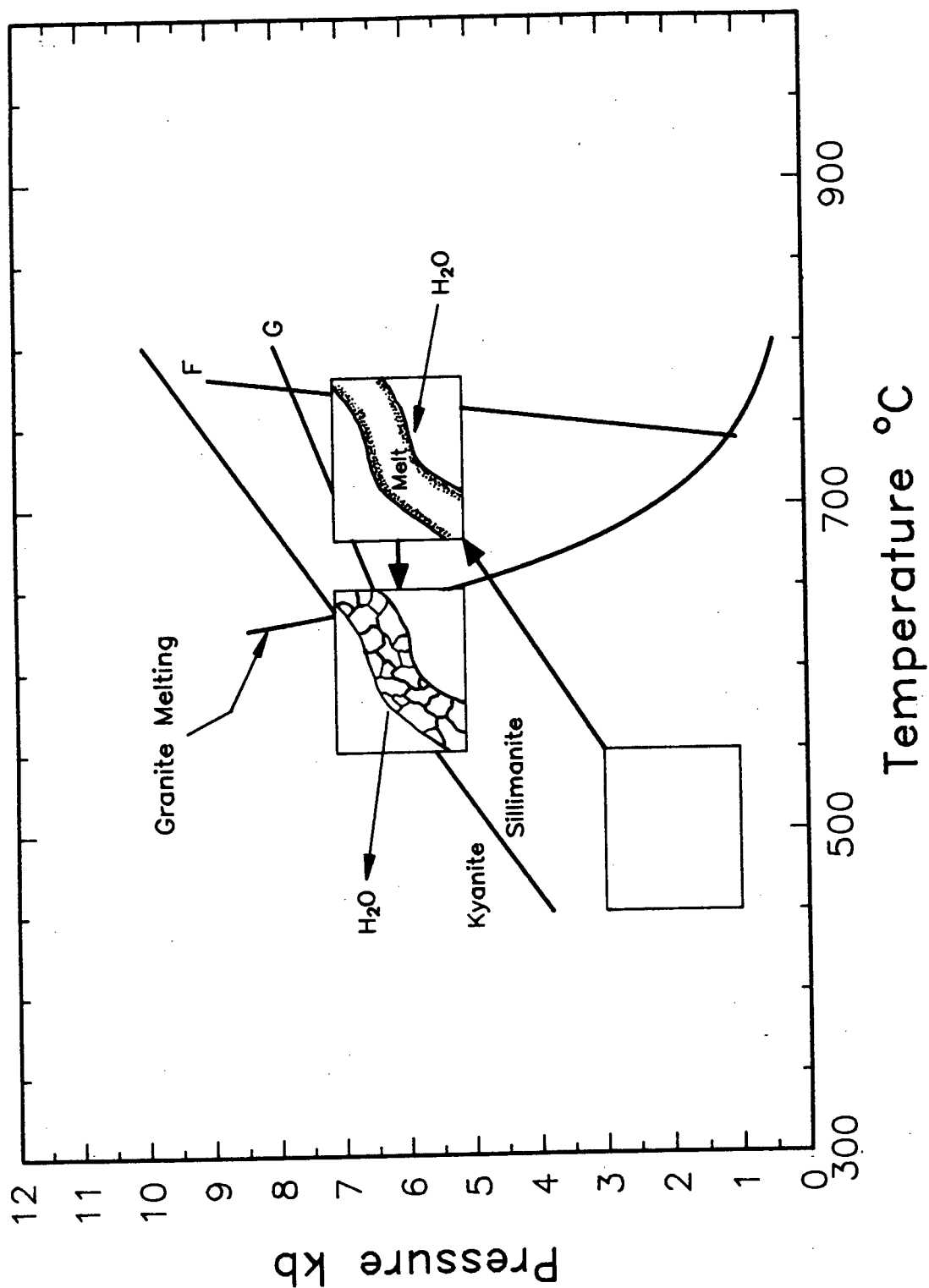


Figure 9.2: A simplified P-T diagram illustrating the proposed metamorphic model for the SMZ rocks (see text for discussion). The boxes represent part of the P-T path for a hypothetical pelitic rock sample. The size of the box is approximately the same as the average expected error of the estimated P-T conditions. Curves F and G and the granite melting curve are as in Figure 3.19.



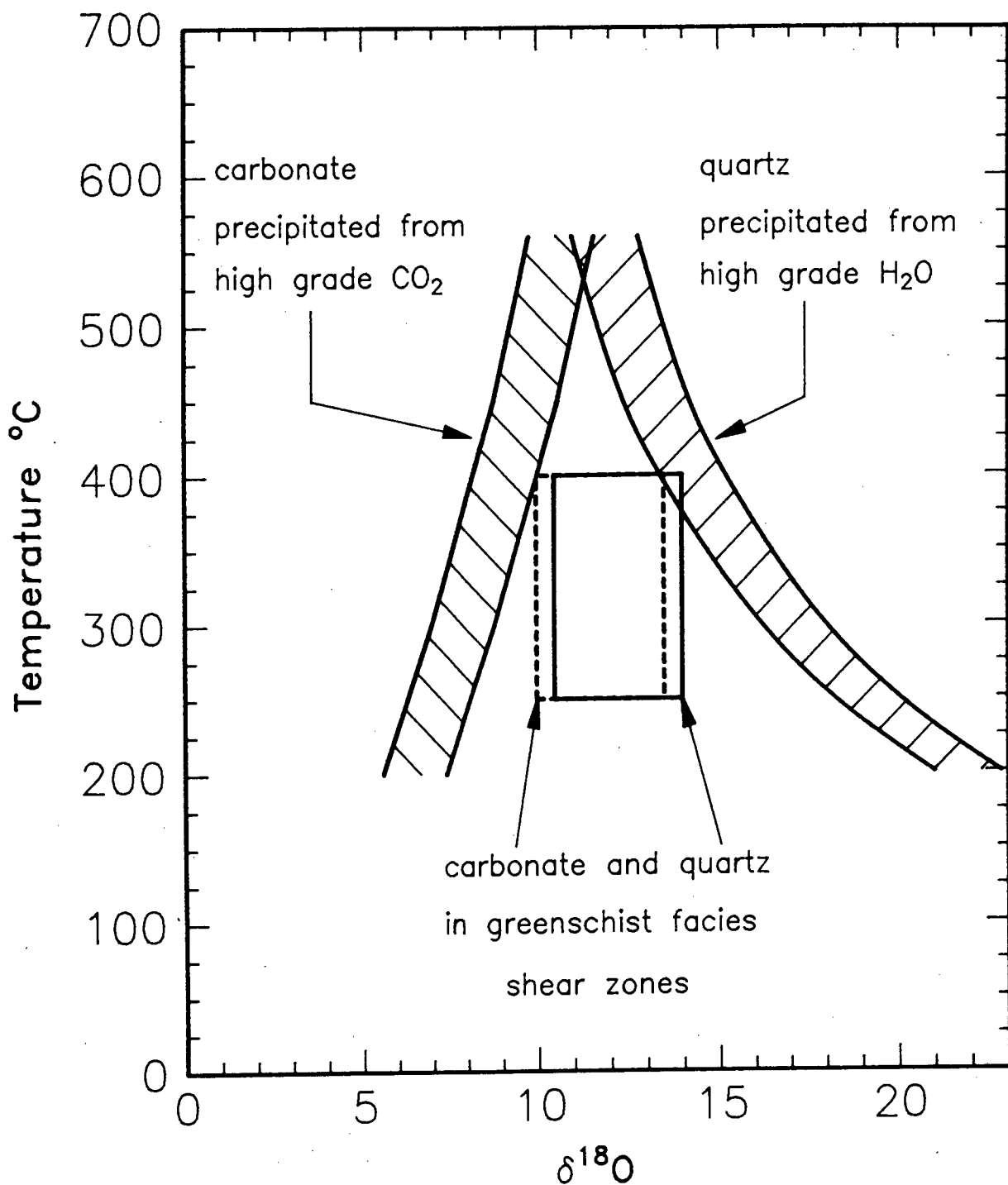


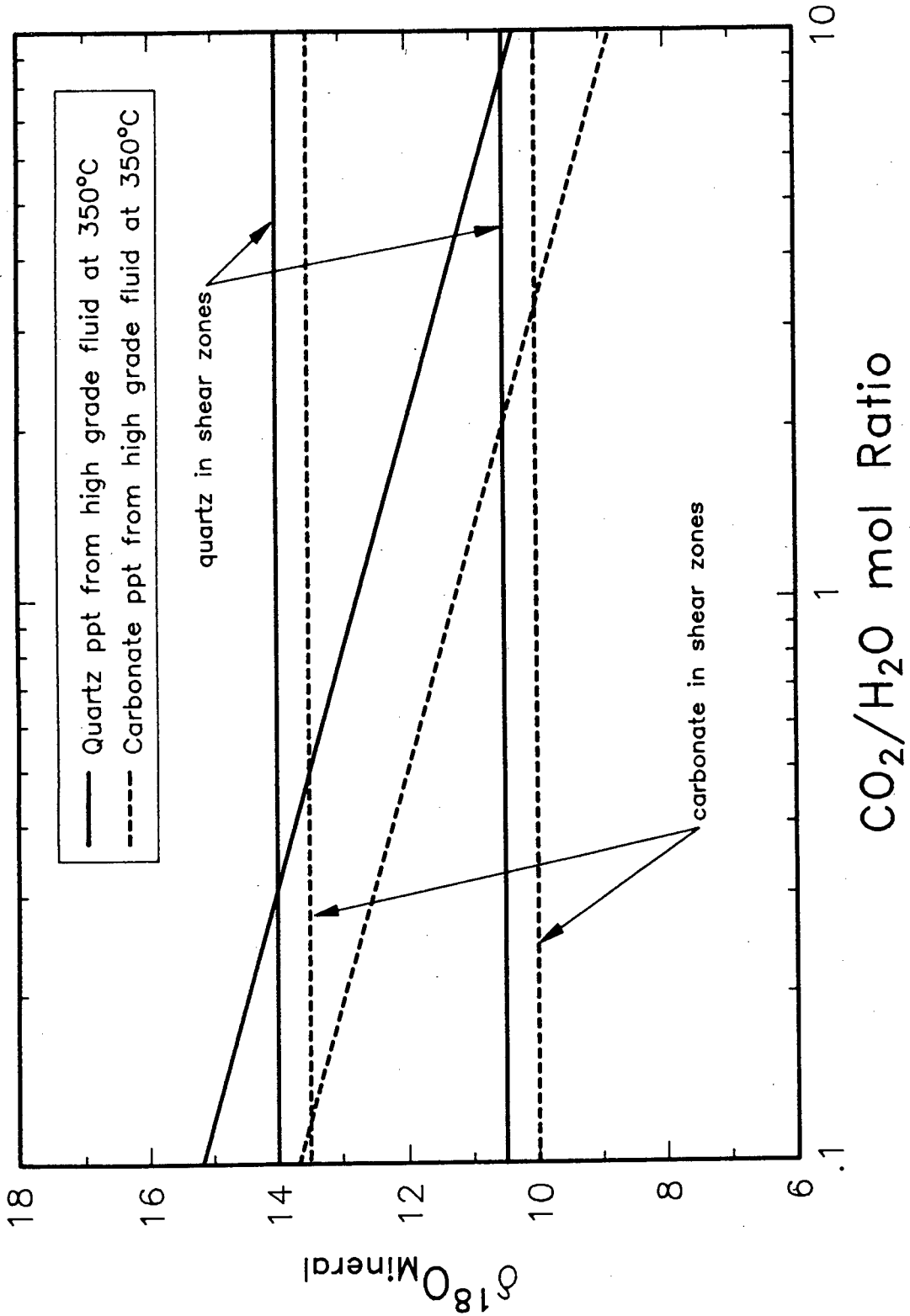
Figure 10.1: Temperature versus  $\delta^{18}O$  plot for quartz and carbonate precipitated from  $H_2O$  and  $CO_2$ , respectively. At 560°C  $\delta^{18}O_{CO_2}$  is calculated to be  $18.1 \pm 0.9\%$  and  $\delta^{18}O_{H_2O}$  is calculated to be  $9.7 \pm 0.9\%$ . Fluid  $\delta^{18}O$  values remain constant during precipitation of quartz and carbonate (high fluid/rock ratios). Also shown are the  $\delta^{18}O$  ranges of quartz and carbonate from mineralized sections in the Murchison and Pietersburg greenstone belts (Smith 1986; 1987) and from some Canadian deposits (Kerrick 1986 a, b).

Table 10.1

Isotopic composition of quartz (Qtz) and calcite (Cc) precipitated from hypothetical fluids derived from the high grade terrane. The 'Fluid'  $\delta^{18}\text{O}$  values are calculated from the average  $\text{H}_2\text{O}$  and  $\text{CO}_2$  isotopic compositions in equilibrium with the pelitic quartz at temperatures of  $560^\circ\text{C}$  ( $\delta^{18}\text{O}_{\text{H}_2\text{O}} = 9.7$  ‰ and  $\delta^{18}\text{O}_{\text{CO}_2} = 18.1$  ‰; see text).

CO <sub>2</sub> :H <sub>2</sub> O	Fluid $\delta^{18}\text{O}$	-- $\delta^{18}\text{O}$ compositions at $350^\circ\text{C}$ --			
		H <sub>2</sub> O	CO <sub>2</sub>	Qtz	Cc
0.1	10.5	9.2	23.1	15.0	13.5
0.2	11.1	8.8	22.7	14.6	13.1
0.5	12.5	7.9	21.8	13.7	12.2
1	13.9	7.0	20.9	12.8	11.3
2	15.3	6.0	19.9	11.8	10.3
5	16.7	5.1	19.0	10.9	9.4
10	17.3	4.7	18.6	10.5	9.0

Figure 10.2:  $\delta^{18}\text{O}_{\text{mineral}}$  versus  $\text{CO}_2/\text{H}_2\text{O}$  mole ratio plot. The  $\delta^{18}\text{O}$  values of quartz and carbonate precipitated at 350°C from fluids of variable  $\text{CO}_2/\text{H}_2\text{O}$  mole ratios are shown as the solid and dashed lines respectively. Also shown by the horizontal lines are the  $\delta^{18}\text{O}$  ranges of the quartz and carbonates from mineralized greenstone belts (see Figure 10.1).



## Appendix A:

Field descriptions, mineralogy and petrography of samples analysed in this thesis.

### Ultramafic Rocks:

#### U7A:

Field: dark, green-brown pyroxenite.

Mineralogy: orthopyroxene, olivine, serpentine, tremolite, spinel (green), chlorite.

Large, fractured orthopyroxene grains show inclusions of spinel (sometimes as trails), and chlorite flakes. It is partially serpentized and chloritized along edges and fractures. Smaller relicts of olivine sit in a mass of serpentine, together with smaller spinel. Needles of tremolite are also present as well as larger flakes of non-pleochroic chlorite which differs from the pleochroic green retrograde chlorite.

#### U10A:

Field: dark brown pyroxenite from Loskop hill, sampled close to a banded iron formation, B4A.

Mineralogy: enstatite, tremolite, anthophyllite, green-brown spinel, chlorite.

Small, equigranular enstatite makes up the bulk of the rock with smaller sections showing bladed tremolite (also occurring as inclusion in enstatite) and patches of chlorite showing good mineral contacts (occasional triple junctions) with enstatite and tremolite. Smaller grains of straight extinction amphibole (anthophyllite) are present showing clean contacts and idioblastic shapes in (001) sections. Light green to brown spinels are present throughout.

#### U6B:

Field: dark green serpentinite interlayered with

tremolitic/actinolitic mafic rocks and banded iron formations from the Pietersburg greenstone belt.

Mineralogy: serpentine, chlorite, opagues, relict, small olivine/pyroxene, carbonates, quartz.

Fine grained serpentinite texture with only very small olivine/pyroxene intergrowths left. Mass of serpentine is cut by fractures filled with abundant opagues, chlorite and occasional carbonate and quartz.

U10B:

Field: hard, dark brown, tremolitic rock from Renosterkoppies greenstone belt; no carbonate alteration.

Mineralogy: tremolite, chlorite, opagues, relict pyroxene/olivine, minor serpentine.

Fine grained mass of intergrown amphiboles and chlorite and serpentine. Coarse grained opagues occur scattered throughout. Small relicts of pyroxene/olivine can be recognized as remnants of larger grains, well replaced by chlorite, tremolite and serpentine.

U17B:

Field: pyroxenite from a small greenstone lens; adjacent to outcrops of banded iron formations, pegmatites and gneisses.

Mineralogy: enstatite, olivine, chlorite, tremolite, spinel, (clinopyroxene), trace carbonate.

Coarse grained enstatite replaces fractured olivine, incorporating the latter as inclusions. Both olivine and enstatite appear to overgrow chlorite, also incorporating it as inclusions. Dark brown spinels occur as trails within large enstatites or along grain boundaries and fractures of the olivine. Small blades of tremolite and minor carbonate are present.

U31C:

Field: serpentinite unit close to ridges of mafic and pelitic rocks (see M27C, V28C, P29C).

Mineralogy: serpentine, chlorite, orthopyroxene, olivine, tremolite, opagues, (clinopyroxene).

Relict, fractured orthopyroxene and olivine are set in a matrix of retrogressive serpentine, chlorite and tremolite. The latter three are fine grained and commonly confined to fractures within orthopyroxene and olivine. Larger orthopyroxene grains tend to show inclusions of olivine. Coarse grained chlorite and tremolite crystals are present. Opagues are scattered throughout and are xenomorphic.

U40C:

Field: dark brown ultramafic rock from a small isolated hill of ultramafic material only.

Mineralogy: orthopyroxene, olivine, tremolite, chlorite, spinel, serpentine.

Orthopyroxene occurs as large, relatively unaltered grains with inclusions of green spinel, chlorite and minor tremolite. When fractured intensely it is serpentized. Olivine is also largely serpentized along fractures. Larger chlorite flakes can be overgrown by serpentine together with opagues. Occasionally twinned tremolites are fairly abundant. Green spinel shows rims of opagues when occurring outside the orthopyroxene.

U44C:

Field: dark brown ultramafic rock lens.

Mineralogy: orthopyroxene, olivine, tremolite, spinel, chlorite, serpentine.

Coarse orthopyroxene grains show inclusions of tremolite, green spinel and chlorite, indicating a prograde nature of the latter three. These three, together with olivine, also occur outside of the orthopyroxene grains, the green spinel being partially rimmed by opagues. Tremolites (twinned) tend to occur in clusters. Chlorite is relatively rare. Olivine can be partially serpentized in places.

## Mafic Rocks:

### M1A:

Field: small, foliated amphibolite lens within grey gneiss.

Mineralogy: hornblende, plagioclase, minor actinolite, quartz.

Banded amphibolite with abundant hornblende (bluish-green) defining foliation planes. Relatively small, partially sericitized feldspars occur within the mass of hornblendes. Alteration is more intense along finer grained bands where actinolite also occurs.

### M2A:

Field: massive amphibolite lens within grey gneiss, sampled about one meter north of a small dolerite dyke within Hout River transition. Surrounded by some felsic segregation material.

Mineralogy: hornblende, plagioclase, clinopyroxene, minor opagues.

Equigranular rock with only partially sericitized plagioclase. Clinopyroxene is, in places, replaced by hornblende which makes up the bulk of the rock. Hornblende is blue-green in colour.

### M3A:

Field: massive amphibolite lens within the gneiss of the Hout River transition and sampled about 6 meters north of the dolerite dyke. Surrounded by some felsic segregation material.

Mineralogy: hornblende, plagioclase, clinopyroxene, minor opagues and quartz.

Well preserved plagioclase shows good triple junctions with tremolitic hornblende (bluish-green) and clinopyroxene. The latter is partially replaced by hornblende, often growing around smaller pyroxenes.

**M5A:**

**Field:** 1x2 meter sized, foliated amphibolitic lens within the grey gneiss of the Hout River transition.

**Mineralogy:** hornblende, plagioclase, minor clinopyroxene and opaques.

Slightly banded rock with plagioclase being somewhat sericitized along fractures. Clinopyroxene occurs as small grains largely replaced by blue-green hornblende which defines the foliation.

**M8A:**

**Field:** massive mafic rock sampled from a trench of the Bochum gold mine.

**Mineralogy:** plagioclase, pyroxene, hornblende, opaques (sulphides and replacement oxides).

All constituent minerals are unaltered, except along narrow zones or fractures, where sulphides are abundant. Clinopyroxene can show fine exsolution lamellae and inclusions of opaques and minor hornblende. Hornblende is brownish-green and can show fine exsolution lamellae of opaques. Larger opaques are abundantly scattered throughout the massively textured, equigranular rock. Triple junctions among minerals are common.

**M11B:**

**Field:** sampled from a dark grey-brown pillow unit, adjacent to ultramafic (serpentinitic) units in the Pietersburg greenstone belt.

**Mineralogy:** actinolite, hornblende, chlorite, quartz and albite.

Fine grained, altered greenschist facies rock with larger, well interlocking grains of amphibole separating small dots of quartz and albite. Chlorite occurs in small patches replacing amphiboles. Opaques occur as small specks throughout the whole rock.

M3C:

Field: sampled from a small xenolithic block within the Hout River Zone, close to pelitic samples P5C and P6C. Sample is rich in hornblende, and is surrounded by felsic segregation material.

M11C:

Field: grey-black, massive amphibolite cut by some coarser grained amphibole-quartz veins.

Mineralogy: plagioclase, hornblende, pyroxenes, opagues.

Equigranular, massive rock with all minerals of random orientation and occasional triple junctions. Clinopyroxene commonly shows exsolution lamellae. Hornblende can show some dusting, probably by fine exolutions of opagues. Coarse opagues can occur as inclusions in pyroxene and hornblende but also as separate, single grains.

M27C:

Field: massive green-black amphibolite unit sampled about 100 meters from thin a pelitic band (P29C).

Mineralogy: clinopyroxene, orthopyroxene, plagioclase, hornblende, opagues.

Coarse grained rock with abundant clinopyroxene and lesser amounts of pleochroic orthopyroxene. Plagioclase shows fine albite twinning and in places undulose extinction. These three minerals show good triple junction contacts. Hornblende is commonly spotted by opagues, in its centre along cleavage plains and around its rims. It also occurs as smaller grains in fractures within the pyroxenes. Hornblende is of a brown-green colour.

Vein crosscutting the sample: blue-green hornblende replaces brownish hornblende and pyroxenes. In intensely altered parts this blue-green hornblende occurs together with plagioclase, quartz and opagues. Where pyroxenes are present they are rimmed by a fine grained mass of blue-green hornblende and quartz. The blue-green hornblende is in places very fibrous.

**M37C:**

**Field:** layered, fairly coarse grained rock from a small, isolated outcrop; cut by quartz-amphibole veins.

**Mineralogy:** hornblende, plagioclase, pyroxene and quartz.

Banding is defined by large, mottled hornblendes and altered pyroxenes. Hornblende can be fibrous in texture and is blue-green in colour. Plagioclase grains are intensely sericitized and surrounded by graphic intergrowth material. Larger quartz grains are also present.

**M41C:**

**Field:** lens of amphibolite close (2m's) to gray gneiss outcrops; cut by small quartz-amphibole veins.

**Mineralogy:** hornblende, plagioclase, trace opaques.

Coarse grained, massive amphibolitic rock with generally unaltered minerals except for minor alteration of the feldspar along grain boundaries and fractures. Hornblende is blue-green in colour. Textural equilibrium is indicated.

**M52C:**

**Field:** fine grained, massive amphibolitic rock sampled close (10m's) to pelitic rocks.

**Mineralogy:** hornblende, plagioclase (sericitized), quartz, pyroxene, opaques, and sphene.

Most of the minerals in this rock appear to be altered, except for the hornblende. Small scale layering between hornblende rich and pyroxene rich layers occurs. Large, altered pyroxenes show abundant inclusions of sphene. Sphene also occurs as a minor constituent throughout the rock.

## Pelitic Rocks:

### P13B:

Field: light brown, schistose, micaceous rock sampled just below some mafic rocks and a banded iron formation in the Pietersburg greenstone belt.

Mineralogy: chloritoid, muscovite, quartz, minor staurolite, andalusite, sphene and fluorite.

Chloritoid laths of random orientation are partially to completely replaced by staurolite. Chloritoid and staurolite pseudomorphs are superimposed over a fine foliation defined by muscovite, quartz and some opagues. Staurolite is sieve textured with inclusions of quartz and sphene.

### P14B:

Field: light brown, schistose rock sampled about 300 meters downslope of P13B.

Mineralogy: chloritoid, staurolite, muscovite, quartz, and minor sphene, chlorite.

Similar to P13B but large chloritoid/staurolite laths are much more abundant in the fine grained matrix of muscovite and quartz. In places the foliation is found to wrap partially around the chloritoid porphyroblasts.

### P5C:

Field: 2x3 meter, banded pelitic gneiss lens outcropping within the well foliated gneiss; in leucosomes large garnets are found.

Mineralogy: garnet, gedrite, quartz, plagioclase, opaque, minor sillimanite.

Inequigranular, medium grained rock with abundant, coarser garnet and gedrite, smaller plagioclase and bimodal quartz. Small as well as larger quartz grains are unstrained. Garnet shows inclusions of quartz, plagioclase and minor gedrite, whereas gedrite only of quartz and plagioclase.

P6C:

Field: 1x0,8 meter pelitic gneiss lens outcropping about 50 meters away from P5C. Similar to P5C but only a feint foliation and no separate leucosomes.

Mineralogy: garnet, gedrite, quartz, plagioclase, opagues, trace biotite.

Irregular shaped, rounded garnets show abundant inclusions of quartz, (plagioclase), opagues and occasional biotites. Smaller gedrite grains occur as glomeroporphyritic aggregates away from garnets, but can also be found to surround the garnet. Variably sized quartz grains are unstrained.

P8C:

Field: coarse grained red-brown pelitic gneiss with abundant biotite; concordant quartz veins are present.

Mineralogy: quartz, plagioclase, biotite, orthopyroxene, cordierite(+), minor garnet, opagues, spinels, (potassium feldspar ?), (aluminosilicate/gedrite?).

Cordierite (with inclusions of green spinel and biotite) and orthopyroxene intergrowths pseudomorph and replace garnets. The cordierite is biaxially positive. Coarser grained orthopyroxene occurs away from such intergrowths. Thin biotite laths are present in these intergrowths, but are more abundant and larger away from such zones. Quartz and plagioclase are generally unstrained, of varying grain size with large grains showing curved irregular grain boundaries. When large quartz grains are present next to symplectitic intergrowths, orthopyroxene is commonly coarser grained. Small K-feldspar crystals can be present close to biotites within intergrowths. Small needles (aluminosilicate and/or gedrite) project into cordierite, while somewhat coarser grained needles also occur within biotites.

P14C:

Field: purplish-brown, hard, pelitic gneiss from a small isolated hillock surrounded by pavements of grey gneiss.

Mineralogy: quartz, plagioclase, orthopyroxene, garnet, biotite, cordierite(+), trace opagues,

(gedrite/aluminosilicate?), antiperthite.

Variably sized quartz and plagioclase show sutured grain boundaries and, when in contact with biotite, the plagioclase is somewhat antiperthitic. The plagioclase can also show myrmekitic intergrowth textures. Abundant cordierite has inclusions of quartz, biotite, garnet and minor spinel. Garnet, with inclusions of quartz, plagioclase, sulphides and biotite, tends to be surrounded by orthopyroxene, cordierite and biotite. Garnet shows clean contacts with orthopyroxene, biotite, quartz and plagioclase. Both cordierite and biotite are partially intergrown with small needles which could be aluminosilicate/gedrite intergrowths. Similarly garnet and orthopyroxene show small fibres on their contacts with cordierite, projecting into the latter.

P16C:

Field: Coarse grained reddish pelite with some concordant leucocratic veins.

Mineralogy: quartz, plagioclase, biotite, orthoamphibole, opagues.

No thin section - minerals identified from hand specimen only.

P17C:

Field: medium to fine grained pelitic gneiss with minor quartz-vein segregations and small garnets within veins.

Mineralogy: quartz, plagioclase, biotite, garnet, minor  $\text{Al}_2\text{SiO}_5$  needles.

Slightly banded rock with equigranular fine grained bands made up of quartz, plagioclase, and biotite indicating good equilibration textures. Coarser bands consist of quartz, plagioclase and skeletal garnet, which appears to replace the small biotite laths. Garnet inclusions are quartz and biotite. Minor aluminosilicate fibres are found within some biotites and very fine needles along feldspar-feldspar boundaries.

P19C:

Field: pelitic gneiss selected from one of a number of small, scattered outcrops.

Mineralogy: orthopyroxene, biotite, cordierite(+), quartz, plagioclase, garnet, minor opagues, spinel, antiperthite, (aluminosilicate/gedrite?).

Medium grained rock with abundant, occasional clusters or stringers of orthopyroxene with inclusions of biotite, quartz and opagues. Biotite is well intergrown with fine needles of what could be aluminosilicate, when in contact with cordierite, and also occurs as inclusion within cordierite. When an inclusion within cordierite, or in contact with it, the biotite shows a fine myrmekite like character. Small aluminosilicate (?) fibres also occur on quartz-feldspar and feldspar-feldspar boundaries. Cordierite has garnet, quartz, and spinel inclusions and is rimmed by needle-like intergrowth (aluminosilicate and gedrite). Inclusion garnet can be idioblastic to subidioblastic. Larger quartz grains are undulose. Plagioclase can be antiperthitic.

P21C:

Field: grey-brown pelitic gneiss showing minor leucocratic veins.

Mineralogy: quartz, plagioclase, cordierite(+), biotite, orthopyroxene, garnet, minor antiperthite, opagues, (aluminosilicate/gedrite?).

Quartz and plagioclase are commonly large, probably recrystallized grains and in the case of large plagioclases can be antiperthitic. Single cordierite grains can be recognized by characteristic needle-like rimming. orthopyroxene crystals form stringers but are in good contact with all other mineral constituents, which is also true for garnet and biotite, except where biotite is in contact with cordierite, when it is replaced by aluminosilicate needles (?). Garnets can be skeletal in growth.

P25C:

Field: grey-brown pelite with no apparent veining.

Mineralogy: quartz, plagioclase, orthopyroxene, garnet, biotite, minor opagues, (aluminosilicate/gedrite?).

Quartz, plagioclase and biotite are medium grained and show good textural equilibrium. Garnet and orthopyroxene are skeletal in shape, poikiloblastic, containing abundant inclusions of the former three minerals and, in the case of orthopyroxene, can be seen to show optical continuity. Orthopyroxene can also occur as smaller grained glomeroporphyritic strands.

P29C:

Field: from a thin band of pelitic gneiss surrounded by mafic rocks (M27C) and occurring close to a small leucocratic pegmatite (V28C).

Mineralogy: orthopyroxene, biotite, garnet, cordierite, quartz, plagioclase, (gedrite/aluminosilicate?).

orthopyroxene and garnet are commonly medium grained and show good sharp contacts with quartz, plagioclase and biotite. The latter three minerals also occur as inclusions in the orthopyroxene and garnet. Fine grained orthopyroxene and garnet are present within the generally wide alteration rims surrounding the cordierite (gedrite/aluminosilicate?). Original shapes of the cordierite crystals can still be recognized through the alteration rims indicating triple junctions. Small biotites, well intergrown with needles, also occur in the cordierite alteration rims but larger, unaltered biotites are common outside these rims. Quartz and plagioclase are present as large grains with undulose extinction and antiperthitic character respectively. In small plagioclase grains the antiperthitic character is absent.

P32C:

Field: brown, foliated rock from a pelitic gneiss band approximately 20 m's long and 3 m's wide.

Mineralogy: biotite, quartz, plagioclase, garnet, gedrite, minor opagues, cordierite, (aluminosilicate?).

Abundant biotite occurs as large flakes which in places are well intergrown with and replaced by needles of gedrite (+ aluminosilicate?). Quartz and plagioclase are variable in

grain size, show sutured crystal edges and undulose extinction. Plagioclase can be sericitized. Generally textural disequilibrium is indicated.

P34C:

Field: coarse grained, pelitic gneiss from a 10x10 meter pelitic lens.

Mineralogy: biotite, quartz, plagioclase, garnet, gedrite, (aluminosilicate?), minor cordierite, graphite, k-feldspar, ore.

Biotite, quartz and plagioclase have similar appearances as in P32C above. Within the fine grained needle mass some small cordierite, quartz, plagioclase and possible k-feldspar can be recognized. Cordierite grains can get fairly large in size, incorporating small biotite flakes as inclusions and growing across the needle-like assemblage. Garnet when surrounded by quartz and plagioclase only, forms large, occasional skeletal grains with minor quartz inclusions. Biotite, together with some quartz, commonly projects into embayments on the edges of the garnet. When the biotite is in contact with the garnet in the segregations, they are separated by a fine grained mass of gedrite needles.

P38C:

Field: sample from a pelitic unit adjacent to pegmatites and amphibolites; contact is cut by a dolerite dyke though.

Mineralogy: quartz, plagioclase, biotite, gedrite, anthophyllite, garnet, minor apatite, opague.

Coarser gedrite and anthophyllite are found adjacent to biotite, occasionally incorporating biotite as an inclusion. Finer grained orthoamphibole is present in lenses containing fine grained quartz and biotite. Within these lenses subidioblastic garnet is present, showing curved inclusion trails but now being replaced by quartz and gedrite. Plagioclase and quartz are of variable size with sutured grain boundaries and undulose extinction.

P41C:

Field: fine grained pelite with a slight schistosity defined by biotite; no veins present; set within grey gneiss.

Mineralogy: quartz, plagioclase, biotite, garnet.

Equigranular rock with a slight foliation defined by biotite laths. Quartz can be recrystallized to smaller aggregates. Garnet is generally rounded, massive and coarser than the other minerals. It shows inclusions of quartz and biotite.

P42C:

Field: coarser grained pelite, sampled about 20 m's away from P41C; no foliation; little veining.

Mineralogy: quartz, plagioclase, garnet, anthophyllite, biotite, minor opagues, graphite.

Quartz and plagioclase are of variable grain size, and in the case of plagioclase somewhat sericitized. Skeletal garnet shows inclusions of quartz, biotite, plagioclase, and opagues. Orthoamphibole occurs as small, needle-like clusters often together with smaller sized garnets. Biotite is present as small equigranular flakes throughout the rock. The rock shows bands which are rich in orthoamphiboles, opagues, and graphite, and in which the plagioclase is preferentially dusted by sericitization. Small graphite flakes occur interstitially.

P45C:

Field: red-brown, coarse grained pelitic gneiss showing some segregation veins.

Mineralogy: plagioclase, quartz, biotite, orthoamphibole, garnet, minor opagues.

Relatively small garnets sit in quartz and feldspar rich sections and are only touched by small stringers of a biotite + orthoamphibole intergrowth. This intergrowth is very fine grained and only pleochroism is indicative of biotite. Quartz and plagioclase are of variable grain size and show sutured grain boundaries.

P50C:

Field: coarse grained, gray-brown pelitic gneiss sampled close to outcrops of mafic rocks (M52C).

Mineralogy: biotite, quartz, plagioclase, garnet, gedrite, anthophyllite, minor opagues, graphite and cordierite.

The foliation within this rock is defined by biotite and gedrite flakes, which in parts form the characteristic intergrowths of needle-like gedrite with biotite (+aluminosilicate?). In larger sized gedrite, the biotite is a common inclusion. Anthophyllite is less abundant than gedrite but is in contact with both the gedrite and the biotite. Garnets are commonly situated within the fine needle-like mass, with small needles cutting through it. Garnet is never found in contact with the gedrite and biotite-garnet contacts are commonly separated by a fine grained mass of needles. Small grains of cordierite with inclusions of spinel are found next to a garnet + biotite + gedrite assemblage. Small flakes of graphite are found interstitially, with similar orientation as larger biotite and gedrite laths. Plagioclase and quartz grew preferentially elongated between foliation planes.

P1D:

Field: medium grained, dark-gray massive pelite with only small lenses of leucocratic veins including garnets.

Mineralogy: plagioclase, quartz, orthopyroxene, biotite, cordierite(+), garnet, minor opagues, (aluminosilicate?).

Equigranular rock with all constituent minerals of random orientation. Abundant orthopyroxene is commonly intergrown with biotite and opagues, both of which are also found as inclusions within the hyperstene, together with some minor quartz and plagioclase. Cordierite is rimmed by fine needles (aluminosilicate/gedrite?) when in contact with other ferromagnesian minerals and is also found intergrown with the biotite, which in turn is rimmed by opagues. Skeletal garnet is confined to leucocratic veins, where it grows along grain edges of plagioclase, quartz, and biotite, showing inclusions of these. It is not in contact with any orthopyroxene nor cordierite in this rock, but is completely surrounded by felsic segregation material.

P3D:

Field: sampled from a metapelitic lens within a pavement of grey gneissic material; contact relationships obscured by pegmatitic veins.

Mineralogy: orthopyroxene, cordierite(+), biotite, plagioclase, quartz, minor needles of (aluminosilicate/gedrite?).

orthopyroxene is present as single, somewhat skeletal grains but also as glomeroporphyritic aggregates. It shows inclusions of biotite, plagioclase and quartz. Cordierite is only partially rimmed by needles (aluminosilicate/gedrite?) and commonly shows inclusions of biotite. Biotite, away from cordierite, occurs as small interstitial grains. Quartz and plagioclase are variable in size.

P5D:

Field: coarse grained, purple-brown pelitic gneiss sampled from the Bandelierkop Quarry close to V6D. Felsic veins are present.

Mineralogy: quartz, plagioclase, orthopyroxene, cordierite(+), biotite, minor opagues, graphite, (aluminosilicate/gedrite?).

orthopyroxene occurs in two modes, one as fingers intergrown with cordierite and biotite, the other as separate coarser grains. Cordierite, still altered along its rims (needles of aluminosilicate/gedrite?), is also present away from these intergrowths, which is the same for the biotite. Where biotite is in contact with the cordierite it is partially replaced by small aluminosilicate(?) needles. Quartz and plagioclase are variable in grain size but are generally unstrained. Larger quartz grains show curved grain boundaries and when occurring next to cordierite-orthopyroxene symplectites, the orthopyroxene is commonly coarser grained. Graphite flakes of random orientation are scattered throughout the rock and are even visible in outcrop.

P7D:

Field: coarse grained, red-brown pelitic gneiss with small lenses and pods of leucocratic material.

Mineralogy: biotite, garnet, quartz, plagioclase, anthophyllite, gedrite, aluminosilicate.

Biotite can be replaced by anthophyllite and gedrite needles around its edges only but also completely, with larger orthoamphibole rimming the biotite. Garnet appears within these intergrowth zones, overgrowing the foliation indicated by the biotite. The garnet does not show any clear contacts with gedrite. Quartz and plagioclase make up more felsic lenses, both showing sutured grain boundaries as well as being recrystallized to smaller aggregates to adopt the general foliation within the rock.

Other Rocks:

B4A:

Field: banded iron formation lens within the grey gneiss sampled close to M2A and M3A (~20m's).

Mineralogy: quartz, magnetite, pyroxene, grunerite, minor plagioclase, and fayalite.

Fine grained bands of quartz and magnetite with lesser pyroxene alternate with coarser grained bands of the same mineralogy. The pyroxene is pigeonite, showing two sets of fine exsolution lamellae (augite and orthopyroxene). In twinned crystals typical herring-bone structures are indicated. As the twin-halves of the crystals extinguish in different positions, the pigeonite has not inverted to its exsolution products. Smaller grains of possibly grunerite are also present, occasionally well altered. In fine grained zones textural equilibrium is indicated.

G9C:

Field: coarse grained quartzo-feldspathic gneiss sampled about 800 m's from sample P8C.

Mineralogy: quartz, plagioclase, biotite, chlorite, potassium feldspar, minor opaques.

Large unstrained quartz grains are set in a mass of medium grained plagioclase (sericitized) and lesser orthoclase. Small biotite laths occur throughout the rock, partially replaced by chlorite and opaques.

V28C:

Field: 1x2 meter pegmatitic outcrop sampled about 5m's away from P29C;

Mineralogy: quartz, feldspar, garnet (from handspeciman only).

V6D:

Field: large pegmatite sampled adjacent (~5 m's) to P5D in

the Bandelierkop quarry.

Mineralogy: plagioclase, quartz, minor potassium feldspar, muscovite, garnet, graphite, sillimanite and opaques.

Coarse grained plagioclase and somewhat strained quartz make up the bulk of this rock. Fine grained graphic intergrowths of plagioclase and quartz also occur. Potassium feldspar is present only in antiperthite. Small garnets and some graphite occur interstitially and, together with some sillimanite, can be recognized in hand specimen while the muscovite is confined to small alteration veins replacing plagioclase. Opaques are present in the alteration veins.

GD49C:

Field: light-coloured grey-pink granitic rock; no foliation.

Mineralogy: quartz, plagioclase, microcline, minor biotite/chlorite.

Coarse grained quartz, plagioclase and microcline resemble a typical granitic rock. While quartz shows undulose extinction and sutured grain boundaries, the feldspars are somewhat sericitized with some biotite/chlorite alteration along their edges.

C4D:

Field: grey-brown, rounded, hard boulders of charno-enderbites occur scattered over a large area; both this sample and C8D were taken from the same area but from different outcrops about 200 meters apart.

Mineralogy: plagioclase, quartz, biotite, orthopyroxene, opaques, minor microcline.

Fine grained mafic minerals are present interstitially to coarser plagioclase (well altered) and recrystallized smaller quartz. orthopyroxene and biotite are both speckled with opaques. Microcline can be present as small grains and as antiperthite. Sillimanite could also be present in small amounts.

## Appendix B

Major and trace element compositions of the ultramafic rocks  
recalculated volatile free.  
Majors in weight % oxides, traces in ppm.

	U10A	U6B	U10B	U17B	U31C	U40C	U44C
SiO <sub>2</sub>	50.92	46.02	47.70	47.01	45.87	48.36	47.30
TiO <sub>2</sub>	.15	.16	.23	.11	.27	.15	.05
Al <sub>2</sub> O <sub>3</sub>	7.69	2.88	4.55	2.79	3.25	4.49	7.35
FeO	7.60	7.44	11.06	7.73	9.01	8.32	6.65
MnO	.13	.12	.15	.12	.14	.14	.13
MgO	31.17	41.75	28.42	40.94	38.07	35.48	33.74
CaO	1.99	1.58	7.69	1.19	3.24	2.99	4.43
Na <sub>2</sub> O	.32	.02	.17	.09	.11	.06	.26
K <sub>2</sub> O	.01	.00	.02	.01	.01	.00	.07
P <sub>2</sub> O <sub>5</sub>	.01	.01	.01	.01	.02	.01	.01
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ba	43	13	5.1	12	48	4.8	2.4
Sc	34	15	24	15	15	20	27
Co	116	141	123	117	121	108	87
Cr	4317	2521	2630	4323	2056	2725	3088
V	116	69	88	53	70	95	87
Zn	53	18	64	46	60	50	38
Cu	4.5	3.8	29	2.1	15	20	4.6
Ni	1808	3285	2000	1848	2208	1811	1441
Nb	1.0	1.0	1.2	1.0	1.1	1.0	1.0
Zr	7.1	5.4	11	6.6	13	7.0	1.9
Y	6.9	4.3	6.3	3.8	5.0	3.2	3.5
Sr	24	6.7	38	11	172	94	18
Rb	1.2	1.2	1.4	1.2	3.7	1.3	1.3
Th	2.7	2.7	3.2	2.7	3.0	2.8	2.7
Pb	3.1	3.2	3.7	3.1	6.2	5.1	3.1

\*\*\* All Fe calculated as FeO \*\*\*

## Appendix B

Major and trace element compositions of the mafic rocks  
recalculated volatile free.  
Majors in weight % oxides, traces in ppm.

	M3A	M5A	M8A	M11C	M27C	M37C	M41C	M52C	M3C	M11B
SiO <sub>2</sub>	51.60	51.74	50.71	50.93	51.36	54.69	51.33	57.52	51.20	54.30
TiO <sub>2</sub>	.33	.18	.61	.86	.62	.35	.65	.57	.72	.44
Al <sub>2</sub> O <sub>3</sub>	15.20	16.26	14.08	14.48	13.61	10.57	12.89	13.82	11.28	12.49
FeO	9.71	8.12	8.74	9.92	10.64	8.83	10.43	5.32	10.78	9.38
MnO	.18	.17	.15	.19	.16	.23	.18	.23	.19	.16
MgO	7.93	9.08	8.96	8.25	10.43	10.70	10.92	6.39	15.15	11.75
CaO	11.57	10.54	13.82	12.19	11.03	12.13	10.25	15.16	8.68	9.65
Na <sub>2</sub> O	2.95	2.92	2.41	2.93	2.05	1.72	2.90	.50	.67	1.60
K <sub>2</sub> O	.47	.99	.44	.21	.05	.74	.37	.32	1.11	.20
P <sub>2</sub> O <sub>5</sub>	.05	.01	.09	.06	.04	.03	.06	.16	.24	.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ba	88	337	65	54	16	80	87	50	359	36
Sc	47	41	38	37	47	36	42	23	36	43
Co	54	51	49	64	62	59	60	48	73	62
Cr	134	471	382	578	676	1132	777	1371	1626	895
V	192	146	220	277	246	168	239	118	183	204
Zn	64	70	62	95	71	62	82	63	108	67
Cu	2.4	3.0	50	34	16	4.6	12	167	2.5	54
Ni	105	212	196	193	185	297	150	416	444	207
Nb	2.6	1.3	4.5	2.0	1.2	2.2	1.2	4.5	4.5	1.1
Zr	30	8.6	41	34	23	28	33	96	85	21
Y	20	7.4	18	21	18	14	15	30	29	11
Sr	104	228	93	133	115	135	272	156	93	205
Rb	5.8	33	3.4	1.4	1.6	24	6.6	9.8	46	5.2
Th	3.2	3.0	3.2	3.2	3.2	3.1	3.2	4.0	4.0	3.1
Pb	3.6	5.5	8.2	3.7	3.7	7.9	14	19	4.1	3.5

\*\*\* All Fe calculated as FeO \*\*\*

## Appendix B

Major and trace element compositions of the pelitic and  
pegmatitic rocks recalculated volatile free.  
Majors in weight % oxides, traces in ppm.

	P17C	P41C	P5C	P6C	P16C	P32C	P34C	P38C	P42C	P45C
SiO <sub>2</sub>	69.24	69.29	61.49	51.58	63.97	58.02	62.67	69.51	61.93	67.63
TiO <sub>2</sub>	.59	.51	.63	.62	.65	.61	.63	.50	.48	.55
Al <sub>2</sub> O <sub>3</sub>	15.57	14.06	13.38	14.06	16.04	19.45	16.27	13.82	13.80	13.61
FeO	4.43	5.27	13.10	23.27	6.86	8.50	7.39	6.29	12.84	6.40
MnO	.04	.06	.13	.10	.06	.06	.08	.06	.11	.00
MgO	3.30	3.40	6.51	7.92	6.66	7.61	6.59	5.99	4.75	6.64
CaO	1.96	1.77	2.61	1.57	1.66	1.50	1.76	1.00	3.93	1.61
Na <sub>2</sub> O	3.01	3.74	2.00	.60	2.31	1.86	2.17	1.18	1.51	2.15
K <sub>2</sub> O	1.79	1.79	.07	.09	1.74	2.30	2.42	1.54	.48	1.35
P <sub>2</sub> O <sub>5</sub>	.06	.11	.08	.20	.04	.09	.02	.13	.17	.05
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ba	541	344	154	337	471	545	567	429	135	310
Sc	9.1	13	20	23	19	28	22	15	18	18
Co	25	25	34	37	50	57	44	43	31	46
Cr	325	336	772	781	876	1021	850	575	465	768
V	89	92	142	154	152	166	155	98	123	134
Zn	58	60	100	108	94	89	100	73	75	99
Cu	67	40	45	58	88	28	44	40	117	66
Ni	89	94	172	247	416	388	353	297	215	332
Nb	6.0	6.1	5.3	4.6	7.1	8.0	7.6	5.3	5.1	7.1
Zr	170	127	101	85	131	112	120	137	99	120
Y	10	15	16	19	18	24	22	19	16	13
Sr	468	195	151	47	195	157	220	106	204	185
Rb	71	72	2.2	4.5	79	109	122	64	26	62
Th	6.4	5.1	3.1	3.8	5.8	5.4	6.0	4.6	7.0	4.1
Pb	13	13	4.9	4.4	13	11	11	8.0	9.7	7.9
K\Rb	210.1	206.3	243.1	159.3	183.1	174.9	165.0	198.1	153.2	182.1
K\Ba	27.5	43.1	3.5	2.1	30.7	35.0	35.4	29.7	29.8	36.2
Rb\Sr	.151	.369	.015	.095	.405	.694	.554	.605	.128	.333
Sr\Ba	.865	.567	.978	.140	.414	.289	.387	.248	1.510	.597

\*\*\* All Fe calculated as FeO \*\*\*

Appendix B (continued)

	P50C	P7D	P25C	P14C	P19C	P21C	P29C	P1D	P8C	P3D
SiO <sub>2</sub>	57.58	57.04	65.52	57.65	54.69	65.46	52.97	63.31	58.61	54.49
TiO <sub>2</sub>	.78	.78	.63	.89	.97	.57	.85	.63	.67	.75
Al <sub>2</sub> O <sub>3</sub>	17.62	16.78	13.25	18.03	21.11	14.48	20.00	16.51	17.46	19.47
FeO	8.50	11.18	7.23	9.84	9.61	7.61	10.25	7.14	7.56	7.93
MnO	.09	.16	.09	.09	.08	.08	.10	.06	.10	.09
MgO	8.81	9.38	6.65	8.95	9.54	5.70	10.42	6.36	10.08	10.98
CaO	2.29	1.06	2.50	1.27	1.12	1.79	1.55	1.85	1.88	1.72
Na <sub>2</sub> O	2.50	1.10	2.81	1.46	1.08	2.43	1.66	2.55	2.27	2.81
K <sub>2</sub> O	1.78	2.47	1.28	1.79	1.79	1.86	2.16	1.54	1.33	1.74
P <sub>2</sub> O <sub>5</sub>	.04	.04	.04	.03	.01	.02	.04	.04	.04	.04
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ba	419	631	345	475	504	506	622	498	272	314
Sc	31	33	20	28	37	21	32	18	29	35
Co	62	59	48	65	69	43	67	44	68	74
Cr	1445	1124	765	1148	1210	738	1248	676	1557	1694
V	181	211	129	214	236	142	243	152	164	191
Zn	112	121	86	119	132	81	134	87	88	107
Cu	40	84	40	91	65	67	63	58	42	30
Ni	568	536	417	494	598	323	619	328	656	796
Nb	6.6	7.3	3.8	7.2	8.7	6.0	7.4	5.8	6.2	6.0
Zr	133	139	101	168	128	135	122	131	110	105
Y	16	35	18	19	26	17	27	5.8	18	15
Sr	189	91	247	146	72	196	139	231	117	235
Rb	75	113	50	100	82	76	89	80	47	85
Th	3.4	7.2	3.5	6.0	5.3	2.8	4.5	6.1	2.8	2.8
Pb	9.4	6.7	8.4	6.7	3.4	10.0	6.7	10.0	4.2	9.0
K\Rb	198.1	181.6	212.2	148.5	180.2	202.3	202.0	159.5	232.2	169.5
K\Ba	35.3	32.5	30.9	31.2	29.4	30.5	28.8	25.7	40.6	45.8
Rb\Sr	.396	1.240	.203	.687	1.150	.388	.640	.348	.405	.362
Sr\Ba	.450	.144	.717	.306	.142	.388	.223	.464	.432	.747

\*\*\* All Fe calculated as FeO \*\*\*

Appendix B (continued)

	P5D	V28C	V6D
SiO <sub>2</sub>	58.23	71.66	72.87
TiO <sub>2</sub>	.64	.01	.02
Al <sub>2</sub> O <sub>3</sub>	17.61	16.16	16.03
FeO	7.15	2.20	1.81
MnO	.07	.14	.04
MgO	10.72	.62	.75
CaO	1.99	3.23	2.01
Na <sub>2</sub> O	2.33	5.53	5.32
K <sub>2</sub> O	1.22	.45	1.09
P <sub>2</sub> O <sub>5</sub>	.04	.00	.05
Total	100.00	100.00	100.00
Ba	308	116	1016
Sc	28	3.9	6.6
Co	65	1.8	4.1
Cr	1566	12	4.7
V	161	3.8	2.0
Zn	93	7.5	9.1
Cu	34	4.3	17
Ni	675	17	10
Nb	4.7	.9	.8
Zr	110	81	37
Y	15	24	6.9
Sr	160	446	536
Rb	42	4.6	9.0
Th	4.2	2.4	2.3
Pb	5.6	11	24
K\Rb	239.1	815.7	999.3
K\Ba	32.8	32.3	8.9
Rb\Sr	.264	.010	.017
Sr\Ba	.520	3.840	.528

\*\*\* All Fe calculated as FeO \*\*\*

## Appendix B

Major and trace element compositions of several other  
lithologies recalculated volatile free.  
Majores in weight % oxides, traces in ppm.

	P13B	P14B	G9C	GD49C	C4D	C8D
SiO <sub>2</sub>	72.19	67.96	70.76	75.82	58.15	59.00
TiO <sub>2</sub>	.62	.63	.34	.04	1.85	2.17
Al <sub>2</sub> O <sub>3</sub>	20.56	21.52	15.48	13.76	14.18	13.48
FeO	2.64	4.86	2.69	.80	9.29	9.67
MnO	.06	.18	.04	.04	.15	.13
MgO	.88	.87	1.46	.13	3.72	2.90
CaO	.36	.43	3.54	.86	6.24	6.05
Na <sub>2</sub> O	1.10	1.40	4.08	5.15	3.56	3.46
K <sub>2</sub> O	1.57	2.08	1.48	3.38	1.84	2.02
P <sub>2</sub> O <sub>5</sub>	.04	.07	.13	.02	1.02	1.13
Total	100.00	100.00	100.00	100.00	100.00	100.00
Ba	127	172	678	202	1474	1706
Sc	62	57	5.8	1.5	18	20
Co	12	19	6.5	1.5	28	26
Mn	439.3	1271.3	272.8	78.3	981.0	973.0
Cr	310	302	29	2.9	104	50
V	268	271	43	1.3	136	160
Zn	33	31	55	12	126	135
Cu	3.9	6.3	21	7.2	27	26
Ni	72	49	16	2.0	66	37
Nb	1.8	1.7	2.1	2.9	24	27
Zr	46	46	116	18	406	459
Y	16	15	6.0	2.6	62	74
Sr	50	73	611	104	785	732
Rb	40	54	42	75	42	43
Th	2.3	2.5	2.4	3.6	4.5	5.8
Pb	2.7	4.1	9.9	33	17	17
K\Rb	327.4	319.1	292.8	374.0	363.2	389.5
K\Ba	102.6	100.7	18.1	139.0	10.3	9.8
Rb\Sr	.786	.740	.069	.722	.053	.059
Sr\Ba	.399	.427	.901	.514	.532	.429

\*\*\* All Fe Calculated as FeO \*\*\*

## Appendix C

Geothermometry and geobarometry: equations and calculation details.

Abbreviations used:

P = pressure

T = temperature

k = equilibrium constant for an exchange reaction

R = universal gas constant (1.987 cal/molK)

$X_{i,j}$  = atomic proportion of component i in phase (or site of  
phase) j

$a_{i,j}$  = activity of component i in phase j

$y_i$  = activity coefficient of component i ( $a = Xy$ )

$W_i$  = interference factor of component i

Mineral abbreviations are as given in Table's 3.1, 3.2, 3.3.

A. Mafic Rocks

Clinopyroxene - Orthopyroxene Geothermometry:

All for pyroxenes based on the structural formula  $(M1)_1(M2)_1T_2O_6$ .

i) Powell (1978):

$$T = -[1600 + 80P + (X_{Ca,M2} - X_{Mg,M2})_{cpx}(6670 - 88P) - 1900X_{Fe,M2,opx}] / \ln k$$

where  $k = (X_{Ca,M2}/X_{Mg,M2})_{opx} * (X_{Mg,M2}/X_{Ca,M2})_{cpx}$ ,

and T in K, P in kbars (6kbars), and M2 contains Ca, Na, Mn, Mg, Fe. Fe and Mg are proportioned into M2 by the mineral Mg/Fe ratio, with all Fe assumed as  $Fe^{2+}$ .

Min. Pair	cpx-M2		X <sub>Ca</sub>	opx-M2		T (°C)
	X <sub>Ca</sub>	X <sub>Mg</sub>		X <sub>Mg</sub>	X <sub>Fe</sub>	
T1-C	0.921	0.032	0.013	0.577	0.394	676
R	0.930	0.029	0.026	0.575	0.385	775
T2-C	0.918	0.033	0.014	0.572	0.397	688
T3-C	0.917	0.032	0.012	0.585	0.388	663
R	0.915	0.037	0.014	0.589	0.383	698
T4-C	0.899	0.048	0.014	0.589	0.385	713
T5-C	0.915	0.036	0.023	0.591	0.374	771

(C = core, R = rim)

Average T<sub>Core</sub> = 702 ± 70°C.

ii) Lindsley (1983):

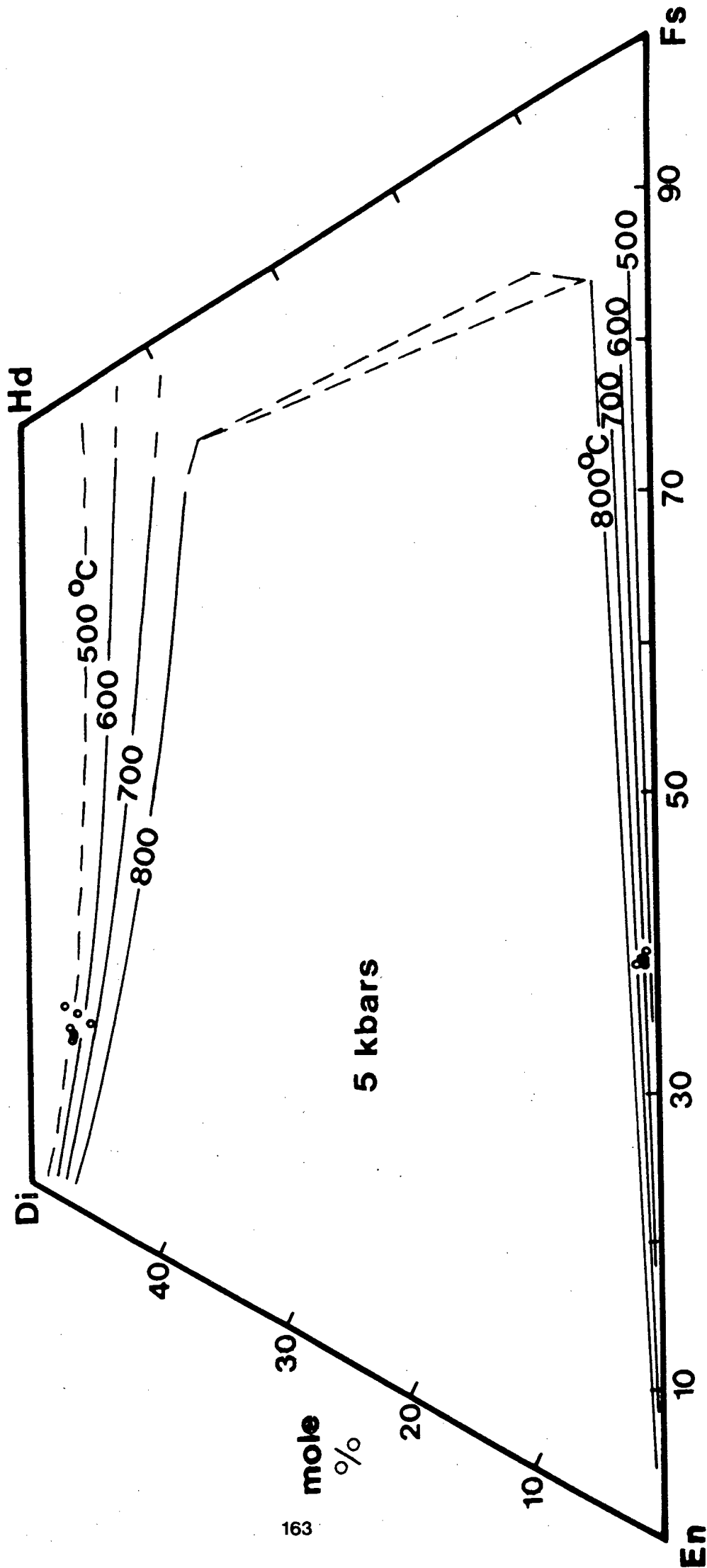
Graphical thermometer where the orthopyroxene - clinopyroxene solvus is represented in the Ca-Mg-Fe pyroxene quadrilateral. Pyroxene components not represented in the quadrilateral have been corrected for during the calculation procedure to obtain the wollastonite, enstatite and ferrosilite components. Temperatures were determined from the 5kbar diagram and calculated for 6kbars using the pressure correction equations given by Lindsley (1983;  $\sim 3^{\circ}\text{C}/\text{kbar}$  for Cpx,  $\sim 3\text{-}4^{\circ}\text{C}/\text{kbar}$  for Opx).

Min. Pair	Cpx				Opx			
	Wo	En	Fs	T <sup>o</sup> C	Wo	En	Fs	T <sup>o</sup> C
T1-C	0.475	0.396	0.129	453	0.007	0.603	0.390	523
R	0.469	0.416	0.115	523	0.014	0.606	0.380	660
T2-C	0.469	0.416	0.115	523	0.007	0.601	0.391	533
T3-C	0.470	0.413	0.117	503	0.006	0.610	0.384	563
R	0.470	0.420	0.110	513	0.007	0.611	0.382	564
T4-C	0.465	0.406	0.130	543	0.007	0.608	0.384	603
T5-C	0.454	0.417	0.129	653	0.012	0.609	0.379	709

(C = Core, R = Rim)

Average T<sub>Core</sub> for Cpx =  $535 \pm 120^{\circ}\text{C}$ ; for Opx =  $586 \pm 120^{\circ}\text{C}$ .  
 Expected accuracy  $\sim 50^{\circ}\text{C}$  (Lindsley, 1983).

Figure C.1: Ca - Mg - Fe quadrilateral after Lindsley (1983) illustrating the pyroxene compositions of sample M27C relative to the clinopyroxene - orthopyroxene solvus isotherms. Di - diopside, En - Enstatite, Fs - Ferrosillite, Hd - hedenbergite.



## B. Pelitic Rocks

### 1) Geobarometry

#### a) Garnet - Orthopyroxene - Plagioclase - Quartz Barometer after Newton and Perkins (1982):

$$P \text{ (bars)} = 3044 + 13.070T(K) + 3.5038T \ln \frac{a_{Ca,gar} (a_{Mg,gar})^2}{a_{An,plg} a_{En,opx}}$$

the activities at a temperature are evaluated from the compositions as follows:

$$\text{Plagioclase : } RT \ln y_{An} = X_{Ab}^2 [W_{An} + 2X_{An}(W_{Ab} - W_{An})]$$

$$\text{where } W_{An} = 2025 \text{ cal and } W_{Ab} = 6746 \text{ cal}$$

$$\text{and } a_{An} = 0.25 y_{An} X_{An}(1+X_{An})^2$$

(the Al-avoidance model).

An = anorthite, Ab = albite,

$$\text{Garnet : } RT \ln y_{Ca} = (3300 - 1.5T) (X_{Mg}^2 + X_{Mg}X_{Fe}),$$

$$RT \ln y_{Mg} = (3300 - 1.5T) (X_{Ca}^2 + X_{Ca}X_{Fe})$$

with garnet as a ternary Ca-Mg-Fe phase.

$$\text{Hypersthene : } a_{En} = X_{Mg,M2} X_{Mg,M1},$$

where M1 site is filled with Al, Ti, Cr, (Fe<sup>3+</sup>), with some of the Al needed to fill the tetrahedral site though, and M2 site is filled by Ca, Na. The rest of M1 and M2 is filled up in equal proportions to the abundances, with Mg and Fe. En = enstatite.

Precision ~ 1.5 kbars, with a T error of 100 K only leading to a few hundred bars difference.

Summary of data : P calculated at 800°C

Sample	a <sub>An</sub>	a <sub>Ca,gar</sub>	a <sub>Mg,gar</sub>	a <sub>En,opx</sub>	P (kbars)
P14C-T2	0.416	0.042	0.350	0.328	5.6
T3	0.416	0.042	0.373	0.333	6.1
T4	0.416	0.040	0.347	0.384	4.8
T6	0.416	0.042	0.363	0.350	5.7
P19C-T1	0.443	0.062	0.355	0.363	6.6
T2	0.443	0.051	0.376	0.377	6.2
P21C-T5	0.348	0.040	0.367	0.342	6.3
T5R	0.348	0.043	0.365	0.390	6.1
P25C-T1	0.402	0.047	0.401	0.423	6.3
T1R	0.405	0.046	0.405	0.434	6.1
T2	0.402	0.044	0.415	0.443	6.1
T3	0.402	0.043	0.423	0.437	6.2
T3R	0.405	0.045	0.421	0.472	6.0
T4	0.402	0.049	0.402	0.430	6.4

(R in the name implies rim compositions)

b) Garnet - Orthopyroxene Barometer after Harley and Green (1982):

$$P \text{ (kbars)} = 1/dVr [ (R \ln k - 2.93)T + 5650 \\ + 5157(1 - X_{Al,M1})(1-2X_{Al,M1})X_{Fe,opx} \\ - 6300(X_{Ca,gar}X_{Fe,gar} + (X_{Ca,gar})^2) ],$$

$$\text{where } k = [ X_{Al,M1}(1 - X_{Al,M1})/(1 - X_{Ca,gar})^3 ],$$

$$\text{and } dVr = - [ 183.3 + 178.98 (X_{Al,M1}(1 - X_{Al,M1})) ],$$

and garnet is a ternary Ca-Fe-Mg system, and  $X_{Fe,opx} = Fe/(Fe + Mg)$ , and  $X_{Al,M1} = Al/2$  in a 6 oxygen pyroxene.

Precision ~ 1kbar.

Summary of data: (P calculated at 800°C)

Sample	$X_{Al,M1}$	$X_{Fe,opx}$	$X_{Ca,gar}$	$X_{Fe,gar}$	k	P kbars
P14C-T2	0.104	0.395	0.032	0.618	0.103	5.1
T3	0.099	0.394	0.032	0.601	0.098	5.5
T4	0.080	0.355	0.031	0.627	0.081	8.0
T6	0.090	0.378	0.032	0.611	0.090	6.6
P19C-T1	0.117	0.365	0.048	0.606	0.120	4.6
T2	0.118	0.354	0.039	0.592	0.117	4.9
P21C-T5	0.126	0.380	0.030	0.608	0.121	4.1
T5R	0.127	0.339	0.033	0.608	0.123	4.7
P25C-T1	0.125	0.313	0.035	0.571	0.122	5.2
T1R	0.129	0.302	0.034	0.568	0.125	5.2
T2	0.119	0.298	0.032	0.559	0.116	5.8
T3	0.130	0.297	0.031	0.552	0.124	5.3
T3R	0.112	0.280	0.033	0.552	0.110	6.6
T4	0.129	0.304	0.036	0.569	0.125	5.2

(R in the name implies rim compositions)

## 2) Geothermometry

### a) Garnet - Orthopyroxene Thermometry

i) After Harley (1984) :

$$T \text{ (K)} = \frac{3740 + 1400X_{\text{Ca,gar}} + 22.86P(\text{kbars})}{R \ln (1/k) + 1.96}$$

ii) After Sen and Bhattacharya (1984) :

$$T \text{ (K)} = \frac{2713 + 0.022P(\text{bars}) + 3300X_{\text{Ca,gar}} + 195(X_{\text{Fe,gar}} - X_{\text{Mg,gar}})}{-R \ln k + 0.787 + 1.5X_{\text{Ca,gar}}}$$

where  $k = (X_{\text{Fe}}/X_{\text{Mg}})_{\text{opx}} / (X_{\text{Fe}}/X_{\text{Mg}})_{\text{gar}}$

and garnet is a ternary Ca-Fe<sup>2+</sup>-Mg phase while orthopyroxene is a binary Fe<sup>2+</sup>-Mg phase.

Accuracy is estimated at ~ 60°C in both cases.

Summary of data : T calculated at 6 kbars

Sample	k	X <sub>Ca,gar</sub>	X <sub>Fe,gar</sub>	X <sub>Mg,gar</sub>	-- T °C --	
					i)	ii)
P14C-T2	0.370	0.032	0.618	0.350	724	763
T3	0.396	0.032	0.601	0.367	759	849
T4	0.301	0.031	0.627	0.342	630	659
T6	0.355	0.032	0.612	0.356	704	763
P19C-T1	0.329	0.048	0.606	0.347	674	722
T2	0.341	0.039	0.592	0.369	687	738
P21C-T5	0.365	0.030	0.608	0.362	716	783
T5 R	0.303	0.033	0.608	0.359	633	662
P25C-T1	0.314	0.035	0.571	0.394	649	681
T1 R	0.303	0.034	0.568	0.398	633	658
T2	0.311	0.032	0.559	0.409	644	670
T3	0.319	0.031	0.552	0.417	654	685
T3 R	0.292	0.033	0.552	0.415	618	635
T4	0.303	0.036	0.569	0.395	634	660

b) Garnet - Biotite Thermometry

i) After Perchuk and Lavrenteva (1983) :

$$T \text{ (K)} = \frac{7843.7 + dV(P - 6000)}{R \ln k + 5.699}$$

where  $k = (X_{Mg}/1-X_{Mg})_{bio} (1-X_{Mg}/X_{Mg})_{gar}$

and  $X_{Mg} = Mg/(Mg + Fe + Mn)$ ,

and  $dV =$  change in volume (cal/bar.mol) at pressure P (bars).

Summary of data :

	Cores		Rims	
	k	T (°C)	k	T (°C)
P17C-T1	6.145	570	5.785	581
T2	4.734	619		
T3	4.841	615		
T4	4.423	633		
T5MX	3.141	711		
T6MX	2.850	735		
P41C-T1	4.600	625	5.769	581
T2	4.034	653	4.906	612 gar rim
T3MX	4.072	651		
T4MX	4.105	649		
P34C-T1MX	4.210	644		
T2MX	3.721	671	3.813	665
P42C-T1	4.676	622	5.408	593
T2	5.332	596	5.360	595 gar rim
T3MX	4.959	610		
P50C-T1	6.559	558	5.558	588
T2	6.896	550	6.178	569 gar rim
T3	6.601	557	6.977	548 bio incl
T4	6.066	572	5.474	591
T5MX	4.931	611		
T6MX	5.009	608		
P7D-T1	4.731	620	5.719	583
T2	5.807	580	4.945	611 gar rim
T3	4.832	615	5.456	592

(continued on the next page)

T4MX	5.354	595		
T5MX	5.354	595		
T6MX	5.404	594		
P25C-T5	3.810	666	4.020	654
T6	4.063	651	4.552	627 gar rim
T7	3.942	658	4.116	649
T8MX	3.033	719	3.303	699 bio rim
T9MX	3.442	689	3.400	692 gar rim
T10MX	3.094	714	3.138	711 bio rim
P14C-T5	5.253	599		
T6	6.010	574		
T11MX	3.620	677		
P19C-T3	4.742	619		
T4	5.676	584		
T7MX	4.026	653		
T8MX	3.732	670		
P21C-T1	4.633	624	5.041	607
T2	4.313	639	4.734	619
T3	4.338	637		
T4	5.617	586	6.080	572 gar rim
T5MX	3.147	710	3.346	695 bio rim
P1D-T1	6.173	569	7.148	543 bio incl
T2	5.924	576	6.360	564
T3MX	4.724	620	4.984	609 bio rim

(MX = matrix biotite grains)

ii) Garnet - Biotite Geothermometer after Indares and Martignole (1985b) :

$$T (K) = [ 12454 + 0.057P(\text{bar}) + 3(-1590X_{\text{Al,bio}} - 7451X_{\text{Ti,bio}}) - 3(-3000(X_{\text{Ca,gar}} + X_{\text{Mn,gar}})) ] / 4.662 - 5.9616 \ln k ,$$

where  $k = (\text{Mg/Fe})_{\text{gar}} / (\text{Mg/Fe})_{\text{bio}}$ ,

$$X_{\text{Al,bio}} = \text{Al}^{\text{VI}} / (\text{Fe} + \text{Mg} + \text{Mn} + \text{Al}^{\text{VI}} + \text{Ti}),$$

$$X_{\text{Ti,bio}} = \text{Ti} / (\text{Fe} + \text{Mg} + \text{Mn} + \text{Al}^{\text{VI}} + \text{Ti}),$$

$$X_{\text{Ca,gar}} = \text{Ca} / (\text{Fe} + \text{Mg} + \text{Ca} + \text{Mn}),$$

$$X_{\text{Mn,gar}} = \text{Mn} / (\text{Fe} + \text{Mg} + \text{Ca} + \text{Mn}).$$

iii) Garnet - Biotite Geothermometer after Ferry and Spear (1978) :

$$T (K) = \frac{12454 + 0.057P}{4.662 - 3 R \ln k}$$

where  $k = (\text{Mg/Fe})_{\text{gar}} / (\text{Mg/Fe})_{\text{bio}}$ , P in bars.

An ideal Fe-Mg mix in biotite - garnet solid solution is assumed.

Calibrated for garnets up to 0.2 = (Ca + Mn)/(Ca + Mn + Mg + Fe), and biotite (Al<sup>VI</sup> + Ti)/(Al<sup>VI</sup> + Ti + Fe + Mg) less than 0.15.

Precision ~ 50°C.

Summary of data :

Sample	k	X <sub>Al,bio</sub>	X <sub>Ti,bio</sub>	X <sub>Ca,gar</sub>	X <sub>Mn,gar</sub>	T °C	
						ii)	iii)
P17C-T1	0.201	0.130	0.048	0.024	0.015	532	626
T1 R	0.177	0.121	0.043	0.024	0.017	495	581
T2	0.217	0.104	0.061	0.025	0.015	547	656
T3	0.212	0.111	0.065	0.023	0.017	530	647
T4	0.233	0.103	0.066	0.023	0.020	567	686
T5MX	0.327	0.102	0.078	0.022	0.016	690	857
T6MX	0.337	0.113	0.080	0.019	0.017	695	875
P41C-T1	0.222	0.115	0.051	0.034	0.013	573	666
T1 R	0.177	0.102	0.049	0.033	0.017	505	581
T2	0.254	0.109	0.053	0.031	0.014	623	723
T2 R	0.209	0.109	0.053	0.026	0.016	547	642 gar R
T3MX	0.251	0.113	0.053	0.038	0.016	623	719
T4MX	0.249	0.116	0.056	0.034	0.013	608	714
P34C-T1MX	0.244	0.101	0.045	0.031	0.014	623	706
T2MX	0.274	0.098	0.046	0.037	0.010	674	761

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T2MX R	0.267	0.100	0.044	0.037	0.014	668	748
P42C-T1	0.217	0.059	0.073	0.076	0.010	574	656
T1 R	0.187	0.062	0.073	0.121	0.009	548	600
T2	0.191	0.057	0.074	0.096	0.010	541	607
T2 R	0.189	0.057	0.074	0.091	0.009	533	603 gar R
T3MX	0.205	0.050	0.081	0.112	0.010	566	633
P50C-T1	0.158	0.096	0.057	0.041	0.022	470	544
T1 R	0.184	0.089	0.060	0.047	0.014	512	594
T2	0.150	0.097	0.053	0.041	0.024	462	529
T2 R	0.165	0.097	0.053	0.027	0.013	474	558 gar R
T3	0.157	0.089	0.057	0.041	0.021	469	542
T3 R	0.148	0.089	0.057	0.045	0.020	455	524
T4	0.170	0.093	0.056	0.044	0.020	494	568
T4 R	0.186	0.093	0.060	0.046	0.013	513	598
T5MX	0.206	0.088	0.060	0.043	0.009	544	636
T6MX	0.206	0.092	0.042	0.041	0.021	578	636
P7D-T1	0.215	0.094	0.037	0.049	0.009	598	653
T1 R	0.177	0.112	0.028	0.051	0.009	540	581
T2	0.178	0.095	0.041	0.041	0.021	529	582
T2 R	0.206	0.095	0.041	0.038	0.013	571	635 gar R
T3	0.210	0.090	0.042	0.040	0.010	577	644
T3 R	0.185	0.106	0.040	0.040	0.008	530	597
T4MX	0.190	0.086	0.044	0.037	0.011	540	606
T5MX	0.190	0.095	0.043	0.037	0.011	538	605
T6MX	0.192	0.086	0.044	0.040	0.023	552	610
P25C-T5	0.269	0.067	0.100	0.041	0.015	587	752
T5 R	0.256	0.057	0.097	0.038	0.014	574	727
T6	0.252	0.068	0.103	0.031	0.014	548	720
T6 R	0.225	0.068	0.103	0.064	0.014	529	670 gar R
T7	0.259	0.065	0.106	0.031	0.014	554	733
T7 R	0.248	0.066	0.104	0.030	0.014	540	713
T8MX	0.338	0.054	0.111	0.035	0.014	670	876
T8MX R	0.311	0.054	0.111	0.035	0.014	630	827 bio R
T9MX	0.299	0.049	0.111	0.038	0.015	617	805
T9MX R	0.302	0.049	0.111	0.031	0.016	617	812 gar R
T10MX	0.331	0.058	0.110	0.034	0.013	659	864
T10MXR	0.326	0.044	0.114	0.034	0.013	649	855 bio R
P14C-T5	0.195	0.063	0.080	0.031	0.014	498	615
T6	0.170	0.080	0.070	0.032	0.014	467	568
T11Mx	0.283	0.067	0.093	0.031	0.016	615	787
P19C-T3	0.217	0.069	0.073	0.044	0.018	554	656
T4	0.181	0.072	0.063	0.044	0.017	508	588
T7MX	0.276	0.067	0.072	0.035	0.015	644	764

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T8MX	0.256	0.067	0.072	0.038	0.018	616	728	
P21C-T1	0.221	0.049	0.110	0.044	0.013	504	664	
T1 R	0.204	0.053	0.108	0.037	0.014	476	632	
T2	0.235	0.058	0.101	0.030	0.007	524	690	
T2 R	0.214	0.053	0.099	0.025	0.009	495	650	
T3	0.234	0.053	0.097	0.029	0.009	532	688	
T4	0.181	0.079	0.066	0.044	0.011	497	589	
T4 R	0.168	0.079	0.066	0.039	0.012	472	563	gar R
T5MX	0.323	0.039	0.110	0.042	0.012	660	850	
T5MX R	0.305	0.041	0.117	0.042	0.012	619	816	bio R
P1D-T1	0.167	0.082	0.064	0.027	0.017	469	561	
T1 R	0.144	0.084	0.063	0.031	0.018	432	517	
T2	0.173	0.093	0.066	0.029	0.015	473	573	
T2 R	0.160	0.078	0.063	0.035	0.013	461	548	
T3MX	0.218	0.069	0.067	0.028	0.018	555	658	
T3MX R	0.207	0.092	0.067	0.028	0.018	529	637	bio R

(R implies rim composition; MX = matrix biotite)

c) Garnet - Cordierite Geothermometry :

i) After Perchuk and Lavrenteva (1983) :

$$T \text{ (K)} = \frac{3020 - 0.018P(\text{bars})}{\ln k + 1.287}$$

where  $k = (X_{Mg}/1-X_{Mg})_{\text{crd}} (1-X_{Mg}/X_{Mg})_{\text{gar}}$ ,

and  $X_{Mg} = Mg/(Mg + Fe + Mn)$ ,

Summary of data :

	Cores		Rims		
	k	T (°C)	k	T (°C)	
P14C-T1	9.374	553	9.600	548	
T2	8.564	575			
T3	7.561	607			
T6	9.313	555			
T7	6.886	632			crd-bio contact
T8	6.972	629			crd-bio contact
P19C-T1	10.370	530	9.595	548	gar rim
T5	9.984	539			
T6	6.183	664			
P21C-T5	8.717	571	8.830	567	gar rim
T6	11.143	514			
T7	8.556	575	10.379	530	

ii) Garnet - Cordierite Geothermometry after  
Bhattacharya et al. (1988) :

$$T \text{ (K)} = [ 1/(1.028 - \ln k) ] *$$

$$[ 1814 + 0.0125P + 1122(X_{Mg}-X_{Fe})_{crd} \\ - 1258(X_{Mg}-X_{Fe})_{gar} + 1510(X_{Ca} + X_{Mn})_{gar} ],$$

where  $k = (X_{Fe}/X_{Mg})_{crd} / (X_{Fe}/X_{Mg})_{gar}$  ,

and P in bars.

Calibrated over a compositional range of  $0.38 < X_{Mg} < 0.92$  and  
from 620 to 860 °C.

Accuracy ~ 65 °C.

Summary of data: T calculated at a P of 6 kbars.

	Cordierite		----- Garnet -----				T °C
	X <sub>Mg</sub>	X <sub>Fe</sub>	X <sub>Fe</sub>	X <sub>Mg</sub>	X <sub>Ca</sub>	X <sub>Mn</sub>	
P14C-T1	0.850	0.150	0.588	0.365	0.032	0.015	667
T1 R	0.851	0.149	0.592	0.361	0.032	0.016	663
T2	0.826	0.174	0.609	0.345	0.031	0.015	690
T3	0.818	0.182	0.592	0.361	0.032	0.015	713
T6	0.842	0.158	0.603	0.352	0.032	0.014	671
T7-B	0.799	0.201	0.600	0.355	0.031	0.014	733
T8-B	0.801	0.199	0.600	0.355	0.031	0.014	731
P19C-T1	0.852	0.148	0.595	0.340	0.047	0.019	660
T1 R	0.852	0.148	0.587	0.361	0.038	0.015	664 gar rim
T5	0.893	0.107	0.569	0.381	0.035	0.015	600
T6	0.794	0.206	0.578	0.370	0.037	0.015	756
P21C-T5	0.836	0.164	0.600	0.357	0.030	0.013	681
T5 R	0.836	0.164	0.600	0.354	0.032	0.013	680 gar rim
T6	0.876	0.124	0.585	0.376	0.029	0.009	623
T7	0.855	0.145	0.566	0.396	0.029	0.010	668
T7 R	0.876	0.124	0.573	0.397	0.020	0.009	627

(R implies rim compositions; B implies cordierite in contact with  
biotite but not garnet.)

## Appendix D

Stable isotope terminology and equations used for temperature calculations:

Fractionation factor  $\alpha$  is defined as:

$$\alpha_{x-y} = \frac{(180/160)_x}{(180/160)_y} = \frac{1 + \delta^{180}_x/1000}{1 + \delta^{180}_y/1000}$$

where x and y are mineral phases considered,  $\delta^{180}$  as in Chapter 2, and

$$\Delta^{180}_{x-y} = 1000 \ln \alpha_{x-y} (\sim \delta^{180}_x - \delta^{180}_y).$$

Temperature equations used (Bottinga and Javoy, 1975; Matthews et al., 1983) refer to the following general equation:

$$1000 \ln \alpha_{x-y} = A_{x-y} + B_{x-y}10^6/T^2,$$

where A and B are experimentally determined constants for the mineral pairs represented as x and y, and T is in Kelvin.

Mineral Pair x-y	Bottinga and Javoy (1975)		Matthews et al. (1983)		Errors in T at	
	A	B	A	B	500	700°C
qtz-gar	---	2.88	---	---	16	32
qtz-pyx	---	2.67	---	2.08	17	35
qtz-amp	-0.3	3.148	---	---	15	29
qtz-plg	---	(0.97+m)	---	(0.5+m)	36	72*
qtz-bio	-0.6	3.69	---	---	13	25
qtz-mgt	---	5.57	---	6.11	8	17
plg-bio	-0.6	(2.72-m)	---	---	19	38*
plg-amp	-0.3	(2.178-m)	---	---	25	49*
plg-pyx	---	(1.70-m)	---	(1.58-m)	33	66*

Note: m = 1.04b for Bottinga and Javoy (1975),  
m = 1.09b for Matthews et al. (1983),  
where b = mole fraction of An in plagioclase.  
\* Errors calculated for b = 0.3.

For the calibration of Clayton et al. (1989), B = (0.92 + m) where m = 1.02b. This calibration results in quartz-plagioclase temperatures that are only 7-10°C lower than those for Bottinga and Javoy (1975), for all the SMZ rocks considered.

Errors in temperatures are calculated for the Bottinga and Javoy (1975) calibrations only. To calculate the errors an error in D of 0.2 ‰ is assumed and the equation of Deines (1977) is used:

$$dT = \frac{0.2 T^3}{-2 B 10^6} \quad \text{where } dt \text{ is the error in } T \text{ and } B \text{ is as above.}$$

For the mineral - fluid calculations the following equations were used :

A. Friedman and O'Neil (1977):

$$1) 1000 \ln \alpha_{\text{CO}_2\text{-Cc}} = -1.8034 \cdot 10^6 / T^2 + 10.611 \cdot 10^3 / T - 2.7798,$$

$$2) 1000 \ln \alpha_{\text{Cc-H}_2\text{O}} = 2.78 \cdot 10^6 / T^2 - 2.89,$$

where Cc = calcite, and combining 1) and 2),

$$3) 1000 \ln \alpha_{\text{CO}_2\text{-H}_2\text{O}} = 0.977 \cdot 10^6 / T^2 + 10.611 \cdot 10^3 / T - 5.67.$$

For quartz - water fractionations:

$$4) 1000 \ln \alpha_{\text{qtz-H}_2\text{O}} = 2.51 \cdot 10^6 / T^2 - 1.46 \text{ at } T = 500\text{-}750^\circ\text{C}$$

$$5) 1000 \ln \alpha_{\text{qtz-H}_2\text{O}} = 3.38 \cdot 10^6 / T^2 - 2.90 \text{ at } T = 200\text{-}500^\circ\text{C}$$

Other mineral-H<sub>2</sub>O equations may be obtained by combining equations 4) and 5) with those for the quartz-mineral pairs listed above.

Combining 4) and 5) with 3) respectively,

$$6) 1000 \ln \alpha_{\text{CO}_2\text{-qtz}} = -1.533 \cdot 10^6 / T^2 + 10.611 \cdot 10^3 / T - 4.21$$

at T = 500-750°C,

$$7) 1000 \ln \alpha_{\text{CO}_2\text{-qtz}} = -2.403 \cdot 10^6 / T^2 + 10.611 \cdot 10^3 / T - 2.77$$

at T = 200-500°C.

B. Wenner and Taylor (1971):

$$8) 1000 \ln \alpha_{\text{chl-H}_2\text{O}} = 1.56 \cdot 10^6 / T^2 - 4.7,$$

$$9) 1000 \ln \alpha_{\text{H}_2\text{O-mgt}} = 0.13 \cdot 10^6 / T^2 + 6.38,$$

where chl = chlorite, mgt = magnetite.