

APPENDIX 2

Representative microprobe analyses of amphibole, epidote, garnet and plagioclase in A1 and A2 amphibolites, and A-X models used for thermodynamic modelling using Thermo-Calc in the NCFMASHTO system

Representative microprobe analyses of minerals from A1 and A2 amphibolites

Amphibole

A1

Wt.%	1rim	1core	7core	8rim	9 rim	10 rim	2rim	2core	3rim	3core	4rim	4core	5rim	5core	6rim	6core
SiO <sub>2</sub>	43.84	45.66	44.09	44.07	43.99	43.81	45.04	44.51	43.56	43.44	43.82	43.81	43.44	45.49	45.01	43.69
TiO <sub>2</sub>	0.51	0.56	0.47	0.48	0.65	0.51	0.44	0.53	0.52	0.66	0.55	0.51	0.59	0.44	0.73	0.50
Al <sub>2</sub> O <sub>3</sub>	14.35	12.47	13.88	13.92	14.62	13.76	13.50	13.08	14.25	14.09	14.27	13.76	14.42	12.05	14.28	14.85
Cr <sub>2</sub> O <sub>3</sub>	0.09	0.09	0.11	0.03	0.03	0.01	0.03	0.01	0.02	0.10	0.04	0.01	0.02	0.09	0.04	0.07
FeO	12.64	11.71	12.85	11.67	11.68	11.48	11.88	11.68	12.39	12.36	11.85	11.48	12.07	11.69	12.89	13.05
MnO	0.25	0.20	0.15	0.18	0.24	0.18	0.19	0.20	0.23	0.19	0.22	0.18	0.15	0.14	0.08	0.11
MgO	10.86	12.08	11.25	11.27	11.16	11.23	11.07	11.30	10.75	10.87	11.11	11.23	10.78	12.16	11.00	10.61
CaO	10.86	10.68	11.07	10.57	9.77	10.60	10.33	10.38	10.46	10.36	10.54	10.60	10.33	10.81	10.25	10.62
Na <sub>2</sub> O	2.25	2.37	2.06	2.48	2.91	2.67	2.24	2.34	2.74	2.46	2.86	2.67	2.70	2.07	2.28	2.24
K <sub>2</sub> O	0.75	0.48	0.62	0.64	0.68	0.65	0.74	0.59	0.67	0.70	0.76	0.65	0.69	0.53	0.51	0.50
ZrO <sub>2</sub>	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.01	0.00	0.04	0.00
Total	96.41	96.30	96.54	95.31	95.76	94.91	95.45	94.62	95.62	95.24	96.03	94.90	95.19	95.46	97.08	95.46
O	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
Si	6.497	6.717	6.523	6.567	6.519	6.560	6.686	6.669	6.504	6.508	6.504	6.560	6.501	6.751	6.585	6.477
Ti	0.057	0.062	0.053	0.054	0.072	0.057	0.049	0.060	0.059	0.074	0.062	0.057	0.066	0.049	0.081	0.055
Al	2.506	2.163	2.421	2.444	2.553	2.429	2.361	2.310	2.509	2.487	2.496	2.429	2.543	2.108	2.463	2.595
Cr	0.010	0.011	0.013	0.003	0.003	0.001	0.003	0.001	0.003	0.012	0.004	0.001	0.003	0.010	0.004	0.009
Fe <sup>3+</sup>	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe <sup>2+</sup>	1.566	1.441	1.590	1.454	1.447	1.438	1.475	1.464	1.547	1.548	1.471	1.437	1.511	1.451	1.577	1.617
Mn	0.032	0.025	0.018	0.023	0.029	0.023	0.024	0.025	0.029	0.024	0.027	0.023	0.019	0.018	0.010	0.014
Mg	2.399	2.649	2.481	2.505	2.466	2.508	2.450	2.525	2.392	2.427	2.458	2.508	2.404	2.690	2.399	2.344
Ca	1.724	1.684	1.755	1.688	1.552	1.701	1.642	1.667	1.673	1.663	1.676	1.701	1.656	1.719	1.607	1.686
Na	0.647	0.676	0.591	0.716	0.837	0.776	0.645	0.679	0.794	0.715	0.824	0.776	0.782	0.594	0.645	0.644
K	0.141	0.090	0.116	0.121	0.129	0.125	0.139	0.113	0.127	0.134	0.144	0.125	0.132	0.099	0.095	0.094
Zr	0.001	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.003	0.000	0.001	0.000	0.001	0.000	0.002	0.000
Total	15.581	15.517	15.561	15.575	15.611	15.618	15.475	15.512	15.639	15.593	15.667	15.618	15.617	15.488	15.468	15.535
A(Hb)	0.39	0.35	0.39	0.37	0.37	0.36	0.38	0.37	0.39	0.39	0.37	0.36	0.39	0.35	0.40	0.41

A2

	1rim	1core	2 core	3rim	3core
SiO <sub>2</sub>	44.20	46.26	45.35	45.02	45.22
TiO <sub>2</sub>	0.41	0.30	0.41	0.32	0.41
Al <sub>2</sub> O <sub>3</sub>	12.10	9.78	11.17	11.48	11.29
Cr <sub>2</sub> O <sub>3</sub>	0.21	0.12	0.13	0.03	0.11
FeO	14.76	13.82	14.32	14.29	14.54
MnO	0.26	0.30	0.32	0.22	0.30
MgO	10.35	11.83	11.29	10.90	11.13
CaO	10.80	11.14	10.87	10.87	11.16
Na <sub>2</sub> O	1.62	1.39	2.00	1.98	1.75
K <sub>2</sub> O	0.75	0.44	0.51	0.56	0.64
ZrO <sub>2</sub>	0.00	0.03	0.00	0.09	0.01
Total	95.45	95.43	96.37	95.75	96.56
O	23	23	23	23	23
Si	6.676	6.934	6.764	6.757	6.744
Ti	0.047	0.034	0.046	0.036	0.046
Al	2.154	1.727	1.963	2.030	1.985
Cr	0.025	0.015	0.015	0.004	0.013
Fe <sup>3+</sup>	0.000	0.000	0.000	0.000	0.000
Fe <sup>2+</sup>	1.864	1.732	1.786	1.794	1.813
Mn	0.033	0.038	0.041	0.028	0.038
Mg	2.331	2.644	2.510	2.440	2.474
Ca	1.748	1.789	1.737	1.748	1.784
Na	0.474	0.404	0.578	0.575	0.507
K	0.145	0.084	0.098	0.107	0.122
Zr	0.000	0.002	0.000	0.006	0.001
Total	15.498	15.403	15.538	15.525	15.525
x(amp)	0.44	0.40	0.42	0.42	0.42

Epidote

A1

Wt.%	1	2	3	4	5	6
SiO <sub>2</sub>	38.72	38.71	38.98	39.10	38.55	39.10
TiO <sub>2</sub>	0.05	0.05	0.14	0.05	0.05	0.08
Al <sub>2</sub> O <sub>3</sub>	31.53	30.99	31.62	31.72	31.38	31.71
Cr <sub>2</sub> O <sub>3</sub>	0.02	0.04	0.09	0.03	0.00	0.06
Fe <sub>2</sub> O <sub>3</sub>	2.23	2.96	1.96	1.98	1.83	1.96
MnO	0.06	0.00	0.01	0.00	0.02	0.05
MgO	0.04	0.02	0.03	0.05	0.01	0.02
CaO	24.65	24.65	24.46	24.50	24.45	24.48
Na <sub>2</sub> O	0.01	0.00	0.03	0.00	0.01	0.02
K <sub>2</sub> O	0.00	0.02	0.02	0.00	0.00	0.01
Total	97.32	97.42	97.33	97.43	96.30	97.49
O	12.5	12.5	12.5	12.5	12.5	12.5

A2

	1	2	3
SiO <sub>2</sub>	39.24	39.01	39.17
TiO <sub>2</sub>	0.07	0.06	0.04
Al <sub>2</sub> O <sub>3</sub>	32.03	31.95	32.14
Cr <sub>2</sub> O <sub>3</sub>	0.01	0.02	0.03
Fe <sub>2</sub> O <sub>3</sub>	1.79	1.50	1.56
MnO	0.00	0.01	0.05
MgO	0.06	0.05	0.04
CaO	24.28	24.47	24.54
Na <sub>2</sub> O	0.02	0.02	0.04
K <sub>2</sub> O	0.00	0.00	0.01
Totals	97.50	97.09	97.61
O	12.5	12.5	12.5

Si	2.981	2.985	2.995	2.999	2.994	2.998
Ti	0.003	0.003	0.008	0.003	0.003	0.005
Al	2.862	2.817	2.864	2.868	2.873	2.866
Cr	0.001	0.002	0.006	0.002	0.000	0.003
Fe <sup>3+</sup>	0.129	0.171	0.113	0.114	0.107	0.113
Mn	0.004	0.000	0.000	0.000	0.001	0.003
Mg	0.005	0.002	0.004	0.006	0.001	0.002
Ca	2.034	2.037	2.014	2.013	2.035	2.012
Na	0.001	0.000	0.004	0.000	0.002	0.003
K	0.000	0.001	0.001	0.000	0.000	0.001
Totals	8.020	8.018	8.009	8.006	8.015	8.008

Si	3.002	2.998	2.995
Ti	0.004	0.004	0.003
Al	2.889	2.895	2.897
Cr	0.001	0.001	0.002
Fe <sup>3+</sup>	0.103	0.087	0.090
Mn	0.000	0.001	0.003
Mg	0.007	0.005	0.004
Ca	1.991	2.015	2.010
Na	0.003	0.003	0.006
K	0.000	0.000	0.001
Totals	7.999	8.009	8.011

F(Ep) 0.04 0.06 0.04 0.04 0.04 0.04

0.03 0.03 0.03

**Garnet**

**A1**

Wt.%	1	2	3	4	5	6
SiO <sub>2</sub>	38.27	37.81	37.19	37.53	37.70	37.19
TiO <sub>2</sub>	0.07	0.05	0.06	0.12	0.05	0.06
Al <sub>2</sub> O <sub>3</sub>	20.77	20.55	19.95	20.08	19.94	19.95
FeO	29.42	29.67	27.03	28.39	27.98	27.03
MnO	0.58	1.03	1.62	0.26	0.35	1.62
MgO	2.81	2.65	0.59	0.75	0.83	0.59
CaO	9.16	8.91	12.51	12.91	13.13	12.51
Na <sub>2</sub> O	0.00	0.00	0.10	0.00	0.10	0.10
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	0.02	0.08	0.00	0.03	0.12	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.00	0.00	0.00	0.00
Total	101.12	100.74	99.05	100.07	100.20	99.05

**A2**

	1	2	3	4	5	6	7	8	9	10	11	12
SiO <sub>2</sub>	37.47	37.45	37.05	37.49	37.28	37.69	37.45	38.03	38.25	38.10	38.17	38.03
TiO <sub>2</sub>	0.06	0.07	0.08	0.03	0.06	0.10	0.06	0.11	0.06	0.05	0.12	0.04
Al <sub>2</sub> O <sub>3</sub>	20.97	20.93	20.81	20.97	20.50	21.43	20.94	21.68	21.74	21.93	21.67	21.73
FeO	26.45	27.91	26.75	25.42	25.29	24.96	27.27	24.87	25.56	27.67	26.67	27.50
MnO	2.61	1.99	4.23	4.07	4.00	2.05	3.13	0.93	1.01	1.25	1.37	1.37
MgO	3.27	3.74	2.56	2.39	2.33	3.12	3.10	3.91	4.92	5.01	4.81	4.34
CaO	8.11	7.13	7.62	9.11	9.19	10.41	7.52	10.53	8.53	6.71	7.69	7.55
Na <sub>2</sub> O	0.03	0.05	0.05	0.03	0.03	0.05	0.03	0.03	0.05	0.04	0.03	0.04
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr <sub>2</sub> O <sub>3</sub>	0.12	0.27	0.32	0.24	0.08	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Total	99.08	99.54	99.46	99.74	98.74	99.79	99.59	100.08	100.12	100.76	100.52	100.59

O	12	12	12	12	12	12
Si	3.011	3.000	3.016	3.009	3.020	3.016
Ti	0.004	0.003	0.004	0.007	0.003	0.004
Al	1.926	1.921	1.906	1.897	1.882	1.906
Cr	0.001	0.000	0.000	0.000	0.000	0.000
Fe <sup>3+</sup>	0.000	0.000	0.000	0.000	0.000	0.000
Fe <sup>2+</sup>	1.936	1.969	1.833	1.904	1.874	1.833
Mn	0.039	0.069	0.111	0.018	0.024	0.111
Mg	0.330	0.313	0.072	0.090	0.098	0.072
Ni	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.001	0.005	0.000	0.002	0.007	0.000
Ca	0.772	0.757	1.086	1.109	1.127	1.086
Total	8.021	8.037	8.028	8.035	8.036	8.028

O	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.995	2.984	2.977	2.991	3.006	2.979	2.991	2.978	2.986	2.971	2.980	2.978
Ti	0.004	0.004	0.005	0.002	0.004	0.006	0.004	0.007	0.004	0.003	0.007	0.002
Al	1.975	1.966	1.971	1.972	1.948	1.997	1.971	2.001	2.000	2.015	1.994	2.006
Cr	0.008	0.017	0.021	0.015	0.005	0.000	0.006	0.000	0.000	0.000	0.000	0.000
Fe <sup>3+</sup>	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe <sup>2+</sup>	1.768	1.860	1.798	1.696	1.705	1.650	1.822	1.629	1.668	1.804	1.741	1.801
Mn	0.177	0.135	0.288	0.275	0.273	0.137	0.212	0.061	0.067	0.083	0.091	0.091
Mg	0.390	0.444	0.307	0.284	0.280	0.368	0.369	0.456	0.573	0.583	0.559	0.506
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.695	0.609	0.656	0.779	0.794	0.881	0.643	0.884	0.713	0.561	0.643	0.634
Total	8.010	8.020	8.022	8.014	8.014	8.017	8.017	8.015	8.011	8.019	8.016	8.017

X(Grt) 0.85 0.86 0.96 0.96 0.95 0.96  
Z(Grt) 0.25 0.25 0.36 0.36 0.36 0.36

x(g) 0.82 0.81 0.85 0.86 0.86 0.82 0.83 0.78 0.74 0.76 0.76 0.78  
z(g) 0.24 0.21 0.24 0.28 0.29 0.30 0.23 0.30 0.24 0.19 0.22 0.22

Alm 0.63 0.63 0.59 0.61 0.60 0.59  
Prp 0.11 0.10 0.02 0.03 0.03 0.02  
Grs 0.25 0.24 0.35 0.36 0.36 0.35  
Sps 0.01 0.02 0.04 0.01 0.01 0.04

0.58 0.61 0.59 0.56 0.56 0.54 0.60 0.54 0.55 0.60 0.57 0.59  
0.13 0.15 0.10 0.09 0.09 0.12 0.12 0.15 0.19 0.19 0.18 0.17  
0.23 0.20 0.22 0.26 0.26 0.29 0.21 0.29 0.24 0.19 0.21 0.21  
0.06 0.04 0.09 0.09 0.09 0.05 0.07 0.02 0.02 0.03 0.03 0.03

A1							Plagioclase							
A1							A2							
Wt.%	1	2	3	4	5	6		1	2	3	4	5	6	7
SiO <sub>2</sub>	64.72	64.67	65.70	65.46	62.86	64.82	SiO <sub>2</sub>	67.14	66.17	67.30	65.36	65.69	62.63	65.74
Al <sub>2</sub> O <sub>3</sub>	21.19	21.10	21.12	21.07	22.67	21.22	Al <sub>2</sub> O <sub>3</sub>	19.67	20.29	19.88	21.59	21.30	22.80	21.24
FeO	0.14	0.09	0.00	0.05	0.41	0.15	FeO	0.19	0.10	0.01	0.02	0.06	0.00	0.15
MnO	0.00	0.00	0.00	0.00	0.00	0.00	MnO	0.08	0.00	0.00	0.02	0.00	0.00	0.04
CaO	2.63	2.58	2.27	2.37	3.74	2.69	CaO	0.75	1.35	1.11	2.57	2.29	4.24	2.31
Na <sub>2</sub> O	10.58	10.86	11.07	10.81	9.10	10.34	Na <sub>2</sub> O	11.52	10.99	11.35	10.62	10.96	9.63	10.96
K <sub>2</sub> O	0.15	0.10	0.09	0.06	1.03	0.15	K <sub>2</sub> O	0.11	0.47	0.14	0.08	0.06	0.19	0.06
Totals	99.39	99.39	100.25	99.81	99.80	99.36	Totals	99.45	99.37	99.79	100.27	100.35	99.49	100.49
O	8	8	8	8	8	8	O	8	8	8	8	8	8	8
Si	2.873	2.873	2.888	2.889	2.799	2.876	Si	2.962	2.929	2.957	2.872	2.884	2.790	2.885
Al	1.109	1.105	1.094	1.096	1.190	1.110	Al	1.023	1.059	1.030	1.119	1.102	1.197	1.099
Fe <sup>2+</sup>	0.005	0.003	0.000	0.002	0.015	0.006	Fe <sup>2+</sup>	0.007	0.004	0.000	0.001	0.002	0.000	0.005
Mn	0.000	0.000	0.000	0.000	0.000	0.000	Mn	0.003	0.000	0.000	0.001	0.000	0.000	0.001
Mg	0.000	0.000	0.000	0.000	0.000	0.000	Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.125	0.123	0.107	0.112	0.179	0.128	Ca	0.035	0.064	0.052	0.121	0.108	0.203	0.108
Na	0.911	0.935	0.944	0.925	0.785	0.890	Na	0.986	0.943	0.967	0.905	0.933	0.832	0.932
K	0.008	0.006	0.005	0.003	0.058	0.008	K	0.006	0.027	0.008	0.005	0.003	0.011	0.004
Totals	5.032	5.045	5.039	5.027	5.027	5.018	Totals	5.022	5.026	5.015	5.023	5.033	5.032	5.034
Ca(Pl)	0.12	0.12	0.10	0.11	0.19	0.13	Ca(Pl)	0.03	0.06	0.05	0.12	0.10	0.20	0.10

A-X models used for thermodynamic modeling of A1 and A2 amphibolites in the NCFMASHTO system.

**Amphiboles:**

Diener, J.F.A., Powell, R., White, R.W., Holland, T.J.B., 2007. A new thermo-dynamic model for clino- and orthoamphiboles in Na<sub>2</sub>O-CaO-FeO-MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O-O. *Journal of Metamorphic Geology*, **25**: 631–656.

**Clinopyroxenes:**

Green, E.C.R., Holland, T.J.B., Powell, R., 2007. An order-disorder model for omphacitic pyroxenes in the system jadeite-diopside-hedenbergite-acmite, with applications to eclogite rocks. *American Mineralogist*, **92**: 1181–1189.

**Chlorite:**

Holland, T.J.B., Baker, J.M., Powell, R., 1998. Mixing properties and activity-composition relationships of chlorites in the system MgO-FeO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O. *European Journal of Mineralogy*, **10**: 395–406.

**Garnet:**

White, R.W., Powell, R., Holland, T.J.B., 2007. Progress relating to calculation of partial melting equilibria for metapelites. *Journal of Metamorphic Geology*, **25**: 511–527.

**Epidote:**

Holland, T.J.B., Powell, R., 1998. An internally consistent thermodynamic dataset for phases of petrological interest. *Journal of Metamorphic Geology*, **16**: 309–343.

**Plagioclase:**

Holland, T.J.B., Powell, R., 2003. Activity-composition relations for phases in petrological calculations: an asymmetric multicomponent formulation. *Contributions to Mineralogy and Petrology*, **145**: 492–501.

**Ilmenite and hematite:**

White, R.W., Powell, R., Holland, T.J.B., Worley, B.A., 2000. The effect of TiO<sub>2</sub> and Fe<sub>2</sub>O<sub>3</sub> on metapelitic assemblages at greenschist and amphibolite facies conditions: mineral equilibria calculations in the system K<sub>2</sub>O-FeO-MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>-H<sub>2</sub>O-TiO<sub>2</sub>-Fe<sub>2</sub>O<sub>3</sub>. *Journal of Metamorphic Geology*, **18**: 497–511.