PARTIAL MELTING AND P-T EVOLUTION OF ECLOGITE-FACIES METAPELITIC MIGMATITES FROM THE EGERE TERRANE (CENTRAL HOGGAR, SOUTH ALGERIA)

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SUPPLEMENTARY MATERIALS

1 – METHODS

A selection of high-grade metapelite samples was studied under scanning electron microscope at Paris-Sorbonne University (http://meb.ufr918.upmc.fr), producing in particular backscattered electron images and X-ray elemental maps. Chemical analyses of minerals (Tables B to G) were undertaken using a CAMECA SX100 electron microprobe at Camparis laboratory in Paris (http://camparis.ecceterra.fr/) with operating conditions of 15 kV and 10 nA; natural standards were used for calibration. Whole-rock analyses of major elements (Table A) were performed by X-ray fluorescence (XRF-M01) at the C.R.P.G. service (Nancy, France; see //www.crpg.cnrs-nancy.fr/SARM for the analytical protocols).

Crystallized melt inclusions ("nanogranitoids") and other melt-related inclusions in garnet were characterized on thin sections using conventional microscope petrography and Zeiss MA-15 and Quanta 400 SEMs at the Instituto Andaluz de Ciencias de la Tierra (CSIC-Universidad de Granada) and Centro de Instrumentación Cientifica (Universidad de Granada).

P–T pseudosections were calculated in the system $MnO–Na_2O–CaO–K_2O–FeO–MgO–Al_2O_3–SiO_2–H_2O–TiO_2–O$, which is a near comprehensive compositional analog of natural metapelitic rocks (White et al. 2014a), using the thermodynamic software THERMOCALC v3.40 (Powell and Holland 1988) and an updated version of the Holland and Powell (2011) data set (file tc-ds62.txt). Fe^{3+} in the bulk compositions is fixed at 10 mol.% of total iron, as advised by Diener and Powell (2010). The activity-composition models used are those of White et al. (2014a, b). Quartz, kyanite, sillimanite, rutile and fluid (H_2O) are pure phases. Isopleth curves for selected minerals show the evolution of their chemical composition with respect to P and T (Fig. 7). The following notations are used: *x(Grt)* = Fe/(Fe + Mg); *z(Grt)* = Ca/(Ca + Fe + Mg + Mn); *x(Bt)* = Fe/(Fe + Mg); *x(St)* = Fe/(Fe + Mg); *Si(Ph)* = Si .

The mineral abbreviations used in the text are from Whitney and Evans (2010).

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2 – FIGURE

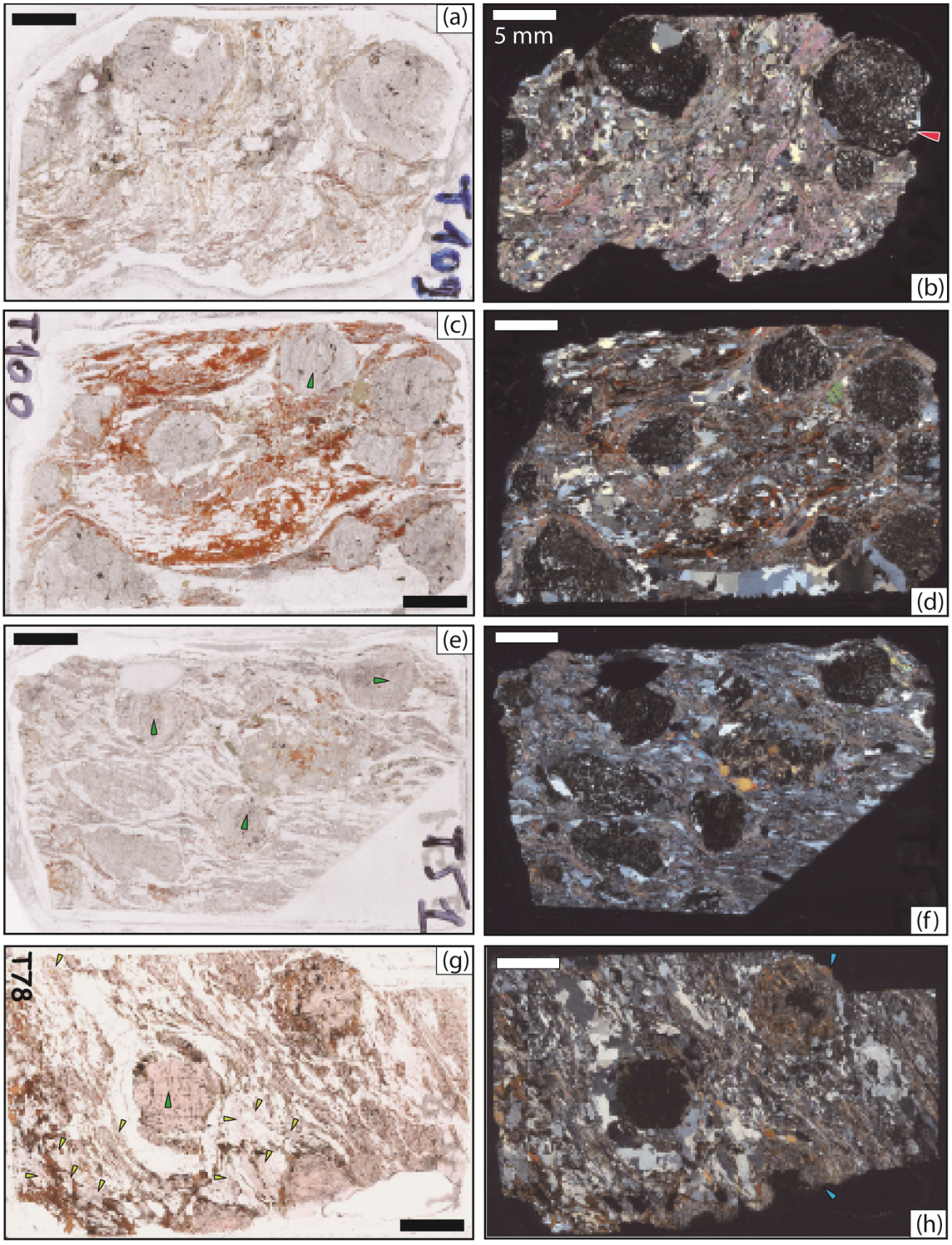

Figure A. Photomicrographs of the rocks studied.

Scale bars correspond to a length of 5 mm; thin sections are seen in plane-polarized (left) and cross-polarized (right) lights. (**a**, **b**) Phengite-rich metapelite. (**c**, **d**) Biotite-rich metapelite, where biotite mainly developed after phengite. (**e**, **f**) Phengite-rich metapelite. (**g**, **h**) Metapelite rich in kyanite (yellow arrows in g) and phengite. The samples show leucocratic bands (*i.e.*, leucosomes) alternating with darker bands rich in garnet and micas. The foliation visible in the matrix, mainly defined by quartz and phengite, wraps around garnet porphyroblasts. The inclusions in garnet define an internal foliation, either sigmoidal (red arrow in b) or straight (green arrows in c, e and g), at variable angles with respect to the foliation in the matrix (see g and f). In many areas, biotite-rich post-foliation fine-grained M_3 assemblages replace the garnet porphyroblasts (blue arrows in h) and especially the phengite flakes Ph_2 (c and d).

3- ANALYZES

Table A: Studied samples coordinates and bulk-rock compositions (in mol %) used for modeling the pseudosections

Sample	SiO_2	TiO_2	Al_2O_3	FeO	MgO	MnO	CaO	Na_2O	K_2O	O	H_2O	Longitude	Latitude
T52	68.18	1.20	10.80	9.95	1.29	0.11	2.67	1.37	2.14	0.50	1.73	5º 51' 34.65" E	25º 58' 31.93" N
T78	60.31	0.99	11.08	6.87	1.71	0.08	1.63	1.31	2.47	0.43	13.12	5º 51' 29.41" E	25º 58' 23.47" N
T133	70.35	1.07	10.65	8.04	2.48	0.01	2.70	1.04	2.12	0.50	1.06	5º 51' 35.56" E	25º 58' 49.78" N
T138	73.34	1.15	8.13	9.03	1.13	0.05	2.18	1.02	2.06	0.50	1.36	5º 51' 35.40" E	25º 58' 42.80" N
T51	–	–	–	–	–	–	–	–	–	–	–	5º 51' 43.11" E	25º 58' 32.17" N
T77	–	–	–	–	–	–	–	–	–	–	–	5º 51' 29.41" E	25º 58' 27.84" N
T100	–	–	–	–	–	–	–	–	–	–	–	5º 51' 35.60" E	25º 58' 41.60" N
T109	–	–	–	–	–	–	–	–	–	–	–	5º 51' 35.40" E	25º 58' 43.50" N

Table B: Representative microprobe analyzes of garnet

Cationic formulas are calculated on the basis of 12 O

Sample	**T52**	**T77**	**T133**		**T138**				**T78**	**T138**	
	Grt$_1$ (core)				**Grt** (rim)		**Grt** (outer rim)		**Grt$_3$**		
SiO_2	37.68	37.94	37.22	37.35	37.59	37.85	37.71	36.35	37.70	37.06	37.31
TiO_2	0.00	0.07	0.10	0.11	0.03	0.04	0.01	0.02	0.00	0.00	0.00
Al_2O_3	21.09	20.58	21.22	20.83	20.85	20.99	21.04	20.06	21.09	20.88	20.93
Cr_2O_3	0.02	0.00	0.00	0.04	0.00	0.01	0.00	0.02	0.03	0.02	0.01
FeO_t	32.79	30.34	30.81	29.94	34.69	34.00	35.03	32.86	35.87	38.19	38.17
MnO	0.19	0.76	2.06	2.31	0.81	0.81	0.56	0.85	1.12	0.14	0.12
MgO	2.65	2.09	0.89	0.95	2.69	2.51	2.50	2.49	3.49	1.61	1.67
CaO	6.92	8.74	8.77	8.95	3.34	4.43	4.83	5.00	1.91	3.06	3.20
Na_2O	0.08	0.06	0.00	0.00	0.00	0.00	0.01	0.03	0.03	0.00	0.02
K_2O	0.02	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Total	101.44	100.71	101.08	100.48	100.01	100.68	101.76	97.80	101.31	100.98	101.47
Si	2.980	3.017	2.971	2.993	3.020	3.018	2.991	2.998	2.997	2.989	2.993
Al	1.966	1.929	1.996	1.967	1.974	1.973	1.966	1.950	1.976	1.985	1.979
Cr	0.000	0.000	0.006	0.007	0.002	0.002	0.001	0.001	0.002	0.001	0.001
Ti	0.001	0.004	0.000	0.003	0.000	0.001	0.000	0.001	0.000	0.000	0.000
Fe^{3+}	0.033	0.067	0.000	0.023	0.024	0.024	0.033	0.048	0.022	0.014	0.021
Fe^{2+}	2.136	1.950	2.057	1.983	2.306	2.243	2.290	2.218	2.363	2.562	2.540
Mn	0.013	0.051	0.139	0.157	0.055	0.055	0.038	0.059	0.076	0.010	0.008
Mg	0.312	0.248	0.106	0.113	0.322	0.298	0.296	0.306	0.414	0.194	0.200
Ca	0.586	0.745	0.750	0.768	0.287	0.378	0.410	0.442	0.164	0.264	0.275
Na	0.012	0.009	0.000	0.000	0.000	0.000	0.002	0.005	0.005	0.000	0.003
K	0.002	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
Σ Cat.	8.043	8.020	8.026	8.015	7.992	7.993	8.027	8.028	8.017	8.018	8.020
X_{Fe}	0.868	0.867	0.893	0.880	0.859	0.864	0.873	0.859	0.829	0.927	0.924
X_{Alm}	0.701	0.651	0.674	0.656	0.776	0.754	0.755	0.733	0.784	0.846	0.840
X_{Sps}	0.004	0.017	0.046	0.052	0.019	0.018	0.012	0.020	0.025	0.003	0.003
X_{Prp}	0.103	0.083	0.035	0.038	0.108	0.100	0.097	0.101	0.137	0.064	0.066
X_{Grs}	0.175	0.215	0.246	0.241	0.085	0.115	0.119	0.122	0.042	0.080	0.080
X_{Adr}	0.016	0.034	0.000	0.012	0.012	0.012	0.016	0.024	0.011	0.007	0.010

Table C: Representative microprobe analyzes of white micas

Cationic formulas are calculated on the basis of $O_{20}(OH,F,Cl)_4$

* Ms_3 within the Bt_3-Pl_3 symplectites after Ph_2;

** Estimated composition of Ti-rich phengite before Ilm_3 exsolution, reconstructed by scanning with the microprobe (see text);

*** H_2O calculated by stoichiometry; O equivalent to F+Cl subtracted from the total weight.

Sample	**T138**				**T52**		**T138**			**T52**		**T138**
	Ph_2 core		**Ph_2** rim		**Ph_1** in Grt_1		**Ms_3** after Ph_2 *		**Ms_3** matrix			**Ti-Ph** **
SiO_2	47.79	47.67	43.68	46.34	46.81	46.76	43.68	45.30	45.68	45.21	47.47	38.04
TiO_2	1.22	1.23	0.92	1.54	1.46	1.77	0.92	0.97	0.39	1.28	1.44	5.88
Al_2O_3	31.86	31.96	35.85	32.98	33.24	33.70	35.85	36.18	36.94	34.33	34.29	29.28
Cr_2O_3	0.05	0.01	0.01	0.03	0.05	0.06	0.01	0.01	0.00	0.04	0.06	0.04
FeO	2.09	1.90	1.33	1.71	1.44	1.49	1.33	1.46	1.47	1.05	1.32	5.25
MnO	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.02	0.01	0.02	0.02	0.04
MgO	1.38	1.24	0.29	0.86	0.90	0.91	0.29	0.29	0.30	0.61	0.80	0.22
CaO	0.01	0.02	0.15	0.11	0.01	0.01	0.15	0.07	0.02	0.01	0.01	0.14
Na_2O	0.46	0.37	0.47	0.40	0.51	0.47	0.47	0.46	0.69	0.53	0.54	0.48
K_2O	11.10	11.36	11.03	11.31	10.95	11.09	11.03	11.98	10.62	11.17	11.12	8.50
F	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00
H_2O* **	4.50	4.49	4.40	4.46	4.48	4.34	4.40	4.52	4.53	4.57	4.43	4.02
Total	100.46	100.29	98.13	99.78	99.88	100.84	98.13	101.26	100.67	98.83	101.50	91.89
Si	6.367	6.364	5.956	6.224	6.253	6.195	5.956	6.008	6.038	6.119	6.226	5.672
Al^{IV}	1.633	1.636	2.043	1.775	1.746	1.804	2.044	1.992	1.961	1.880	1.773	2.328
Al^{VI}	3.369	3.393	3.719	3.444	3.487	3.457	3.718	3.664	3.795	3.596	3.526	2.819
Cr	0.005	0.002	0.001	0.003	0.005	0.007	0.001	0.001	0.000	0.004	0.005	0.005
Ti	0.122	0.123	0.094	0.155	0.146	0.176	0.094	0.097	0.038	0.130	0.142	0.660
Fe	0.233	0.212	0.151	0.191	0.161	0.165	0.152	0.162	0.163	0.119	0.145	0.655
Mn	0.000	0.005	0.000	0.004	0.000	0.000	0.000	0.002	0.001	0.002	0.002	0.005
Mg	0.274	0.247	0.059	0.172	0.178	0.179	0.059	0.057	0.058	0.122	0.155	0.050
Ca	0.001	0.002	0.021	0.015	0.001	0.001	0.022	0.010	0.002	0.001	0.001	0.022
Na	0.119	0.095	0.123	0.104	0.132	0.119	0.124	0.118	0.177	0.139	0.137	0.138
K	1.886	1.934	1.918	1.937	1.865	1.874	1.919	2.027	1.791	1.928	1.860	1.618
Σ cat.	14.010	14.013	14.089	14.030	13.979	13.988	14.089	14.139	14.028	14.044	13.978	13.970
X_{Fe}	0.46	0.46	0.72	0.53	0.47	0.48	0.72	0.73	0.74	0.49	0.48	0.92

Table D: Representative microprobe analyzes of biotite

Cationic formulas are calculated on the basis of $O_{20}(OH,F,Cl)_4$.

* H_2O calculated by stoichiometry; O equivalent to F+Cl subtracted from the total weight.

Sample	**T133**		**T77**	**T52**	**T138**				
	Bt_3, after Grt, with Pl_3 (partially chloritized)			**Bt_3**, after Ph_2 and in the matrix, with $Pl_3 \pm St_3 \pm Sil_3$			**Bt_3**, as exsolution lamellas in Ph_2		
SiO_2	36.11	36.19	34.64	34.07	33.26	33.07	33.49	34.17	34.48
TiO_2	3.10	3.02	2.97	3.42	4.05	3.03	2.27	2.90	2.98
Al_2O_3	19.45	20.36	18.48	19.15	19.06	19.28	19.78	19.45	20.23
Cr_2O_3	0.01	0.03	0.03	0.14	0.05	0.15	0.12	0.06	0.10
FeO_t	15.19	15.38	20.71	22.15	26.85	29.74	24.10	23.44	23.15
MnO	0.05	0.08	0.05	0.04	0.00	0.00	0.00	0.03	0.01
MgO	11.23	10.86	8.53	6.17	3.85	2.58	6.74	6.52	5.79
CaO	0.03	0.00	0.02	0.02	0.06	0.00	0.27	0.01	0.08
Na_2O	0.17	0.11	0.18	0.19	0.20	0.17	0.18	0.17	0.17
K_2O	9.74	10.21	9.62	10.24	9.45	9.43	9.14	10.25	10.22
F	0.00	0.00	0.32	0.05	0.00	0.00	0.00	0.53	1.14
Cl	0.02	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00
H_2O*	3.93	4.05	3.74	3.84	3.83	3.80	3.87	3.65	3.39
Total	99.10	100.29	99.16	99.49	100.67	101.27	99.96	100.96	101.26
Si	5.398	5.354	5.334	5.286	5.195	5.201	5.188	5.249	5.264
Al^{IV}	2.602	2.645	2.666	2.713	2.805	2.798	2.812	2.750	2.735
Al^{VI}	0.824	0.903	0.688	0.786	0.704	0.776	0.801	0.770	0.905
Cr	0.001	0.004	0.004	0.017	0.006	0.018	0.014	0.006	0.012
Ti	0.349	0.336	0.344	0.399	0.475	0.358	0.265	0.334	0.341
Fe	1.899	1.903	2.667	2.873	3.507	3.911	3.122	3.011	2.955
Mn	0.006	0.010	0.007	0.004	0.000	0.000	0.000	0.003	0.001
Mg	2.502	2.395	1.958	1.427	0.897	0.605	1.556	1.492	1.316
Ca	0.005	0.000	0.003	0.003	0.010	0.000	0.045	0.001	0.013
Na	0.049	0.032	0.054	0.057	0.060	0.051	0.055	0.050	0.050
K	1.857	1.927	1.890	2.027	1.884	1.892	1.806	2.008	1.989
Σ cat.	15.493	15.510	15.615	15.600	15.544	15.620	15.664	15.680	15.590
X_{Fe}	0.431	0.44	0.58	0.67	0.80	0.87	0.67	0.67	0.69

Table E: Representative microprobe analyzes of feldspars.

Cationic formulas are calculated on the basis of 8 O. Fe is considered as Fe^{3+}.

Sample	**T138**							**T52**	**T77**	**T78**	**T138**	
	Pl_3, in pseudo-morph after Ph_2		**Pl**, around Qz_1 in Grt_1	**Pl**, around Bt_1 inclusion in Grt_1		**Pl**, included in Grt_1		**Pl_3**, associated with Bt_3±St_3±Kfs_3±Sil_3			**Kfs_3**, as corona between Ph_2 & Qz_2	
SiO_2	58.74	58.35	61.27	61.26	62.72	63.09	59.11	64.64	60.34	60.59	64.59	64.42
TiO_2	0.01	0.07	0.01	0.01	0.00	0.03	0.00	0.00	0.05	0.02	0.00	0.00
Al_2O_3	24.74	26.88	20.77	25.63	25.85	24.49	24.38	22.36	25.84	25.38	18.81	18.54
Cr_2O_3	0.00	0.02	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.02	0.02
Fe_2O_3t	0.32	0.59	0.68	0.48	0.43	0.68	0.33	0.11	0.01	0.16	0.06	0.03
MnO	0.01	0.00	0.01	0.03	0.01	0.00	0.04	0.03	0.01	0.04	0.00	0.00
MgO	0.00	0.10	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
CaO	7.06	7.03	3.08	6.51	6.47	4.94	6.59	3.07	7.10	7.09	0.03	0.03
Na_2O	8.60	7.29	10.30	7.17	6.17	9.03	8.28	10.27	8.00	8.03	0.56	0.46
K_2O	0.13	1.02	0.12	0.14	0.19	0.20	0.19	0.28	0.07	0.13	16.10	16.88
Total	102.21	101.35	96.26	101.17	101.84	102.46	98.95	100.76	101.42	101.45	100.19	100.39
Si	2.647	2.587	2.826	2.689	2.717	2.736	2.672	2.835	2.654	2.667	2.980	2.980
Al	1.314	1.405	1.129	1.326	1.320	1.252	1.299	1.156	1.340	1.317	1.023	1.011
Fe^{3+}	0.012	0.020	0.024	0.016	0.014	0.022	0.011	0.004	0.000	0.006	0.002	0.001
Cr	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.001
Ti	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.001	0.000	0.000
Mn	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.001	0.000	0.002	0.000	0.000
Mg	0.000	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Ca	0.341	0.334	0.152	0.306	0.300	0.230	0.319	0.144	0.335	0.335	0.001	0.001
Na	0.752	0.627	0.921	0.610	0.518	0.759	0.726	0.873	0.682	0.686	0.050	0.041
K	0.008	0.058	0.007	0.008	0.011	0.011	0.011	0.016	0.004	0.008	0.948	0.996
Σ cat.	5.074	5.040	5.061	4.956	4.880	5.011	5.041	5.029	5.017	5.022	5.006	5.032
X_{An}	0.312	0.328	0.141	0.331	0.362	0.230	0.302	0.140	0.328	0.326	0.001	0.001
X_{Ab}	0.683	0.615	0.853	0.660	0.625	0.759	0.687	0.845	0.668	0.667	0.050	0.040
X_{or}	0.007	0.057	0.007	0.008	0.013	0.011	0.010	0.015	0.004	0.007	0.948	0.959

Table F: Representative microprobe analyzes of staurolite.

Cationic formulas are calculated on the basis of $O_{46}(OH,F,Cl)_2$.

* H_2O calculated by stoichiometry; O equivalent to F+Cl subtracted from the total weight.

Sample	**T78**				**T138**			**T52**	
	St$_1$ (inclusion in Grt$_1$)				**St$_3$** (matrix)				
SiO_2	26.37	26.48	27.37	26.72	25.56	25.99	25.01	23.82	25.23
TiO_2	0.71	0.87	0.72	0.64	0.63	0.52	0.56	0.69	0.49
Al_2O_3	54.89	54.55	54.45	54.55	56.89	56.42	55.74	58.01	56.64
FeO	14.23	14.27	13.79	13.10	14.82	14.52	14.16	13.71	14.17
MnO	0.16	0.20	0.23	0.22	0.05	0.00	0.03	0.06	0.00
MgO	1.22	1.22	1.36	1.25	0.53	0.64	0.65	0.73	0.88
ZnO	0.89	0.93	1.38	1.09	1.03	1.16	0.88	0.61	0.62
CaO	0.06	0.07	0.02	0.04	0.02	0.01	0.02	0.04	0.00
Na_2O	0.08	0.13	0.11	0.10	0.05	0.06	0.04	0.10	0.12
K_2O	0.01	0.01	0.00	0.02	0.02	0.03	0.01	0.01	0.00
F	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H_2O*	1.08	1.06	1.07	1.04	1.06	1.06	1.04	1.05	1.05
Total	99.86	99.98	100.72	99.01	100.71	100.42	98.17	98.89	99.21
Si	7.329	7.519	7.704	7.620	7.206	7.334	7.214	6.808	7.184
Al	17.980	18.256	18.062	18.335	18.903	18.765	18.948	19.542	19.007
Ti	0.148	0.186	0.152	0.137	0.134	0.110	0.122	0.148	0.105
Fe	3.308	3.389	3.246	3.124	3.494	3.427	3.416	3.277	3.374
Mn	0.038	0.048	0.055	0.053	0.012	0.000	0.007	0.015	0.000
Mg	0.505	0.516	0.571	0.531	0.223	0.269	0.279	0.311	0.374
Zn	0.183	0.194	0.287	0.230	0.214	0.242	0.187	0.129	0.131
Ca	0.018	0.021	0.006	0.012	0.006	0.003	0.006	0.012	0.000
Na	0.043	0.072	0.060	0.055	0.027	0.033	0.022	0.055	0.066
K	0.004	0.004	0.000	0.007	0.007	0.011	0.004	0.004	0.000
Σ Cat.	29.556	30.205	30.143	30.106	30.226	30.195	30.204	30.302	30.241
X_{Mg}	0.13	0.12	0.14	0.13	0.06	0.07	0.07	0.08	0.10