GSA DATA REPOSITORY 2014146 Hoisch et al.

Jurassic Barrovian metamorphism in a western U.S. Cordilleran metamorphic core complex, Funeral Mountains, California

Supplemental Information: Additional information on the methods used to calculate pseudosections and PT paths, and microprobe run conditions

BULK COMPOSITION CALCULATION

Bulk compositions were determined by performing a weighted sum of mineral compositions expressed as weight percents of the oxides (see Table DR1c). The weightings were determined by converting volume proportions based on point counts (modes) to weight proportions. Normalization to 10 cations yielded the bulk composition in atomic proportions. Modes were normalized to 100% after excluding accessory phases (oxides, tourmaline, apatite, and zircon) as these were not considered to be part of the reactive assemblage. Bulk compositions entered into THERIAK-DOMINO excluded Ti because the thermodynamic database used in this study (*tcdb55c2d*) lacks data for the Ti-bearing components of the reactive assemblage (e.g., Ti-muscovite). Thus, the system considered for the bulk composition was Si-Al-Fe^{2+}-Mg-Mn-K- Na-Ca-O-H. Excess H_2O was added.

WHITE MICA SOLID SOLUTION ASSUMPTIONS

In the THERIAK-DOMINO database *tcdb55c2d,* the white mica (PHNG) solid solution model was modified to exclude the phengitic components (celadonite and Fe-celadonite) and include margarite so that the results would be compatible with mica model 16 in the GIBBS database *SPAC2007*. To describe non-ideality in both margarite-muscovite and margarite-paragonite solid solutions in the database *tcdb55c2d*, Margules parameters of W_H=40,000 (J), W_S=0 (J/K) and W_V=0 (J/bar) were used. This allowed K to enter margarite and Ca to enter muscovite in minute quantities. The mica activity model also incorporated the V_i values from Coggon and Holland (2002) (0.37 for Na and Ca, and 0.67 for K).

Mica model 16 in the GIBBS database *SPAC2007* is an ideal K-Na-Ca model, whereas the mica model used in THERIAK-DOMINO is non-ideal. In considering the implications of the different assumptions for calculating PT paths, we note that with regard to differential thermodynamic calculations based on the Gibbs phase rule, activity coefficients appear to have little discernible effect (Spear and Selverstone, 1983). Comparisons of PT paths calculated using ideal versus non-ideal models show that this also holds true in differential thermodynamic calculations based on Duhem's theorem.

RUN CONDITIONS FOR ELECTRON PROBE MICROANALYSIS

Minerals were analyzed with an accelerating voltage of 15 kV and a beam current of 10 nA. Garnet traverses used a spot size of 1 µm. Matrix minerals were analyzed with a spot size of 3-5µm. Element maps were generated using an accelerating voltage of 15 kV and beam current of 250 nA.

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Table DR1. Data tables: A: Sample locations and garnet growth simulation data: initial, final and measured (actual) values, B: Garnet growth model monitor parameters, nucleation densities, initial P&T, and ending P&T, and C: Mineral chemistry and bulk compositions

Table A. Sample locations and garnet growth simulation data: initial, final and measured (actual) values

Sample SSFM30711D						Sample CC68I					
Location: Lat. 36°38'11.66"N, Long. 116°48'2.91"W						Location: Lat. 36°38'24.50"N, Long. 116°47'47.23"W					
Mineral[e]	Parameter[a]	Actual[b]	Initial[c]	End G1[d]	End G2[d]	Mineral	Parameter[a]	Actual[b]	Initial[c]	End G4[d]	End G5[d]
Ctd	XMg	0.159	0.139	0.139	0.138	Ctd	XMg	0.179	0.145	0.153	0.153
Ctd	XFe	0.823	0.825	0.837	0.837	Ctd	XFe	0.809	0.817	0.821	0.820
Ctd	XMn	0.018	0.035	0.024	0.025	Ctd	XMn	0.012	0.038	0.026	0.026
Mus	KA	0.830	0.803	0.803	0.803	Mus	KA	0.808	0.798	0.797	0.797
Mus	NaA	0.169	0.185	0.184	0.184	Mus	NaA	0.192	0.190	0.190	0.190
Mus	CaA	0.001	0.012	0.013	0.013	Mus	CaA	0.000	0.012	0.013	0.013
Mar	KA	n/a	0.000	0.000	0.000	Mar	KA	n/a	0.000	0.000	0.000
Mar	NaA	n/a	0.002	0.002	0.002	Mar	NaA	n/a	0.002	0.002	0.002
Mar	CaA	n/a	0.998	0.998	0.998	Mar	CaA	n/a	0.998	0.998	0.998
CHL	SiT1	2.000	2.000	2.000	2.000	CHL	SiT1	2.000	2.000	2.000	2.000
CHL	SiT2	0.623	0.828	0.832	0.831	CHL	SiT2	0.601	0.824	0.823	0.829
CHL	AlT2	1.377	1.172	1.168	1.169	CHL	AlT2	1.399	1.176	1.177	1.171
CHL	AlM1	0.505	0.172	0.168	0.169	CHL	AlM1	0.654	0.176	0.177	0.171
CHL	MgM1	0.234	0.285	0.296	0.294	CHL	MgM1	0.151	0.294	0.303	0.306
CHL	FeM1	0.403	0.538	0.532	0.533	CHL	FeM1	0.436	0.526	0.518	0.521
CHL	MnM1	0.001	0.005	0.004	0.004	CHL	MnM1	0.001	0.005	0.003	0.003
CHL	AlM3	1.000	1.000	1.000	1.000	CHL	AlM3	1.000	1.000	1.000	1.000
CHL	MgM2	1.848	1.829	1.855	1.850	CHL	MgM2	1.772	1.877	1.898	1.900
CHL	FeM2	1.918	2.151	2.132	2.136	CHL	FeM2	1.827	2.102	2.088	2.086
CHL	MnM2	0.005	0.020	0.014	0.014	CHL	MnM2	0.009	0.021	0.014	0.014
G1 core	Xpy	0.052	0.052	n/a	n/a	G4 core	Xpy	0.053	0.053	n/a	n/a
G1 core	Xal	0.615	0.615	n/a	n/a	G4 core	Xal	0.591	0.591	n/a	n/a
G1 core	Xsp	0.193	0.193	n/a	n/a	G4 core	Xsp	0.216	0.216	n/a	n/a
G1 core	Xgr	0.140	0.140	n/a	n/a	G4 core	Xgr	0.139	0.139	n/a	n/a
G1 rim	Xpy	0.062	n/a	0.058	n/a	G4 rim	Xpy	0.063	n/a	0.062	n/a
G1 rim	Xal	0.651	n/a	0.654	n/a	G4 rim	Xal	0.644	n/a	0.645	n/a
G1 rim	Xsp	0.136	n/a	0.136	n/a	G4 rim	Xsp	0.148	n/a	0.148	n/a
G1 rim	Xgr	0.152	n/a	0.152	n/a	G4 rim	Xgr	0.145	n/a	0.145	n/a
G2 core	Xpy	0.053	0.053	n/a	n/a	G5 core	Xpy	0.054	0.054	n/a	n/a
G2 core	Xal	0.603	0.603	n/a	n/a	G5 core	Xal	0.597	0.597	n/a	n/a
G2 core	Xsp	0.205	0.205	n/a	n/a	G5 core	Xsp	0.215	0.215	n/a	n/a
G2 core	Xgr	0.139	0.139	n/a	n/a	G5 core	Xgr	0.134	0.134	n/a	n/a
G2 rim	Xpy	0.061	n/a	n/a	0.059	G5 rim	Xpy	0.064	n/a	n/a	0.061
G2 rim	Xal	0.641	n/a	n/a	0.643	G5 rim	Xal	0.638	n/a	n/a	0.641
G2 rim	Xsp	0.149	n/a	n/a	0.149	G5 rim	Xsp	0.149	n/a	n/a	0.149

G2 rim	Xgr	0.149	n/a	n/a	0.149	G5 rim	Xgr	0.149	n/a	n/a	0.149
QZ	mode	33	39.119	39.088	39.089	QZ	mode	30	32.557	32.542	32.509
MUS	mode	46	40.860	40.975	40.967	MUS	mode	42	40.022	40.131	40.106
MAR	mode	0	0.302	0.140	0.160	MAR	mode	0	0.132	-0.079	-0.063
CHL	mode	17	15.409	15.051	15.104	CHL	mode	25	22.442	22.035	21.976
CTD	mode	1	4.310	4.460	4.433	CTD	mode	1	4.846	4.991	5.054
GAR	mode	3	0.000	0.286	0.247	GAR	mode	2	0.000	0.380	0.359

a. Mineral compositional parameters. For chlorite, the parameters were converted from THERIAK's labeling system and atom fraction values to GIBBS' labeling system and formula-based values

b. Measured values

c. Initial values for garnet growth simulations. Mineral modes and compositions were calculated using THERIAK, except for garnet compositions, which were taken to be the measured values. Modes were normalized to 100% after subtracting THERIAK's calculated garnet modes of 1.074 for SSFM307-11D and 0.4791 for CC68I

d. Values reported by GIBBS at the end of the simulated segment of garnet growth

Table B. Model monitor parameters, nucleation densities, initial T&P, and ending P&T

Model	Monitor 1 ΔXgr	Monitor 2 ΔXsp	Nucleation Density	T °C initial	P bars initial	T °C final	P bars final
SSFM30711D-G1	0.012	-0.057	4000	524	5000	533.2	5571
SSFM30711D-G2	0.010	-0.056	6500	524	5000	533.3	5504
CC68I-G4	0.006	-0.068	2500	524	5000	536.3	5450
CC68I-G5	0.015	-0.066	2500	524	5000	534.3	5678

Table C. Mineral chemistry and bulk compositions

	Sample SSFM30711D							Sample CC68I						
	CTD	MUS	CHL	QZ[a]	GAR CORE	GAR RIM	BULK	CTD	MUS	CHL	QZ[a]	GAR CORE	GAR RIM	BULK
modes (%)	1	46	17	33	0.75	2.25	n/a	1	42	25	30	0.5	1.5	n/a
	weight percents of the oxides							weight percents of the oxides						
Na_2O	0.012	1.268	0.004	0.000	0.000	0.000	0.584	0.000	1.405	0.006	0.000	0.000	0.000	0.589
MgO	2.654	0.364	12.937	0.000	1.287	1.927	2.308	2.952	0.366	12.162	0.000	1.336	1.927	3.405
Al_2O_3	40.123	35.703	22.646	0.000	20.359	20.590	21.369	41.289	35.934	24.638	0.000	20.520	20.828	22.545
SiO_2	24.902	46.133	24.297	100.000	36.279	36.450	59.621	24.692	46.775	24.640	100.000	36.927	36.689	55.366
K_2O	0.008	9.496	0.153	0.000	0.000	0.000	4.388	0.004	9.000	0.032	0.000	0.000	0.000	3.769
CaO	0.009	0.013	0.021	0.000	5.405	3.755	0.193	0.000	0.006	0.037	0.000	4.619	3.634	0.126
TiO_2	0.288	0.211	0.059	0.000	0.000	0.000	0.110	0.025	0.145	0.098	0.000	0.000	0.000	0.086
MnO	0.519	0.000	0.063	0.000	8.505	3.785	0.236	0.348	0.002	0.119	0.000	9.358	4.495	0.204
FeO	24.413	1.989	25.698	0.000	26.756	32.064	6.609	23.805	1.869	25.630	0.000	26.306	31.330	8.628
Total	92.928	95.178	85.878	100.000	98.591	98.570	95.417	93.114	95.503	87.363	100.000	99.066	98.903	94.718

	Formulas							Formulas						
Na	0.002	0.164	0.001	0.000	0.000	0.000	0.112	0.000	0.180	0.001	0.000	0.000	0.000	0.114
Mg	0.325	0.036	2.082	0.000	0.158	0.236	0.341	0.359	0.036	1.923	0.000	0.163	0.234	0.505
Al	3.887	2.802	2.882	0.000	1.974	1.992	2.494	3.972	2.798	3.054	0.000	1.974	2.004	2.643
Si	2.046	3.072	2.623	1.000	2.985	2.991	5.904	2.016	3.090	2.601	1.000	3.015	2.996	5.506
K	0.001	0.807	0.021	0.000	0.000	0.000	0.554	0.000	0.758	0.004	0.000	0.000	0.000	0.478
Ca	0.001	0.001	0.002	0.000	0.477	0.330	0.021	0.000	0.000	0.004	0.000	0.404	0.318	0.013
Ti	0.018	0.011	0.005	0.000	0.000	0.000	0.008	0.002	0.007	0.008	0.000	0.000	0.000	0.006
Mn	0.036	0.000	0.006	0.000	0.593	0.263	0.020	0.024	0.000	0.011	0.000	0.647	0.311	0.017
Fe^{2+}	1.678	0.111	2.321	0.000	1.841	2.201	0.547	1.625	0.103	2.263	0.000	1.796	2.139	0.718
	Basis for normalization[b]							Basis for normalization[b]						
	12 ox	11 ox	14 ox	2 ox	12 ox	12 ox	10 cat	12 ox	11 ox	14 ox	2 ox	12 ox	12 ox	10 cat

a. Quartz was not analyzed. It was assumed to be 100% SiO_2 in the bulk compostion calculation

b. Hydrous minerals were normalized to the number of anhydrous oxygens in the formula

TABLE DR2. Lu-Hf isotope data for garnet and whole rock from garnet-chloritoid schist of the Johnnie Formation, sample SSFM307-11f[e], Indian Pass, Funeral Mountains

Sample	Lu (p.p.m.) [a]	Hf (p.p.m.) [a]	$^{176}Lu/^{177}Hf$ [b]	$^{176}Hf/^{177}Hf$ [c]	± [d]
G1	5.85	0.542	1.533	0.287086	0.000013
G2	2.72	0.280	1.384	0.286653	0.000010
G3	3.48	0.159	3.106	0.291789	0.000021
G6	3.48	0.884	0.5584	0.284251	0.000005
G7	3.85	0.561	0.9737	0.285455	0.000010
G8	3.83	0.786	0.6914	0.284462	0.000011
BWR	0.556	10.2	0.0077	0.282040	0.000006
SWR	4.10	7.11	0.0819	0.282538	0.000005

[a] Lu and Hf concentrations determined by isotope dilution with uncertainties estimated to be better than 0.5%.

[b] Uncertainties for $^{176}Lu/^{177}Hf$ for the purpose of regressions and age calculations is estimated to be 1.0%

[c] $^{176}Hf/^{177}Hf$ ratios were corrected for instrumental mass bias using $^{179}Hf/^{177}Hf = 0.7935$ and normalized relative to $^{176}Hf/^{177}Hf = 0.282160$ for JMC-475 (Vervoort and Blichert-Toft, 1999). Epsilon Hf values calculated with Lu-Hf CHUR values of Bouvier et al., 2008 and the ^{176}Lu decay constant value of Scherer et al., 2001 and Söderlund et al., 2004.

[d] Reported errors on $^{176}Hf/^{177}Hf$ represent within-run uncertainty expressed as 2σ, standard error. Estimated total uncertainty on individual $^{176}Hf/^{177}Hf$ measurements is estimated to be 0.01% or about 1 ε_{Hf} unit. These are added to the within-run uncertainties in quadrature for the purpose of regressions and age calculations.

[e] Sample location: Lat. 36°38'11.66"N, Long. 116°48'2.19"W

Table DR3 – $^{40}Ar/^{39}Ar$ data tables

MB07FM-19, muscovite, 4.70 mg, J = 0.001717 ± 0.21%

Sample location: Lat. 36°38'16.25"N, Long. 116°47'8.67"W

4 amu discrimination = 1.05174 ± 0.86%, 40/39K = 0.0109 ± 63.49%, 36/37Ca = 0.000243 ± 24.65%, 39/37Ca = 0.000605 ± 14.11%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	40Ar*/39ArK	Age (Ma)
1	650	12	0.821	0.025	3.932	6.756	451.60	51.7	1.0	33.041688	99.55
2	720	12	0.578	0.018	0.214	5.793	391.74	62.3	0.8	39.998806	119.83
3	750	12	0.288	0.021	0.156	5.669	289.83	78.5	0.8	37.234941	111.80
4	770	12	0.173	0.012	0.222	13.183	612.80	95.7	1.9	43.189252	129.06
5	790	12	0.250	0.018	0.476	31.438	1493.69	96.8	4.6	45.674624	136.21
6	810	12	0.294	0.015	0.790	53.606	2649.95	97.7	7.8	48.306901	143.75
7	820	12	0.217	0.014	0.908	62.056	3130.44	98.8	9.0	49.889456	148.27
8	830	12	0.166	0.016	0.816	58.105	2927.93	99.2	8.5	50.015643	148.63
9	840	12	0.129	0.014	0.646	46.058	2293.03	99.4	6.7	49.423484	146.94
10	850	12	0.108	0.019	0.502	36.785	1829.05	99.6	5.4	49.323678	146.66
11	860	12	0.107	0.022	0.430	30.373	1505.40	99.5	4.4	48.999153	145.73
12	880	12	0.115	0.021	0.046	32.610	1596.46	99.4	4.8	48.384518	143.98
13	910	12	0.131	0.017	0.529	37.041	1815.30	99.3	5.4	48.424030	144.09
14	950	12	0.155	0.019	0.573	40.737	1980.90	99.0	5.9	47.963331	142.77
15	1000	12	0.174	0.018	0.557	39.162	1908.03	98.7	5.7	47.878079	142.53
16	1050	12	0.171	0.020	0.580	38.707	1888.81	98.7	5.6	47.962283	142.77
17	1100	12	0.180	0.016	0.689	48.016	2388.26	98.8	7.0	49.100658	146.02
18	1170	12	0.167	0.015	1.098	78.710	3950.96	99.4	11.5	50.012138	148.62
19	1400	12	0.138	0.023	0.302	21.015	1075.21	99.1	3.1	49.763645	147.92
								Cumulative %39Ar rlsd =	100.0	Total gas age	144.20
										Plateau age	145.96
										(steps 6-13)	
										No isochron	

MB07FM-18, muscovite, 2.70 mg, J = 0.001585 ± 0.14%

Sample location: Lat. 36°38'3.91"N, Long. 116°47'56.42"W

4 amu discrimination = 1.05174 ± 0.86%, 40/39K = 0.0109 ± 63.49%, 36/37Ca = 0.000243 ± 24.65%, 39/37Ca = 0.000605 ± 14.11%

step	T (C)	t (min.)	36Ar	37Ar	38Ar	39Ar	40Ar	%40Ar*	% 39Ar rlsd	40Ar*/39ArK	Age (Ma)
1	650	12	1.969	0.021	0.659	18.23	1093.68	50.5	6.4	29.924247	83.60
2	730	12	0.789	0.018	0.481	23.479	1935.32	82.3	8.3	39.733777	110.18
3	790	12	0.301	0.018	0.589	40.686	1935.32	96.8	14.3	45.877998	126.64
4	830	12	0.303	0.020	1.117	77.876	4379.76	98.6	27.4	55.622886	152.43

5	840	12	0.193	0.014	0.655	45.152	2494.54	98.7	15.9	54.516764	149.52
6	850	12	0.150	0.018	0.332	22.491	1294.10	98.5	7.9	56.157764	153.83
7	860	12	0.125	0.018	0.196	12.692	749.39	98.4	4.5	56.788731	155.49
8	870	12	0.110	0.020	0.139	8.376	490.45	98.4	2.9	55.380139	151.79
9	880	12	0.104	0.024	0.101	5.698	333.20	98.2	2.0	53.873836	147.83
10	890	12	0.101	0.018	0.068	3.801	230.69	97.7	1.3	53.784641	147.59
11	910	12	0.104	0.018	0.064	3.306	211.47	97.0	1.2	55.718790	152.68
12	950	12	0.111	0.018	0.072	3.678	229.52	96.4	1.3	54.411910	149.24
13	990	12	0.127	0.027	0.078	3.499	228.11	94.2	1.2	55.494653	152.09
14	1030	12	0.116	0.021	0.071	3.454	234.33	95.8	1.2	58.935912	161.11
15	1070	12	0.098	0.021	0.067	3.168	230.76	98.2	1.1	64.734532	176.21
16	1120	12	0.096	0.023	0.057	2.929	222.20	99.6	1.0	67.264018	182.76
17	1170	12	0.096	0.019	0.054	2.411	186.88	99.5	0.8	66.937079	181.92
18	1240	12	0.106	0.019	0.041	1.698	139.97	96.8	0.6	65.513105	178.23
19	1400	12	0.131	0.027	0.053	1.571	127.87	92.3	0.6	60.945203	166.36
								Cumulative %39Ar rlsd =	100.0	Total gas age	141.56

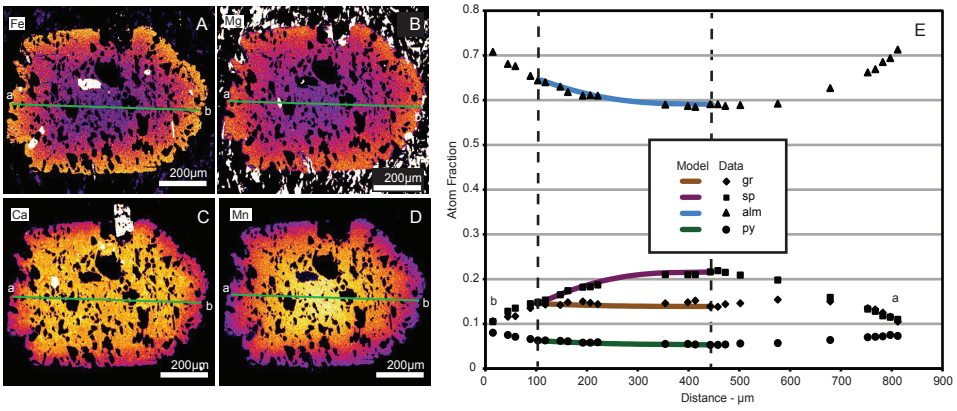
note: isotope beams in mV, rlsd = released, error in age includes J error, all errors 1 sigma

(36Ar through 40Ar are measured beam intensities, corrected for decay for the age calculations)

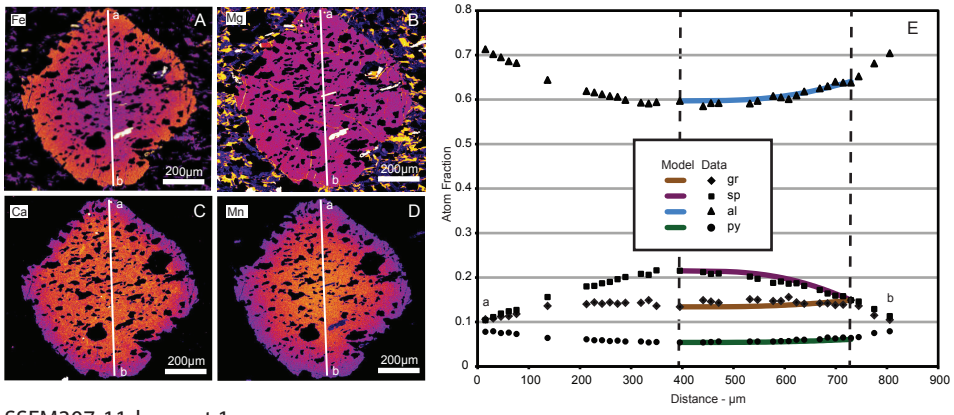
Plateau age	152.55
(steps 4-8)	
No Isochron	

Figure DR1. Garnet elements maps (A-D), line traverses and garnet growth simulations (E).

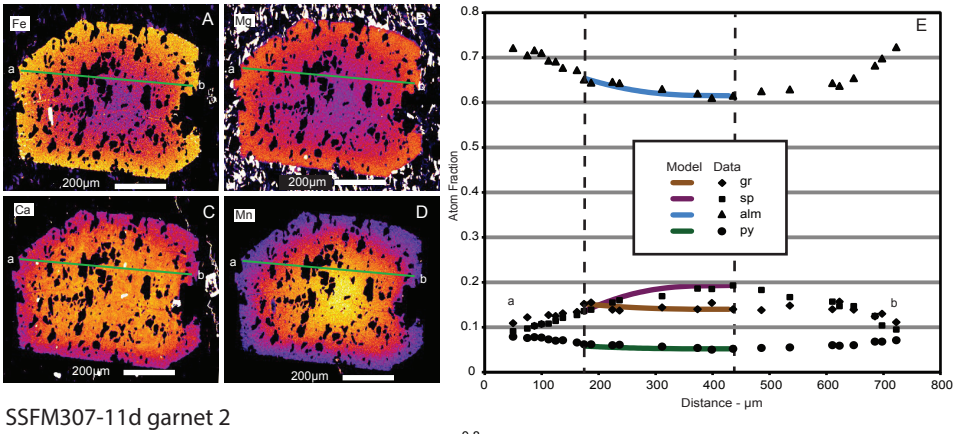
CC68l garnet 4



CC68l garnet 5



SSFM307-11d garnet 1



SSFM307-11d garnet 2