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Enrichment of manganese to spessartine saturation in granite-pegmatite systems

Supplementary Material A

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Table S1: Compositions of starting materials (wt.% oxides)

Mineral	<u>Orthoclase</u>	<u>Albite</u>	<u>Forsterite</u>	<u>Mn-Fayalite</u>	<u>Rhodonite</u>	<u>Spessartine</u>	<u>Almandine</u>
SiO ₂	64.96	68.83	40.8	30.01	47.1	35.59	36.09
Al ₂ O ₃	18.52	19.76	0.01	0.01	0.01	20.43	20.73
Fe ₂ O ₃	ND	ND	ND	ND	ND	ND	ND
FeO*	0.01	0.01	9.08	62.64	4.01	2.35	19.83
MnO	ND	ND	0.12	5.6	40.96	41.67	23.16
MgO	ND	ND	50.17	1.12	1.91	0.00	0.05
CaO	0.00	0.07	0.07	0.05	5.41	0.14	0.33
Na ₂ O	0.85	11.59	ND	0.00	0.00	ND	ND
K ₂ O	15.35	0.24	ND	0.00	ND	ND	ND
Total	99.72	100.82	100.67	99.65	99.41	100.18	100.19
N	60	5	45	15	25	20	20

Orthoclase: Little Three pegmatite mine, Ramona, CA

Albite: Copelinha, Brazil

Forsterite: San Carlos, AZ

Mn-Fayalite: Sardinia, Italy

Rhodonite: Brazil

Spessartine: Little Three pegmatite mine, Ramona, CA

Almandine: location unknown, University of Oklahoma mineral collection

S2: Proportions of
starting materials in
powdered mixtures
(Bulk Compositions)
(units: weight percent)

	<u>GT1.3</u>	<u>MnGT-BC-4.1</u>
Orthoclase	19.5	---
Synthetic Orthoclase	---	23.2
Albite	15.6	27.6
Quartz	39.0	26.5
Forsterite	2.7	---
Mn-Fayalite	1.8	---
Rhodonite	3.9	---
Spessartine	---	5.0
Almandine	---	4.4
Kaolinite	13.6	---
Al ₂ O ₃ ·nH ₂ O	---	2.2
B ₂ O ₃	3.9	11.0

Table S3: Average compositions of cordierite

System	American Mineralogist: November 2019 Deposit AM-19-116938															
GT1.3	GBT-		GBT-		GBT-		GBT-		GBT-		GBT-		GBT-		GBT-	
Exp #	90		101		101		88		102		102		103		103	
T (°C)	850		850/750		850/750		850/750		850/700		850/700		850/650		850/650	
t (hrs)	48		42/456		42/456		24/168		48/336		48/336		42/456		42/456	
¹ Direction	F		F		F		F		F		F		F		F	
Location of analysis			Core		Rim		Rim		Core		Rim		Core		Rim	
Weight Percent Oxides																
SiO ₂	46.56	(0.58)	47.73	(0.77)	47.35	(0.34)	47.28	(0.41)	47.35	(0.44)	47.48	(0.36)	46.81	(0.68)	45.79	(0.68)
Al ₂ O ₃	32.79	(0.39)	32.64	(0.23)	32.30	(0.24)	32.82	(0.26)	32.84	(0.15)	32.14	(0.35)	33.02	(0.44)	32.00	(0.25)
FeO*	3.35	(0.31)	3.19	(0.44)	3.92	(0.38)	4.59	(0.09)	3.12	(0.22)	3.09	(0.16)	3.58	(0.32)	5.03	(0.29)
MnO	2.66	(0.36)	2.73	(0.46)	4.12	(0.25)	3.15	(0.19)	2.42	(0.27)	4.26	(0.67)	2.67	(0.16)	6.89	(0.98)
MgO	9.89	(0.45)	10.30	(0.60)	8.91	(0.10)	9.22	(0.18)	10.50	(0.31)	9.24	(0.38)	9.95	(0.30)	6.23	(0.50)
CaO	0.09	(0.03)	0.05	(0.02)	0.03	(0.02)	0.05	(0.02)	0.05	(0.02)	0.04	(0.02)	0.07	(0.02)	0.07	(0.03)
Na ₂ O	0.25	(0.06)	0.21	(0.07)	0.15	(0.03)	0.18	(0.06)	0.26	(0.07)	0.18	(0.06)	0.33	(0.03)	0.40	(0.16)
K ₂ O	0.19	(0.05)	0.07	(0.02)	0.06	(0.01)	0.08	(0.02)	0.10	(0.05)	0.05	(0.02)	0.13	(0.03)	0.07	(0.03)
Total	95.83	(0.39)	96.94	(0.89)	96.86	(0.55)	97.43	(0.49)	96.69	(0.32)	96.51	(0.51)	96.59	(0.50)	96.50	(0.34)
# Pts (N)	14		10		10		20		10		10		15		15	
Atoms per formula unit (18 oxygen basis)																
Si	4.889	(0.045)	4.942	(0.033)	4.953	(0.023)	4.914	(0.028)	4.912	(0.023)	4.968	(0.034)	4.882	(0.045)	4.906	(0.045)
Al	4.058	(0.053)	3.983	(0.028)	3.982	(0.026)	4.020	(0.027)	4.016	(0.023)	3.964	(0.036)	4.058	(0.065)	4.041	(0.045)
Fe	0.295	(0.028)	0.277	(0.039)	0.343	(0.033)	0.399	(0.008)	0.271	(0.020)	0.270	(0.014)	0.312	(0.029)	0.451	(0.026)
Mn	0.236	(0.032)	0.239	(0.042)	0.365	(0.022)	0.278	(0.018)	0.213	(0.024)	0.377	(0.059)	0.236	(0.015)	0.625	(0.091)
Mg	1.548	(0.064)	1.590	(0.085)	1.389	(0.015)	1.428	(0.027)	1.624	(0.041)	1.441	(0.057)	1.546	(0.040)	0.994	(0.075)
Ca	0.010	(0.003)	0.005	(0.002)	0.004	(0.002)	0.005	(0.002)	0.006	(0.002)	0.005	(0.002)	0.008	(0.002)	0.008	(0.004)
Na	0.051	(0.012)	0.042	(0.013)	0.030	(0.006)	0.036	(0.012)	0.053	(0.014)	0.036	(0.012)	0.067	(0.006)	0.084	(0.034)
K	0.025	(0.006)	0.009	(0.002)	0.007	(0.002)	0.010	(0.003)	0.013	(0.007)	0.007	(0.003)	0.017	(0.004)	0.009	(0.004)
ΣCations	11.116	(0.029)	11.090	(0.025)	11.074	(0.013)	11.095	(0.017)	11.110	(0.022)	11.070	(0.017)	11.129	(0.015)	11.119	(0.041)
ΣM site	2.079	(0.021)	2.106	(0.025)	2.097	(0.010)	2.105	(0.022)	2.107	(0.011)	2.088	(0.024)	2.094	(0.018)	2.070	(0.012)
Normative End-Member Components																
% Ind	74.46	(8.28)	75.50	(10.96)	66.24	(3.02)	67.83	(3.39)	77.07	(5.40)	68.98	(7.75)	73.84	(5.27)	48.01	(9.17)
% Sek	14.17	(2.91)	13.14	(3.96)	16.36	(3.19)	18.97	(1.73)	12.84	(1.98)	12.95	(1.66)	14.91	(2.84)	21.79	(3.54)
% MnCrd	11.37	(3.23)	11.36	(4.16)	17.40	(2.22)	13.20	(0.95)	10.09	(2.36)	18.07	(5.85)	11.26	(1.52)	30.20	(9.49)

Ind: Mg₂Al₄Si₅O₁₈ (indialite), Sek: Fe₂Al₄Si₅O₁₈ (sekaninaite), MnCrd: Mn₂Al₄Si₅O₁₈ ("Mn-cordierite")

2σSD in parentheses

¹Direction: Forward (F) or Reverse (R) thermal direction

Table S4: Average compositions of garnet

System	GT 1.3				American Mineralogist: November 2019 Deposit AM-19-11693				MnGT-BC-4.1							
Exp #	GBT-90	GBT-88	GBT-89	GBT-101	GBT-103	MnGT-77	MnGT-56	MnGT-49								
T (°C)	850	850/750	750	850/750	850/650	800/750	800/700	800/700								
t (hrs)	45	24/168	168	42/456	42/456	168/24	336/336	168/264								
¹ Direction	F	F	F	F	F	R	R	F								
Location of Analysis	Rim	Rim	Rim	Rim	Rim	Rim	Rim	Rim								
¹ Direction: Forward (F) or Reverse (R) thermal direction																
Weight Percent Oxides																
SiO ₂	36.00	(0.26)	35.80	(0.53)	34.76	(0.27)	35.33	(0.28)	33.75	(0.54)	36.42	(0.33)	35.63	(0.39)	35.68	(0.24)
TiO ₂	0.98	(0.11)	1.11	(0.14)	1.27	(0.29)	1.19	(0.07)	0.95	(0.30)	ND		ND		0.05	(0.02)
Al ₂ O ₃	20.37	(0.30)	20.26	(0.17)	19.25	(0.68)	19.28	(0.23)	19.20	(0.20)	19.55	(0.55)	19.54	(0.59)	19.05	(0.29)
FeO*	10.62	(1.02)	12.38	(0.18)	10.05	(0.53)	10.56	(0.70)	6.78	(0.63)	7.14	(0.27)	6.19	(1.34)	9.10	(0.98)
MnO	22.68	(0.67)	25.42	(0.51)	30.39	(0.89)	28.89	(1.30)	36.23	(0.57)	33.62	(0.23)	37.09	(2.32)	31.88	(1.30)
MgO	6.61	(0.56)	4.46	(0.31)	2.80	(0.26)	3.64	(0.45)	0.99	(0.07)	3.13	(0.16)	1.54	(0.79)	2.37	(0.29)
CaO	0.18	(0.01)	0.17	(0.02)	0.35	(0.04)	0.19	(0.02)	0.36	(0.04)	0.07	(0.01)	0.10	(0.01)	0.09	(0.01)
Na ₂ O	0.01	0.00	0.01	(0.01)	0.02	(0.04)	0.01	(0.01)	0.01	(0.01)	ND		ND		ND	
K ₂ O	0.04	(0.01)	0.02	(0.01)	0.05	(0.01)	0.02	(0.01)	0.03	(0.01)	ND		ND		ND	
Total	97.58	(0.34)	99.67	(0.59)	98.96	(0.48)	99.12	(0.28)	98.39	(0.39)	99.94	(0.59)	100.09	(0.60)	98.22	(0.30)
# Pts (N)	3		21		18		10		12		6		13		57	
Atoms per formula unit (based on 12 oxygens)																
Si	2.923	(0.006)	2.905	(0.026)	2.892	(0.019)	2.914	(0.016)	2.868	(0.032)	2.982	(0.008)	2.953	(0.009)	2.987	(0.013)
Ti	0.060	(0.007)	0.068	(0.009)	0.079	(0.018)	0.074	(0.004)	0.060	(0.019)	ND		ND		0.003	(0.001)
Al	1.949	(0.020)	1.938	(0.018)	1.887	(0.062)	1.874	(0.022)	1.922	(0.015)	1.885	(0.035)	1.908	(0.041)	1.880	(0.025)
Fe	0.721	(0.071)	0.840	(0.010)	0.699	(0.038)	0.728	(0.047)	0.482	(0.045)	0.489	(0.022)	0.429	(0.090)	0.637	(0.069)
Mn	1.561	(0.054)	1.748	(0.041)	2.142	(0.066)	2.019	(0.096)	2.608	(0.042)	2.331	(0.037)	2.604	(0.174)	2.261	(0.095)
Mg	0.800	(0.063)	0.539	(0.036)	0.347	(0.031)	0.447	(0.055)	0.126	(0.008)	0.382	(0.016)	0.190	(0.094)	0.295	(0.036)
Ca	0.016	(0.001)	0.015	(0.001)	0.032	(0.004)	0.017	(0.002)	0.032	(0.004)	0.006	(0.001)	0.009	(0.001)	0.008	(0.001)
Σ X-site	3.097	(0.029)	3.142	(0.032)	3.219	(0.071)	3.211	(0.017)	3.247	(0.024)	3.209	(0.042)	3.232	(0.057)	3.201	(0.033)
Σ Cations	8.030	(0.011)	8.053	(0.020)	8.078	(0.024)	8.073	(0.011)	8.098	(0.009)	8.076	(0.013)	8.093	(0.019)	8.071	(0.013)
Normative End-Member Components																
%Sps	50.63	(1.65)	55.89	(1.12)	67.17	(0.94)	63.20	(2.86)	81.12	(1.53)	72.80	(0.33)	80.83	(5.70)	70.80	(2.96)
%Alm	23.38	(2.08)	26.86	(0.38)	21.93	(0.98)	22.80	(1.48)	14.98	(1.34)	15.26	(0.52)	13.29	(2.81)	19.95	(2.07)
%Prp	25.99	(2.26)	17.24	(1.13)	10.89	(1.13)	14.00	(1.75)	3.91	(0.26)	11.93	(0.64)	5.89	(3.01)	9.25	(1.15)

2σSD in parentheses

Sps: Spessartine, Alm: Almandine, Prp: Pyrope

Table S5: Average compositions of tourmaline

System	MnGT-BC-4.1										American Mineralogist: November 2019 Deposit AM-19-116938		GT 1.3
Exp #	MnGT-77		MnGT-49		MnGT-56		MnGT-66		MnGT-67		GBT-103		
T (°C)	800/750		800/700		800/700		800/700		800/700		850/650		
¹ Direction	R		F		R		R		R		F		
t (hrs)	168/24		168/264		336/336		336/24		336/72		42/456		
Weight Percent Oxides													
SiO ₂	34.86	(0.60)	34.69	(0.58)	33.79	(0.83)	34.34	(0.62)	34.29	(0.78)	34.77	(1.04)	
TiO ₂	0.04	(0.02)	0.04	(0.02)	0.04	(0.02)	0.04	(0.02)	0.04	(0.02)	0.45	(0.22)	
B ₂ O ₃	10.97	(0.38)	11.11	(0.34)	11.32	(0.37)	11.24	(0.30)	11.50	(0.39)	10.81	(0.57)	
Al ₂ O ₃	30.80	(1.94)	31.26	(1.33)	29.70	(1.47)	29.73	(1.48)	29.71	(1.20)	29.87	(2.18)	
FeO*	9.24	(0.99)	8.00	(0.56)	9.82	(0.77)	9.13	(0.37)	9.36	(0.72)	9.11	(1.09)	
MnO	0.67	(0.06)	0.57	(0.08)	0.92	(0.19)	1.02	(0.15)	0.98	(0.17)	1.51	(0.25)	
MgO	6.11	(0.49)	5.60	(0.41)	6.27	(0.51)	6.48	(0.52)	6.50	(0.45)	6.25	(0.87)	
CaO	0.44	(0.07)	0.45	(0.07)	0.46	(0.11)	0.41	(0.07)	0.42	(0.09)	0.79	(0.29)	
Na ₂ O	2.09	(0.03)	2.18	(0.08)	2.22	(0.08)	2.25	(0.07)	2.21	(0.06)	2.08	(0.21)	
Total	95.22	(1.19)	93.90	(0.66)	94.54	(0.72)	94.66	(0.73)	95.03	(0.55)	95.64	(1.08)	
# Pts (N)	6		31		69		19		25		14		
2σSD in parentheses													
Atoms per Formula Unit (29 Oxygens)													
Si	5.861	(0.105)	5.864	(0.122)	5.749	(0.140)	5.818	(0.101)	5.785	(0.122)	5.859	(0.160)	
Ti	0.005	(0.002)	0.005	(0.003)	0.005	(0.002)	0.005	(0.002)	0.005	(0.003)	0.057	(0.029)	
B	3.184	(0.097)	3.240	(0.086)	3.324	(0.111)	3.287	(0.096)	3.349	(0.113)	3.145	(0.138)	
Al	6.098	(0.307)	6.227	(0.234)	5.956	(0.258)	5.933	(0.258)	5.908	(0.226)	5.933	(0.442)	
Fe	1.301	(0.151)	1.130	(0.083)	1.398	(0.118)	1.294	(0.061)	1.321	(0.108)	1.284	(0.153)	
Mn	0.095	(0.009)	0.081	(0.012)	0.133	(0.027)	0.146	(0.021)	0.140	(0.023)	0.216	(0.035)	
Mg	1.531	(0.130)	1.411	(0.110)	1.592	(0.134)	1.638	(0.141)	1.635	(0.112)	1.569	(0.216)	
Ca	0.079	(0.013)	0.081	(0.012)	0.084	(0.020)	0.075	(0.013)	0.076	(0.016)	0.143	(0.053)	
Na	0.682	(0.018)	0.716	(0.028)	0.731	(0.030)	0.740	(0.025)	0.723	(0.021)	0.678	(0.069)	
Sum	18.835	(0.065)	18.755	(0.057)	18.971	(0.071)	18.937	(0.064)	18.943	(0.056)	18.884	(0.105)	
Mg [#]	0.541	(0.031)	0.555	(0.014)	0.532	(0.025)	0.558	(0.015)	0.553	(0.024)	0.550	(0.027)	
Mg [#] =Mg/Mg+Fe													
Normative End-Member Components													
Schorl	25.53		27.98		28.05		27.44		27.44		24.03		
Dravite	39.59		34.90		40.80		41.61		40.21		36.99		
Tsilaisite	3.19		2.72		4.42		4.88		4.67		7.21		
Uvite	0.43		4.52		4.41		4.09		4.10		7.78		
Feruvite	0.36		3.62		3.98		3.36		3.50		6.54		
Foite	14.18		9.10		8.70		8.40		9.25		7.97		
Mg-Foite	16.71		11.35		9.64		10.22		10.82		9.47		
Olenite	0.00		5.80		0.00		0.00		0.00		0.00		

¹Direction: Forward (F) or Reverse (R) thermal direction

Table S6: Average compositions of glass

American Mineralogist: November 2019 Deposit AM-19-116938

System	GT1.3											
Exp#	GBT90	GBT88		GBT101		GBT89		GBT102		GBT103		
T (°C)	850	850/750		850/750		750		850/700		850/650		
t (hrs)	45	24/168		42/456		168		48/336		42/456		
¹ Direction	F	F		F		F		F		F		
F: Forward thermal direction; R: reverse thermal direction												
SiO₂	68.85	(1.48)	68.32	(0.77)	69.36	(0.55)	70.58	(0.40)	68.33	(0.96)	66.09	(1.01)
TiO₂	ND											
B₂O₃	3.81	(0.54)	3.50	(0.35)	5.10	(0.32)	2.01	(0.26)	5.12	(0.32)	5.12	(0.25)
Al₂O₃	10.74	(0.55)	10.93	(0.36)	10.51	(0.20)	11.44	(0.26)	10.65	(0.42)	11.71	(0.17)
FeO*	1.32	(0.13)	1.05	(0.05)	0.49	(0.07)	0.67	(0.05)	0.46	(0.09)	0.30	(0.04)
MnO	1.45	(0.15)	1.23	(0.06)	1.16	(0.04)	0.68	(0.04)	1.17	(0.10)	0.93	(0.03)
MgO	0.89	(0.09)	0.51	(0.02)	0.41	(0.07)	0.23	(0.01)	0.29	(0.02)	0.13	(0.01)
CaO	0.22	(0.07)	0.23	(0.05)	0.28	(0.04)	0.29	(0.04)	0.27	(0.05)	0.25	(0.04)
Na₂O	1.84	(0.16)	1.96	(0.08)	2.06	(0.12)	2.59	(0.09)	2.21	(0.11)	2.48	(0.07)
K₂O	2.93	(0.21)	3.27	(0.11)	3.56	(0.15)	4.21	(0.12)	3.59	(0.10)	4.46	(0.16)
Total	92.04	(0.75)	90.99	(0.56)	92.94	(0.88)	92.70	(0.59)	92.09	(0.60)	91.46	(1.12)
H₂O	7.96	(0.75)	9.01	(0.56)	7.06	(0.88)	7.30	(0.59)	7.91	(0.60)	8.54	(1.12)
Femic	3.66	(0.35)	2.78	(0.13)	2.06	(0.17)	1.58	(0.09)	1.91	(0.15)	1.36	(0.07)
N	25		20		15		15		12		10	
ASI	1.630	(0.139)	1.522	(0.046)	1.356	(0.034)	1.223	(0.037)	1.329	(0.040)	1.254	(0.040)
K[#]	0.546	(0.016)	0.524	(0.013)	0.532	(0.018)	0.517	(0.010)	0.534	(0.043)	0.542	(0.010)
Mn[*]	52.785	(1.530)	54.249	(0.760)	70.625	(2.171)	50.417	(0.902)	72.215	(4.036)	75.882	(1.927)
Mg[#]	0.546	(0.002)	0.465	(0.010)	0.598	(0.013)	0.383	(0.011)	0.531	(0.043)	0.426	(0.008)

ASI=aluminum saturation index (molar: Al/(Na+K+Ca))

K[#]=K/(K+Na)Mn^{*}=Mn/(Mn+Fe)*100Mg[#]=Mg/(Mg+Fe)¹Direction: Forward (F) or Reverse (R) thermal direction

Table S6 cont.: Average compositions of glass

System	MnGT-BC-4.1		American Mineralogist: November 2019 Deposit AM-19-116938											
Exp#	MnGT111	MnGT103	MnGT77	MnGT104	MnGT110	MnGT112	MnGT126							
T (°C)	850	850/750	800/750	850/750	850/750	850/750	750							
t (hrs)	168	168/0	168/24	168/24	168/168	168/336	720							
¹Direction	F	R	R	R	R	R	F							
SiO₂	59.41	(1.20)	60.10	(1.21)	61.98	(1.02)	63.16	(1.49)	60.69	(1.38)	60.58	(1.45)	64.63	(1.35)
TiO₂	0.01	(0.01)	0.01	(0.01)	0.00	(0.00)	0.01	(0.01)	0.00	(0.01)	0.01	(0.01)	ND	
B₂O₃	8.97	(0.30)	9.65	(0.74)	8.81	(0.77)	7.05	(0.53)	8.52	(0.96)	9.14	(0.38)	8.20	(0.86)
Al₂O₃	12.23	(0.18)	11.77	(0.37)	11.70	(0.13)	12.33	(0.58)	11.81	(0.41)	11.81	(0.28)	10.55	(0.15)
FeO*	0.76	(0.02)	0.77	(0.09)	0.63	(0.04)	0.48	0.09	0.63	(0.05)	0.34	(0.04)	0.40	(0.02)
MnO	1.88	(0.05)	1.87	(0.10)	1.46	(0.10)	1.88	(0.22)	1.77	(0.05)	1.82	(0.06)	0.99	(0.05)
MgO	0.45	(0.01)	0.41	(0.05)	0.43	(0.01)	0.44	(0.05)	0.38	(0.02)	0.41	(0.01)	0.17	(0.01)
CaO	0.09	(0.09)	0.09	(0.06)	0.07	(0.03)	0.08	(0.06)	0.07	(0.07)	0.08	(0.07)	0.08	(0.00)
Na₂O	2.86	(0.13)	2.78	(0.21)	2.81	(0.11)	2.93	(0.22)	2.87	(0.17)	2.78	(0.27)	2.62	(0.10)
K₂O	3.36	(0.11)	3.37	(0.17)	3.34	(0.12)	3.47	(0.19)	3.35	(0.24)	3.32	(0.22)	3.54	(0.04)
Total	90.03	(1.26)	90.84	(1.33)	91.25	(0.54)	91.85	(0.95)	90.13	(1.19)	90.32	(1.86)	91.19	(0.83)
H₂O	9.97	(1.26)	9.16	(1.33)	8.75	(0.54)	8.15	(0.95)	9.87	(1.19)	9.68	(1.86)	8.81	(0.83)
Femic	3.08	(0.07)	3.05	(0.22)	2.53	(0.12)	2.80	(0.30)	2.79	(0.08)	2.57	(0.10)	1.56	(0.06)
N	20		20		20		20		20		15		25	
ASI	1.438	(0.04)	1.405	(0.071)	1.398	(0.034)	1.414	(0.090)	1.394	(0.080)	1.423	(0.108)	1.273	(0.031)
K[#]	0.436	(0.01)	0.443	(0.020)	0.439	(0.011)	0.437	(0.022)	0.434	(0.025)	0.439	(0.025)	0.470	(0.011)
Mn*	55.010	(0.66)	71.120	(1.872)	70.090	(1.611)	79.950	(2.996)	73.952	(1.566)	84.289	(1.482)	71.733	(0.963)
Mg[#]	0.231	(0.00)	0.489	(0.019)	0.550	(0.016)	0.624	(0.044)	0.520	(0.019)	0.679	(0.027)	0.439	(0.016)

Table S6 cont.: Average compositions of glass

System	MnGT-BC-4.1		American Mineralogist: November 2019 Deposit AM-19-116938											
Exp#	MnGT65	MnGT66	MnGT67	MnGT49	MnGT56	MnGT125	MnGT114							
T (°C)	800/700	800/700	800/700	800/700	800/700	700	850/650							
t (hrs)	336/0	336/72	336/120	168/264	336/336	720	168/0							
¹Direction	R	R	R	F	R	F	R							
SiO₂	60.45	(2.36)	60.67	(0.72)	61.71	(1.50)	62.92	(0.72)	61.71	(0.64)	64.01	(1.67)	61.66	(1.52)
TiO₂	0.01	(0.01)	0.01	(0.01)	0.00	(0.01)	0.01	(0.01)	0.01	(0.01)	ND		0.01	(0.01)
B₂O₃	10.21	(1.20)	9.53	(0.34)	9.71	(0.62)	9.56	(0.46)	10.29	(0.36)	8.73	(1.10)	8.59	(0.53)
Al₂O₃	11.70	(0.20)	11.56	(0.19)	10.92	(0.30)	11.03	(0.22)	11.00	(0.21)	10.00	(0.20)	12.22	(0.28)
FeO*	0.70	(0.05)	0.44	(0.03)	0.37	(0.03)	0.34	(0.04)	0.32	(0.02)	0.28	(0.02)	0.46	(0.04)
MnO	1.62	(0.10)	1.60	(0.08)	1.36	(0.12)	0.89	(0.05)	1.02	(0.09)	0.59	(0.03)	2.03	(0.06)
MgO	0.43	(0.03)	0.25	(0.03)	0.20	(0.08)	0.15	(0.03)	0.11	(0.01)	0.09	(0.01)	0.36	(0.02)
CaO	0.09	(0.08)	0.07	(0.04)	0.06	(0.04)	0.06	(0.04)	0.07	(0.03)	0.07	(0.00)	0.10	(0.07)
Na₂O	2.91	(0.19)	2.97	(0.15)	2.95	(0.13)	2.94	(0.10)	2.98	(0.11)	2.65	(0.15)	2.84	(0.20)
K₂O	3.33	(0.20)	3.44	(0.08)	3.46	(0.15)	3.56	(0.10)	3.71	(0.12)	3.77	(0.09)	3.45	(0.20)
Total	91.45	(1.78)	90.53	(0.79)	90.74	(0.77)	91.47	(0.74)	91.22	(0.68)	90.20	(1.08)	91.73	(1.61)
H₂O	8.55	(1.78)	9.47	(0.79)	9.26	(0.77)	8.53	(0.74)	8.78	(0.68)	9.80	(1.08)	8.27	(1.61)
Femic	2.76	(0.13)	2.28	(0.13)	1.92	(0.22)	1.38	(0.10)	1.45	(0.10)	0.96	(0.04)	2.85	(0.09)
N	20		20		20		45		20		25		15	
ASI	1.371	(0.061)	1.325	(0.038)	1.257	(0.040)	1.253	(0.028)	1.218	(0.032)	1.167	(0.044)	1.423	(0.066)
K[#]	0.430	(0.023)	0.433	(0.013)	0.436	(0.012)	0.443	(0.011)	0.451	(0.012)	0.484	(0.013)	0.444	(0.026)
Mn*	70.079	(2.066)	78.712	(1.656)	78.893	(3.882)	72.686	(2.758)	76.677	(1.646)	67.867	(1.632)	81.675	(1.550)
Mg[#]	0.522	(0.023)	0.503	(0.025)	0.488	(0.087)	0.437	(0.033)	0.372	(0.019)	0.354	(0.016)	0.581	(0.022)

Table S6 cont.: Average compositions of glass

System	MnGT-BC-4.1		American Mineralogist: November 2019 Deposit AM-19-116938			
Exp#	MnGT116		MnGT117		MnGT124	
T (°C)	850/650		850/650		650	
t (hrs)	168/24		168/720		720	
¹Direction	R		R		F	
SiO₂	64.76	(1.11)	62.11	(1.13)	62.42	(0.53)
TiO₂	0.01	(0.01)	0.01	(0.01)	ND	
B₂O₃	6.74	(0.73)	8.84	(0.49)	9.59	(0.69)
Al₂O₃	11.83	(0.43)	11.76	(0.32)	10.43	(0.17)
FeO*	0.34	(0.03)	0.30	(0.04)	0.22	(0.01)
MnO	1.73	(0.12)	1.84	(0.08)	0.35	(0.03)
MgO	0.24	(0.03)	0.32	(0.01)	0.04	(0.00)
CaO	0.08	(0.09)	0.07	(0.07)	0.08	(0.00)
Na₂O	2.81	(0.25)	2.74	(0.19)	2.84	(0.13)
K₂O	3.41	(0.21)	3.30	(0.25)	4.13	(0.08)
Total	91.97	(1.44)	91.30	(1.48)	90.11	(0.89)
H₂O	8.03	(1.44)	8.70	(1.48)	9.89	(0.89)
Femic	2.32	(0.15)	2.46	(0.09)	0.62	(0.03)
N	15		20		25	
ASI	1.398	(0.064)	1.435	(0.089)	1.125	(0.035)
K[#]	0.444	(0.022)	0.443	(0.022)	0.489	(0.013)
Mn[*]	83.716	(1.535)	86.279	(1.526)	61.764	(2.608)
Mg[#]	0.561	(0.035)	0.659	(0.027)	0.258	(0.022)

Table S7: Mineral-melt partition coefficients

Garnet-Melt Partition Coefficients

	Exp #	BC	T (°C)	D _{FeO}	D _{MnO}	D _{MgO}	
Gr/melt	GBT-90	1.3	850	8.07	15.62	7.45	w/Crd
Gr/melt	GBT-88	1.3	750	11.82	20.74	8.74	w/Crd
Gr/melt	GBT-101	1.3	750	21.56	24.85	8.91	w/Crd
Gr/melt	GBT-89	1.3	750	14.91	44.96	11.93	w/Crd
Gr/melt	MnGT-77	4.1	750	11.31	23.01	7.23	w/Tur
Gr/melt	MnGT-49	4.1	700	26.78	35.69	16.01	w/Tur
Gr/melt	MnGT-56	4.1	700	19.95	36.37	14.02	w/Tur
Gr/melt	GBT-103	1.3	650	22.53	38.76	7.93	w/Crd&Tur
Gr/melt	7.2-4		750	15.32	45.73	---	Icenhower (1995)
Gr/melt	4+2		750	22.31	45.80	---	"
Gr/melt	4.1-1		750	20.12	35.53	---	"
Gr/melt	4.2-1		750	16.36	43.78	---	"
Gr/melt	4C-8		750	19.12	42.43	---	"
Gr/melt	4C-10		750	14.20	48.97	---	"
Gr/melt	7.2-2		700	19.22	58.17	---	"
Gr/melt	15-9		700	20.57	47.80	---	"
Gr/melt	15-10		700	18.35	46.52	---	"
Gr/melt	7.2-1		650	27.43	58.16	---	"
Gr/melt	7.1-1		650	27.07	50.67	---	"
Gr/melt	4.1-2		650	15.67	54.00	---	"
Gr/melt	4.2-2		650	22.51	56.53	---	"

BC: Bulk Composition

Mineral abbreviations after Whitney and Evans (2010)

Errors for mean D values are less than 10% relative, and most commonly ~ 5%.

Table S7: Mineral-melt partition coefficients

Cordierite-Melt Partition Coefficients

	Exp #	BC	T (°C)	D _{FeO}	D _{MnO}	D _{MgO}	
Crd/melt	GBT-90	1.3	850	2.55	1.83	11.14	w/Grt
Crd/melt	GBT-88	1.3	750	4.39	2.57	18.07	w/Grt
Crd/melt	GBT-101	1.3	750	8.01	3.54	21.84	w/Grt
Crd/melt	GBT-102	1.3	700	6.79	3.64	31.95	w/Grt
Crd/melt	GBT-103	1.3	650	16.73	7.37	49.77	w/Grt&Tur
Crd/melt	4.1-1		750	11.15	7.19	32.56	Icenhower (1995)
Crd/melt	4C-8		750	13.71	10.50	37.44	"
Crd/melt	4C-11		750	19.49	14.46	---	"
Crd/melt	4.2-1		750	11.60	9.93	41.64	"
Crd/melt	5-17		700	13.98	9.33	43.68	"
Crd/melt	5-18		700	14.73	8.57	42.17	"
Crd/melt	5-19		700	16.02	8.93	43.87	"
Crd/melt	6M-3		700	14.18	8.92	32.62	"
Crd/melt	5+11		700	15.00	7.66	28.80	"
Crd/melt	15-10		700	12.65	11.92	33.60	"
Crd/melt	4.1-2		650	16.92	15.08	38.17	"
Crd/melt	4.2-2		650	18.43	8.50	55.09	"
Crd/melt	4C-13		650	17.00	---	61.00	"
Crd/melt	HGTR-26		750	6.30	3.60	31.80	from Wolf and London (1997)
Crd/melt	HGTR-38		750	8.50	4.60	64.30	"
Crd/melt	HGTR-39		750	7.70	3.40	60.00	"
Crd/melt	BeP-57		750	4.95	4.70	44.37	"
Crd/melt	BeP-58		800	3.63	3.00	23.17	"
Crd/melt	BeP-68		800	3.81	3.08	24.30	"
Crd/melt	BeP-105		850	2.72	1.92	13.40	"
Crd/melt	BeP-95		700	9.90	7.56	60.29	"
Crd/melt	BeP-96		750	10.29	5.30	40.24	"
Crd/melt	BeP-19		800	3.28	3.40	27.51	"
Crd/melt	BeP-97		800	4.72	3.60	30.47	"

BC: Bulk Composition

Mineral abbreviations after Whitney and Evans (2010)

Errors for mean D values are less than 10% relative, and most commonly ~ 5%.

Table S7: Mineral-melt partition coefficients

Tourmaline-Melt Partition Coefficients

	Exp #	BC	T (°C)	D _{FeO}	D _{MnO}	D _{MgO}	
Tur/melt	MnGT-77	4.1	750	14.64	0.46	14.11	w/Grt
Tur/melt	MnGT-49	4.1	700	23.52	0.64	37.88	w/Grt
Tur/melt	MnGT-56	4.1	700	31.11	0.90	---	w/Grt
Tur/melt	MnGT-66	4.1	700	20.89	0.64	26.14	Tur only
Tur/melt	MnGT-67	4.1	700	25.42	0.72	33.02	Tur only
Tur/melt	GBT-103	1.3	650	30.28	1.62	49.93	w/Grt&Crd
Tur/melt	HGTR-25		750	5.1	0.4	20.4	Wolf and London (1997)
Tur/melt	HGTR-27		750	4.3	0.4	27.3	
Tur/melt	HGTR-28		750	4.1	---	27.7	
Tur/melt	HGTR-30		750	9.6	0.4	27.9	
Tur/melt	HGTR-40		700	7.0	0.5	44.3	
Tur/melt			800	---	0.34	---	van Hinsberg (2011)

BC: Bulk Composition

Mineral abbreviations after Whitney and Evans (2010)

Errors for mean D values are less than 10% relative, and most commonly ~ 5%.

Table S7: Mineral-melt partition coefficients

Biotite-Melt Partition Coefficients

	Exp #	BC	T (°C)	D _{FeO}	D _{MnO}	D _{MgO}	
Bt/melt	6+4		750	18.42	3.71	67.33	Icenhower and London (1995)
Bt/melt	7+4		750	17.83	3.78	72.40	"
Bt/melt	5+6		750	16.80	3.50	76.00	"
Bt/melt	5+9		700	20.49	3.25	68.78	"
Bt/melt	5+7		700	19.60	5.00	49.54	"
Bt/melt	6+7		700	22.19	4.50	85.71	"
Bt/melt	6+5		700	27.96	5.50	84.29	"
Bt/melt	7+7		700	20.75	3.75	74.00	"
Bt/melt	7+5		700	21.03	4.63	54.91	"
Bt/melt	7+10		650	28.45	6.83	73.63	"
Bt/melt	7+6		650	27.89	5.57	76.25	"
Bt/melt	5+14		650	23.38	4.86	54.55	"
Bt/melt	5+15		650	20.19	5.43	37.63	"
Bt/melt	5+8		650	23.69	4.25	50.42	"
Bt/melt		Dacite		22.20	6.00	---	Higuchi and Nagasawa (1969) - GERM
Bt/melt		Dacite		25.10	7.47	---	Ewart and Griffin (1994)
Bt/melt		High silica rhyolite		59.10	15.50	---	Ewart and Griffin (1994)
Bt/melt		Low silica rhyolite		22.10	5.70	---	Ewart and Griffin (1994)
Bt/melt		Dacite		---	5.95	---	Matsui et al. (1977)
Bt/melt		High silica rhyolite		---	13.4 - 7.9	---	Mahood and Hildreth (1983)
Bt/melt		Rhyolite		---	205 - 13.6	---	Nash and Crecraft (1985)

GERM: <http://earthref.org/KDD/>

BC: Bulk Composition (rock type for data from GERM)

Mineral abbreviations after Whitney and Evans (2010)

Errors for mean D values are less than 10% relative, and most commonly ~ 5%.

S8: Parameters and results for
Rayleigh fractional crystallization
model

Partition Coefficients (D) - MnO

	Crd/melt
850°C	1.83
650°C	7.37
	Bt/melt
850°C	4.61
650°C	4.61

Bulk partition coefficients (WD) -
MnO

	Crd, Bt granite	Bt granite
850°C	0.2	0.41
650°C	0.55	0.41

Normative Mineralogy

Granite type	Crd, Bt granite	Bt granite
Qtz	28.27	30.99
Kfs	28.94	25.47
Pl	34.55	34.38
Bt	1.67	5.85
Crd	6.46	---
Ms	---	---
Als	0.1	3.31

Initial concentrations (C₀)

Granite type	Crd, Bt granite	Bt granite
MnO (wt.%)	0.08	0.08

Rayleigh parameters (T&F)

Granite type	Crd, Bt granite	Bt granite
T range (°C)	850 --> 650	850 --> 650
F (liquid fraction)	1.0 --> 0.01	1.0 --> 0.01

Final concentrations (C)

Granite type	Crd, Bt granite	Bt granite
MnO (wt.%)	0.64	3.23