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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	---	23.2
Orthoclase		
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																
Exp #	90		GBT-101		GBT-101		GBT-88		GBT-102		GBT-102		GBT-103		GBT-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)
% MnCrδ	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	American Mineralogist: November 2019 Deposit AM-19-116938-MnGT-BC-4.1															
GT 1.3			GBT-88		GBT-89		GBT-101		GBT-103		MnGT-77		MnGT-56		MnGT-49	
Exp #	GBT-90		88		89		101		103		77		56		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										GT 1.3	
	American Mineralogist: November 2019 Deposit AM-19-116938											
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	
Foitite	14.18		9.10		8.70		8.40		9.25		7.97	
Mg-Foitite	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											
SiO ₂	68.85	(1.48)	68.32	(0.77)	69.36	(0.55)	70.58	(0.40)	68.33	(0.96)	66.09	(1.01)
TiO ₂	ND		ND		ND		ND		ND		ND	
B ₂ O ₃	3.81	(0.54)	3.50	(0.35)	5.10	(0.32)	2.01	(0.26)	5.12	(0.32)	5.12	(0.25)
Al ₂ O ₃	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)
Na ₂ O	1.84	(0.16)	1.96	(0.08)	2.06	(0.12)	2.59	(0.09)	2.21	(0.11)	2.48	(0.07)
K ₂ O	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)
H ₂ O	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)*100

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