

Supplementary Materials

The Saint-Honoré Carbonatite REE Zone, Québec, Canada: Combined Magmatic and Hydrothermal Processes

Table S1. Results for whole rock geochemical analyses.

Depth (m)	51	81	111	136	164	192	222	249	252	255	258	276
SiO ₂ (%)	8.4	10.6	17.1	5.8	4.4	11.2	1.2	2.3	2.0	1.9	3.8	2.6
Al ₂ O ₃ (%)	3.4	4.6	5.9	2.6	1.8	4.6	0.5	0.9	0.8	0.8	1.7	0.7
Fe ₂ O ₃ (%)	12.2	14.7	11.5	12.6	11.8	16.4	12.9	15.3	15.2	13.7	14.7	11.6
MgO (%)	11.7	12.6	11.3	13.7	13.1	12.0	11.8	11.5	11.3	11.0	11.4	11.8
CaO (%)	23.4	21.2	18.3	23.7	23.6	19.3	27.2	23.3	22.2	23.2	22.7	23.9
Na ₂ O (%)	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1
K ₂ O (%)	0.4	0.6	3.0	0.3	0.1	0.6	DL	DL	0.02	0.01	DL	0.02
TiO ₂ (%)	0.4	0.6	0.2	0.2	0.4	0.3	0.1	0.1	0.4	0.3	0.4	0.8
P ₂ O ₅ (%)	1.9	2.0	0.8	0.9	0.4	0.2	0.9	0.9	0.5	0.3	0.5	0.0
MnO (%)	1.5	1.1	1.0	1.3	1.5	1.2	1.9	2.0	1.9	1.8	1.8	1.5
BaO (%)	0.09	0.03	0.1	0.03	1.8	0.04	0.04	2.6	3.8	5.0	2.8	3.8
SrO (%)	0.2	0.3	0.3	0.4	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.3
Nb ₂ O ₅ (%)	0.3	0.1	0.1	0.2	0.2	0.2	0.03	0.1	0.2	0.1	0.2	0.4
CO ₂ (%)	32.9	34.8	38.3	35.1	34.2	30.6	39.2	32.1	37.6	37.9	37.6	35.9
S (%)	3.2	2.8	1.7	0.6	2.5	2.5	1.4	2.7	0.8	1.5	1.8	2.1
Cl (%)	0.08	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
TREEO (%)	2.0	0.6	0.6	1.4	2.4	1.5	2.2	1.9	2.0	1.9	2.1	2.2
Total (%)	102.2	106.7	110.3	99.00	98.6	100.9	99.6	96.1	99.1	99.9	101.8	97.7
La (µg/g)	4780	970	1280	3400	5720	3340	4420	4010	4320	4110	4440	5580
Ce (µg/g)	8120	2230	2540	5770	9460	5900	8850	7520	8060	7840	8610	9040
Pr (µg/g)	840	280	290	610	1000	640	1060	870	910	890	910	920
Nd (µg/g)	2770	1060	1030	2030	3320	2190	3700	2970	3190	3030	3190	2910
Sm (µg/g)	310	130	120	210	350	250	400	330	390	320	340	330
Eu (µg/g)	66	28	26	41	77	57	79	74	101	74	89	81
Gd (µg/g)	159	67	58	87	163	125	169	138	229	139	228	170
Tb (µg/g)	16	7	6	9	16	13	15	13	26	14	23	18
Dy (µg/g)	49	25	21	35	58	45	45	50	90	47	90	60
Ho (µg/g)	6.2	3.9	3.1	5.4	7.3	5.2	5.4	6.3	8.9	5.2	10.8	6.1
Er (µg/g)	12.1	9.4	6.1	11.2	12.8	8.4	11.0	12.8	14.2	9.5	21.0	8.9
Tm (µg/g)	1.2	1.1	0.6	1.2	1.1	0.7	1.2	1.3	1.3	1.0	1.9	0.6
Yb (µg/g)	6.0	6.0	3.0	6.0	6.0	4.0	6.0	7.0	6.0	5.0	9.0	3.0
Lu (µg/g)	0.8	0.8	0.3	0.7	0.7	0.5	0.8	0.8	0.7	0.7	1.2	0.3
Zn (µg/g)	486	225	156	112	125	211	71	129	287	128	136	145
Th (µg/g)	437	220	235	202	388	373	409	403	475	221	618	470

Table S1. Cont.

Depth (m)	306	336	366	396	423	483	513	543	573	603	633	660
SiO ₂ (%)	1.3	3.2	2.9	4.0	3.0	4.2	1.9	1.9	4.4	2.1	3.3	2.9
Al ₂ O ₃ (%)	0.5	1.6	1.5	2.1	1.0	0.7	0.6	0.4	1.1	1.0	1.6	1.4
Fe ₂ O ₃ (%)	28.4	20.6	14.2	22.2	15.8	13.8	21.9	13.1	13.5	13.2	13.6	14.2
MgO (%)	10.5	10.4	11.2	11.0	11.3	11.0	10.7	10.1	12.1	10.8	11.2	10.8
CaO (%)	13.0	17.9	22.3	16.0	20.8	21.0	16.1	21.2	23.2	23.2	21.6	20.8
Na ₂ O (%)	0.2	0.2	0.4	0.3	0.3	0.3	0.2	0.3	0.3	0.2	0.4	0.3
K ₂ O (%)	DL	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.08	0.02	0.03	0.02
TiO ₂ (%)	0.04	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.7	1.5
P ₂ O ₅ (%)	0.4	0.5	0.7	0.8	0.4	0.7	0.1	0.3	0.2	0.1	0.0	0.0
MnO (%)	3.0	2.0	1.6	2.0	1.7	1.7	2.4	1.8	1.5	1.7	1.4	1.5
BaO (%)	2.5	3.6	3.6	3.6	4.4	5.6	5.1	8.7	2.1	4.9	4.9	5.7
SrO (%)	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.4	0.3	0.3	0.3
Nb ₂ O ₅ (%)	0.04	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.4	0.8
CO ₂ (%)	37.9	37.0	38.0	35.9	32.0	34.3	34.0	35.9	34.6	39.8	32.6	38.6
S (%)	1.8	1.8	2.0	1.7	2.2	1.8	2.3	1.3	1.1	1.2	2.7	1.6
Cl (%)	0.02	0.1	0.4	0.4	0.4	0.3	0.2	0.3	0.4	0.3	0.3	0.4
TREEO (%)	1.9	1.9	2.4	1.8	1.7	1.8	2.0	1.8	1.3	1.7	2.2	2.0
Total (%)	101.6	101.4	101.7	102.2	95.5	97.8	97.9	97.6	96.7	100.7	97.2	102.8
La (µg/g)	3780	3910	5920	3870	3720	3580	3410	3750	2880	3510	5080	4450
Ce (µg/g)	7790	7750	9830	7610	7140	7370	8260	7630	5210	6930	8990	8110
Pr (µg/g)	940	900	1010	870	770	820	970	820	560	780	980	870
Nd (µg/g)	3260	3120	3260	2870	2580	2750	3450	2700	1860	2630	3140	2870
Sm (µg/g)	360	370	390	300	290	280	370	260	200	300	360	320
Eu (µg/g)	75	84	93	62	63	62	85	60	47	73	98	91
Gd (µg/g)	134	170	181	109	117	123	181	121	103	170	267	268
Tb (µg/g)	11	17	15	9	9	12	16	12	11	18	32	37
Dy (µg/g)	36	57	48	25	25	34	46	35	42	54	102	120
Ho (µg/g)	3.6	5.5	4.9	2.4	2.9	3.8	4.7	4.3	5.8	6.2	10.6	12.9
Er (µg/g)	5.6	8.3	8.0	3.9	5.0	6.8	6.3	8.1	12.6	9.8	14.1	22.2
Tm (µg/g)	0.5	0.7	0.7	0.4	0.5	0.9	0.6	0.9	1.8	1.1	1.1	2.3
Yb (µg/g)	2.0	3.0	3.0	2.0	3.0	5.0	3.0	5.0	10.0	6.0	5.0	12.0
Lu (µg/g)	0.3	0.4	0.5	0.3	0.3	0.8	0.4	0.7	1.6	0.8	0.6	1.6
Zn (µg/g)	169	128	103	180	106	180	294	127	63	70	91	234
Th (µg/g)	475	583	727	405	428	352	566	335	324	524	730	654

Table S1. Cont.

Depth (m)	717	747	753	777	807	837	867	927
SiO ₂ (%)	1.3	4.0	4.5	1.2	1.7	1.4	2.7	2.3
Al ₂ O ₃ (%)	0.3	1.3	0.9	0.3	0.6	0.3	0.8	1.1
Fe ₂ O ₃ (%)	11.4	14.8	14.4	17.0	15.1	13.3	12.6	15.4
MgO (%)	11.3	11.0	10.5	10.9	11.6	11.0	12.8	12.2
CaO (%)	24.3	20.8	19.5	20.8	20.5	21.8	24.5	21.7
Na ₂ O (%)	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2
K ₂ O (%)	0.02	0.02	0.01	0.01	DL	DL	0.02	0.01
TiO ₂ (%)	0.2	0.3	0.1	0.1	0.3	0.1	0.1	0.1
P ₂ O ₅ (%)	1.8	0.4	0.5	0.5	1.2	1.0	0.7	1.1
MnO (%)	1.6	1.5	1.6	2.1	1.8	1.7	1.5	1.7
BaO (%)	4.4	5.3	7.2	4.1	6.1	6.5	1.9	3.3
SrO (%)	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3
Nb ₂ O ₅ (%)	0.2	0.1	0.1	0.03	0.2	0.1	0.2	0.1
CO ₂ (%)	40.5	31.7	38.9	38.9	36.5	35.1	37.6	36.0
S (%)	1.2	2.0	1.8	1.6	1.9	1.3	1.6	1.2
Cl (%)	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.2
TRREO (%)	2.4	1.9	2.0	2.4	1.9	3.2	1.6	2.6
Total (%)	101.8	95.9	102.7	100.5	100.1	97.5	99.6	99.5
La (µg/g)	5050	4050	4150	5050	4420	6880	3570	5620
Ce (µg/g)	9990	8010	8730	10500	7920	13300	6570	11100
Pr (µg/g)	1020	830	920	1060	800	1400	680	1180
Nd (µg/g)	3300	2760	3080	3500	2630	4570	2250	3960
Sm (µg/g)	320	300	320	330	270	430	240	390
Eu (µg/g)	76	72	72	71	71	96	58	88
Gd (µg/g)	187	166	159	157	142	189	127	178
Tb (µg/g)	25	16	16	15	16	18	14	17
Dy (µg/g)	93	54	47	44	57	55	46	54
Ho (µg/g)	11.5	6.5	5.2	5.0	7.2	6.6	5.8	7.0
Er (µg/g)	22.2	11.5	8.7	8.4	12.9	11.7	12.5	12.8
Tm (µg/g)	2.6	1.2	0.8	0.9	1.3	1.2	1.7	1.1
Yb (µg/g)	14.0	7.0	5.0	5.0	6.0	6.0	10.0	5.0
Lu (µg/g)	1.6	0.9	0.7	0.7	1.0	0.8	1.4	0.6
Zn (µg/g)	67	495	340	161	189	452	102	187
Th (µg/g)	425	555	471	388	566	530	404	513

Table S1. Cont.

Depth (m)	987	1014	1044	1074	1104	1131	1164	1194	1224	1254	1284	1311
SiO ₂ (%)	1.7	1.4	1.8	1.2	1.5	0.9	0.8	2.2	1.7	1.3	2.4	5.7
Al ₂ O ₃ (%)	0.7	0.7	0.8	0.5	0.4	0.3	0.2	0.3	0.3	0.2	0.5	1.8
Fe ₂ O ₃ (%)	21.7	15.4	24.4	18.8	23.5	17.7	11.5	14.7	10.9	13.0	11.0	14.6
MgO (%)	11.4	11.8	11.1	11.4	12.4	11.8	14.0	12.3	11.0	11.6	11.2	8.6
CaO (%)	13.8	19.0	10.2	16.4	11.1	15.9	24.8	17.7	16.8	18.7	19.5	20.1
Na ₂ O (%)	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.2
K ₂ O (%)	DL	0.01	DL	0.01	0.02	DL	DL	0.02	0.01	DL	0.01	0.05
TiO ₂ (%)	0.01	DL	0.04	0.03	0.1	0.1	0.1	0.04	0.1	0.2	0.1	0.7
P ₂ O ₅ (%)	0.6	2.1	1.0	0.9	0.4	1.2	0.2	1.0	1.0	0.5	1.2	4.1
MnO (%)	2.6	1.9	2.6	2.2	2.5	2.1	1.7	1.9	1.3	1.6	1.3	1.2
BaO (%)	6.7	6.8	9.2	8.0	7.6	6.7	1.7	6.2	14.0	9.2	11.2	8.8
SrO (%)	0.2	0.4	0.2	0.2	0.2	0.2	0.4	0.3	0.4	0.4	0.5	0.4
Nb ₂ O ₅ (%)	0.02	0.01	0.01	0.03	0.1	0.03	0.1	0.1	0.1	0.1	0.1	0.3
CO ₂ (%)	39.1	36.0	38.2	32.8	35.2	37.5	37.5	40.0	41.4	38.2	33.0	31.0
S (%)	1.1	0.5	0.9	1.0	1.8	1.4	1.1	1.1	1.0	1.1	0.7	0.5
Cl (%)	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
TREO (%)	2.5	2.9	2.1	2.2	2.1	4.4	2.0	2.7	2.6	2.5	3.3	2.3
Total (%)	102.4	99.3	102.9	95.9	99.3	100.5	96.4	100.8	103.1	98.9	96.3	100.5
La (µg/g)	5720	6540	4510	5000	4850	10800	4470	6830	7910	6590	8660	6000
Ce (µg/g)	10900	12300	9120	9510	9270	18800	8510	11700	10600	10600	13600	9840
Pr (µg/g)	1110	1190	930	940	880	1750	830	1060	910	1000	1300	930
Nd (µg/g)	3500	3760	2980	2960	2640	5250	2640	3040	2450	2960	3930	2760
Sm (µg/g)	290	310	250	270	190	390	210	180	180	240	410	240
Eu (µg/g)	62	75	61	68	46	84	44	40	48	51	101	56
Gd (µg/g)	104	135	104	124	81	152	84	67	105	86	195	105
Tb (µg/g)	8	12	10	11	7	14	7	7	12	7	17	11
Dy (µg/g)	20	40	30	28	20	40	18	20	39	21	47	38
Ho (µg/g)	2.5	5.8	3.6	2.9	2.3	4.6	1.9	2.5	5.0	2.3	4.3	4.7
Er (µg/g)	4.2	12.6	6.1	4.6	3.7	7.4	3.2	4.6	8.0	3.4	6.1	9.0
Tm (µg/g)	0.4	1.2	0.5	0.4	0.3	0.6	0.3	0.4	0.6	0.3	0.5	0.8
Yb (µg/g)	2.0	6.0	2.0	2.0	1.0	2.0	1.0	2.0	2.0	1.0	2.0	4.0
Lu (µg/g)	0.2	0.7	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.5
Zn (µg/g)	984	467	2920	1080	3800	2190	1070	1580	428	624	477	52
Th (µg/g)	285	464	333	551	285	388	245	200	327	271	895	367

Table S2. Representative REE results in µg/g for apatite, carbonates and barite by LA-ICP-MS.

	Apatite			Carbonates														
	Ap 1	Ap 2	Ap 3	Car 1	Car 2	Car 3	Car 4	Car 5	Car 6	Car 7	Car 8	Car 9	Car 10	Car 11	Car 12	Car 13	Car 14	Car 15
La	110	185	155	50	11	5.0	9.7	13	11	3.1	2.9	9.0	5.2	30	0.8	1.6	20	4.5
Ce	375	585	491	98	21	20	18	40	28	7.9	11	22	14	98	3.4	5.8	54	12
Pr	63	105	81	9.2	2.4	2.8	2.0	3.2	3.5	1.0	1.8	2.4	1.6	8.5	0.6	1.0	6.3	1.7
Nd	401	608	505	29	9	11	7	12	13	4.2	8	9	6	25	4	5	24	8
Sm	160	214	188	3.8	1.9	2.0	1.4	2.2	3.1	1.4	2.3	2.0	1.5	3.8	1.4	2.0	5.1	1.8
Eu	52	65	59	0.9	0.7	0.5	0.4	0.6	0.9	0.5	0.7	0.8	0.4	0.8	0.4	0.6	1.3	0.5
Gd	148	178	165	2.4	2.5	1.2	1.1	1.5	2.8	1.2	1.9	2.7	1.1	1.8	1.1	1.5	3.4	1.6
Dy	123	124	125	1.1	3.2	0.9	1.5	1.2	2.6	1.0	1.6	4.3	0.8	0.7	0.6	1.0	1.9	1.6
Ho	23	22	23	0.2	0.6	0.2	0.3	0.2	0.4	0.2	0.3	0.8	0.1	0.1	0.1	0.2	0.3	0.3
Er	54	50	53	0.4	1.6	0.6	0.8	0.5	1.1	0.5	0.6	2.0	0.4	0.2	0.2	0.5	0.7	0.9
Tm	6	5.6	6.3	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.3	0.1	0.0	0.0	0.1	0.1	0.1
Yb	35	29	34	0.6	2.0	1.2	0.9	0.6	1.3	0.7	0.7	1.9	0.5	0.3	0.3	0.5	0.6	0.8
Lu	3.5	2.8	3.4	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.3	0.1	0.0	0.0	0.1	0.1	0.1

Barite									
	Bar1	Bar2	Bar3	Bar4	Bar5	Bar6	Bar7	Bar8	Bar9
La	31	20	20	32	58	9	12	7	7
Ce	18	5.3	12	21	81	5	20	0.5	0.3
Pr	3.8	0.6	2.3	2.5	37	2.3	1.3	0.1	0.1
Nd	11	2.7	10	9	61	7	4	0.3	0.4
Sm	4.5	2.5	3.4	2.2	4.5	1.4	1.2	0.8	0.9
Eu	19	16	16	13	12	11	12	9	8
Gd	27	26	18	12	25	23	12	15	17
Dy	2.0	0.5	0.9	0.3	2.4	0.5	0.1	0.1	0.0
Ho	0.3	0.2	0.2	0.0	0.1	0.1	0.0	0.0	0.0
Er	0.6	0.3	0.7	0.1	0.2	0.4	1.1	0.0	0.0
Tm	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Yb	1.6	1.5	1.6	1.2	1.0	1.8	0.8	0.9	1.1
Lu	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1