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Mineralogical evolution of the northern Bossoroca ophiolite, São Gabriel terrane

Amanda Juliano Massuda, Léo Afraneo Hartmann1, Gláucia Nascimento Queiroga, Marco Paulo de Castro, Carolina Gonçalves Leandro, Jairo Francisco Savian

Supplementary Table 1. Analytical methods, EPMA. Analytical methodology is similar to Arena et al. (2019) and Hartmann et al. (2019) in the same UFOP laboratories.

Electron microprobe analyses (EMPA) of tourmaline and chlorite from Bossoroca tourmalinite were perfomed on polished mounts using a JEOL JXA-8230 superprobe, equipped with five wavelength dispersive spectrometers (WDS), Laboratory of Microscopy and Microanalysis (DEGEO-UFOP-Brazil). Eight different crystals were used: thallium acid phthalate on H-type spectrometer (TAPH in WDS 1), thallium acid phthalate (TAP in WDS 2), lithium floride on H-type spectrometer (LIFH in WDS 3), pentaerythritol on H-type spectrometer (PETH in WDS 3), high reflectivity pentaerythritol (PETJ in WDS 4), lithium fluoride (LIF in WDS 4), pentaerythritol (PETL in WDS 5) and lithium fluoride (LIFL in WDS 5). The JEOL EMPA software Ver3.0.1.16 package was used to perform the calibration, overlap corrections and quantification. The work distance on EMPA is fixed at 11 mm with no variation during analysis. The following standards were used for calibration: anorthoclase (Na), CaF_2 (F), quartz (Si), corundum (Al), olivine (Mg), magnetite (Fe), scapolite (Cl), fluor-apatite (P, Ca), rutile (Ti), chromite (Cr), microcline (K) and MnO_2 (Mn). Counting time for Cr, Mn and P was set at 30 s at peak and 15 s at background while for Na, F, Si, Al, Mg, Fe, Cl, Ti, Ca and K was set at 10 s at peak and 5 s at background. The major spectral interferences were corrected during analysis of standards and during quantification. Kα X-ray was used for all elements. Standard deviation for each element was: Na (1%), F (1.05%), Si (0.29%), Al (0.28%), Mg (0.51%), Fe (0.4%), Cl (0.97%), P (0.61%), Ti (0.39%), Cr (1,03%), Ca (0.25%), K (0.49%) and Mn (0.43%).

Tourmaline structural formulae were calculated on the basis of 31 anions, assuming stoichiometric amounts of B_2O_3 (B = 3 apfu), H_2O (OH + F = 4 apfu) and Li_2O (Li = 15 – (T + Z + Y), and that all Fe is present as Fe^{2+} (Tindle et al., 2002).

Element maps were recorded in WDX mode using a spot mode beam at an accelerating voltage of 15 kV and a probe current of 20 nA. In the stage scanning mode a step size of 1 µm was used in X and Y directions. The counting time for each step was 1000 ms.

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Table of conditions EPMA analyses, silicates and chromite.

Standard conditions EPMA of silicates
Spot Size = 5 micrometers
Accel. Voltage = 15Kv
Probe current = 20nA
Measurement Condition
WDS elements

	Element	X-ray	Crystal	CH	Acc.v	Peak Pos. (nm)	BG_L	BG_U	(mm)
1	Na	Ka	TAPH	1	15	130.208	1.19101	2.594	1.464
2	F	Ka	TAPH	1	15	199.418	1.832	3.747	1.997
3	Zr	La	TAP	2	15	65.969	0.60705	4.255	2.139
4	Si	Ka	TAP	2	15	77.43	0.71254	2.723	1.73
5	Al	Ka	TAP	2	15	90.607	0.83393	2.385	1.331
6	Mg	Ka	TAP	2	15	107.44	0.989	2.641	1.187
7	Ba	La	PETH	3	15	88.105	0.27759	1.065	1.202
8	Fe	Ka	LIFH	3	15	134.28	0.1936	1.104	1.228
9	Cl	Ka	PETH	3	15	150.955	0.47278	2.013	1.079
10	Cr	Ka	LIFH	3	15	158.909	0.22897	1.348	1.13
11	Ca	Ka	PETJ	4	15	107.368	0.33584	1.063	0.696
12	P	Ka	PETJ	4	15	196.819	0.6157	0.65	0.887
13	Sr	La	PETJ	4	15	219.478	0.68628	1.782	0.718
14	Ti	Ka	PETL	5	15	87.134	0.27485	1.009	0.974
15	K	Ka	PETL	5	15	119.144	0.37414	1.055	0.684
16	Mn	Ka	LIFL	5	15	145.49	0.21018	1.07	1.117

	Element	Peak	Back	Pksk	Gain	High.V	Base.L	Window.W	Mode
1	Na	10	5.0 (s)	2	16	1622	0.7	0 (V)	Int
2	F	10	5.0 (s)	2	16	1622	0.7	0 (V)	Int
3	Zr	10	5.0 (s)	1	8	1668	0.5	0 (V)	Int
4	Si	10	5.0 (s)	1	8	1668	0.5	0 (V)	Int
5	Al	10	5.0 (s)	2	8	1668	0.5	0 (V)	Int
6	Mg	10	5.0 (s)	2	8	1668	0.5	0 (V)	Int
7	Ba	30	15.0 (s)	2	32	1686	1	0 (V)	Int
8	Fe	10	5.0 (s)	1	8	1772	1	0 (V)	Int
9	Cl	10	5.0 (s)	2	32	1686	1	0 (V)	Int
10	Cr	10	5.0 (s)	2	8	1772	1	0 (V)	Int
11	Ca	10	5.0 (s)	2	64	1620	0.7	0 (V)	Int
12	P	10	5.0 (s)	2	64	1620	0.7	0 (V)	Int
13	Sr	30	15.0 (s)	2	64	1620	0.7	0 (V)	Int
14	Ti	10	5.0 (s)	2	16	1754	0.4	9.3 (V)	Dif
15	K	10	5.0 (s)	2	16	1754	0.4	9.3 (V)	Dif
16	Mn	10	5.0 (s)	2	8	1754	0.4	9.6 (V)	Dif

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Measurement Order	of WDS				
Order	Channel 1	2	3	4	5
1	Na_1TAPH	Zr_2TAP_	Ba_3PETH	Ca_4PETJ	Ti_CH5_P
2	F_1TAPH_	Si_2TAP_	Fe_3LIFH	P_4PETJ_	K_5PETL_
3	0	Al_2TAP_	Cl_3PETH	Sr_4PETJ	Mn_5LIFL
4	0	Mg_2TAP_	Cr_3LIFH	0	0

Calc. Elements : O (Anion)

Standard Data

Element		Standard	Mass(%)	ZAF Fac.	Z	A	F
1	Na2O	Anorthoclase	9.31	5.3131	10.7359	0.493	1.0038
2	F	CaF2	48.668	5.5587	22.0589	0.252	1
3	ZrO2	Zircon	66.32	2.5439	3.4089	0.7463	1
4	SiO2	Quartz	99.99	3.5148	4.3603	0.8061	1
5	Al2O3	Gahnite	55.32	3.2839	6.1449	0.5344	1
6	MgO	Olivine	49.42	4.7794	7.8823	0.6046	1.003
7	BaO	BaSO4	65.6984	0.5358	0.5747	0.9322	1
8	FeO	Magnetite	91.1215	0.2147	0.2175	0.987	1
9	Cl	Scapolite (Meionite)	1.43	1.6105	1.9865	0.8077	1.0038
10	Cr2O3	Chromite	60.5	0.361	0.3628	0.9799	1.0155
11	CaO	Fluor-Apatite	54.02	0.8863	0.9521	0.9308	1
12	P2O5	Fluor-Apatite	40.78	2.7803	3.4076	0.8119	1.005
13	SrO	Strontianite	67.67	3.4703	4.3967	0.7892	1.0001
14	TiO2	Rutile	100	0.5913	0.606	0.9757	1
15	K2O	MIcrocline	15.14	1.0691	1.202	0.8894	1
16	MnO	Mn	129.1098	0.3051	0.3104	0.9828	1

Standard Intensity of WDS

	Element	Curr.(A)	Net(cps)	Bg-(cps)	Bg+(cps)	S.D.(%)	Date	
1	Na	2.00E-08	1617.9	57.5	45.7	0.99	10/22/2018	12:24:21
2	F	2.00E-08	1507.2	39.5	46.7	1.03	10/22/2018	12:29:50
3	Zr	2.00E-08	5065.4	685.3	213.7	0.58	9/24/2018	11:04:14
4	Si	2.00E-08	17461.7	228.9	95.7	0.3	1/21/2019	10:33:37
5	Al	2.00E-08	7524.3	131	73.8	0.45	1/21/2019	10:58:57
6	Mg	2.00E-08	7124.1	81	74.9	0.46	10/22/2018	12:47:29
7	Ba	2.00E-08	15529	370.7	333.3	0.25	10/22/2018	12:55:47
8	Fe	2.00E-08	9050.5	73.3	97.7	0.38	1/24/2019	10:16:03
9	Cl	2.00E-08	567.5	17.4	15.7	1.3	10/22/2018	13:10:47
10	Cr	2.00E-08	4459.2	30.4	50.4	0.51	10/22/2018	13:17:15
11	Ca	2.00E-08	5258.2	47.6	44.3	0.5	1/24/2019	10:10:54
12	P	2.00E-08	1224.1	13.9	10.6	0.97	10/22/2018	13:32:23
13	Sr	2.00E-08	944.4	24.2	25	1.12	10/22/2018	13:57:22
14	Ti	2.00E-08	34275.1	146.8	176.8	0.18	10/22/2018	13:39:06
15	K	2.00E-08	7044.8	73.8	68	0.47	10/22/2018	13:44:15
16	Mn	2.00E-08	9188.9	50.4	64.8	0.35	10/22/2018	13:50:40

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UNK No. : 1 2 3 4 5 6 7

The followings are different from previous specimens

UNK No. : 8 9 10 11 12 13

14 15 16 17

The followings are different from previous specimens

UNK No. : 18 19 20 21 22 23

24 25 26 27 28

29 30 31 32 33 34

The followings are different from previous specimens

UNK No. : 35 36 37 38 39 40

41 42 43 44 45

46 47 48 49 50

Standard EPMA conditions for chromite analyses

Spot Size = 5 micrometers
Accel. Voltage = 15Kv
Probe Current = 20nA
Measurement Condition
WDS elements

	Element	X-ray	Crystal	CH	Acc.v	Peak Pos. (nm)	BG_L	BG_U	(mm)
1	Na	Ka	TAPH	1	15	130.208	1.19101	2.594	1.464
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3	Si	Ka	TAP	2	15	77.43	0.71254	2.723	1.73
4	Al	Ka	TAP	2	15	90.607	0.83393	2.385	1.331
5	Mg	Ka	TAP	2	15	107.44	0.989	2.641	1.187
6	Zn	Ka	LIFH	3	15	99.388	0.14352	1.275	1.131
7	Fe	Ka	LIFH	3	15	134.28	0.1936	1.104	1.228
8	Cl	Ka	PETH	3	15	150.955	0.47278	2.013	1.079
9	Cr	Ka	LIFH	3	15	158.909	0.22897	1.348	1.13
10	Ca	Ka	PETJ	4	15	107.368	0.33584	1.063	0.696
11	Ni	Ka	LIF	4	15	115.633	0.16579	1.349	1.055
12	P	Ka	PETJ	4	15	196.819	0.6157	0.65	0.887
13	Ti	Ka	PETL	5	15	87.134	0.27485	1.009	0.974
14	K	Ka	PETL	5	15	119.144	0.37414	1.055	0.684

15	Mn	Ka	LIFL	5	15	145.49	0.21018	1.07	1.117

	Element	Peak	Back	Pksk	Gain	High.V	Base.L	Window.W	Mode
1	Na	10	5.0 (s)	2	16	1622	0.7	0 (V)	Int
2	F	10	5.0 (s)	2	16	1622	0.7	0 (V)	Int
3	Si	10	5.0 (s)	1	8	1668	0.5	0 (V)	Int
4	Al	10	5.0 (s)	2	8	1668	0.5	0 (V)	Int
5	Mg	10	5.0 (s)	2	8	1668	0.5	0 (V)	Int
6	Zn	30	15.0 (s)	2	8	1772	1	9.0 (V)	Int
7	Fe	10	5.0 (s)	1	8	1772	1	0 (V)	Int
8	Cl	10	5.0 (s)	2	32	1686	1	0 (V)	Int
9	Cr	10	5.0 (s)	2	8	1772	1	0 (V)	Int
10	Ca	10	5.0 (s)	2	64	1620	0.7	0 (V)	Int
11	Ni	30	15.0 (s)	2	32	1642	0.7	0 (V)	Int
12	P	10	5.0 (s)	2	64	1620	0.7	0 (V)	Int
13	Ti	10	5.0 (s)	2	16	1754	0.4	9.3 (V)	Int
14	K	10	5.0 (s)	2	16	1754	0.4	9.3 (V)	Int
15	Mn	10	5.0 (s)	2	8	1754	0.4	9.6 (V)	Int

Measurement Order	Order	of	WDS			
Order	Channel	1	2	3	4	5
1	Na_1TAPH		Si_2TAP;_	Zn_3LIFH	Ca_4PETJ	Ti_CH5_P
2	F_1TAPH_		Al_2TAP_	Fe_3LIFH	Ni_4LIF_	K_5PETL_
3	0		Mg_2TAP_	Cl_3PETH	P_4PETJ_	Mn_5LI
4	0		0	Cr_3LIFH	0	0
Calc.	Elements :		O	(Anion)		

Standard Data

	Element	Standard	Mass(%)	ZAF Fac.	Z	A	F
1	Na2O	Anorthoclase	9.31	5.3131	10.7359	0.493	1.0038
2	F	CaF2	48.668	5.5587	22.0589	0.252	1
3	SiO2	Quartz	99.99	3.5148	4.3603	0.8061	1
4	Al2O3	Gahnite	55.32	3.2839	6.1449	0.5344	1
5	MgO	Olivine	49.42	4.7794	7.8823	0.6046	1.003
6	ZnO	Gahnite	42.5	0.0585	0.0588	0.9938	1
7	FeO	Magnetite	91.1215	0.2147	0.2175	0.987	1
8	Cl	Scapolite(Meionite)	1.43	1.6096	1.9854	0.8077	1.0038
9	Cr2O3	Chromite	60.5	0.361	0.3628	0.9799	1.0155
10	CaO	Fluor-Apatite	54.02	0.8863	0.9521	0.9308	1
11	NiO	Ni	127.2513	0.1257	0.1271	0.9886	1
12	P2O5	Fluor-Apatite	40.78	2.7803	3.4076	0.8119	1.005
13	TiO2	Rutile	100	0.5913	0.606	0.9757	1
14	K2O	MIcrocline	15.14	1.0691	1.202	0.8894	1
15	MnO	Mn	129.1098	0.3051	0.3104	0.9828	1

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Standard Intensity of WDS

	Element	Curr.(A)	Net(cps)	Bg-(cps)	Bg+(cps)	S.D.(%)	Date	
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3	Si	2.00E-08	17461.7	228.9	95.7	0.3	1/21/2019	10:33:37
4	Al	2.00E-08	7524.3	131	73.8	0.45	1/21/2019	10:58:57
5	Mg	2.00E-08	7124.1	81	74.9	0.46	10/22/2018	12:47:29
6	Zn	2.00E-08	3050.1	89.2	98.2	0.72	12/17/2018	16:17:28
7	Fe	2.00E-08	9050.5	73.3	97.7	0.38	1/24/2019	10:16:03
8	Cl	2.00E-08	567.5	17.4	15.7	1.3	10/22/2018	13:10:47
9	Cr	2.00E-08	4459.2	30.4	50.4	0.51	10/22/2018	13:17:15
10	Ca	2.00E-08	5258.2	47.6	44.3	0.5	1/24/2019	10:10:54
11	Ni	2.01E-08	3230.7	33.6	36.5	0.69	12/17/2018	16:22:26
12	P	2.00E-08	1224.1	13.9	10.6	0.97	10/22/2018	13:32:23
13	Ti	2.00E-08	34275.1	146.8	176.8	0.18	10/22/2018	13:39:06
14	K	2.00E-08	7044.8	73.8	68	0.47	10/22/2018	13:44:15
15	Mn	2.00E-08	9188.9	50.4	64.8	0.35	10/22/2018	13:50:40

UNK No. : 1

The followings are different from previous specimens

UNK No. : 2 3 4 5
The followings are different from previous specimens:

UNK No. : 6 7 8 9 10 11
12 13 14 15 16 17