CHEMICAL CHARACTERIZATION AND CHROMOPHORE ELEMENTS IN ELBAITES FROM BORBOREMA PROVINCE, BRAZIL

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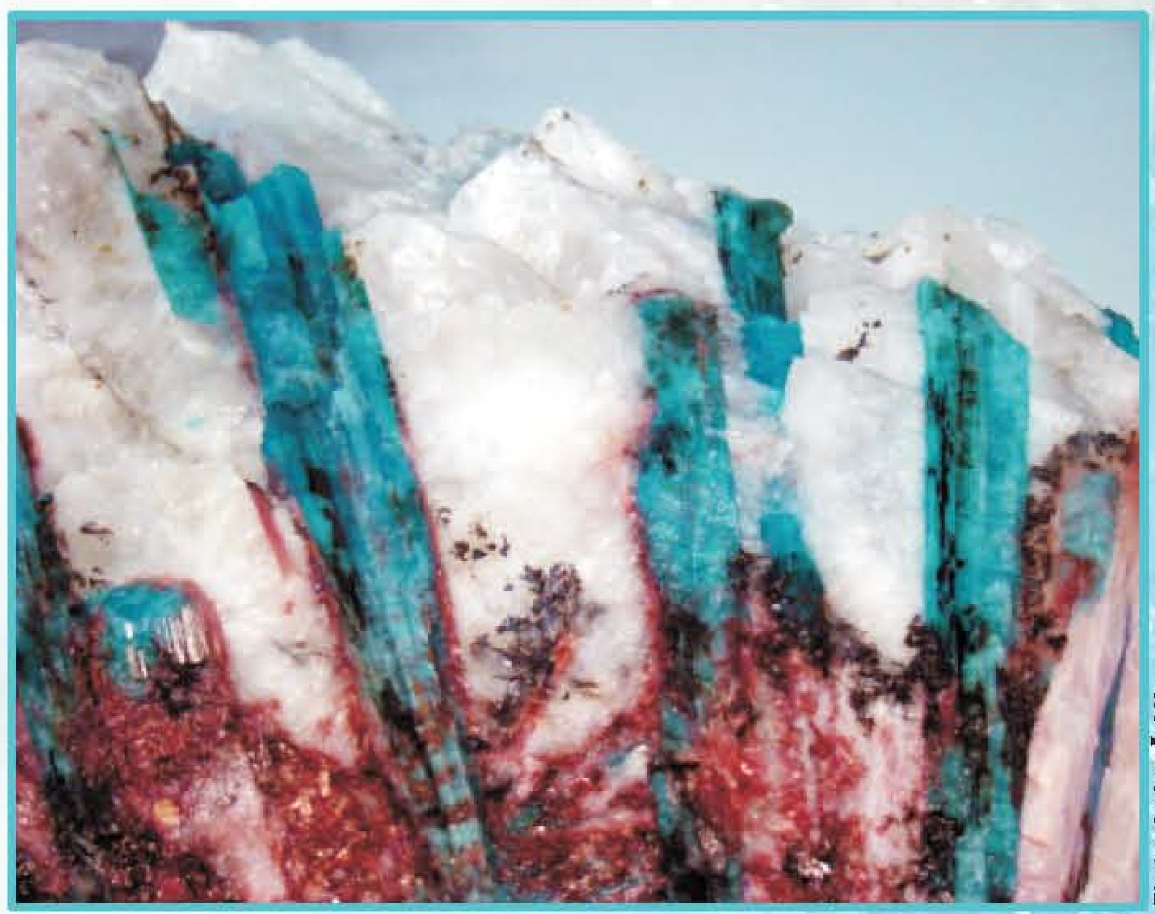
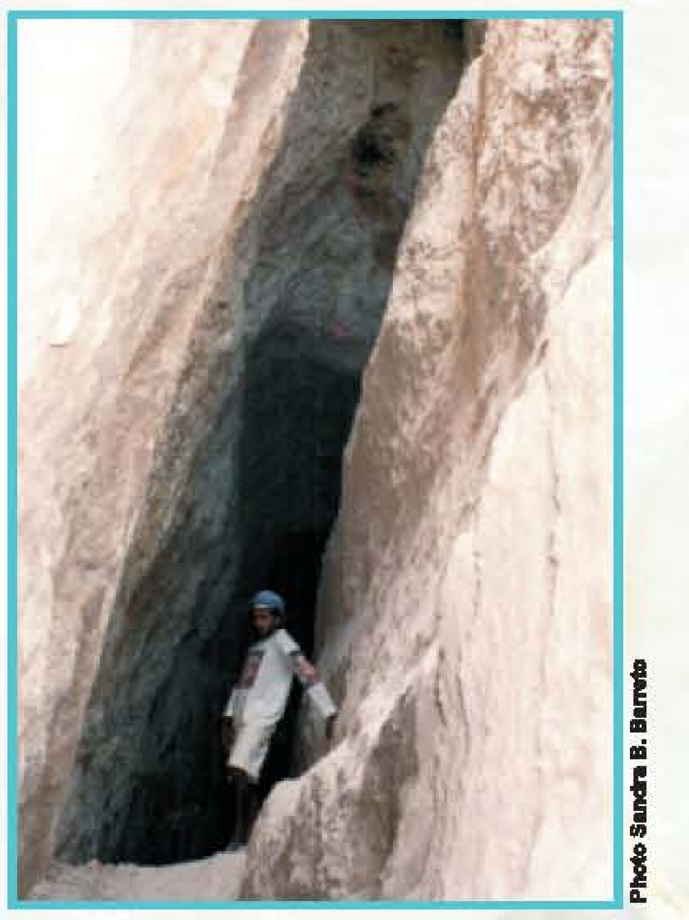


INTRODUCTION

Tourmalines from the northeast of Brazil (Borborema Pegmatite Province - BPP) have attracted attention of mineralogists and gemologists for their extraordinary characteristics, especially their color. The most appreciated are blue – colored, also known as "Paraiba" tourmalines.

The knowledge about the color of these tourmalines is not complete and the cause is always a controversy subject. Most of them are related to transition elements substitutions, such as Fe, Mn and Ti, occurring in different valence states incorporated in the Y site of the tourmaline structure.

On the other side, the models for color centers are based on optical absorption data and crystal theory, and in generally are assigned to electron-hole traps (Nassau 2001). In this work focus is on correlation of different colors of these tourmalines and possible chromophore elements.



EXPERIMENTAL

Samples

▶ Samples of differently colored tourmaline from BPP were used for this study - blue, green, pink and turquoise tourmaline .

Chemical composition

▶ ICP-MS, model Perkin Elmer Elan 6000 was used for analyses with previously analysed samples of tourmaline as internal tourmaline standards.

▶ Electron Microprobe, model CAMECA SX50 with 15nA/6kV for analyses of F and B, and with 30nA/25kV for Mn, Fe, Cu, Zn, Ca, Bi, Ti, Na, Si, Al, and Mg, employing tourmaline as standard, were used.

RESULTS and DISCUSSION

ICP-MS

ppm	blue PAD -16	green PAD -17	turquoise PAD -14	pink PAD -08
Na	19234 ± 457	15833 ± 1355	16184 ± 136	14089 ± 1496
Li	6305 ± 72	7094 ± 198	7218 ± 38	8028 ± 618
Ca	1305 ± 112	<660	<1381	2726 ± 1153
Mg	<125	599 ± 89	<287	<251
Mn	**12824 ± 101**	**4000 ± 86**	**15324 ± 1617**	**1925 ± 139**
Fe	**18265 ± 323**	**16671 ± 153**	**3094 ± 356**	**<45**
Ti	**<62**	**1454 ± 15**	**<138**	**<120**
Zn	**20018 ± 161**	**575 ± 42**	**543 ± 37**	**<194**
Ga	128 ± 0,4	163 ± 1	169 ± 0,01	121 ± 8
Sr	<5	<5	<5	6 ± 0,4
Bi	42 ± 0,4	318 ± 72	18 ± 1	<828
Sc	<5	<5	<5	7 ± 2
Ce	<1	<2	<2	2 ± 0,4
Nb	<1	6 ± 0,2	<1	4 ± 0,4
K	235 ± 21	1412 ± 118	249 ± 53	<169
Pb	<70	<70	<70	271 ± 14
Sn	31 ± 1	<30	<30	308 ± 27
U	<0,2	2 ± 0,03	<0,2	<0,2
Be	12 ± 0,1	19 ± 0,43	5 ± 0,15	14 ±
Cs	4 ± 0,01	0,7 ± 0,16	<5	1 ± 0,1
Rb	<2	8 ± 2	<2	<2
Ge	20 ± 0,5	3 ± 0,2	2 ±	13 ± 0,4
Cu	**25 ± 7**	**3914 ± 44**	**11310 ± 67**	**<44**

ICP - MS data show small, but significant variations in chemical composition for different colors correlated with several elements or even combinations of these elements (Fe, Mn, Cu and Ti).

Electron Microprobe

sample wt.% color	PAD-16 blue	C7A blue	C9A greenish blue	S6VA greenish blue	PAD-17 green	PAD-14 tourquoise	PAD-08 pink/red	B-11R pink/red
SiO_2	37.84	37.25	37.44	37.09	37.14	37.43	37.67	39.15
TiO_2	0.01	0.02	0.00	0.00	0.31	0.01	0.01	0.00
B_2O_3	12.56	14.64	9.54	12.13	14.04	14.19	14.95	15.61
Al_2O_3	37.00	35.62	38.60	40.62	39.43	38.79	42.98	40.71
B_2O_3	0.01	0.00	0.00	0.01	0.05	0.00	0.00	0.00
MgO	0.00	0.00	0.03	0.00	0.09	0.00	0.00	0.00
CaO	0.18	0.14	0.28	0.08	0.50	0.13	0.44	0.13
MnO	1.53	1.19	1.09	0.75	0.52	1.95	0.28	0.11
FeO	2.36	3.10	4.94	3.16	2.21	0.36	0.01	0.01
CuO	0.01	0.00	0.00	0.00	0.80	1.54	0.01	0.00
ZnO	2.47	2.71	0.07	0.11	0.09	0.07	0.00	0.00
Na_2O	2.45	2.38	2.29	2.00	1.51	1.88	1.17	1.22
H_2O	3.00	2.97	2.96	3.33	3.30	3.32	3.58	3.44
F	1.59	1.75	1.43	0.82	1.18	1.07	0.22	0.84
O=F	0.67	0.74	0.60	0.34	0.49	0.45	0.09	0.47
total	101.00	101.77	98.88	100.10	101.15	100.54	101.32	100.92

sample apfu color	PAD-16 blue	C7A blue	C9A greenish blue	S6VA greenish blue	PAD-17 green	PAD-14 tourquoise	PAD-08 pink/red	B-11R pink/red
Si	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Ti	0.001	0.000	0.000	0.000	0.038	0.001	0.001	0.000
B	3.438	4.071	2.394	3.387	3.915	3.927	4.111	4.103
Al	6.915	6.763	7.291	7.745	7.508	7.329	8.069	7.354
Bi	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000
Mg	0.000	0.000	0.007	0.000	0.022	0.000	0.000	0.000
Ca	0.031	0.024	0.048	0.014	0.087	0.022	0.075	0.021
Mn	0.205	0.162	0.148	0.103	0.071	0.265	0.038	0.014
Fe total	0.312	0.418	0.662	0.428	0.299	0.048	0.001	0.001
Cu	0.001	0.000	0.000	0.000	0.098	0.189	0.001	0.000
Zn	0.289	0.322	0.008	0.013	0.011	0.008	0.000	0.000
Na	0.753	0.743	0.712	0.627	0.473	0.522	0.361	0.363
F	0.797	0.891	0.725	0.420	0.593	0.542	0.111	0.310
H_2O	1.589	1.598	1.579	1.789	1.781	1.778	1.905	1.761
cations	18.742	19.394	17.995	18.737	19.117	18.863	18.768	18.166

*B_2O_3- value obtained by calculating stoichiometric. **H_2O – obtained value based on thermogravimetric and thermodiferencial analysis ATD-TG.

Formula calculations of tourmalines based on microprobe data

Blue Tourmaline

▶presence of significant concentration of **Fe**, **Zn**, **Mn**. Lower copper content and higher of **Zn**.

Green Tourmaline

▶important concentration of **Fe, Mn, Ti and Cu**.

Tourquoise Tourmaline

▶color is caracterized for the significant concentration of **Mn** and **Cu**.

Pink Tourmaline

▶presence of low concentration and almost absence of **Fe** and high concentrations of **Mn**.

▶The **blue coloration** could be a result of intervalence charge transfer connected to **Fe** content. Absence of correlation between **Fe** and **Ti** for all colors indicate that **Ti** has no influence in coloration in this tourmalines. Due to this, we can think that combination of homonuclear intervalence charge transfer **(Fe^{2+} - Fe^{3+})** combined with low **Cu** concentration produce the blue color.

▶Higher concentration of **Cu** change the color towards **green** and **tourquoise**.

▶The **pink/red color** seems connected with Mn content.

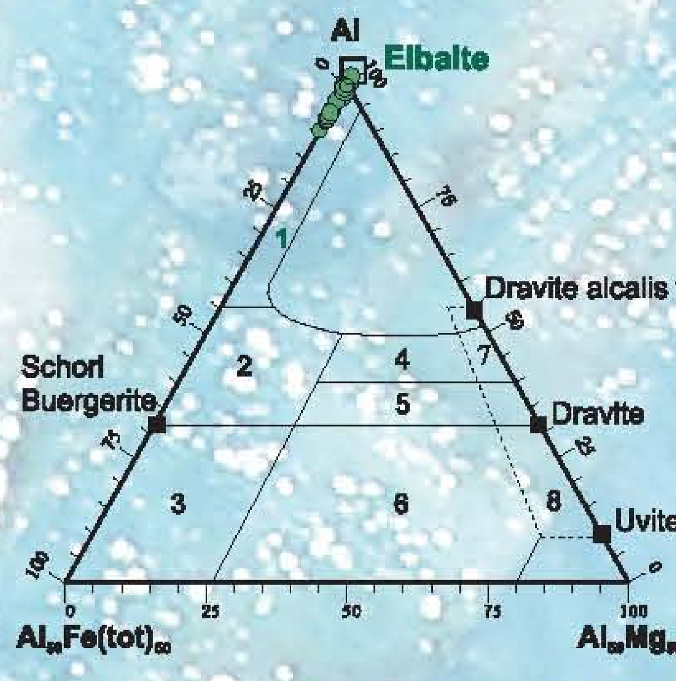


Diagram Al-$Fe_{(total)}$-Mg (molecular proportions) for tourmalines from different rock types with data from the analysis plotted. (1) granites and granitic pegmatites rich in Li and aplite (after Henry and Guidotti,1985).

REFERENCES

Henry, D.J. & Guidotti, C. V. (1985): Tourmaline as a petrogenetic indicator mineral: an example from the staurolite-grade metapelites of NW Maine. *American Mineralogist*, **70**, 1-15

Nassau, K. (2001): The physics and chemistry of colors. The fifteen causes of color. John Wiley & Sons, Inc. New York, 481 p.

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