Geology and mineralogy of tourmaline-bearing Mozambican pegmatites

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Minerals of the tourmaline supergroup are constituted by rhombohedral borosilicates with a *R*3*m* space group, and with the general formula $XY_3Z_6[T_6O_{18}](BO_3)_3V_3W$. Over the last decade, Mozambique has established itself as one of the most important producers of high-quality tourmalines in the world; those samples mainly occur in pegmatites of the Alto Ligonha region. A set of 69 tourmalines from that region were investigated with various techniques, including single-crystal X-ray structure refinements, electron-microprobe analyses, and Laser Ablation Inductively Coupled Plasma Time-Of-Flight Mass Spectrometry (LA-ICP-TOF-MS). Most of the samples were collected in Mozambique, in the Alto Ligonha Pegmatite Province (ALPP), from 14 pegmatites and one placer, ranging from well-known to newly discovered deposits. A detailed mapping of those pegmatites has been realized whenever possible, and the position of each sample in its respective deposit is accurately known.

The studied pegmatites are hosted within Mesoproterozoic medium- to high-grade gneisses and migmatites from the Nampula Complex. These rocks have been reworked during the Pan-African Orogenic Event and intruded by early Palaeozoic granitoids and pegmatites. Most economically viable pegmatites of this region are dated between 481 and 440 My (Bettencourt Dias and Wilson, 2000) and they belong to the LCT family, with sometimes NYF family affinities. Complex zonations have been observed in the most evolved bodies, and like most pegmatites in the Alto Ligonha Pegmatitic Field, a major part of the studied pegmatites suffered from intense hydrothermal-metasomatic alteration and weathering, leading to a deep kaolinization of the original paragenesis. Most important pegmatites such as Muiane reach up to 1600 m in length. They are mainly operated for Nb-Ta oxides, lithium minerals (mainly lepidolite and spodumene) and gem-graded mineral species such as tourmalines, beryls or quartz.

A detailed cation distribution has been established on each tourmaline studied, showing that the B site is fully occupied by boron, and that the T site is mainly occupied by Si and sometimes by minor amounts of B. Most samples are Na-dominant on the X site and therefore belong to the alkali group. The vacant group is also represented in some samples, whereas only one tourmaline sees X sites dominated by Ca^{2+}. Fluorine is the dominant anion on the W site in most of the crystals except for two of them, which then belong to the hydroxy-series. Most of the samples are (fluor-) elbaites, where similar proportions of Al^{3+} and Li^{+} are sharing the Y positions. But strong Fe^{2+}, Mg^{2+} and $Mn^{2+,3+}$ components have been observed in some of these fluor-elbaites. Fluor-schorls and fluor-dravites are also represented, in small proportions among, the sampling. Three samples do not reach the six Al^{3+} atoms per formula unit (*apfu*) required to fill the Z sites and are currently under investigation.

For most samples, these compositions are consistent with the single-crystal data, which indicate *a* unit-cell parameters varying between 15.8647 and 15.9503 Å, and *c* parameters ranging from 7.107 to 7.1545 Å. These values are similar to those obtained for Brazilian tourmalines of the fluor-elbaite to fluor-schorl solid solution (Bomal et al., 2025). However, five crystals from the Marinia pegmatite display very high unit-cell parameters values ($15.9909 < a < 16.0474$ Å; $7.2058 < c < 7.2338$ Å), which could be explained by the presence of Mn^{3+} in the structure. Similar parameters and Mn-enrichment have been observed in one tourmaline extracted from the well-known Mavuco placer, located close to the Marinia pegmatite, and hosting the only copper-bearing Paraiba-like tourmalines found in Mozambique. Further investigations are currently ongoing to determine the primary origin of this sample.

Finally, the trace element contents, including REE, are discussed in detail, and appear to be influenced by both the geochemical pegmatitic context, and by crystal-chemical constraints. Analysis revealed the presence of non-negligeable Zn, Ti and Pb components in multiple samples. A copper enrichment has been detected in one tourmaline from the Mavuco secondary deposit. The same crystal also displays a unique rare-earth element (REE) fingerprint, with the presence of small concentrations of both light, medium, and heavy elements in the sample. Different trace element (including REEs) profiles have been

identified among the samples and are discussed. Trace element fingerprints are also compared to those obtained for Brazilian tourmalines from the Eastern Brazilian Pegmatite Province, Minas Gerais, Brazil.

References

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