Mineralogical and geochemical characterization of tourmaline from Tres Arroyos (Badajoz)

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INTRODUCTION

The Tres Arroyos (TA) granite-pegmatite system is located to the south of the Central-Iberian-Zone of the Variscan orogen. This area occurs to the southwest of the easternmost part of the Nisa-Alburquerque (NA) batholith. The main facies of the NA batholith corresponds to a peraluminous monzogranite, with minor two-mica leucogranitic facies (González-Menéndez, 1998). In the TA area the batholith exhibits a marginal facies (Gallego-Garrido, 1992) characterized by a finer grain size, a higher abundance of tourmaline and certain enrichment in F, Li and Fe in the muscovite. Three types of aplopegmatites are distinguished in the TA field, the most fractionated being highly enriched in Li and F.

Tourmaline appears frequently as an accessory phase in granitic rocks. The occurrence of tourmaline crystals indicates the presence of B in the system, but there is no agreement in the boron concentration needed to saturate a melt with respect to tourmaline (Pesquera et al., 2013). Some pegmatitic systems are poor in Fe and Mg, and so crystallization of black tourmaline is quite restricted, usually to the less evolved facies. Moreover, it is relatively common that the hosting rock of pegmatites has suffered a more or less intense tourmalinization. Tourmaline is stable over a wide range of P-T-X space, and its composition reflects the bulk chemistry of the system, as well as the crystallization conditions. For those reasons tourmaline from TA has been studied.

PETROGRAPHY

Tourmaline has been only found in three of the five facies described in the TA area. In the monzogranite this borosilicate occurs as an accessory phase, whereas in the marginal granitic facies it is more abundant, but not enough to be considered a main mineral. In the barren aplopegmatites tourmaline is also a common accessory phase. In addition, the metasediments hosting the aplopegmatites exhibit an important tourmalinization in the proximities of the bodies.

RESULTS AND DISCUSSION

Tourmaline Classification and Chemical Composition

According to textural features, four petrographic types of tourmaline have been distinguished in TA: (1) in the monzogranite tourmaline may occur as isolated, small, black, anhedral grains (<1 mm). It is clearly a late phase and, hence, its shape depends on the interstitial space between feldspar, micas and quartz crystals; (2) tourmaline crystals with euhedral to subhedral prismatic habit, homogeneously distributed in the marginal granitic facies and barren aplopegmatites. The crystal size is variable from 1 up to 5 mm. It is common to observe a chromatic zonation under the microscope, with a marked pleochroism from orange to yellow in the core, and to greenish in the rims; (3) poikilitic tourmaline crystals with numerous quartz inclusions (< 100 µm) are also observed in the barren aplopegmatites; and, (4) very fine (< 0.5 mm) tourmaline prisms formed by the tourmalinization of the host rock due to metasomatic processes related to the activity of a B-rich hot fluid exsolved from the pegmatitic melt. Crystals appear mainly as parallel oriented euhedral prisms, the orientation most probably inherited from the replaced biotite crystals present in the hosting mica-schists.
moderate. Values vary in the ranges: SiO$_2$ (33.16-36.48 wt.%), TiO$_2$ (0.04-1.75 wt.%), Al$_2$O$_3$ (31.79-36.66 wt.%), FeO (7.48-15.60 wt.%), MgO (0.05-4.95 wt.%), CaO (0-0.19 wt.%), Na$_2$O (1.28-2.47 wt.%), and F (0.07-0.81 wt.%). In TA there is a significant increase in the Fe/(Fe+Mg) ratio from the monzogranite, through the marginal granitic facies up to the barren aplegmatites (0.631-0.622, 0.796-0.973 and 0.945-0.994, respectively), indicating the increasing degree of fractionation from the monzogranite to the aplegmatites. Tourmaline from the metasediments is the Al-poorest one, followed by that from the monzogranite, with the highest Al-contents observed in tourmaline form the marginal granitic facies and the barren aplegmatites. Regarding Li variability, tourmaline from the hosting metasediments and from the monzogranite is clearly poorer in this element than that of the marginal leucogranite and the aplegmatites. The highest Na contents (at X site) are presented by tourmaline from the barren aplegmatites. Assuming that the marginal granitic facies crystallized at a lower temperature than the monzogranite, it could be expected that tourmaline from the former was Na-richer than that from the latter. However, values are just the opposite. In this case, the lower Na-content in tourmaline from the marginal granitic facies could be related to a higher H$_2$O concentration in the melt in comparison to the monzogranite, as H$_2$O-rich systems favour alkali-defect substitution (Gallagher, 1988).

Tourmaline proportion decreases from the marginal granite to the barren aplegmatites, where this mineral coexists with Fe-Mn phosphates. Actually, this decrease could be related to the increase in the P concentration in the barren aplegmatites (P$_2$O$_5$ wt.% mean bulk concentration for monzogranite, marginal granitic facies and barren aplegmatites are 0.33-0.48; 0.6-1.04; and 1.17 respectively), as the stability of tourmaline is lower when P content increases (Wolf and London, 1994).

**Substitution mechanisms**

The controlling substitutions in tourmaline during the crystallization are variable. The dravite-schorl substitution (Mg,Fe) has certain influence only during the first stages of fractionation, thus, mainly for tourmaline associated with the less fractionated granitic facies. The chemical evolution of tourmaline from the marginal granitic facies was strongly influenced by the schorl-foidite exchange mechanism (alkali-defect: $\text{Al}[\text{X}]\text{Fe}^{2+}I_{\text{Na},2}$. In contrast, tourmaline from the barren aplegmatites follows a different evolutionary trend, with a lower influence of this exchange vector, and a clear control of the schorl-olivenite exchange mechanism (proton-loss: $\text{Al}_{5}\text{O}({\text{R}}^{2+},\text{OH})_{2}$), with a higher Al-increase in the tourmaline structure. Lithium was most probably included in the tourmaline structure of the Li-richest tourmalines from both the marginal granitic facies and the barren aplegmatites via the schorl-elbaite substitution vector ($\text{Al}[\text{L}]\text{Fe}^{2+}I_{\text{Fe}^{2+},2}$).

**CONCLUSIONS**

The salient points of this work can be summarized as follows:

- Most of the analysed tourmaline from the TA area plots in the alkali group. The majority corresponds to the schorl term.
- The Fe/(Fe+Mg) ratio may be used as a petrogenetic indicator, with a gradual increase from the monzogranite, through the marginal granitic facies, up to the barren aplegmatites which is in agreement with a continuous increase in the fractionation degree.
- An increase in the phosphorous bulk-rock content in the barren aplegmatites in comparison to the marginal granite may be related to the decrease in the tourmaline concentration in the former, as P may destabilize tourmaline.
- The dravite-schorl exchange vector has a higher influence during the first stages of fractionation, in the granitic facies, together with the alkali-defect; whereas later, during the crystallization of tourmaline from the barren aplegmatites, the proton-loos substitution had a stronger influence.

**REFERENCIAS**


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