

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.

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.

RESULTS AND DISCUSSION

Tourmaline Classification and Chemical Composition

According to the nomenclature proposed by Henry et al. (2011) most of the tourmaline crystals from the TA granite-pegmatite system are classified as alkaline tourmaline. Only some crystals from the marginal granitic facies are rich in vacancies in the X-site. The $\text{vac(X)}/(\text{vac(X)+Na})$ and $\text{Mg}/(\text{Mg+Fe})$ ratios vary in a moderate range, clearly in relation to the associated facies: metasediments 0.26-0.35 and 0.44-0.54; monzogranite 0.27-0.31 and 0.37-0.38; marginal granitic facies 0.29-0.58 and 0.03-0.2; barren aplopegmatites 0.19-0.30 and 0.01-0.06, respectively. Taking into account the chemical variations, most of the analyzed tourmaline belongs to the schorl-dravite and schorl-foitite solid-solutions.

The chemical variations of tourmaline associated with granitic facies as well as barren aplopegmatites are low to

moderate. Values vary in the ranges: SiO₂ (33.16- 36.48 wt.%), TiO₂ (0.04-1.75 wt.%), Al₂O₃ (31.79-36.66 wt.%), FeO (7.48-15.60 wt.%), MgO (0.05-4.95 wt.%), CaO (0-0.19 wt.%) Na₂O (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 aplopegmatites (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 aplopegmatites. Tourmaline from the metasediments is the Al-poorest one, followed by that from the monzogranite, with the highest Al-contents observed in tourmaline from the marginal granitic facies and the barren aplopegmatites. 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 aplopegmatites. The highest Na contents (at X site) are presented by tourmaline from the barren aplopegmatites. 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 H₂O concentration in the melt in comparison to the monzogranite, as H₂O-rich systems favour alkali-defect substitution (Gallagher, 1988).

Tourmaline proportion decreases from the marginal granite to the barren aplopegmatites, where this mineral coexists with Fe-Mn phosphates. Actually, this decrease could be related to the increase in the P concentration in the barren aplopegmatites (P₂O₅ wt.% mean bulk concentration for monzogranite, marginal granitic facies and barren aplopegmatites 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 (Mg₁Fe) 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-foitite exchange mechanism (alkali-defect: ^YAl[X]Fe²⁺₋₁ ^XNa₋₁). In contrast, tourmaline from the barren aplopegmatites follows a different evolutionary trend, with a lower influence of this exchange vector, and a clear control of the schorl-olenite exchange mechanism (proton-loss: ^YAlO(R²⁺₋₁OH₋₁), with a higher Al-increase in the tourmaline structure. Lithium was most probably included in the tourmaline structure of the Li-richer tourmalines from both the marginal granitic facies and the barren aplopegmatites via the schorl-elbaite substitution vector (^YAl^YLi^YFe²⁺₋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 aplopegmatites which is in agreement with a continuous increase in the fractionation degree
- An increase in the phosphorous bulk-rock content in the barren aplopegmatites 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 aplopegmatites, the proton-loss substitution had a stronger influence.

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