Sensibility of Tourmaline Chemistry to Granitic Magma Composition and Oxygen Fugacity

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Abstract

Extensive granitic magmatism is a dominant feature of the Central Iberian Zone (CIZ) of the Variscan Orogen. For the most part, these are S-type peraluminous granitic rocks exhibiting variable degrees of evolution and compositions ranging from granodiorites, through monzogranites and granites to leucogranites, bearing either biotite and muscovite, or just muscovite in the more evolved facies. Tourmaline is a common and essential accessory mineral in many of these peraluminous granitic rocks. Several granite-hosted tourmaline sets from the Castelo Branco, Idanha-a-Nova and Penamacor-Monsanto plutons were used to investigate how tourmaline chemistry reflects granitic magma composition and oxygen fugacity. Additionally, previously published data on tourmalines and their host-granites from Rebordelo (CIZ, Portugal) and the Alamo Complex and several Araya-type granitic batholiths (CIZ, Spain) were used to test the trends obtained. Most tourmaline components and component ratios, however, seem substantially impervious to granitic magma composition and oxygen fugacity. Exceptions are the Mg/(Mg + Fe) ratio and Ti contents of tourmaline, which show evident variation with the degree of evolution and oxygen fugacity of host granitic rocks. From both mineralogical and petrological point of view, it seems of interest that these compositional features of tourmaline may be used as indicators of the degree of evolution and of specific characteristics of the granitic magmas that produced them.

Keywords

Tourmaline • Granitic rocks • Central Iberian Zone

1 Introduction

Most peraluminous granitic rocks contain accessory tourmaline, besides micas. Tourmaline is stable over a sizeable P–T range and can accommodate a wide variety of primary and trace elements.

We have investigated how the degree of evolution of granitic magmas and their oxygen fugacity affect the composition of granite-hosted tourmalines using relevant components of tourmalines and bulk-rock parameters (e.g. MgO/(MgO + FeOT), $Fe_2O_3/(FeO + Fe_2O_3)$, Rb/Ba ratio, P_2O_5 content and ASI index) from several granitic facies of the Castelo Branco (Antunes 2006; Martins et al. 2015), Idanha-a-Nova (Antunes 2006; Martins et al. 2015) and Penamacor-Monsanto (Costa et al. 2014) plutons. The trends obtained were tested with average compositions of tourmalines from other Variscan granitic rocks, namely from the Rebordelo pluton (CIZ, Portugal) (Neiva et al. 2007), from the Alamo Complex leucogranites and several Araya-type monzogranitic batholiths (CIZ, Spain) (Pesquera et al. 2013, 2005) (details in the legend of Fig. 1).

These previous studies have underlined the importance of tourmaline in the characterisation of Variscan granitic magmas.

2 Geological Setting and Analytical Methods

The Castelo Branco (Antunes 2006), Idanha-a-Nova (Antunes Mineralogia 2006) and Penamacor-Monsanto (Costa et al. 2014) granitic plutons intrude the ante-Ordovician Schist-Greywacke Complex (SGC), in the southern sector of the Central Iberian Zone (CIZ) of the Variscan orogenic belt.

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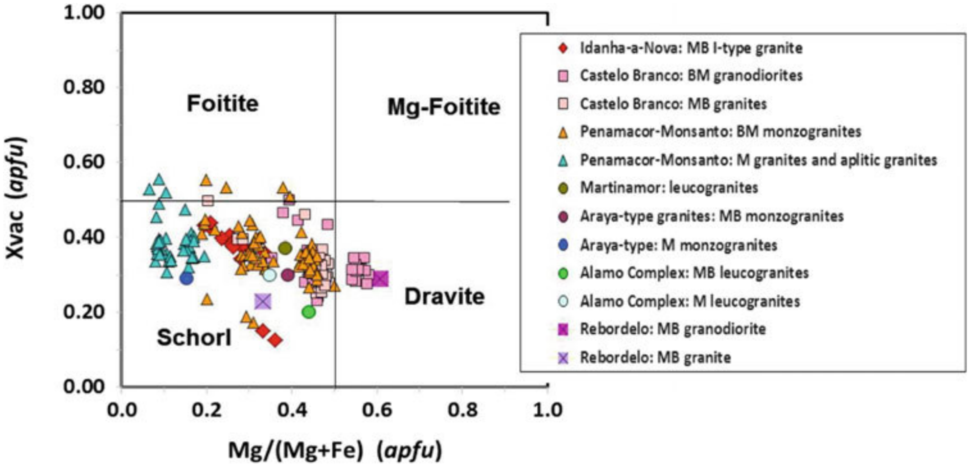

Fig. 1 Xvac versus Mg/(Mg + Fe) diagram for tourmaline classification. (M—muscovite, B—biotite, in granite facies designations)

Bulk-rock geochemistry for the Castelo Branco and Idanha-a-Nova granites (6 samples) was obtained by X-ray fluorescence at the Southampton Oceanographic Centre (UK); Fe titration was carried out at the Departamento de Ciências da Terra, Universidade de Coimbra (Portugal).

Whole-rock data for the Penamacor-Monsanto tourmaline-bearing granites (13 samples) were determined at ACTLABS (Canada), by Fusion-ICP-MS, INAA-Neutron Activation Analysis (REE), Fusion-ISE (F) and titration (ferrous iron).

Penamacor-Monsanto tourmalines were analysed on a JEOL JXA-8500 electron microprobe, at LNEG—Laboratório Nacional de Energia e Geologia (S. Mamede de Infesta, Portugal), under the following analytical conditions: 3–5 mm beam diameter, 15 kV accelerating voltage and counting times of the 20 s and 10 s for peak and background readings. Standards used were: orthoclase (Si, Al, K), albite (Na), apatite (Ca), MgO (Mg), Fe_2O_3 (Fe), Mn-standard (Mn), TiO_2 (Ti), Cr_2O_3 (Cr) and vanadinite (V). ZAF corrections were applied. The analytical error was £1% for the elements analysed.

Tourmalines from Idanha-a-Nova and Castelo Branco granitic rocks were analysed with a JEOL JXA-8200 electron microprobe, at the Departamento de Geologia, Faculdade de Ciências (ULisboa) under similar analytical conditions. Structural formulae of tourmalines were normalised for 15 (T + Z + Y) cations (Costa et al. 2014).

3 Results

Most granite-hosted tourmalines investigated occur as isolated grains, often showing some primary concentric zonation, and correspond to schorl compositions, only a few overlapping onto the dravite and foitite fields (Fig. 1).

4 Discussion

Although most tourmaline compositional variations seem unrelated to the degree of evolution of the studied granitic sets, components such as Ti and the Mg/(Mg + Fe) ratio definitely correlate with several parameters which are commonly considered good indicators of magmatic evolution, such as the MgO/(MgO + FeO^T) ratio (Fig. 2a, b, the Rb/Ba ratio, the P_2O_5 (Fig. 2c) and REE contents and the peraluminosity index (ASI = $[Al_2O_3]/([CaO] + [Na_2O] + [K_2O])$.

On the other hand, the Mg/(Mg + Fe) ratios in tourmaline tend to decrease with increasing oxygen fugacity in the granitic magma, indicated by the $Fe_2O_3/(FeO + Fe_2O_3)$ ratios of the granitic rocks (Fig. 2d).

5 Conclusions

Notwithstanding the relatively wide compositional range that tourmalines exhibit within each granitic facies, their Mg/(Mg + Fe) ratios and Ti contents correlate to geochemical features indicative of the degree of evolution of the host granitic magmas, such as their bulk MgO/(MgO + FeO^T) and Rb/Ba ratios, P_2O_5 contents and ASI index.

Oxygen fugacity in granitic magmas also affects the Mg/(Mg + Fe) ratio in tourmalines, which tends to decrease in more evolved granitic rocks, with typically higher Fe oxidation ratios.

Tourmalines from the I-type Idanha-a-Nova granite comply with the correlations found for S-type granite-hosted tourmaline sets, implying that magma composition, rather than genetic processes, is the main factor controlling tourmaline composition.

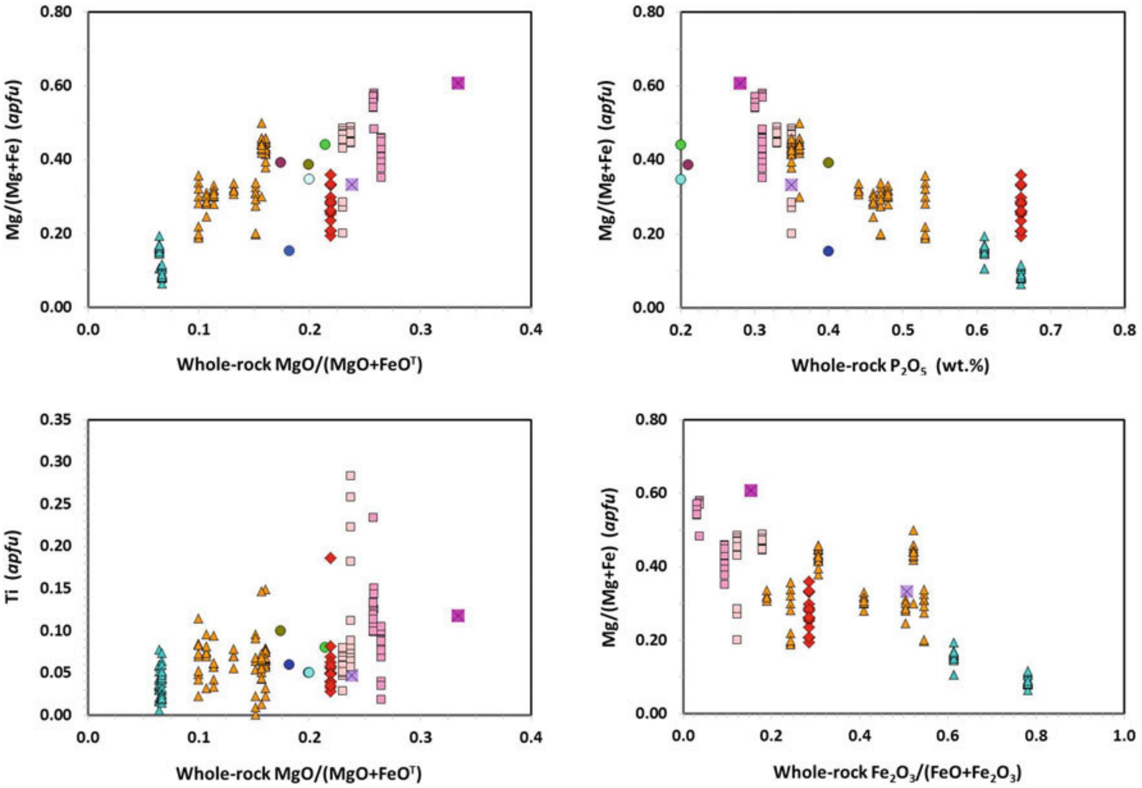

Fig. 2 Diagrams showing positive correlations between (A) Mg/(Mg + Fe) ratios and (B) Ti contents in tourmalines and host-rock MgO/(MgO + FeO^T) ratios, and negative correlations between Mg/(Mg + Fe) ratios in tourmalines and (C) P_2O_5 contents and (D) Fe_2O_3/(FeO + Fe_2O_3) ratios of host granitic rocks. (Graphic markers as in Fig. 1)

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