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Transition metals responsible for striking colour variation in tourmalines: an EMP study of tourmalines from granites and quartz-tourmaline rocks associated to the Penamacor-Monsanto pluton (Eastern Central Portugal)

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The late-Hercynian Penamacor-Monsanto granite pluton (Eastern Central Portugal), intrusive into a massive metapelitic sequence, including tourmaline-bearing granite facies, and is also associated to several occurrences of quartz (+ mica) -tourmaline rocks along the narrow contact zone. Detailed petrographic and textural study of the latter rocks suggests that some may have formed by direct precipitation of tourmaline (+ quartz + mica) from B-rich late-magmatic fluids, while others may result from metasomatic replacement of biotite-rich regional rocks close to the granite margins.

A very striking feature of all these tourmalines is their colour variety, sometimes even in tourmalines from the same location. In order to detect the likely causes for such colour variation, we have carried out an electron microprobe study, using tourmalines from granites and from the different kinds of quartz-tourmaline rocks.

Granite tourmalines exhibit strong pleochroism in brown colours (often very similar to those of biotite) or bluish-brown/bluish-green shades, show the highest Fe/(Fe+Mg) ratios (> 0.65), relatively wide ranges of Ti (0 – 0.10 a.p.f.u.) and Mn (0.003 – 0.023 a.p.f.u.) and low Cr contents (< 0.005 a.p.f.u.).

At the other extreme, sky-blue tourmalines from newly-formed quartz-tourmaline rocks, also showing relatively high Fe/(Fe+Mg) ratios (0.6 – 0.7), stand out by their high Mn contents (0.008 – 0.030 a.p.f.u.), lack of Ti and a moderately variable Cr contents (0.004 – 0.010 a.p.f.u.).

Tourmalines from fine-grained quartz-tourmaline banded rocks, which seem likely to have resulted from biotite replacement in regional phyllites, exhibit strong colour variation from sample to sample: brown, very pleochroic and are the most common tourmaline. However, a few of these tourmalines have a distinct greenish hue and one sample exhibits abundant yellow but are not very pleochroic. Fe/(Fe+Mg) ratios are quite variable in brown tourmalines (0.35 – 0.75), more restricted in greenish tourmalines (0.40 – 0.45) and much lower in the yellow tourmalines (0 – 0.40); Ti contents, though also variable, are usually highest in the brown and yellow varieties (0.02 – 0.20 a.p.f.u., and 0.06 – 0.11 a.p.f.u., respectively), and much lower in the greenish tourmalines (< 0.05 a.p.f.u.); Mn contents in these differently coloured tourmalines are invariably lower than 0.010 a.p.f.u., but they overlap in a wide range; Cr contents, on the other hand, seem more discriminative, with yellow tourmalines exhibiting by far the highest Cr contents (> 0.010 a.p.f.u.), and greenish varieties showing slightly higher Cr contents (0.005 – 0.010 a.p.f.u.) than brown varieties (0 – 0.010 a.p.f.u.). Vanadium was also analysed in these tourmalines, but no significant correlation was found between Cr contents and specific tourmaline colour.

We conclude that brown tourmalines usually exhibit high Fe/(Fe+Mg) ratios and highest Ti contents; greenish varieties, with somewhat lower Fe/(Fe+Mg) ratios and Ti contents, tend to have nonetheless slightly higher Cr contents, which reach maximum values in Fe-depleted yellow varieties. While the referred features may be perceived as a gradation according to specific local variations, probably related to regional rock compositions, blue tourmalines, characterized by high Mn contents and no Ti whatsoever, hint at distinct genetic processes.