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Tourmaline of the elbaite-schorl series from the Himalaya Mine, Mesa Grande, California: A detailed investigation

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ABSTRACT

Chemical, structural, infrared, optical, and Mössbauer spectroscopic data were obtained on tourmalines from gem pockets in the Himalaya mine, San Diego County, California, including a strongly color-zoned crystal. Calcium and Li abundances increase from core to rim, whereas Mn^{2+} and F increase, reach a maximum, and then decrease. Upon initiation of crystallization of lepidolite, F contents in tourmaline decrease. The black core is a Mn-bearing "oxy-schorl." The grayish-yellow, intermediate zone is Mn-rich "fluor-elbaite" that contains a relatively high Mn content with ~6 wt% MnO. The nearly colorless "fluor-elbaite" rim has the highest Li content of all zones. There is an inverse correlation between the lattice parameter *a* (for values ≥15.84 Å) and the Li content (r^2 = 0.96). Mössbauer studies from the different zones within this crystal show that the Fe^{3+}/Fe(total) ratio increases continuously from the Fe-rich core to the Fe-poor near-rim zone, consistent with increasing oxygen fugacity during pegmatite pocket evolution. There is a high positive correlation between lattice parameter *a* (for values ≥15.84 Å) and (Fe^{2+}+Mn^{2+}) content in tourmalines from the elbaite-schorl series (r^2 = 0.99). Values lower than 15.84 Å for *a* are likely a consequence of greater $^{[4]}$B contents in samples that usually have a (Fe^{2+}+Mn^{2+}) content of <0.1 apfu. Positive correlations between Al at the Y site and $^{[4]}$B (r^2 = 0.93), and between (Mn^{2+}+Fe^{2+}) and $^{[4]}$Al (r^2 = 0.99) were found in tourmalines from the Himalaya Mine. These correlations indicate that, in the short-range order configurations, ^{Y}Al is coupled with $^{[4]}$B, whereas Mn^{2+} and Fe^{2+} are coupled with $^{[4]}$Al.

To obtain the most accurate OH data, different analytical methods were used: SIMS, hydrogen manometry, continuous-flow mass spectrometry, and IR overtone spectroscopy. Some elbaites contain a mixed occupation of F, OH, and O at the W site. Based on these data, the assumption OH = 4 – F appears to be valid only for elbaitic tourmalines with FeO+MnO < 8 wt%.

In terms of the conditions of formation, whether gel or glass, the transition from low to high viscosity of the pocket-forming medium occurs before primary crystallization within the pockets ceased. At the pocket stage, Li contents of residual hydrosilicate melt were evidently high enough to promote a continuous transition from schorl-foitite at the pegmatite margin to elbaite-rossmanite-liddicoatite in the final stages of consolidation of the pegmatite interior.

Keywords: Tourmaline, elbaite, schorl, crystal structure, Himalaya Mine, Mesa Grande, spectroscopy