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 $\geq 15.84$ 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 positive correlation between lattice parameter $a$ (for values $\geq 15.84$ Å) and (Fe$^{3+}$+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 $[B]$ contents in samples that usually have a (Fe$^{3+}$+Mn$^{2+}$) content of $<0.1$ apfu. Positive correlations between Al at the Y site and $[B]$ ($r^2 = 0.93$), and between (Mn$^{2+}$+Fe$^{3+}$) and $[Al]$ ($r^2 = 0.99$) were found in tourmalines from the Himalaya Mine. These correlations indicate that, in the short-range order configurations, $[Al]$ is coupled with $[B]$, whereas Mn$^{2+}$ and Fe$^{3+}$ are coupled with $[Al]$.

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 elbaite 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

INTRODUCTION

The Himalaya Mine has been the most productive tourmaline mine for gem and specimen-grade elbaite in North America. The mine, famous for multi-colored elbaite, is found in a miarolitic boron-enriched LCT-type granitic pegmatite in a norite country rock (Fisher et al. 1998, 1999). K/Ar and $^{40}$Ar/$^{39}$Ar ages, determined on muscovite, lepidolite, and biotite, are in the range of ~98–93 Ma (Foord 1976; Snee and Foord 1991; Fisher et al. 1998, 1999). Mining operations on the Himalaya dike system began at the Himalaya claim in 1898. In 1899, tourmaline was discovered on the San Diego property, and in 1904, the San Diego Tourmaline Mining Company was organized to work the deposits (Foord 1977). In addition to tourmaline, quartz, feldspar (oligoclase-albite, microcline, and orthoclase), lepidolite, muscovite, schorl, and spessartine are also common. Foord (1977) and Fisher et al. (1998) further described beryl, fluorapatite, manganocolumbite-manganotantalite, stibiocolumbite-stibiotantalite, microlite (sometimes uranium-bearing), and gahnite...