

Mineral chemistry of Ti-rich biotite from pegmatite and metapelitic granulites of the Kerala Khondalite Belt (southeast India): Petrology and further insight into titanium substitutions

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ABSTRACT

Precise chemical composition, including Fe³⁺ and H, of biotite from a pegmatite dike and its host granulite from the Kerala Khondalite Belt of SE India has been determined using a multi-technique approach involving EMP, SIMS, Mössbauer, and C-H-N elemental analysis. Biotite in these rocks formed at $T > 800\text{--}850\text{ }^{\circ}\text{C}$ and $P = 5 \pm 1\text{ kbar}$.

The full analyses were normalized on the basis of $[\text{O}_{12-(x+y+z)}(\text{OH})_x\text{Cl}_y\text{F}_z]$. Biotite in the pegmatite is Ti-, F-, and Cl-rich (0.33, 0.46, and 0.16 apfu, respectively), H₂O-poor (OH = 0.86 pfu), has $X_{\text{Mg}} = 0.49$ and $\text{Fe}^{3+}/\text{Fe}_{\text{tot}} \leq 3\%$. The low octahedral vacancies (0.06 pfu) and the high oxygen content in the hydroxyl site (OH + F + Cl = 1.49 pfu) confirm the role of the Ti-oxy substitution as a major exchange vector in these high- T biotites.

In the host granulite, fine-grained biotite is Fe³⁺-free, has low Cl (0.03 apfu), and more variable composition, with Ti, F, and X_{Mg} in the ranges 0.26–0.36, 0.52–0.67, and 0.67–0.77, respectively. The number of octahedral vacancies is relatively large (0.10–0.18 pfu) and the sum of volatiles (OH + F + Cl) varies from 1.71 to 2.06 pfu. Systematic variations of X_{Mg} are a function of the microstructural position and are in agreement with retrograde exchange reactions: biotite included in or in contact with garnet has the maximum values, whereas crystals in the matrix have the minima. Titanium has systematic negative correlations with F, X_{Mg} , and (OH + F + Cl), whereas Al and octahedral vacancies are virtually constant.

These trends indicate that the Ti-vacancy, along with substitutions involving Al, cannot explain the observed short-scale variations. Conversely, the Ti-oxy exchange appears to be active, resulting from combination of two vectors: the more conventional hydroxylation $\text{Ti}^{4+} + 2\text{O}^{2-} = (\text{Fe,Mg})^{2+} + 2\text{OH}^-$ and the “fluorination” $\text{Ti}^{4+} + 2\text{O}^{2-} = (\text{Fe,Mg})^{2+} + 2\text{F}^-$. The systematic retrograde redistribution involves not only Fe and Mg as commonly observed, but also Ti, F, and H, in a way such to eliminate the primary Ti-oxy component of biotite.

Keywords: Biotite, crystal-chemistry, granulite, pegmatite, retrograde diffusion, titanium