

## 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 Fe<sup>3+</sup> 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), H<sub>2</sub>O-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 Fe<sup>3+</sup>-free, has low Cl (0.03 apfu), and more variable composition, with Ti, F, and  $X_{\text{Mg}}$  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  $X_{\text{Mg}}$  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,  $X_{\text{Mg}}$ , 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  $\text{Ti}^{4+} + 2\text{O}^{2-} = (\text{Fe},\text{Mg})^{2+} + 2\text{OH}^-$  and the “fluorination”  $\text{Ti}^{4+} + 2\text{O}^{2-} = (\text{Fe},\text{Mg})^{2+} + 2\text{F}^-$ . 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