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Assessment of cation substitutions along the gallium and fluorine analogue of the tremolite-glaucophane join

MICHAEL S. PAVLOVICH JR.* AND DAVID M. JENKINS

Department of Geological Sciences and Environmental Studies, Binghamton University, Binghamton, New York 13902-6000, U.S.A.

ABSTRACT

Assessment of the glaucophane substitution, $^{[M4]}Ca + {}^{[VI]}Mg \leftrightarrow {}^{[M4]}Na + {}^{[VI]}Al$, along the Ga and F analogue of the tremolite-glaucophane join, $\square Ca_2Mg_5Si_8O_{22}F_2$-$\square Na_2Mg_3Ga_2Si_8O_{22}F_2$ (= F-Ga-glauc), was conducted at 900 °C and 1.5 GPa in 10 mol% increments. Several chemical exchanges deviating from the glaucophane substitution were identified, namely the "edenite" substitution $^{[A]}\square + {}^{[IV]}Si \leftrightarrow {}^{[A]}Na + {}^{[IV]}Ga$ toward F-Ga-nyböite, the $^{[A]}\square + {}^{[M4]}Na + {}^{[VI]}Ga + {}^{[IV]}Si \leftrightarrow {}^{[A]}Na + {}^{[M4]}Mg + {}^{[VI]}Mg + {}^{[IV]}Ga$ exchange toward F-Ga-Na-magnesiokatophorite, and the $^{[A]}\square + {}^{[VI]}Ga \leftrightarrow {}^{[A]}Na + {}^{[VI]}Mg$ exchange toward F-Ga-eckermannite. Minor displacements from the join due to the $^{[M4]}Na + {}^{[VI]}Ga \leftrightarrow {}^{[M4]}Mg + {}^{[VI]}Mg$ exchange toward "cummingtonite" and the richterite exchange $^{[A]}\square + {}^{[M4]}Ca \leftrightarrow {}^{[A]}Na + {}^{[M4]}Na$ were also observed. Amphibole syntheses with low F-Ga-glauc contents (≤60 mol%) were primarily influenced by the "edenite" exchange, while those with high F-Ga-glauc contents (≈70 mol%) were dominated by the "glaucophane" substitution. Powder X-ray diffraction Rietveld refinements were obtained without restrictions for the amphiboles formed in the range 0–40 mol% F-Ga-glauc. Refinements for samples in the ranges of 50–70 and 100 mol% F-Ga-glauc were possible only after applying some restrictions to the A- and M4-site occupancies because of the appearance of a layered silicate and an unidentified Ga-rich phase that complicated the refinement. The successful refinements indicated that amphibole exhibits $^{[VI]}Ga$ ordering at the M2 site and $^{[IV]}Ga$ ordering at T1. The refinements also show a transition in A-site occupancy from A2 to A*m* with increasing F-Ga-glauc content. The inability to synthesize stoichiometric glaucophane and the types of chemical deviations that are observed in this analogue system are virtually identical to what has been observed in previous studies. Extrapolation of the results from this and previous studies suggests that ideal glaucophane would be obtained at approximately 3.85 GPa and 585 °C.