CHOPINITE-SARCOPSIDE SOLID SOLUTION, (Mg,Fe)₃(PO₄)₂, IN LODRANITE GRA95209

E. S. Grew¹, M.G. Yates¹, R.J. Beane², C. Floss³ and C. Gerbi¹.
¹University of Maine, Orono 04469-5790 USA. E-mail: esgrew@maine.edu. ²Bowdoin College, Brunswick 04011 USA ³Washington University, St. Louis 63130 USA

Introduction: Four phosphate minerals have the stoichiometry (M²⁺)₃(PO₄)₂. Sarcopside and graftonite, both Fe dominant, are found in meteorites and terrestrial rocks. Chopinite, the recently discovered Mg-dominant analogue of sarcopside occurring in terrestrial granulite-facies metasediments, is inferred to have formed at 800-860°C, 6-7 kbar [1] and is a high-pressure polymorph of farringtonite [2], which has been found only in meteorites. Unidentified (Mg,Fe)₃(PO₄)₂ phases with \(X_{Mg} = Mg/(Mg+Fe)\) ranging from 0.01 to 0.87, together with chladniite, Ca₉Na₅(Ca₄Na₄)(Mg,Fe)₅₃(PO₄)₆₀, or its Fe-dominant analogue, johnsomervilleite, have been reported as minor constituents in Graves Nunatak 95209, a lodranite containing Fe-Ni metal masses and forsterite-orthopyroxene aggregates [3, 4].

Results: To identify the unknown (Mg,Fe)₃(PO₄)₂ phases we determined the Fe-Mg-Mn distribution between contiguous grains of (Mg,Fe)₃(PO₄)₂ and chladniite-johnsomervilleite and obtained electron backscatter diffraction patterns of the (Mg,Fe)₃(PO₄)₂ phases. Electron microprobe analyses of contiguous grains of (Mg,Fe)₃(PO₄)₂ and chladniite-johnsomervilleite in three sections of GRA95209 give two trends for Mg-Fe, one for johnsomervilleite and chladniite with \(X_{Mg} \leq 0.738\), the second for chladniite only with \(X_{Mg} \geq 0.738\). The first trend is tightly constrained with a distribution coefficient, \(K_D = (Mg/Fe)_{UNK}/(Mg/Fe)_{C-J} = 0.584\), which is nearly identical to Mg-Fe distribution between terrestrial sarcopside and johnsomervilleite, \(K_D = 0.588\) [1]. This suggests that the unknown (Mg,Fe)₃(PO₄)₂ phase is sarcopside (for compositions \(X_{Mg} = 0.28-0.43\)) and chopinite (for compositions \(X_{Mg} = 0.57-0.65\)). Mn-Fe distribution is consistent with the (Mg,Fe)₃(PO₄)₂ phases being sarcopside or chopinite, not graftonite, which would have contained much more Mn. The second trend in Mg-Fe gives \(K_D \sim 1.51\). In this case, we infer that the unknown (Mg,Fe)₃(PO₄)₂ phase is farringtonite (\(X_{Mg} = 0.80-0.89\)). Electron backscatter diffraction patterns and maps of magnesian (Mg,Fe)₅(PO₄)₂ phases confirm identification of chopinite and farringtonite.

In contrast to the phosphates, our analyses show that associated forsterite and enstatite vary little in composition, viz., \(X_{Mg} = 0.93\) and 0.92-0.93, respectively, except for fayalite overgrowths on forsterite (\(X_{Mg} \geq 0.2\)).

Discussion: Using the experimental data for the end-member reaction [2], an isopleth calculated as in [1] at 500–1050°C for chopinite \(X_{Mg} = 0.65\), but with measured \(K_D = (Mg/Fe)_{AB}/(Mg/Fe)_{CH} = 2.10\), gives 4–7 kbar for this chopinite-farringtonite pair, pressures far too high for any meteorite. We suggest that Fe-rich sarcopside initially formed by oxidation and replacement of P-rich metal; subsequent exchange with a large reservoir of Mg-rich silicates resulted in Mg enrichment of the phosphates and, consequently, Fe-rich overgrowths on forsterite. As GRA95209 cooled, Mg-enriched sarcopside failed to transform into farringtonite, leaving chopinite as a metastable phase.