Chopinite-Sarcopside Solid Solution, (Mg, Fe)(3)(PO(4))(2), in Lodranite GRA 95209

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CHOPINITE-SARCOPSIDE SOLID SOLUTION, (Mg,Fe)$_3$(PO$_4$)$_2$, IN LODRANITE GRA 95209

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Introduction: Four phosphate minerals have the stoichiometry (Mg$^2+$)$_3$(PO$_4$)$_2$: Sarcopside and graffonite, both Fe dominant, are found in meteorites and terrestrial rocks. Chropinite, 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)$_3$(PO$_4$)$_2$ phases with $X_{Mg} = Mg/(Mg + Fe)$ ranging from 0.01 to 0.87, together with chladnite, CaNa$_2$(Ca$_2$Na$_3$)(Mg,Fe)$_3$(PO$_4$)$_6$ or its Fe-dominant analogue, johnsonsvilleite, have been reported as minor constituents in Graves Nunatak (GRA) 95209, a lodranite containing Fe-Ni metal masses and forsterite-orthopyroxene aggregates [3, 4].

Results: To identify the unknown (Mg,Fe)$_3$(PO$_4$)$_2$ phases, we determined the Fe-Mg-Mn distribution between contiguous grains of (Mg,Fe)$_3$(PO$_4$)$_2$ and chladnite-johnsonsvilleite and obtained electron backscatter diffraction patterns of the (Mg,Fe)$_3$(PO$_4$)$_2$ phases. Electron microprobe analyses of contiguous grains of (Mg,Fe)$_3$(PO$_4$)$_2$ and chladnite-johnsonsvilleite in three sections of GRA 95209 give two trends for Mg-Fe, one for johnsonsvilleite and chladnite with $X_{Mg} ≤ 0.738$, the second for chladnite only with $X_{Mg} ≥ 0.738$. 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 johnsonsvilleite, $K_D = 0.588$ [1]. This suggests that the unknown (Mg,Fe)$_3$(PO$_4$)$_2$ 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)$_3$(PO$_4$)$_2$ phases being sarcopside or chopinite, not graffonite, which would have contained much more Mn. The second trend in Mg-Fe gives $K_D = 1.51$. In this case, we infer that the unknown (Mg,Fe)$_3$(PO$_4$)$_2$ phase is farringtonite ($X_{Mg} = 0.80$–0.89). Electron backscatter diffraction patterns and maps of magnesian (Mg,Fe)$_3$(PO$_4$)$_2$ 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 ($X_{Mg} ≥ 0.2$).

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 $K_D = (Mg/Fe)_{VAR}/(Mg/Fe)_{C-J} = 2.10$, 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 GRA 95209 cooled, Mg-enriched sarcopside failed to transform into farringtonite, leaving chopinite as a metastable phase.