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Chopinite-sarcopside solid solution, $[(Mg,Fe)_3\square](PO_4)_2$, in GRA95209, a transitional acapulcoite: Implications for phosphate genesis in meteorites

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Abstract

Orthophosphate, $(Mg,Fe,Mn)_3(PO_4)_2$ with X_{Mg} = Mg/(Mg+Fe) = 0–0.89 and Mn/Fe = 0.05–0.3 and chladniite-johnsomervilleite, $MnNa_8(Ca_4Na_4)(Mg,Fe,Mn)_{43}(PO_4)_{36}$ with X_{Mg} = 0.44–0.81 and Mn/Fe = 0.3–0.8, are minor constituents of meteorite Graves Nunataks (GRA) 95209, a transitional acapulcoite consisting mostly of forsterite (Fa_7) and enstatite ($Wo_3Fs_{7–8}$) with subordinate clinopyroxene ($Wo_{41–45}$ $Fs_{4–6}$) and plagioclase ($Or_{1–2}An_{10–19}$), and cut by Fe,Ni metal veins. Electron backscatter diffraction patterns and maps, together with chemical analyses and Fe-Mg-Mn distribution among phosphates, confirm identification of the orthophosphate as sarcopside, chopinite, and farringtonite; no graftonite was found. Phosphates are found as (1) narrow rims between metal and forsterite or orthopyroxene; (2) aggregates having the same outline as metal; and (3) inclusions and stringers in metal, including a ring around a graphite rosette. Electron microprobe analyses of sarcopside/chopinite-johnsomervilleite/chladniite pairs give a regular Fe-Mg distribution with $K_D = (Mg/Fe)_{Src/Chp}/(Mg/Fe)_{Jhn/Cld}$ = 0.584 consistent with terrestrial sarcopside-johnsomervilleite pairs, whereas analyses of farringtonite-chladniite pairs give K_D = 1.51, but the Mg-Fe distribution is less regular. Textural relations suggest that Fe-Mn sarcopside originally formed by oxidation of P in metal and replacement of the metal and, through interaction with silicates, was converted to magnesian sarcopside-chopinite and farringtonite, i.e., the silicate matrix acted as a reservoir of Mg that could be exchanged with Fe and Mn in the sarcopside. Using the farringtonite-chopinite univariant curve determined in hydrothermal experiments by F. Brunet and others, isopleths calculated for the most magnesian chopinite in GRA95209, X_{Mg} = 0.65, give 4–7 kbar at 500–1100 °C, pressures far too high for the acapulcoite-lodranite parent body. Two scenarios could explain the discrepancy: (1) chopinite and magnesian sarcopside persisted metastably into the farringtonite stability field as Mg-Fe exchange progressed and the source volume for GRA95209 cooled; (2) a very mild shock event was intense enough to convert Fe-rich farringtonite (X_{Fe} = 0.4–0.6) to magnesian sarcopside and chopinite, but not enough to deform olivine in the source volume. Whether metastability could have played a role in chopinite formation would best be answered by experiments on the $Mg_3(PO_4)_2$–$Fe_3(PO_4)_2$ system under anhydrous conditions. If the transformation was found to be as kinetically fast as in the hydrothermal experiments, then shock would become the more plausible explanation for the presence of chopinite in this meteorite.

Keywords: Meteorite, phosphate, electron microprobe, electron backscatter diffraction, chopinite, sarcopside, chladniite, achondrite