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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 $(M^{2+})_3(PO_4)_2$. 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 $(Mg,Fe)_3(PO_4)_2$ phases with $X_{Mg} = Mg/(Mg + Fe)$ ranging from 0.01 to 0.87, together with chladniite, $CaNa_8(Ca_4Na_4)(Mg,Fe)_{43}(PO_4)_{36}$, or its Fe-dominant analogue, johnsomervilleite, 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 chladniite-johnsomervilleite 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 chladniite-johnsomervilleite in three sections of GRA 95209 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 $(Mg,Fe)_3(PO_4)_2$ 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 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 $(Mg,Fe)_3(PO_4)_2$ 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 ($X_{Mg} \geq 0.2$).

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 $K_D = (Mg/Fe)_{FAR}/(Mg/Fe)_{CHO} = 2.10$, 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.

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ORIGIN OF SCHLIREN BANDS IN CHINGA ATAXITE

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Introduction: It is well known the presence of macroscopic selective reflection bands (Schliren bands or oriented sheen) in various ataxites IVB [1, 2]. However, the origin of Schliren bands is not clear yet. There were several different suggestions such as variety of chemical and phase compositions, shock alteration, and twinning to explain Schliren bands formation, but these explanations were not evident. In the present work we suggest an origin of the Schliren bands basing on Chinga ataxite IVB multiscale study.

Experimental: Chinga ataxite IVB fragments were studied using textural X-ray diffraction (XRD), optical microscopy with image analysis (OM), scanning electron microscopy (SEM) with EDX and EBSD, atom probe microscopy (APM), and transmission electron microscopy (TEM).

Results and Discussion: It was shown that Schliren bands in Chinga ataxite IVB were parallel dark and light lines with a width in the range of 1–10 mm and the same chemical composition. XRD and TEM demonstrated the presence of α and γ phase mixture with 20 ± 5 vol% of phase for both dark and light bands. Texture of α phase was complicated in both bands and presented by six crystallographic orientations. However, the set of orientations was different for dark and light bands. The presence of retained γ phase after martensite transformation (γ_R) as well as exsolved γ phase from martensite (γ_E) was shown earlier [3, 4]. We observed that orientation of γ_R phase was the same in dark and light bonds. This fact excludes twinning origin of the bands. It was further shown that planes (111) for γ_R and (011) for α were parallel. The directions [1$\bar{1}$0] for γ_R and [100] for α in both dark and light bands were also parallel that was close to Nashiyama-Vasserman martensite orientation relationship. These results demonstrated that taenite decomposition in Chinga ataxite was by martensite type reaction: $\gamma_R \rightarrow \alpha_2 + \gamma_R \rightarrow \alpha' + \gamma_E + \gamma_R$. Thus, we can conclude that Schliren bands appeared due to formation of different crystallographic set of submicroscopic products during martensite transformation.

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