

COMPLEX ZONING IN THE NAKHLITE AND CHASSIGNITE MARTIAN METEORITES.

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Introduction: The nakhlite and chassignite martian meteorite suite is made up of 29 samples sharing crystallization and ejection ages (~1.3 Ga and ~11 Ma, respectively), and they therefore comprise the largest single-origin suite from Mars [1]. There are no spatial constraints on the relative emplacement histories of the nakhlites (clinopyroxene-rich cumulates) and chassignites (dunites); they may have been emplaced together or separately as flows or sills [1]. They may have originated from one or many parental magmas, and the two cumulus phases of the nakhlites (augite and olivine) may have formed together or from separate magmas [1–3]. Cumulus phases in nakhlites and chassignites do not retain zoning of divalent cations, however, slowly diffusing elements, such as Cr in pyroxene and P in olivine are preserved [4,5]. In olivine, P is highly incompatible but can be incorporated during periods of disequilibrium crystallization [4]. Chromium is compatible in pyroxene but also in other late-stage minor phases, and thus, preserves changes in magma composition from mixing or co-crystallization [5]. Imaging and quantifying these elements, along with others, may help reveal the magmatic and eruptive histories of the nakhlites and chassignites.

Methods: We conducted major and minor element mapping (Cr, P, Ti, Al) with the electron probe microanalyzer (EMPA) JEOL JXA-8200 Superprobe at Rutgers University with a 2 μm pixel spacing, 15 kV accelerating voltage, 300 nA beam current, and a dwell time of 500 ms. Mapped minerals were then quantitatively analyzed along traverses on the EMPA JEOL JXA-8900 at the University of Nevada, Las Vegas (UNLV) using a 15 kV accelerating voltage, 300 nA beam current, and beam diameter of 1 μm . Trace element analyses have been conducted on the Thermo Fisher Scientific iCAP Qc inductively coupled plasma mass spectrometer and Excimer NWR193 laser ablation system at UNLV. We used a 15 Hz rep rate, 6.7 J/cm³ fluence, and a 50 μm spot size. Analyses have been completed for nakhlites Northwest Africa (NWA) 11013, Caleta el Cobre (CeC) 022, NWA 10645, and chassignite NWA 2737.

Results: Nakhlite olivine contains relict high-P, subrounded anhedral cores (Fig. 1A). Quantitative traverses show that nakhlite olivine rims are slightly more P-enriched (in CeC 022: 860 ppm, 1 σ 140 ppm) than their cores (653 ppm). Iron is slightly enriched in olivine rims, but Mg and Fe have undergone exchange and nakhlite olivine is largely homogenous in terms of divalent cations. Analyzed nakhlite pyroxene contain Cr- and V-depleted rims that are relatively enriched in rare earth elements (REE) (Fig. 1C). Nakhlite pyroxene is homogenous in terms of Ca, but rims are slightly enriched in Fe. Phosphorus-mapping in olivine in the chassignite NWA 2737 reveals hopper morphology and oscillatory zoning (Fig. 1B) [6]. Incompatible trace elements increase generally from core to rim in chassignite olivine.

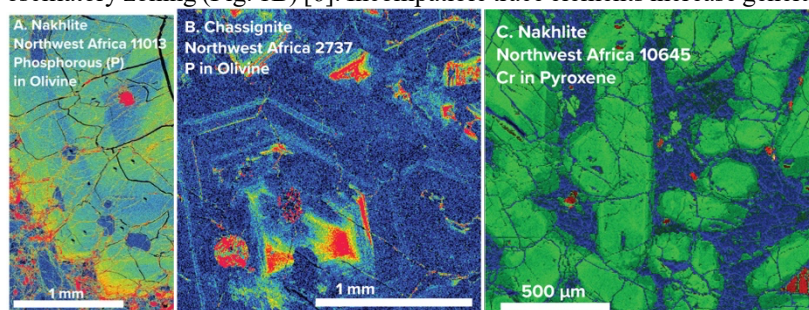


Figure 1, from left to right: (A) P-zoning in nakhlite NWA 11013 olivine; (B) P-zoning in chassignite NWA 2737 olivine; (C) Cr-zoning in nakhlite NWA 10645 pyroxene

Discussion: Subrounded cores in olivine are likely features formed by resorption [e.g., 7]. Higher P concentrations in the rims of nakhlite olivine may thus indicate later additional crystallization from a new magma onto a resorbed, antecrystic core. Chassignite olivine formed during periods of significant undercooling to result in rapid formation of hopper grains, and thus possibly crystallized in conditions unique from the nakhlites [6]. Nakhlite pyroxene imaged for this study differ from reports of Cr-depleted cores in the Miller Range nakhlites [8]. Pyroxene core depletion and rim enrichment in Cr may represent mafic magma rejuvenation and mixing, whereas Cr depletion in the rims of pyroxene may represent co-crystallization of oxide phases. These potential unique crystallization sequences preserved by slowly diffusing elements in nakhlite and chassignite cumulus minerals indicate the possibility that they are formed in unique magmas or are emplaced separately.

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