COMPLEX ZONING IN THE CHASSIGNITE AND NAKHLITE MARTIAN METEORITE SUITE.

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Introduction: The chassignite and nakhlite martian meteorites are made up of 34 unpaired samples sharing crystallization ages (~1.3 Ga) and ejection ages (~11 Ma), and they therefore comprise the largest single-origin suite of rocks from Mars [1]. There is no spatial constraint on the relative emplacement histories of the nakhlites (clinopyroxene-rich cumulates) and chassignites (dunites), but they may have been emplaced together or separately as flows or sills [1]. They may have formed from one or many parental magmas, and the two cumulus phases of the nakhlites may have originated from one or more magmas [1–3]. Cumulus phases in the suite do not retain zoning of divalent cations (Mg, Fe), but do retain zoning of slowly-diffusing elements, such as Cr in pyroxene and P in olivine [4,5]. In olivine, P is highly incompatible but can be incorporated during disequilibrium crystallization [4]. Chromium is compatible in pyroxene but also in other late-stage minor phases, and so it 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 qualitative major and minor element mapping (Cr, P, Ti, Al) with the electron probe microanalyzer (EMPA) *JEOL* JXA-8200 Superprobe at Rutgers university using a 15 kV accelerating voltage, 300 nA beam current, and a dwell time of 500 ms. Minerals were then quantitatively analyzed 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 a 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 *NWR* 193nm laser ablation system at UNLV. We used a 15 Hz rep rate, 6.7 J/cm³ fluence, and a 50 µm spot size. We will present findings for nakhlites Northwest Africa (NWA) 11013, Caleta el Cobre (CeC) 022, NWA 10645, and chassignites NWA 2737 and Chassigny.



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

Results: Nakhlite olivine contains high-P, subrounded anhedral cores (Fig. 1A). Quantitative data show that nakhlite olivine rims are slightly more P-enriched (in CeC 022: 860 ppm, 1σ 140 ppm) than their cores (645 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. Phosphorous-mapping in olivine in the chassignites reveals hopper morphology and oscillatory zoning (e.g., Fig. 1B) [6]. Incompatible trace elements generally increase from core to rim in chassignite olivine.

Discussion: Subrounded cores in olivine are possibly features formed by resorption [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 in significant undercooling that resulted in rapid formation of hopper grains, and thus possibly crystallized in conditions unique from the nakhlites [6]. The 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 recharge, 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 the nakhlite and chassignite mineralogy indicate the possibility that they are formed in unique magmas or are emplaced separately.

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