ZONING OF PHOSPHORUS WITHIN THE OLIVINES OF THE OLIVINE-PHYRIC SHERGOTTITE DHOFAR 019. M. E. Ennis[1], H. Y. McSween[1], A. Patchen[1], and L. A. Taylor[1]; [1]Planetary Geoscience Institute and Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, USA (mennis2@utk.edu).

Introduction: The composition of olivine is relatively simple with a solid solution between forsterite and fayalite that incorporates few other major cations. This simplicity limits the amount of knowledge that may be attained via the analysis of olivine, especially in grains that have experienced long residence times in high-temperature magmas, which allows the rapid diffusing divalent Mg and Fe cations to homogenize.

Technological advancements have improved our ability to produce precise scientific measurements, and more importantly to observe trace-element chemical variations on the scale of microns. Recent studies have shown that phosphorus concentrations in igneous olivine grains can vary from below detectable limits to 0.2-0.4 wt. % over a few microns [1]. X-ray intensity maps of olivine grains have yielded a variety of phosphorus zoning patterns [1], which are often correlated with the distribution of Cr and to a lesser degree, Al, especially in experimental olivines or more equilibrated samples [2]. There is no apparent correlation to Fo content [1, 3]. The distributions of these cations in the crystal reflect their relative distribution coefficents, $D_{Al}>D_{Cr}>D_P$, where the distribution of the slow-diffusing phosphorus may reveal aspects of the otherwise unattainable early crystallization history of the magma. Phosphorus zoning in olivines has been observed in terrestrial igneous rocks, including basalts, komatiites, andesites, and dacites, as well as extraterrestrial samples including Martian meteorites, ordinary chondrites, and lunar samples [1-4].

Martian meteorites are relatively young igneous rocks that are similar in many respects to terrestrial rocks [5]. These samples, collectively known as SNC's, are classified into three distinct groups based on their petrology: shergottites, nakhlites, and chassignites. Shergottites are the most abundant and can be further subdivided into basaltic, lherzolitic, or olivine-phyric. Phosphorus zoning has been described in a lherzolitic shergottite (ALHA 77005) [1, 3]. Preliminary results of P zoning in a chassignite (Chassigny) and several olivine-phyric shergottites (DaG 489, EETA 79001, RBT 04261/2, and Y980459) have also been presented [3].

Dhofar 019 is a 1.06 kg olivine-phyric shergottite that was collected in the desert region of Oman in January 2000 [6]. Here we examine whether phosphorus zonation also occurs in this meteorite, and explore whether it can be used to infer the evolution of its parent magma.

Methodology: Chemical analysis of Dhofar 019 was conducted at the University of Tennessee using a Cameca SX-100 electron microprobe. Qualitative P, Cr, and Mg K_α x-ray intensity maps of olivine grains were obtained using a beam current of 200 nA and dwell times of 900 ms at 15 KeV. Point analyses were then attained to quantify the elemental abundances and variations within these grains.

Petrography and Chemistry of Dhofar 019 Olivine: In thin-section, Dhofar 019 is porphyritic with olivine megacrysts set in a matrix of smaller pyroxene, maskelynite, and olivine grains. Approximately 12% of the sample is comprised of subhedral, yellowish-brown olivine grains, ranging in size from ~0.5 mm to 3 mm, with the larger grains often containing melt inclusions. A compositional range of Fo_{53-38} was observed, which is within the previously reported range of Fo_{73-25} [6].

Results: Two mapped olivine grains are discussed, to illustrate differences observed within this meteorite. The olivine megacryst in Fig. 1 contains two high-phosphorus regions within the core, with no apparent correlation to Cr or Fo content. These high-P regions likely represent a glomerocryst, which subsequently served as a nucleation point for further olivine growth. The glomerocryst formed during an initial period of undercooling when small phenocrysts touched and attached to each other, followed by more rapid overgrowth of the surrounding olivine [1]. The rim of this olivine grain contains two high-P bands that are positively correlated with Cr.

The second olivine megacryst (Fig. 2) exhibits a completely different zoning pattern in which high-P regions correlate with low-Cr regions and produce an overall skeletal pattern. Melt inclusions are abundant within this grain, where the region directly adjacent to the melt inclusions is depleted in P and Cr. Olivine that is enriched in P may reflect "solute trapping" through rapid skeletal olivine growth, suggesting that the P-enriched olivine is not in equilibrium with the melt [1].

Implications: The agglomeration of early crystallized olivine is consistent with the results of the cluster analysis of this sample [6], which showed that the small olivine grains within the meteorite either grew from clusters of nuclei or accumulated in clusters, rather than as individual, randomly distributed grains.

Crystallization of the Dhofar 019 melt was previously modeled using the MELTS program [6]. The

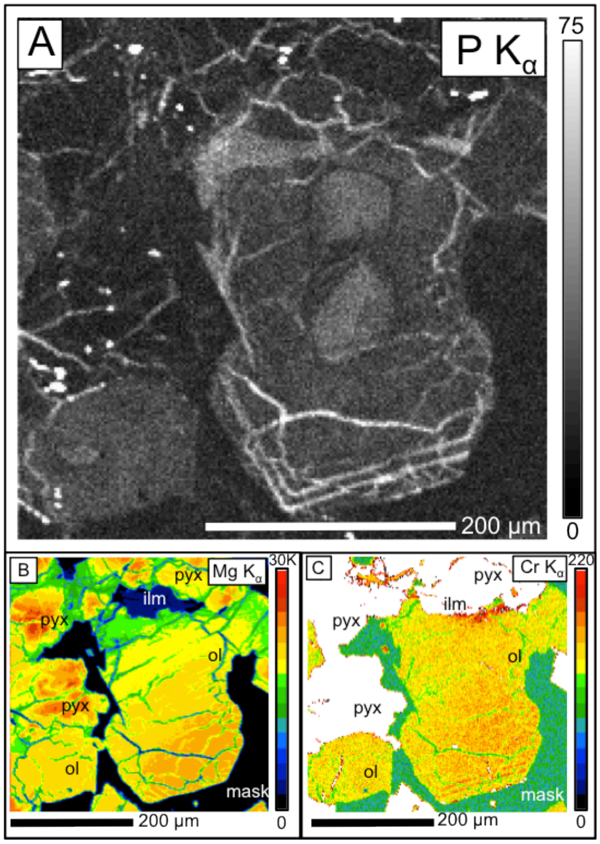

Fig. 1: a) Phosphorus K_α intensity map of olivine revealing two different centers of zoning. b) Mg K_α intensity map illustrates that the P zonation is uncorrelated to Fo content. c) Cr K_α intensity map illustrates the positive correlation of Cr with P in the bands along the rim, which is not observed in the high-P cores.

interpretation of the modeling results suggests that some fractionation of the magma resulted through isolation of growing crystals and restriction of diffusive exchange during cooling and crystallization [6]. The agglomeration of early-crystallized olivine (Fig. 1) may have aided in the fractionation of the melt.

Contrary to the P zoning, crystal size distribution (CSD) analysis [6] suggests that, aside from a few possible cumulate grains, the olivine grains constitute a single population that formed under steady-state conditions of nucleation and growth, with subsequent minor annealing.

Additional P zonation studies, coupled with new CSD studies, will further expand our knowledge of the early crystallization history and evolution of Martian magmas and resolve differences between interpretations of crystallization histories using various techniques.

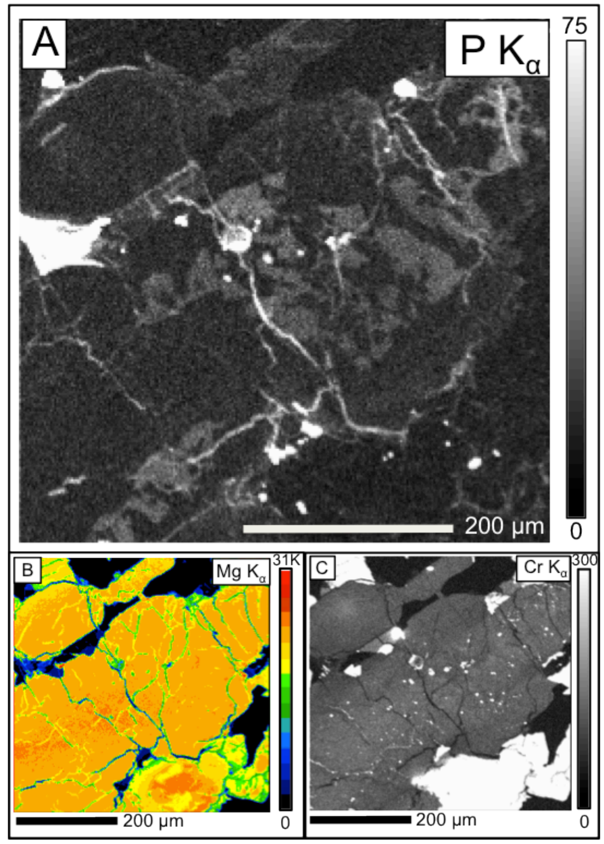

Fig. 2: a) Phosphorus K_α intensity map of olivine revealing a skeletal core. b) Mg K_α intensity map shows normal zoning of Fo content within the olivine. c) Cr K_α intensity map illustrates the positive correlation between both the Mg and P.

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