THE ORIGIN OF OLIVINE IN MARTIAN METEORITE ALH 84001. THE OXYGEN ISOTOPIC SYSTEMATICS OF THE OLIVINE. Shearer, C.K.[1] and Leshin, L. A. [2]. [1]Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131-1126. [2] Department of Earth and Space Sciences, UCLA, Los Angeles, California 90095-1567.

INTRODUCTION: Irregular-shaped olivine inclusions in orthopyroxene were first recognized in ALH 84001 by Harvey and McSween [1]. These olivine inclusions do not occurs randomly as might be expected if they were simple reabsorbed within the orthopyroxene. Rather, the olivine occurs as "clusters" within a limited number of textural settings [2]. Many of the olivine inclusions occur in orthopyroxene adjacent to fractures containing disrupted carbonate globules [3, 4] and high-K plagioclase glass [5]. A most intriguing element of this texture is that the olivine occurs in the orthopyroxene at the base of the carbonate globules (Figure 1). This textural information is useful in our interpretation of the origin of the olivine, yet this information alone does not allow us to distinguish a model in which the olivines are magmatic inclusions in the orthopyroxene that were redistributed during shock-event(s) from a model in which the olivines were produced by a reaction among CO_2, shock glass and orthopyroxene which resulted in a loss of Si to the glass component and the formation of carbonate. These two models have different implications for the thermal and chemical history of ALH 84001, and may significantly modify the observations and conclusions reached by McKay et al. [6]. The former interpretation implies that the olivine grains are magmatic in origin and therefore do not constrain the temperature of the alteration event. Whereas, the latter interpretation implies that the olivine-forming event occurred at high temperature and is associated with metasomatic activity subsequent to the formation of the magmatic mineral assemblage. Our approach to deciphering the origin of the olivine in ALH 84001 is two fold. First, in a companion abstract [2], we report the distribution of olivine inclusions in ALH 84001. Here, we report the oxygen isotopic characteristics of the olivine.

METHOD: Prior to oxygen isotope analysis, the distribution, morphology, and composition of olivine was determined in two thin sections of ALH84001: ,83 and ,87. We used a JOEL 733 Superprobe electron microprobe (EMP) equipped with an Oxford LINK eXL II analyzer for both image and compositional analysis. Details of the image analysis are presented by Shearer and Adcock [3]. Oxygen isotopic compositions of two of the larger olivine grains and three areas on adjacent orthopyroxene grains were analyzed with the UCLA CAMECA ims 1270 ion microprobe. Negative secondary ions were sputtered by a ~0.15 nA Cs+ primary beam defocused to a ~12-15 µm diameter spot. A normal-incidence electron gun was utilized to flood the analysis area with low energy electrons for charge compensation. Secondary ions with initial kinetic energies of ~0-30 eV were measured at a mass resolving power (M/DM) of ~3500, sufficient to eliminate any hydride interferences. Each measurement comprised 20 cycles of counting 16O for 2 s and 18O for 10 s. The secondary 16O– current was measured with a faraday cup (FC), and 18O– ions were counted with an electron multiplier (EM). The analysis conditions resulted in typical count rates of 60 million counts per second of 16O–; peak intensities were corrected for background (FC) and deadtime (EM). Because of the small size of the olivine grains, the analyses do contain minor contamination from the surrounding pyroxene grains, however, this does not affect the interpretation of the results. The data were corrected for instrumental mass fractionation assuming that the opx has a d18O value of +4.6 [7,8] and assuming no matrix effect between the orthopyroxene and olivine. Based on analysis of laboratory standards, a slight matrix effect could exist, but it would likely be at a level of <1-2‰.

OXYGEN ISOTOPIC SYSTEMATICS OF THE OLIVINE: The d18O values of the 2 olivine spots and 3 orthopyroxene spots analyzed range from +4.3 to +5.3 ‰ and are indistinguishable from each other within analytical uncertainty. The mean d18O of the 2 olivine spots is +5.1 ± 1.4 (2s) ‰, and the d18O of the 3 orthopyroxene spots is +4.6 (by design) ± 1.2 (2s) ‰. These

values are compared to oxygen isotopic analysis analyses of carbonate and SiO_2 in ALH 84001 in Figure 2 [9,10,11].

DISCUSSION: It is clear that there is no significant isotopic difference between the olivine and the orthopyroxene. The values are most consistent with the two phases having equilibrated at or near magmatic temperatures. The isotopic data are in agreement with data from mineral geothermometers using olivine and associated phases which record a high temperature, subsolidus envirnoment. Fe-Mg distribution between olivine and chromite inclusions in olivine gives equilibrium temperatures of 850 to 900°C [11]. Calibration for the Fe-Mg exchange reaction between Ca-free olivines and orthopyroxene yield temperatures of 800 to 900°C [12]. Far less relavent because of their non-equilibrium textural relationship is the suggested equilibrium temperature of 1040°C obtained from the olivine and augite [1]. These subsolidus temperatures perhaps reflect a reequilibration stage in the life of ALH 84001 in which the olivine was remobilized along fractures in the orthopyroxene. Similar subsolidus textures have been observed in terrestrial mafic igneous assemblages. Within the uncertainties of the oxygen isotopic data, we cannot rule the possibility that the olivines equilibrated with the orthopyroxene later during a "high temperature" subsolidus event (at 600°C $D_{en\text{-}ol}$ ~+1.2; [13]). However, it seems unlikely that these olivines formed in the same event which gave rise to the carbonates in ALH 84001, which have more elevated and variable d18O values [9,10], and were probably formed from fluids which were not in isotopic equilibrium with the orthopyroxene.

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Figure 1. BSE image illustrating the location and morphological charateristics of olivine in ALH 84001. The olivine occurs as small light colored patches in the orthopyroxene. Note that the olivine occurs in the orthopyroxene adjacent to the base of the large carbonate globule.

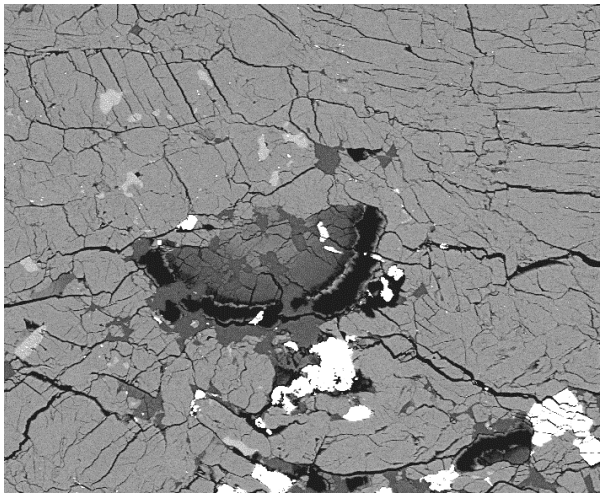

Figure 2. Oxygen isotopic systematics of olivine and associated phases in ALH 84001.