DERIVATION OF ISOLATED OLIVINE GRAINS IN THE CARBONACEOUS CHONDRITE ALH A77307 BY FRAGMENTATION OF CHONDRULES. Rhian H. Jones, Institute of Meteoritics, Department of Geology, University of New Mexico, Albuquerque, NM 87131, USA.

Introduction. Considerable controversy surrounds the origin of isolated olivine grains in carbonaceous chondrites. Arguments for their derivation by fragmentation of chondrules [1-4], based mostly on textural similarities and major element compositions, have been proposed for both CM2 and CO3 groups. The opposing view [5-8] suggests that isolated forsterites in particular are the direct products of gas/solid condensation. For CO3 chondrites, arguments for the latter origin have largely been based on minor element contents of isolated forsterites [7,8]. I have reexamined this problem by determining major and minor element compositions, and by examining textural evidence for all occurrences of isolated olivine in the CO3 chondrite ALH A77307. Isolated olivine grains are compared with olivine in chondrules from which they may have been derived. ALH A77307, subtype 3.0 [9], shows minimal secondary alteration so it is possible to examine any relationships present without complications from metamorphic effects.

Forsterite-rich isolated grains. Isolated Fo-rich grains (FeO = 0.2-6.0 wt%) ranging in size from 10-300 μm are common in ALH A77307 and other CO3 chondrites [2-4]. They are frequently angular and sometimes have fragments of glass and/or low-Ca pyroxene attached [2]. Electron microprobe analyses show ranges of minor element contents within the group (wt%) as follows: MnO 0.0-0.8, Cr_2O_3 0.3-0.8, CaO 0.2-0.7, TiO_2 0.00-0.06, Al_2O_3 0.0-0.4. These ranges are similar to those in isolated forsterites in carbonaceous chondrites determined by Steele [7]. Fo-rich olivines in reduced, FeO-poor, type I chondrules in CO3 chondrites also have very similar minor element contents [9]. In addition to showing similar ranges, the distributions of analyses on variation diagrams are also very similar for isolated and chondrule forsterites in ALH A77307 (Fig. 1). Zoning profiles in isolated Fo grains commonly show small increases in Fe, Cr and Mn and decreases in Ca towards the edges of grains, similar to profiles across olivine grains in type IA chondrules in ALH A77307 [9].

Fayalite-rich isolated grains. Fa-rich isolated olivines are also common [2-4]. Sizes range from 10-400 μm, and grains are often angular. Strong Fe zoning may be observed in back-scattered electron (BSE) images on some or all faces of isolated grains. FeO contents range from 20-40 wt%. Minor element contents lie in the ranges: MnO 0.1-0.4, Cr_2O_3 0.3-0.4, CaO 0.1-0.3, Al_2O_3 0.0-0.1 TiO_2 <0.02 (wt%). Minor element contents and distributions on variation plots are very similar to those of olivines in type II (oxidized, FeO-rich) chondrules in ALH A77307 (Fig. 2). Strong correlations are observed between Fe, Ca and Mn. Zoning profiles from cores towards visibly zoned rims are very similar to those in type II olivine grains in the same chondrite [9], with Cr, Mn and Ca all correlated with Fe, and increasing towards the rims. Cr contents often decrease in the region close to the rim, similar to effects observed in chondrules [9].

Complex isolated grains. A third, less common, population of isolated grains is that of complex, zoned grains which consist of Fo-rich cores with Fa-rich rims. These grains have not been described previously. Grain sizes range from 20-150 μm and Fa-rich rims are of varying width (5-50 μm). Cores and rims are optically continuous and the interface is diffuse in BSE images. These rims are different from Fa-rich rims on Fo grains in Allende which are interpreted as condensates [10,11]. Rims on complex isolated olivines in ALH A77307 do not have the porous appearance, or the very sharply defined chromite-rich layer at the core/rim interface associated with Allende rims. Core, Fo-rich regions of complex grains in ALH A77307 have compositions very similar to both isolated Fo grains and type I chondrule olivines (Fig. 1). Rim, Fa-rich regions have compositions very similar to isolated Fa-rich grains and type II chondrule olivines (Fig. 2). These grains also have counterparts in chondrules: in type II chondrules in ALH A77307 relic Fo grains are common, overgrown with Fa-rich rims during chondrule formation. Similar grains are observed in type II chondrules in Ornans [8] and Semarkona [12]. Zoning profiles from core to rim of relic Fo grains in type II chondrules and complex isolated grains show very strong similarities (Fig. 3). In addition, zoning profiles are consistent with derivation of the Fo cores from type I chondrules: Fe and Mn contents increase and Ca contents decrease towards the core/rim interface (R). It appears that Fo grains derived from type I chondrules were incorporated into type II chondrules where Fa-rich rims grew during chondrule formation. Subsequent fragmentation of type II chondrules produced isolated complex grains.

Discussion. The evidence from minor elements supports several previous studies, arguing in favour of a strong genetic relationship between isolated olivine grains and chondrule olivines in CO3 chondrites [2-4]. Most importantly, this interpretation also holds for isolated forsterite grains. It is unlikely that such markedly similar compositions and zoning profiles could result from completely different processes, i.e. condensation in isolated grains and igneous crystallization in chondrule olivines. Because there is strong evidence that chondrule olivines in this chondrite grew from liquids during chondrule formation [9], it follows that isolated olivines must have originated in a similar environment. This argues for the derivation of most, if not all, isolated olivines by fragmentation of chondrules. The presence of isolated complex grains indicates that fragmentation of chondrules and recycling of fragmented olivine grains were common and efficient processes in the chondrule-forming region.

Conclusions. In ALH A77307 isolated Fo grains are very similar to type I chondrule olivines, isolated Fa-rich grains are very similar to type II chondrule olivines, and complex isolated Fo grains with Fa-rich rims are very similar to relic Fo grains in type II chondrules. Most, if not all, isolated grains appear to be derived from chondrules in this chondrite.

References. [1] Richardson SM & McSween HY Jr (1978) EPSL 37, 485-491. [2] McSween HY Jr (1977) GCA 41, 477-491. [3] Nagahara H & Kushiro I (1982) Mem. Natl. Inst. Polar Res. Spec Issue 25, 66-77. [4] Rubin AE et al. (1985) Meteoritics 20, 175-196. [5] Fuchs LH et al. (1973) Smithsonian Contrib. Earth Sci. 10, 1-39. [6] Olsen E & Grossman L (1978) EPSL 41, 111-127. [7] Steele IM (1986) GCA 50, 1379-1395. [8] Steele IM (1989) GCA 53, 2069-2080. [9] Scott ERD & Jones RH (1990) GCA 54, 2485-2502. [10] Peck JA & Wood JA (1987) GCA 51, 1503-1510. [11] Hua X et al. (1988) GCA 52, 1389-1408. [12] Jones RH (1990) GCA 54, 1785-1802.

Acknowledgement. Supported by NASA grant NAG9-30, Klaus Keil, P.I. and the Institute of Meteoritics at UNM.

Figures: Electron microprobe analyses of olivines in ALH A77307.

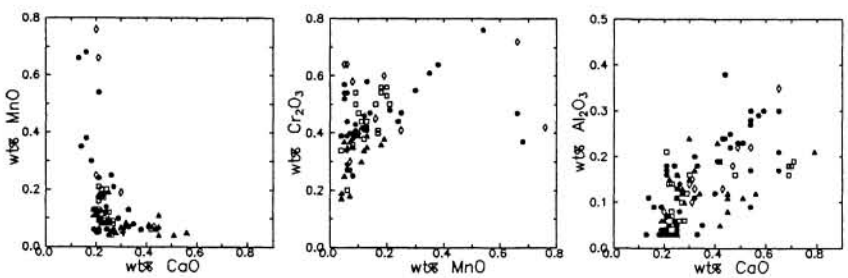

Figure 1. Minor element variation plots for isolated and chondrule forsterites.

Legend (Figs. 1 and 2) :
Chondrule olivines: type I (1) and type II (2)
Fo relics (1) and their rims (2) in type II chondrules
Isolated olivines: Fo (1) and Fa-rich (2)
Complex isolated grains: cores (1) and rims (2)

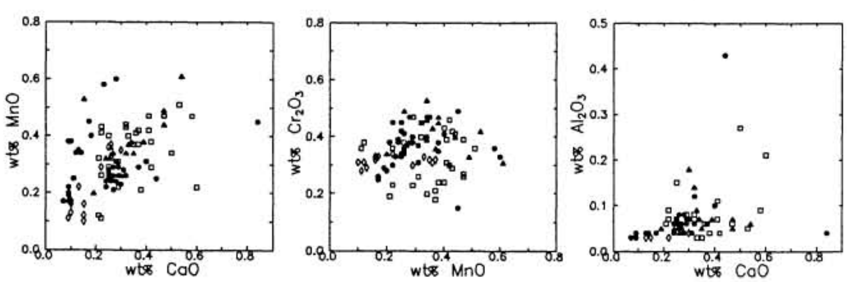

Figure 2. Minor element variation plots for isolated and chondrule fayalite-rich olivines.

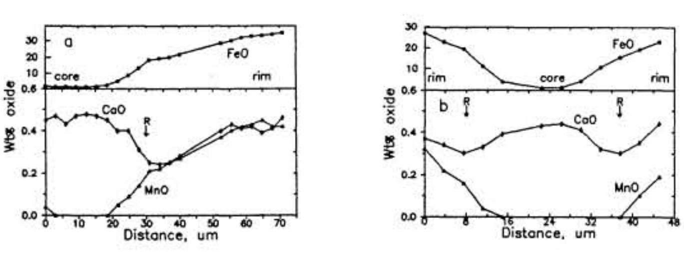

Figure 3. Zoning profiles across (a) complex isolated grain and (b) relic Fo in a type II chondrule. R = core/rim interface.