A CHONDRULE ORIGIN FOR DUSTY, RELICT OLIVINE GRAINS. Rhian H. Jones and Lisa R. Danielson, Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131.

"Dusty", relict olivine grains are commonly observed in FeO-poor chondrules [1-4]. These grains contain many small, micron-sized blebs of Ni-poor, Fe metal which gives them their dusty appearance in transmitted light. They are interpreted as the products of solid-state reduction of more FeO-rich olivine which was reduced before or during chondrule formation. The source of the original FeO-rich olivine has been suggested to be either primitive condensate material [2], or derivation from previous generations of chondrules [3]. Here, we examine the possibility that these grains could be derived from previous generations of chondrules, by comparing the compositions of dusty olivines with olivine compositions in FeO-rich chondrules which are the most likely chondrule precursors. Similarities in major and minor element compositions between these two occurrences of olivine argue that dusty relics do indeed originate from a chondrule source. This observation places important constraints on the frequency of chondrule recycling in the chondrule forming region.

Dusty olivine grains were selected from Semarkona (LL3.0), Chainpur (LL3.4), Ragland (LL3.5), Inman (L3.4) and Murchison (CM2). Three lines of evidence were used to assess the possibility of a chondrule origin for these grains by comparing them with compositions of olivines in FeO-rich chondrules: a) estimates of the original FeO content of dusty grains, b) comparison of minor element contents, c) compositions of FeO-rich relic grains that are incompletely reduced.

a) The original FeO content of the dusty grain precursors can be estimated if the volume% of metal is known, by considering either of the two possible equations for the reduction reaction:

\[ \text{Fe}_2\text{SiO}_4 \rightarrow 2\text{Fe} + \text{SiO}_2 + \text{O}_2 \]  
(Olivine / Silica, Iron: OSI)

or,

\[ \text{Fe}_2\text{SiO}_4 \rightarrow \text{FeSiO}_3 + \text{Fe} + 0.5\text{O}_2 \]  
(Olivine / Pyroxene, Iron: OPI).

It is not clear which of these two reactions predominates, because the reaction products have not yet been identified in dusty olivine grains. Estimates of the density of metal vary: [3] estimated a mean density of 2 wt% metal (<1 vol%), based on broad beam electron microprobe analysis, whereas [5] suggested that the mean density is considerably higher, around 10 vol%. This high value was obtained based on image analysis of BSE images in the electron microprobe. It is possible that the apparent diameter of the metal grains was exaggerated in this analysis, and this possibility is currently being investigated. Mean diameters of grains determined in the image analysis were approximately 1.5 μm. For the same number of metal grains, if the true mean diameter is 1 μm, the estimated metal abundance would be 4.4 vol%. This may be a more realistic value for the grains measured. Metal densities vary among dusty olivines from grain to grain.

The figure shows proportions of solid reaction products expected from the OSI and OPI reactions, for a range of initial Fa contents of olivine. All use a final olivine composition of Fa6, typical of the compositions of dusty relict grains, and for the OPI reaction, a pyroxene product composition of Fs6.

Initial olivine compositions in the range Fa10-20, typical of compositions in FeO-rich, type IIA and type IIAB, chondrules in ordinary chondrites [e.g. 6,7], produce proportions of metal in the range 1-5 vol%. A metal abundance of 10 vol% would require a precursor olivine composition of about Fa35. There are no obvious chondrule precursors for olivines with such high Fa contents in ordinary chondrites.
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b) Minor element contents of dusty relics are compared with those of olivines from FeO-rich chondrules in the plots below. Olivines from type IIA and IIAB chondrules from Semarkona [6,7] and type IIA chondrules in ALH A77307 (C03.0) [8] have well-defined minor element contents. Dusty olivine grains in Semarkona (S) and Murchison (M) have very similar compositions to type II chondrules. In the partly equilibrated chondrites, Chainpur (C) and Ragland (R), CaO and Cr$_2$O$_3$ contents of dusty olivine grains are low. These values are consistent with comparably low values in normal chondrule olivines, in chondrites of subtype >3.2 [e.g. 9], and are attributable to the effects of metamorphism.

![Minor element contents plot](image)

![Minor element contents plot](image)

c) We have observed two grains that have undergone only partial reduction. One in Inman is a large grain, 1100 x 550 µm, that has a dusty olivine texture in an outer zone approximately 100 µm wide. The interior of the grain has a composition Fa$_4$, with minor element contents CaO = 0.1, MnO = 0.06, Cr$_2$O$_3$ = 0.2 wt%. This grain is apparently derived from a relatively FeO-poor chondrule: its composition matches olivine from type IAB chondrules in Semarkona [5], apart from its relatively low Cr$_2$O$_3$ content which may be attributable to mild metamorphism. One of the dusty grains described by [3] (Saint Mary’s County, grain D) has a similar, partially reduced texture, with a clear core of composition Fa$_8$. The second grain, in Semarkona (S* in the minor element plots above), is an FeO-rich olivine relict, ~80 µm across, that has a very limited number of Ni-free metal blebs near one edge. This grain has a composition Fa$_{16}$, and shows zoning within the relict, in the form of increasing concentrations of FeO and minor elements from core to edge. The compositions and zoning properties are very similar to olivines in type II, FeO-rich chondrules in Semarkona [6,7], which are a very likely candidate source for the grain. For both grains, the normal olivines in the host chondrules have Fa contents within a few wt% of the relict Fa contents: Fa$_{0.5}$ in the Inman chondrule, and Fa$_{10}$ in the Semarkona chondrule. The incomplete reduction observed in these cases may be the result of relatively small differences in oxygen fugacity between relict and host, compared with most examples of dusty textures.

Conclusions. These three lines of evidence suggest an origin of dusty, relict olivine grains from previous generations of chondrules. Since dusty relics are common, occurring in approximately 10% of chondrules in ordinary chondrites, considerable recycling of chondrule material must have occurred in the chondrule-forming region of the nebula, with disruptive collisions between chondrules occurring frequently.


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