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Low-iron, manganese-ennriched olivine in amoeboid olivine aggregates in carbonaceous chondrites.

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Introduction:

Low-iron, manganese-enriched (LIME) silicates (olivine and pyroxene) are important components found in some primitive materials formed in the early solar system. This type of silicate has wt % MnO/FeO >0.1, and usually <1.0 wt.% FeO, and is interpreted as a condensate that preserves the redox state of solar nebula gas [1]. LIME silicates were originally identified in IDPs and matrix in primitive chondrites [2], and subsequently found in chondrules in primitive chondrites [3], and in cometary particles from the Stardust samples [e.g., 4].

LIME olivine has been also described in amoeboid olivine aggregates (AOAs) from CR chondrites [5], and Y-81020 and Acfer 094 [6]. In this study, we have studied seven carbonaceous chondrites (Efremovka, Leoville, Vigarano, Y-86009, Allende, Y-81020, NWA 1152) with variable degree of alteration in order to examine the relationship between Mn content in olivines and their formation and alteration conditions.

Results and Discussion:

Low-Fe, Mn-rich olivine is observed in AOAs from Y-81020 (CO3.0) and Y-86009 (CVoxB). In the NWA 1152 (ungrouped C) AOAs, most olivines are forsteritic (Fo92-99), and several olivine analyses show enrichments in MnO (up to 0.4wt.%) and MnO/FeO ratio up to 0.7. Although the MnO/FeO ratio of Mn-rich olivine in NWA 1152 AOAs is not as high as in LIME olivine, it is likely that the formation of Mn-rich olivine is related to LIME olivine. Thermodynamic models show that LIME-like olivine in AOAs can form by gas-solid reactions as temperature declines to near 1100 K [e.g., 1]. The model of Ebel et al. [1] indicates that Mn-rich, Fe-poor olivine forms under relatively low oxygen fugacities (solar composition, no dust enrichment). Based on our observations, when the Mn-rich olivine is present in AOAs, it generally occurs at the edges of the inclusion. This is consistent with the condensation calculation that predicts Mn-enrichment with decreasing temperature [1].

The CV chondrites are subdivided into the reduced (CVred) and two oxidized subgroups. The CVoxB (e.g., Kaba, Bali) experienced hydrous alteration that resulted in formation of phyllosilicates, magnetite, fayalite, andradite, and salite-hedenbergite pyroxenes [7]. On the other hand, the CVoxA (e.g., Allende) experienced alteration under different conditions resulting in formation of nepheline, sodalite, andradite, salite-hedenbergite pyroxenes, fayalitic olivine, and zoning toward Fe-rich rims (~Fo55) in primary olivines (~Fo98). Compared to the oxidized subgroups, secondary minerals are rare in CVred.

Mn-rich olivine is observed in Y-86009 (CVoxB), however, it is not observed in reduced CV chondrites and Allende. Thermal alteration occurred in both reduced CVs (to a minor extent) and Allende (to a higher degree). The absence of Mn-rich olivine in the two types of meteorites may indicate the loss of Mn from olivine during the thermal alteration. Because Fe is introduced to AOA olivines during thermal alteration [e.g., 8], loss of Mn from olivine would occur with the Fe-enrichment in olivines.

It has been also shown that the rimmed AOAs which experienced annealing after aggregation tend to have lower Mn contents [6]. This is consistent with our prediction that Mn was lost by heating. It is likely that Mn-rich olivine was originally present in many AOAs as a primary phase, and then lost during the thermal processing. Therefore, Mn-rich olivine in AOAs can be a sensitive indicator for the thermal processes such as annealing in the solar nebula [1] and parent body thermal alteration.

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