FE/MN IN OLIVINE OF CARBONACEOUS METEORITES.

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Olivines in primitive meteorites show a range of Fe/Mn both within one grain and among grains suggesting that they have recorded changing conditions during or after growth. Because olivine should be an early forming phase, Fe/Mn is used here to infer these earliest conditions. Initial Fe/Mn in cores of isolated, euhedral forsterite in both C2 and C3 meteorites ranges from 25 to 35 but differs at grain edge. Murchison (C2) forsterites show Fe/Mn approaching 1.0 at the grain edge while Ornans Fe/Mn is near 60 at grain edge. These values are lower than the matrix Fe/Mn for both meteorites and the distinct difference in zoning profile indicates different processes operating during and after grain growth.

The Fe/Mn of bulk samples from a particular source such as the Moon is near constant. Individual samples show variation suggesting that there is some fractionation of Mn from Fe. Minerals have their individual ranges of Fe/Mn which has been used to recognize different types of olivine within one meteorite (1). Extreme values of Fe/Mn below 1.0 occur in forsterite from some IDPs, UOC matrix (2) and C1 meteorites (3). There are apparently no detailed studies of Fe/Mn variation within single olivine grains.

Forsterite grains in C2 and C3 carbonaceous chondrites show complex zoning and the nearly pure forsterites (Fo> ~99.5) have high levels of some minor elements including Ti, Al, V and Sc (4). There is disagreement on the original source of these grains and both chondrule (4) and vapor (5) growth have been proposed. In addition, there is clear evidence that diffusion has affected the outer margins but in some cases the whole grain. Within the cores, the FeO range is limited and if growing under constant conditions the Fe/Mn should be near constant as there is little fractionation of Mn from Fe by forsterite and there are apparently no co-crystallizing phases as evidenced by a lack of common inclusions in the forsterites. These observations are now followed by analyses of isolated olivine grains in C2 and C3 meteorites.

Plots of FeO vs Fe/Mn are given below (Fig. 1a,b) for scans from interior to edge of isolated grains in Murchison (C2) and Ornans (C3O). The FeO values clearly show a wider range in the Ornans grain and the trend for Fe/Mn with increasing FeO (from interior to edge) is distinctly different from that of Murchison. Because the Mn level is near the detection level of the electron microprobe in the interior of both grains, Fe/Mn shows wide scatter for low FeO concentrations. To obtain accurate Fe/Mn at low Mn concentrations, special analyses were made with counting times 300sec on both peak and background giving a Fe/Mn of 24 and 35 in Murchison and Ornans olivine cores, respectively. The Murchison trend shows a decrease in the Fe/Mn from 24 to near 1.4 at the grain edge where MnO and FeO have values of about 0.6 and 0.8 wt%, respectively. The Ornans grain is very different where Fe/Mn increases to values of about 60, similar to values for Allende (5).

The enrichment of Murchison forsterite in Mn (Fig. 2) and the low Fe/Mn at the grain edge is reminiscent of the published data for some matrix olivines in Semarkona (UOC) (2) where olivines were reported with up to 1.0 wt% MnO and Fe/Mn of 0.5, but not as extreme as some IDP forsterites (2). These chemical trends are additional evidence of a relationships among several types of extraterrestrial olivines found in micrometeorites, C1 and C2 meteorites, UOC matrix, and IDPs (5). In addition, the interior trace element abundances of forsterites are indistinguishable in all extraterrestrial material suggesting a common origin (6).

While the increase in both Fe and Mn at the grain edges can be attributed to diffusion of a more Fe,Mn rich reservoir, the Fe/Mn is not the same as the core and does not match that of the present matrix with an Fe/Mn over 100. Diffusion of Fe is known to be more rapid than Mn (7) and diffusion alone would also give a higher Fe/Mn toward the grain interior which is not observed for Ornans. Thus for Ornans, diffusion from a reservoir intermediate in Fe/Mn and contemporaneous progressive growth is invoked to explain the chemical trends. The extreme Mn enrichment in Murchison forsterite edges suggests an environment very different from that in which the grain interior grew and unlike the present surrounding matrix. A Mn enriched reservoir suggested by these data is not represented by other recognized extraterrestrial material. The oxygen isotope composition of Ornans forsterite is similar to that of Allende forsterite and different from the bulk meteorite, indicating no direct relation to matrix (C2 forsterite oxygen has not been measured). The observations are consistent with an initial assemblage of homogeneous olivine grains which then followed two diverse chemical paths possibly due to reaction with an inhomogeneous nebula. The distinctly different Fe/Mn trends are most easily explained by a variation

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in the oxidation state of Fe where the Ornans grains show both an increase in FeO and an increase in Fe/Mn indicating progressively more oxidizing conditions. Based on O16-rich oxygen of several Fe-rich matrix grains, some of the matrix probably was formed during growth of the larger forsterite grains. The Murchison grains show only a marginal increase in Fe and a decrease in Fe/Mn indicating a low concentration of oxidized Fe and a competition between Fe and Mn during growth resulting in both a weak enrichment in FeO under reducing conditions such that the oxidized Fe was removed from the system and effectively decreasing the Fe/Mn of its reservoir. Like the C3 meteorites some matrix grew under the same conditions and has been recognized within the matrix of Semarkona.

Both the observations and proposed mechanism of growth require an inhomogeneous nebula in which at least two chemical/isotopic paths were followed. This was followed by mixing of the components (at least represented by matrix) but not of the coarser fraction. The inhomogeneity of the nebula is represented in chemistry, oxidation state, and oxygen isotopic composition.

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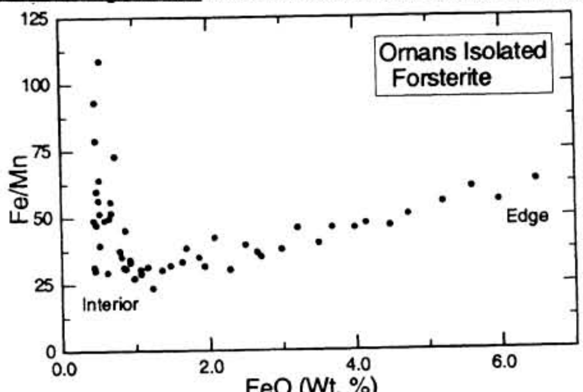

Fig. 1a. Variation of Fe/Mn as function of FeO in Ornans isolated forsterite. Because FeO increases from interior to edge, the FeO is a function of distance from edge. Mn is very low in interior giving large scatter shown for FeO<0.7%. Detailed analyses show the the Fe/Mn in the interior as near constant with a average value of 35. Toward the edge the Fe/Mn increases to 60.

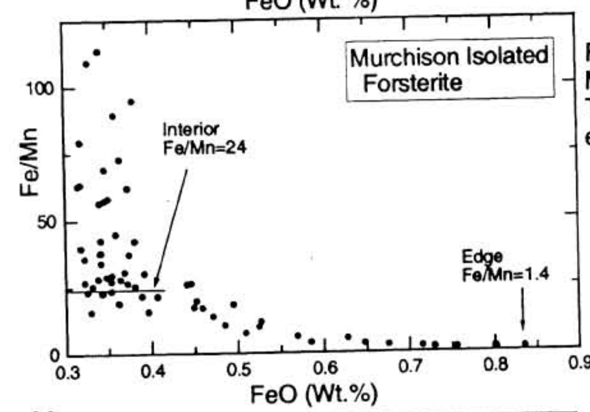

Fig. 1b.Variation of Fe/Mn as function of FeO in Murchison isolated forsterite. In contrast to 2a, The Fe/Mn decreases to values near 1.0 at grain edge from an internal value near 24.

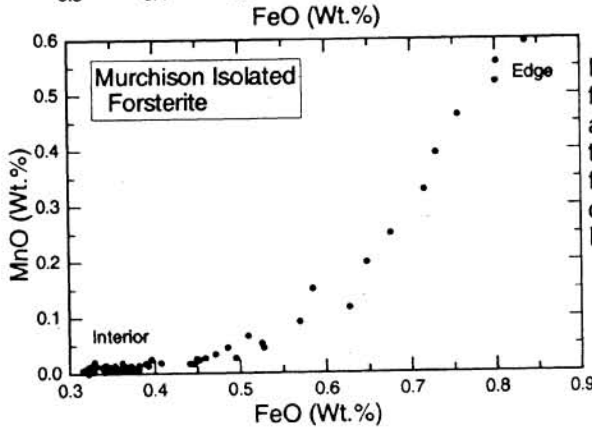

Fig. 2. MnO vs FeO for isolated Murchison forsterite. FeO is near constant in the interior and increases near the edge. MnO is very low in the interior and increases toward edge but at a faster rate than FeO. The edge MnO is comparable to values found in forsterites in many IDPs (2).