FORSTERITE IN C1 METEORITES AND INTERPLANETARY DUST: MINOR ELEMENTS AND COMPARISON WITH OTHER METEORITE TYPES. Ian M. Steele, Dept. of Geophysical Sciences, Univ. of Chicago, 5734 S. Ellis Ave., Chicago, IL 60637.

Forsterite is the most abundant high-temperature phase in the primitive meteorites and as such should record the early conditions in the nebula and allow comparison among the meteorite groups. With exception of the most Mg-rich forsterites, forsterites differ between the C2 and C3-UOC meteorites allowing recognition based on single grain analysis and provide evidence that these two groups followed different chemical evolutions not restricted to the abundant matrix (1). Forsterites of deep sea particles match with C2 forsterites suggesting that they are related (2). A logical extension is to examine forsterite of C1 meteorites and interplanetary dust (IDP) to see what relation these have to the forsterites of other primitive meteorite groups.

Silicate grains larger than 5 microns are extremely rare in the C1 meteorites, but extensive searching with Mg-Kα and BSE scanning images located about 20 forsterite grains each in Orgueil and Alais, both C1 meteorites. While more Fe-rich grains have been reported (3,4) and grains with Mg higher than enstatite could be recognized in the present study, none were found. The largest grains were about 30 microns while grains as small as 2 microns could be recognized. All grains are angular and many have holes or negative features possibly with flat faces similar to negative crystals. Two forsterites were associated with other phases: 1) a tiny grain of diopside was securely attached to a forsterite of Orgueil, and 2) a grain of Alais contained a 1 micron inclusion of Ni-Fe. Repeat analysis on large grains did not show evidence of zoning as reported (3). As previously noted (3), silicate grains tend to be clustered and angular. Several examples were found where multiple grains were present but without clear evidence of a broken preexisting grain; these examples are thought to be clusters of grains.

Each grain larger than about 5 microns was analyzed for Mg, Al, Si, Ca, Cr, Mn, Fe and Ni at 15kV, 25nA, CAMECA probe. The largest grains were analyzed at 20kV, 100nA for these elements as well as Ti, V and Sc. Particular care was made to show that there was negligible contribution from the enclosing matrix by secondary fluorescence, scattered electrons or stray electrons during analysis of the tiny grains. This was done by: 1) repeat analyses at the center and within 4 microns of the edge of larger grains; 2) extracting several grains from the matrix, removing any adhering matrix and remounting in epoxy for analysis; 3) analyzing grains for S which is not to be expected in the olivine structure but which is at the 6% level in the surrounding matrix. All tests showed no matrix contribution is expected for grains larger than about 6 microns. These data are combined with data for Orgueil forsterites obtained several years ago but with quite different conditions: 25kV, 100nA, ARL probe. Two IDP's (RB-27A19 and U2-11A19A) as polished sections contained large forsterite grains and were analyzed with these latter Orgueil grains.

Results: FeO ranges from 0.3 to 3.0 wt% which is within the range of C2 and C3-UOC forsterites (1). The lack of Fe-rich olivines although observed in other studies might best be explained by an inhomogeneous distribution of silicates. All grains analyzed for Ti, V and Sc showed values consistently near or below the detection level of 50ppmw. Where C2 and C3-UOC forsterites typically show Ti at the several hundred ppm level and V about one-fifth of Ti. Sc is seen only rarely in any forsterite. For all grains Al, Ca, Cr, Mn and Ni were commonly above detection. Possibly the most interesting element is Ni because it is seldom found above the detection level of 100 ppm in C2 and C3-UOC forsterites. Figure 1 shows the Ni-Fe variation with a weak positive correlation. The high NiO values of several hundred ppmw have been confirmed by detailed wavelength scans. Although there is overlap, Alais forsterites tend to have lower Ni than Orgueil forsterites although the bulk meteorite differs little in Fe and Ni (5). A Ni-Fe positive correlation has been seen for Fe-rich olivines in Murchison (6) and has been explained as crystallization of olivine in the presence of metal under differing oxidation conditions. Indeed one forsterite grain was associated with metal. Manganese (Fig. 2) is generally below about 200 ppm in C3-UOC forsterites and has a very restricted but higher range in C2 forsterites. In C1 forsterites, consistently high values are found up to 0.6 wt. % although overlap does occur with C2 forsterites. Aluminum, calcium and chromium are present at levels not unlike that of C2 and C3-UOC forsterites. The two IDP forsterites (2 analyses each) show Ni near detection but high values of Mn similar to C1 forsterite (Figs. 1,2). High Mn values have also been reported (7) for other IDP's.

The minor element data presented here indicate that the most primitive, or Mg-rich, olivine in carbonaceous and unequilibrated ordinary chondrites belongs to 3 different chemical groups as found in the C2, C3-UOC, and C1 meteorites. This does not apply to the most Mg-rich forsterites which correspond to the blue luminescing compositions with FeO less than about 0.5 wt% which are identical within probe error in the C2 and C3-UOC meteorites. Data are too few to determine if there are C1 forsterites which also belong to this forsterite group.

The recognition of forsterite compositions specific to the three types of chondrites shows that the individual chemical identity of these chondrite groups can be recognized in the earliest phases. It is not known whether these differences were established during primary growth or whether chemically equivalent forsterite was altered by diffusion or other processes in different environments. The chemical equivalence of the most Mg-rich forsterites in the C2 and C3-UOC chondrites is evidence of an original homogeneous forsterite population which with either additional growth or alteration took on a chemical signature unique to the chondrite type. The C1 forsterites have lower refractory minor elements (Ti, V) and relatively high Mn and Ni indicating an origin somewhat evolved from the C2 and C3-UOC forsterites. The high Mn content reported here and in (7) suggests that IDP grains are related to C1 forsterites. Interplanetary dust has been associated with comets (8) and the chemical similarity between IDP and C1 forsterite indirectly indicates that C1 meteorites are also related to comets.

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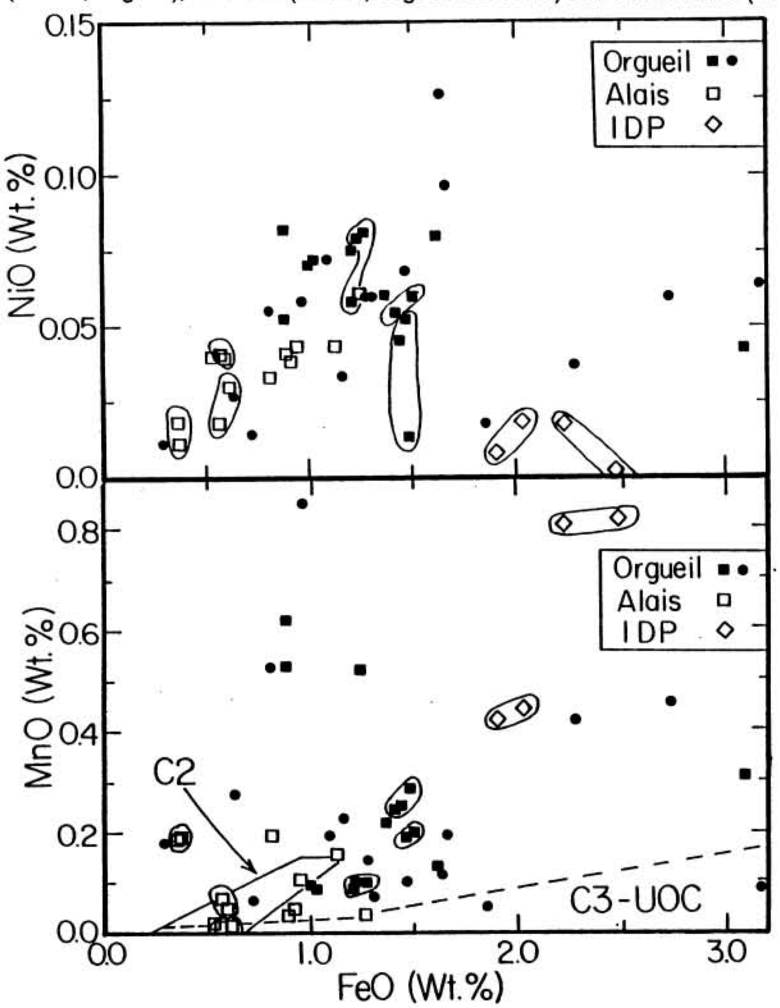

Fig.1. Ni-Fe variation of C1 and IDP forsterites. Solid circles are old Orgueil analyses, solid squares are new. Ringed data represent multiple analyses.

Fig. 2. Mn-Fe variation of C1 and IDP forsterites with generalized ranges indicated for C2 and C3-UOC forsterites (1). Other details as in Fig. 1.