MINERALOGIC EVIDENCE FOR PRE-CHONDRULE NEBULAR CONDITIONS. Ian M. Steele and J.V. Smith, Dept. of Geophysical Sciences, University of Chicago, 5734 S. Ellis Avenue, Chicago, IL 60637.

Some minerals predate the formation of the chondrules in primitive chondrites. Their chemical properties and textural relations can be used to control speculations on the processes and events which affected the earliest solid material within the solar nebula. For simplicity, it is normally assumed that all the material in the primitive chondrites was crystallized in the solar nebula itself. However, the present ideas for chondrite formation only in the solar nebula could be modified to include crystallization in interstellar clouds and other nebula. After all, the philosophical concept of relativity implies that if we consider the loss of comets from the solar system, we should consider the gain of comets from elsewhere. The figure summarizes a possible sequence of events for the formation of early phases in primitive chondrites with time increasing downwards.

A remarkable type of blue-luminescing olivine, with a characteristic minor-element signature, occurs in all primitive meteorites so far studied as single grains or as cores with Fe-rich olivine rims in chondrules (1). This widespread occurrence suggests either a common source of blue olivine with subsequent dispersal into various environments characteristic of each type of primitive meteorite, or independent growth of blue olivine under similar initial conditions. Making a distinction between these two types of occurrence is a major aim of our current research. Quantitative cathodoluminescence studies will be made as soon as the spectrometer is fully calibrated and demonstrated to give reproducible precise results. If spectral differences are consistently found in many olivines, trace-element analyses will be made of selected grains. Oxygen isotope systematics may offer another test of the commonality of the blue olivines after further development of ion microprobe techniques.

All blue forsterite cores are zoned to a rim richer in Fe over a narrow interval of tens of micrometers. The minor-element signature of the olivine rim is characteristic of the type of meteorite. Because only one chemical type of rim occurs in each type of meteorite, each olivine rim must have developed in a distinct source region of the host meteorite with no subsequent intermingling of olivines with different types of rims. Furthermore the sharpness of the core-rim boundary in luminescence photographs indicates that any annealing and chemical diffusion were insufficient to erase the primary texture.

While the extent and nebular origin of the original blue forsterite is not known, some constraints can be placed on the environment of its formation. First, evidence (1) was presented that these cores represent vapor growth. Second, Fe metal is not associated with the grains, and they contain a small percentage of the Fe_2SiO_4 unit (0.25-0.30 mol%); lower values have not been found although specifically sought. This presumably indicates an equilibrium of the type:

$$(Fe + Si + O)\ \text{vapor} \longleftrightarrow Fe_2SiO_4\ \text{(solid)}$$

constrained to a sufficiently oxidizing condition that Fe did not condense as metal. That the olivine contains some iron disagrees with the simple condensation model of Grossman (2) in which the initial olivine would contain no Fe. In order to match the conditions for growth of blue forsterite, The Grossman model requires adjustment to a higher oxidation state.

Spinel is the only mineral which occurs within the blue forsterite core, and is thus older than the olivine. Although rare, spinel occurs in both chondrules and in single forsterite grains. The occurrence is quite different from the spinels in CAI where many grains are included within plagioclase, melilite and pyroxene and the spinel composition is close to pure $MgAl_2O_4$. Only one spinel grain occurs within the blue olivine forsterite grains, and the Cr content is high (~10%; further measurements are needed to establish the range). The apparent implication is that the spinel as with the surrounding forsterite crystallized in an oxidizing environment with Cr entering the spinel either as Cr^{+3} or possibly as Cr^{+2}. The occurrence of only a single grain of spinel within each forsterite grain could be explained by oriented nucleation of olivine on the spinel. This can be tested by determining the relative crystallographic orientation between the close-packed oxygen layers of the two structures. At least one of the spinel grains shows sector zoning.

The above features are seen especially well in C3 meteorites. For C2 meteorites, spinel occurs included within zoned forsterite: however, in contrast to C3 and UOC olivines, the olivines in C2 clearly have gone through an event after formation of the Fe-rich zone during which most grains were broken such that the interior is now exposed. In addition, these grains did not commonly form chondrules but rather exist as broken grains included within the fine-grained matrix.

While many features of C3 and UOC forsterite grains are similar, detailed and complex zoning is common within many UOC forsterites. Interpretation is difficult, but the intersecting textures suggest repeated growth and solution of a single grain. If one accepts that these grains grew in a vapor, this would represent condensation and evaporation, processes often discussed in creating refractory rich assemblages which in the extreme may give CAI and mass fractionation effects.

To conclude: detailed study of the olivine cores and spinel inclusions should place constraints on the early history of the solar nebula, and perhaps on events outside the solar system.

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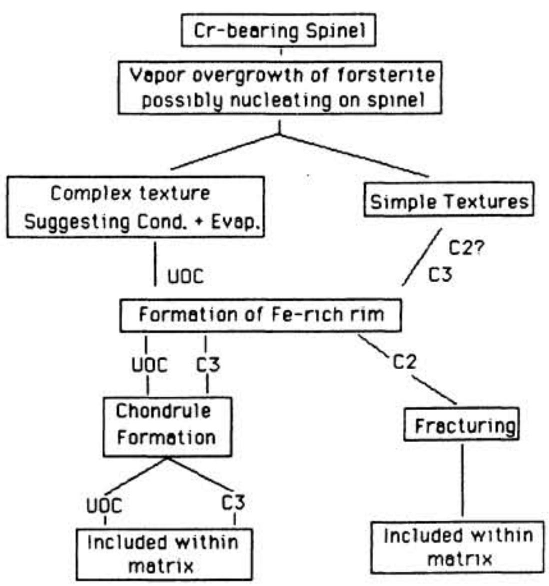

Figure: Mineralogic and textural observations which suggest nebular processes prior to chondrule formation. Oldest events are at top. Ordering of observations is based on textural superposition. Diagram relates only to forsterite and associated minerals and textures.