EVAPORATIVE LOSS AND DEGREE OF MELTING IN SEMARKONA TYPE I CHONDRULES

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Abstract

Bulk compositions have been determined by broad beam techniques for Semarkona type I (FeO-poor) chondrules. The finest grained (least melted) approach CI in composition, and abundances of moderately volatile elements (K, Na, Fe, Ni, S) decrease as grain size (degree of melting) increases. This is unequivocal evidence of evaporative loss during chondrule formation.

Approach

Nucleation density decreases, and therefore on crystallization grain size increases, for greater degree of melting (1). It is difficult to measure grain sizes of fine-grained objects accurately. We therefore determined chondrule nucleation density by counting the number of olivine crystals per unit area in BSE images or in the optical microscope when size permitted. We converted this to a nominal grain size by taking the reciprocal of the square root of the nucleation density.

Bulk compositions of chondrules in Semarkona USNM 1805-4 were determined by broad beam analysis on a Cameca electron microprobe. Although this technique has limitations (2), the order of magnitude differences of concentrations in chondrules in the thin section are clearly greater than the errors involved. All the finer grained chondrules were analyzed, plus randomly selected coarser grained ones.

Results

The dominant textures are microporphyritic and "cryptoporphyritic" (porphyritic in BSE but granular or dark-zoned in PPL). However, for nominal grain size under 4 μm, the chondrules resemble the aggregational chondrules of (3), glass is mainly interstitial and irregularly distributed, and subsolidus minerals include metal, troilite, pentlandite and magnetite (4). Such chondrules (2-4μm) have a composition close to CI (Figure 1). Chondrules with grain size 4-10μm are depleted in ΣFe, Ni, P and S and, with grain size coarser than 10 μm, K and Na are also depleted. A small depletion may be present for Si, Cr and Mn, but as Si/Mg varies widely independently of Fe, it could be the result of higher olivine/pyroxene in the precursors.

Discussion

The more extensively melted type I chondrules have lower concentrations of S, P, Ni, Fe, Na and K than the finest grained type I chondrules. This is entirely consistent with evaporative loss during chondrule formation, and the extent of mass loss may explain the fact that type I are smaller than type II (5). In the MgO-ΣFeO-SiO2 triangle (Figure 1), the data follow the residue trend from evaporation experiments (6), although there is scatter in Mg/Si in the unaveraged data which we attribute to fractionated precursors. Similarly variations in Al/Si are due to prior nebular fractionation (7). Preliminary data show that the finest grained type II chondrules are surprisingly similar to the finest type Is, except for their olivine compositions. Type II chondrules must have been heated under very different conditions to remain volatile-rich.

References

Figure 1  Broad beam analyses of type I (FeO-poor) chondrules in Semarkona compared to their nominal grain size (square root of reciprocal of nucleation density). CI (filled squares, data of Anders and Grevesse) arbitrarily assigned a grain size of 1 μm.