

Sears, D. W. G.; Shaoxiong, H.; Benoit, P. H. (1994b) Open-system behavior during chondrule formation. In *Papers Presented to the Conference on Chondrules and the Protoplanetary Disk* p 37-38. Lunar and Planetary Inst., Houston.

OPEN-SYSTEM BEHAVIOR DURING CHONDRULE FORMATION. D. W. G. Sears, H. Shaoxiong, and P. H. Benoit, Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville AR 72701, USA.

The question of whether chondrules behaved as open systems during formation is crucial to our understanding of both chondrule and chondrite formation [1]. The very large range of chondrule types is best summarized by the compositional classification scheme [2,3], wherein the primitive chondrule groups (i.e., those not produced by metamorphic processes) are A1, A2, A5, and B1. In the Semarkona (LL3.0) chondrite, 10.5%, 25.0%, 5.0%, and 56.9% (by number) of the chondrules are groups A1, A2, A5, and B1, respectively [2]. We argue that groups A1 and A2 were produced by reduction and evaporation during chondrule formation of material originally resembling group B1 chondrules. The important but relatively rare group A5 chondrules will not be discussed here [4].

The following observations are relevant to present the question: (1) Group A1 and A2 chondrules contain olivines with low FeO and metal with Ni contents lower than observed in the metal of group B chondrules [5-7]. The coexistence of low-FeO silicates and high-Fe metal *a priori* implies formation of some fraction of the metal by reduction. (2) Group A1 and A2 chondrules show fractionated elemental compositions, while group B1 chondrules show flat elemental abundance patterns [6,8]. In the group A chondrules, Na and K are depleted by factors of 5-100, while Si, Cr, and Mg are depleted by 10-20%. While attention often focuses on Na and K loss during chondrule formation [9], several authors have also discussed Si loss [10]. (3) The ratio of olivine to pyroxene shows the complex variations expected during progressive volatilization of material of

initially chondritic composition [11]; loss of Fe by volatilization decreases the olivine FeO (to 2-4 wt%) and causes the px/ol ratio to increase so that many group A2 chondrules are pyroxene-rich. Further evaporation Fe (and reduction of FeO in the olivine to <2 wt%) is associated with significant losses of Si and a decrease of the px/ol ratio to group A1 levels. If the chondrules were random mixtures of precursor grains, there is no reason to expect a relationship between the relative abundance and composition of the olivine and pyroxene. (4) All chondrule groups show a wide range of sizes (Fig. 1 [12]). Figure 1 also shows data for group A3 and B2 chondrules from Krymka, LL3.1. (The slight metamorphism experienced by Krymka is not expected to seriously affect chondrule sizes.) Mean diameters for groups A1, A2, A3, B1, and B2 are 807 ± 398 , 838 ± 392 , 764 ± 299 , 1052 ± 419 , and 970 ± 367 μm , respectively. The student's *t* test indicates that the A groups differ significantly from the B groups at the 0.01 level and that group A chondrules are significantly smaller, as a group, than group B chondrules. Other authors have made the same conclusion [13]. Huang et al. point out that the size difference is consistent with the compositional differences between group A and group B chondrules [12].

Additional evidence for devolatilization during chondrule formation is the compositional zoning observed in the mesostasis of several Semarkona group A chondrules. The alkali elements are higher in the outer quarter of the chondrule radius, suggesting that alkalis are reentering the chondrule, having once been lost [14]. It is difficult to see how precursor heterogeneities could produce such profiles, or how they could be produced by crystallization or other closed-system processes. Sears and Lipschutz recently argued that abundance patterns of highly mobile trace elements in several chondrules from low type 3 ordinary chondrites reflected a similar kind of process [15].

Group A chondrules clearly formed by major devolatilization and reduction during chondrule formation from material initially resembling group B chondrules. The different chondrite classes seem to contain chondrules with different size distributions, and the chondrite classes show different lithophile-element abundances and degrees of Fe reduction. It will be of great interest to explore the role of the different chondrule groups, and thereby the chondrule formation process, in accounting for these different chondrite properties.

Acknowledgments: Supported by NASA grant NAGW 3519.

References: [1] Grossman J. N. (1988) in *Meteorites and the Early Solar System* (J. F. Kerridge and M. S. Matthews, eds.), 680-696, Univ. of Arizona, Tucson. [2] Sears D. W. G. et al. (1992) *Nature*, 357, 207-211. [3] DeHart J. M. et al. (1992) *GCA*, 3791-3807. [4] Huang et al. (1994) *LPS XXV*, 573-574. [5] Jones R. H. and Scott E. R. D. (1989) *Proc. LPSC 19th*, 523-536. [6] Jones R. H. (1990) *GCA*, 54, 1785-1802. [7] Snellenberg J. (1978) Thesis, New York State Univ., Stonybrook. [8] Lu J. et al. (1990) *LPS XXIII*, 720-721. [9] Hewins R. H. (1991) *GCA*, 55, 935-942. [10] Walter L. S. and Dodd R. T. (1972) *Meteoritics*, 7, 341-352. [11] Hashimoto A. (1983) *Geochem. J.*, 17, 111-145. [12] Huang et al. (1994) in preparation. [13] Dodd R. T. (1971) *Contrib. Mineral. Petrol.*, 31, 281-291. [14] Matsunami et al. (1993) *GCA*, 57, 2101-2110. [15] Sears D. W. G. and Lipschutz M. E. (1994) *LPS XXV*, 1229-1230.

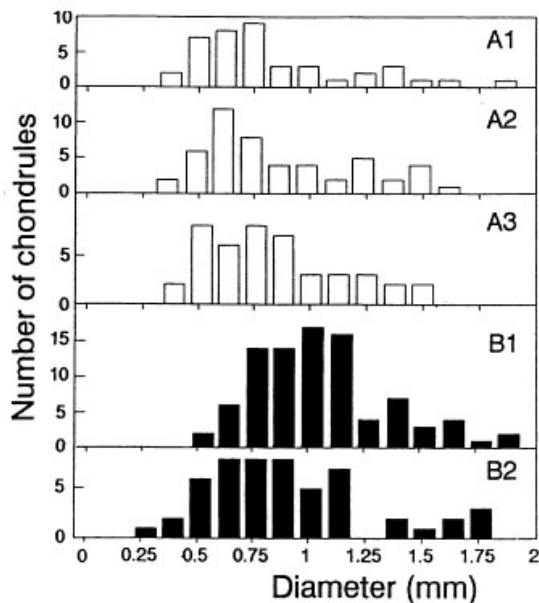


Fig. 1. Chondrule size distribution in chondrules from Semarkona and Krymka.