SIZE DISTRIBUTIONS AND AERODYNAMIC EQUIVALENCE OF METAL CHONDRULES AND SILICATE CHONDRULES IN ACFER 059. William R. Skinner, Department of Geology, Oberlin College, Oberlin, OH 44074, and James M. Leenhouts, Department of Geology, University of Arizona, Tucson, AZ 85721.

The CR2 chondrite Acfer 059 is unusual in that original droplet shapes of metal chondrules are well preserved. We determined separate size distributions for metal chondrules and silicate chondrules; the two types are well sorted and have similar size distributions about their respective mean diameters of 0.74 mm and 1.44 mm. These mean values are aerodynamically equivalent for the contrasting densities, as shown by calculated terminal settling velocities in a model solar nebula. Aerodynamic equivalence and similarity of size distributions suggest that metal and silicate fractions experienced the same sorting process before they were accreted onto the parent body. These characteristics, together with depletion of iron in Acfer 059 and essentially all other chondrites relative to primitive CI compositions, strongly suggests that sorting in the solar nebula involved a radial aerodynamic component and that sorting and siderophile depletion in chondrites are closely related.

Chondrule diameters were determined by direct measurements of major and minor dimensions taken from enlarged photographs of six thin sections cut from a single piece of Acfer 059. The apparent diameter in thin section was obtained from the average of the two orthogonal dimensions. Most chondrules are almost circular or are slightly flattened (elliptical) as seen in thin section. A total of 64 metal chondrules, 412 silicate chondrules, and 19 "composite chondrules" (consisting of major proportions of both metal and silicate) were measured. The "composite chondrules" were not plotted nor otherwise considered in this study. Figure 1 shows the apparent size distributions of metal chondrules and silicate chondrules as measured in thin section; note that standard deviations for these two populations are quite small. Sorting is actually better than is indicated by the distribution seen in thin section [1], so that adjusted distributions of actual diameters would plot with steeper slopes. The size of

![Figure 1. Apparent size frequency distributions of metal chondrules (n=64, std. dev. = 0.32) and silicate chondrules (n=412, std. dev. = 0.58) measured in six thin sections of Acfer 059.](image-url)
SIZE DISTRIBUTIONS OF CHONDRULES: Skinner W.R. and Leenhouts J.M.

the largest object in each distribution would remain the same, but smaller diameters would be shifted to larger values. The adjusted mean diameters are 0.74 mm for metal chondrules, 1.44 mm for silicate chondrules, and 1.84 mm for "composite chondrules" (1.251 times the apparent mean diameters [1]).

Many of the silicate chondrules, especially the larger ones, exhibit an agglomerated or accretionary habit and contain small metal inclusions; metal is also commonly attached to their perimters. Metal chondrules generally have original droplet shapes; terrestrial weathering has partly converted some metal to iron oxides, but the original chondrule outlines are easily discerned. Metal content of Acfer 059 is about 10 vol% [2].

The size distributions determined here reveal a high degree of size sorting of both metal chondrules and silicate chondrules. The distributions about their respective mean values are similar for the two populations as shown by the nearly parallel curves in Figure 1. Aerodynamic terminal velocities of spherical objects falling in a model solar nebula were calculated for the two mean sizes using estimated densities of 7.8 gm/cc for metal chondrules and 3.76 gm/cc for silicate chondrules. The latter figure include 10% metal inclusions in the silicate chondrules based on a visual estimate. Calculated terminal velocities are 515 cm/sec for the mean metal chondrule (diameter 0.74 mm) and 504 cm/sec for the mean silicate chondrule (diameter 1.44 mm). These values are virtually identical, strongly supporting an interpretation that the two types of chondrules were sorted aerodynamically at the same time.

The intimate association of metal chondrules and silicate chondrules having metal inclusions seems to indicate that both metal and silicate chondrules formed in the same high temperature event. Chemical similarity of metal chondrules and metal included in silicate chondrules in Renazzo [3] supports this hypothesis. It has been shown for ordinary chondrites that silicate chondrules were formed in a wider size range than that represented in the accreted chondrites [4]. The present study indicates that a wide range of metal and silicate chondrules that formed in a high temperature event (or events) were later sorted into the narrow size ranges observed here. The size ranges of silicate and metal chondrules produced by chondrule-forming events are not known, but it is possible that the same process that sorted chondrules also produced a silicate/metal fractionation. This would account for the depletion of iron and other siderophile elements in chondrites relative to CI compositions [5].

Simple models for parent body formation that consider only vertical settling of particles to the nebular midplane do not explain the overabundance of chondrites with siderophile depletion and the extreme rarity of those with excess metal (and even these rare types, e.g. ALH 85085, were most likely extensively processed on the parent body [6] and may have acquired their metal-rich character after accretion). Strictly vertical settling models should produce abundant metal-enriched chondrites as well as metal-depleted ones, which are not observed. Models that include a radial transport component in the sorting mechanism thus seem to be indicated and could account for transport of the missing metal to regions other than those zones of the asteroid belt from which sampled meteorites are derived.

The correlation in this study between the size sorting of metal and silicate fractions strongly suggests that sorting and siderophile depletion in chondrites are closely connected. It also supports the view that aerodynamic drag is an important process in the preaccretionary history of all chondrites.

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