SIZE SORTING OF METAL, SULFIDE, AND CHONDRULES IN SHARPS (H3.4). P.H. Benoit, G. Akridge, and D.W.G. Sears. Cosmochemistry Group, Dept. Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701, USA. E-mail: COSMO@uafsysb.uark.edu.

Abstract. *Size sorting of chondrules occurs in most major chondrite classes and silicate-metal fractionation is a prominent feature in these meteorites. We have measured the dimensions of chondrules and isolated metal and sulfide grains in the Sharps (H3.4) chondrite, this being the least metamorphosed unweathered H chondrite known. These three components are all size-sorted, with sizes decreasing chondrules >> sulfide grains > metal grains. In size-density space, all three components are in the regime of fluidization, i.e., aerodynamic sorting in a gravity field, such as might occur when a volatile-rich parent body is impact or internally heated. Fluidization could also produce metal/silicate fractionation displayed by the meteorite groups.*

Introduction. Chondrules in ordinary and carbonaceous chondrites exhibit a fairly restricted range in size, and they display log-normal size distributions [1-3]. Chondrule-like objects in lunar breccias also exhibit narrow log-normal size distributions [4]. One interpretation of these data is that these objects have experienced gravitational or aerodynamic sorting, either in temporary “atmospheres” on parent bodies [5] or in the nebula [6]. Metal particles in the ordinary chondrites have also been observed to exhibit size-sorting [5]. Another chondrite property indicative of formation processes is metal-silicate fractionation [5,7]. The metal/silicate ratio varies between major chondrite classes and may also vary slightly within chondrite classes. This variation has also been interpreted as a nebula process, although we have suggested that metal-silicate fractionation may be linked to chondrule size-sorting on the meteorite parent body [5]. In order to explore these processes, we have determined the size distribution of chondrules, sulfide grains, and metal grains in the Sharps (H3.4) ordinary chondrite. Sharps is the least metamorphosed H chondrite [8], except for RC 075 which is highly weathered [9]. Dodd described the chondrules and measured chondrule sizes in Sharps [5,10].

Methods. A thin-section (USNM 640-5) with an area of about 5 cm^2 was examined. Only complete chondrules were measured, chondrule fragments and irregularly shaped clasts being excluded. Maximum and minimum diameters of chondrules were measured using a calibrated micrometer and a transmitted light microscope. Sulfide and metal grains were measured using a reflected light microscope. Only grains that could clearly be identified as isolated grains outside of chondrules or chondrule rims were measured. The largest and smallest dimensions were averaged.

For fluidization experiments [11], we used a mixture of sand grains and iron pellets (81 and 19 wt. %, respectively) of approximately the same diameter as chondrules and metal grains in Sharps. The mixture was completely fluidized in a column and then gas pressure slowly lowered until the grains settled. Samples were taken at intervals throughout the column.

Results. We measured 96 chondrules, 90 sulfide grains, and 78 metal grains in this section. Our size data are reported without correction factors [12]. Chondrule diameters range from 45 to 1000 µm, averaging ~320 µm (Fig. 1). In agreement with Dodd [10], we find that porphorhyitic chondrules are the most common type. Barred olivine chondrules tend to be the same size, or perhaps slightly larger than porphyritic chondrules, while fine grained chondrules tend to be slightly smaller. Sulfide grains range in size from 40 to 320 µm, averaging ~ 100 µm; metal grains range in size from 10 to 320 µm, averaging ~ 65 µm in diameter. Plots of cumulative frequency distributions on probability axes show approximately linear trends, indicating that chondrules, metal and sulfide grains approximately conform to log-normal size distributions.

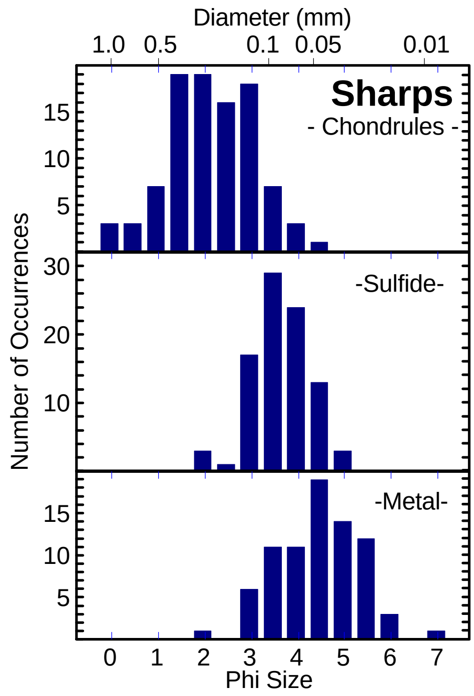

Fig. 1. Size of constituents of Sharps.

Discussion. Dodd's [5] measurements on Sharps indicate that "silicate" and metal grain sizes were somewhat larger than noted here, "silicate" grains have a median diameter of ~290 µm and metal grains having a median diameter of ~160 µm. It is likely that this reflects differences in choice of objects. Dodd's "silicate" grains include chondrules, but may also include clasts, or objects of uncertain classification [2]. His metal grains may include many incorporated in chondrules or in chondrule rims. Of course, given the limitations of section analysis, it is possible that some of our grains are also in rims despite our efforts to avoid these grains.

We find that chondrules, metal and sulfide grains in Sharps are size-sorted, with chondrules tending to be larger than sulfides, which, in turn, are slightly larger than metal grains. Possibly such differences reflect kinetics of grain formation in a nebula. However, size differences mirror density differences, sulfide grains being slightly less dense than metal. Dodd [5] suggested that such a dependence could indicate either gravitational or aerodynamic sorting, both of which are density dependent. Another scenario is a combination of gravitation and aerodynamic sorting, taking place on a parent body as gas evolved from the interior passes through an unconsolidated "regolith". This process is similar to the chemical engineering procedure known as "fluidization" and might occur early in the history of parent bodies if the parent bodies were water rich and degassed during aggregation [13]. The size ranges for particles of different densities observed in Sharps fit a relative density-size regime in which fluidization occurs easily, coinciding with gas bubbling, an important sorting agent [14] (Fig. 2). Metal, sulfide, and chondrules do not plot in regimes of "cohesive" or "channeling" behavior, in both of which fluidization does not occur and gas flow does not produce appreciable sorting.

Our fluidization experiments, similar to those described by Akridge and Sears [11], used an initial metal/silicate mixture consisting of 19% metal, this being an equivalent to a CI chondrite if iron is converted to metal. It is fairly similar to typical H chondrite composition. We find that metal grains tend to be depleted in the lower portion of the fluidization bed and concentrated in the upper portion, with most of the bed being moderately enriched relative to the starting composition (Fig. 3). Sharps has relatively low metal content (12%) compared to other H chondrites, which could be interpreted as reflecting placement in the lower portion of the regolith.

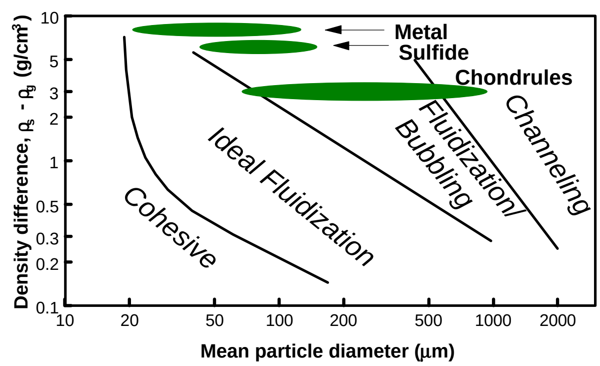

Fig. 2. Chondrule, metal, and sulfide size ranges for Sharps, relative to fluidization regimes [14].

Conclusions. Chondrules and isolated metal and sulfide grains in Sharps (H3.4) exhibit size-sorting, with chondrules >> sulfide grains > metal grains, an inverse relationship to density, each exhibiting approximately log-normal size distributions. These data can be interpreted in relation to density/size-related processes, and suggest fluidization on a parent body. Metal/silicate varation within meteorite groups may also reflect this process.

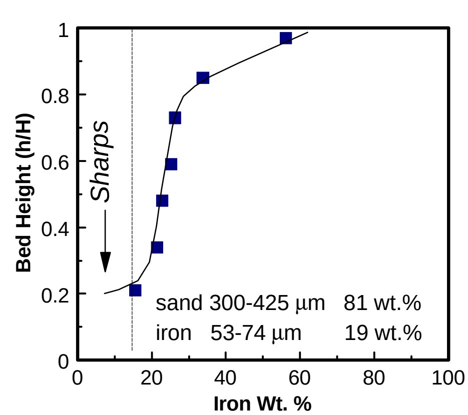

Fig. 3. Segregation of metal in a fluidized column of sand and metal. Dashed line shows original (homogeneous) distribution, points show distribution after fluidization. For the given grain size populations, metal tends to be segregated to the top of the bed.

References. [1] King and King (1979) *Meteoritics* **14**, 91. [2] Hughes (1978) *EPSL* **38**, 391; Martin and Mills (1978) *EPSL* **38**, 385; Rubin and Keil (1984) *Meteoritics* **19**, 135. [3] King and King (1978) *Meteoritics* **13**, 47; ; Rubin (1989) *Meteoritics* **24**, 179. [4] King *et al.* (1972) *Proc. LPSC*, 673; Symes *et al.* (1998) *Meteor. Planet. Sci.* (in press). [5] Dodd (1976) *EPSL* **30**, 281. [6] Weidenschilling (1977) *Mon. Not. R. Astron. Soc.* **180**, 57; Clayton (1980) *EPSL* **47**, 199. [7] Larimer and Anders (1970) *GCA* **34**, 367. [8] Sears *et al.* (1991) *Proc. LPS* **21**, 493. [9] McCoy *et al.* (1993) *Meteortics* **28**, 681. [10] Dodd (1971) *Contr. Mineral. Petrol.* **31**, 201. [11] Akridge and Sears (1998) This meeting. [12] Hughes (1978) *EPSL* **38**, 391; Eisenhour (1996) *Meteor. Planet. Sci.* **31**, 243. [13] Huang *et al.* (1996) *JGR* **101**, 29373. [14] Kunii and Levenspiel (1991) *Fluidization Engineering* (2nd ed.), Butterworth-Heinemann, Boston.