GRAIN SIZE SORTING IN THE OUTER NEBULA ACCRETION DISK. P. Wozniakiewicz[1,2], H. A. Ishii[1], J. P. Bradley[1], A. T. Kearsley[3], M. J. Burchell[2] and M. C. Price[2]. [1]Institute of Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, Livermore, CA 94550, USA (pwozniakiewicz@yahoo.com). [2]School of Physical Sciences, University of Kent, Canterbury, Kent CT2 7NH, UK. [3]Department of Mineralogy, Natural History Museum, London SW7 5BD, UK.

Introduction: Grain size sorting accompanying radial transport from inner to outer disk regions in the solar system is inferred from astronomical observations of protoplanetary disks around other stars [e.g. 1]. Pre-accretional aerodynamic sorting in our solar nebula has been demonstrated among components of the inner solar system asteroids: Limited studies carried out to date show that large-grain components of chondrites (silicate chondrules and metal/sulfide grains) demonstrate equivalence in their average size-density products ($r\rho$) [2-4]. It has also been suggested that larger porous aggregates of fine-grained material were similarly aerodynamically sorted and accreted with the large-grained components to form the fine-grained matrices of chondrites [5]. The recent identification of a few, much smaller (µm-sized) inclusions of refractory minerals (calcium-aluminum inclusions or CAIs) and chondrules formed in the hot inner regions of the nebula [6-8], within samples from the Kuiper Belt comet 81P/Wild 2, indicates transport and sorting extended into the Kuiper Belt. Accordingly, we have investigated aerodynamic sorting in the outer solar nebula by examining the sizes and densities of grains in chondritic porous (CP) IDPs whose parent bodies are believed to be Kuiper Belt comets from a range of heliocentric distances, and comparing with comet 81P/Wild 2 and an ordinary chondrite.

Data collection and analysis: We have examined silicate and sulfide crystals (the dominant components) in three CP IDPs: U2-11B6, SP-75 and C-11. We also compiled size and density data for silicate and sulfide grains from 81P/Wild 2 [3,9], believed to have accreted beyond 20 astronomical units (AU). Evidence for sorting is found in the grain size distributions, by comparing the geometric mean size-density products ($r\rho$) for their silicate and sulfide components.

Results and Discussion: Fig. 1 shows grain size distributions of components of inner and outer solar system objects. Silicate chondrules and metal/sulfide grains in the Kelly LL4 chondrite are plotted in Fig. 1A and 1B (from original data provided by K. Kuebler [see 6]). Silicate and sulfide crystals in CP IDP U2-11B6 are plotted in Figures 1C and 1D. The grain size ranges for this CP IDP are similar to those for SP-75 and C11 and those reported for other CP IDPs [e.g. 10, 11, 12]. Since the number of single silicate or sulfide grains is small, the size distribution of all 81P/Wild 2 grains (both in single mineral and multiple mineral impacts), derived from measurements of impact craters, are plotted in Fig. 1E. Fig. 1 shows that although the size distributions of the inner solar system chondrite components peak at sizes 3 – 4 orders of magnitude larger, they show similar log-normal size distribution profiles to the outer solar system CP IDP grains.

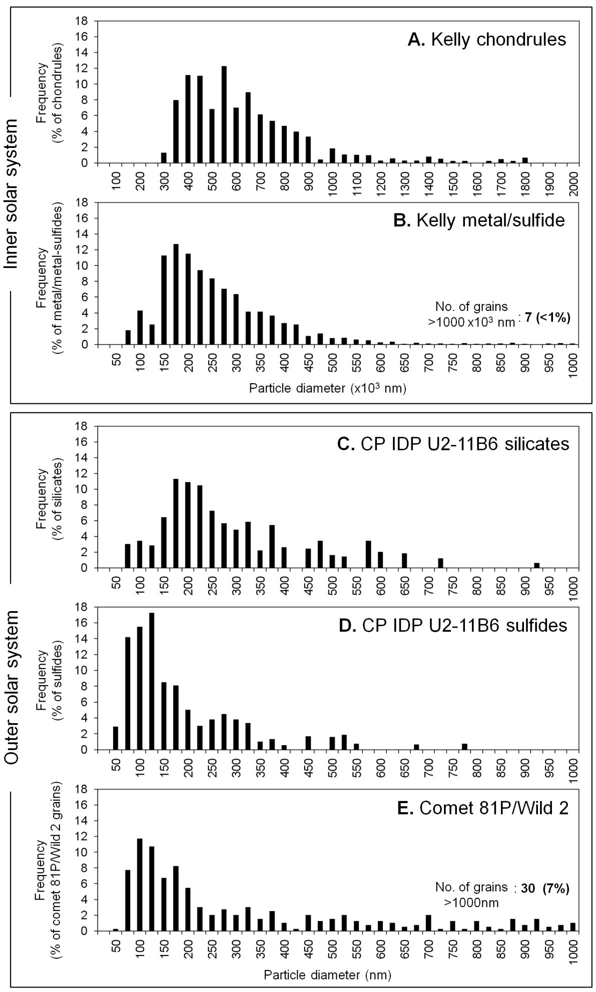

Fig. 1: Grain size distributions for components in inner and outer solar system objects. Inner solar system components are (A) silicate chondrules and (B) metal/sulfide grains from the Kelly LL4 chondrite (from original data set provided by K. Kuebler [see 6]). Outer solar system components include (C) crystalline silicates and (D) sulfides in CP IDP U2-11B6. The size distribution of all comet 81P/Wild 2 grains responsible for the impact craters measured in the Preliminary Examination of the NASA Stardust mission aluminum foil collector surface is plotted in (E) [data from 9].

The geometric mean size-density products ($r\rho$) for silicate versus sulfide components in outer nebula cometary samples are plotted against one another in Fig. 2. All data points fall on or near the 1:1 line. Within the standard error of the mean, the 81P/Wild 2 and CP IDPs C-11, U2-11B6 and SP-75 data points lie at 1.06:1, 1.06:1, 1.12:1 and 1.08:1 respectively. The aerodynamic equivalence among components in inner (reported previously) and outer solar system objects (Fig. 2) demonstrate that both nebula-wide radial transport and efficient aerodynamic sorting of crystalline grains with a wide range of sizes occurred prior to accretion of asteroids and comets.

We note that aerodynamically-sorted dust formed in the inner disk region of the solar system and incorporated into meteorites from the inner solar system plot at larger average values of $r\rho$ relative to that in the cometary objects from the outer solar system. (They plot outside the range exhibited in Fig. 2). The relevance of this observation is uncertain at present because the aerodynamic sorting mechanism(s) operating is(are) not constrained and it is not possible to unambiguously assign a specific aerodynamic sorting mechanism since log-normal size distributions and $r\rho$ selectivity are common to aerodynamic processes.

One possible interpretation would have major implications: If the radial transport process(es) that moved dust from inner to outer disk regions also resulted in aerodynamic sorting of the dust available to accrete into parent body objects, then the size-density plot in Fig. 2 acts as a direct indicator for heliocentric distance of accretion. Alternatively, the aerodynamic sorting in Fig. 2 may have occurred by some other means following transport: Turbulent concentration of size-density-selected dust in low vorticity zones in a weakly turbulent nebula may have resulted in accretion of size-density selected dust [13]. As we continue to analyze the size-density relationships in more known bodies, we will achieve a better understanding of the sorting mechanism(s) that operated and their relation to transport.

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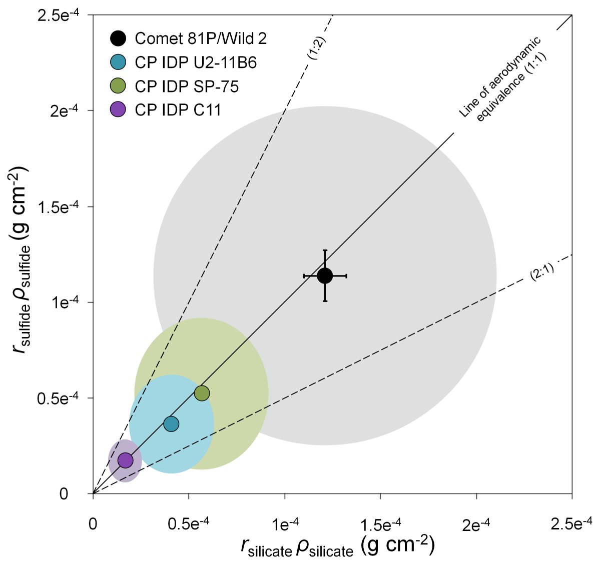

Fig. 2. Comparison of mean size-density product $r\rho$ for crystalline Mg-silicates and sulfides from outer solar system objects: Comet 81P/Wild 2 and the parent bodies of the CP IDPs U2-11B6, SP-75 and C-11. All data points fall on or near the 1:1 line of aerodynamic equivalence indicating aerodynamic sorting in the Epstein gas drag regime. The standard errors of the means lie within the symbols on the plot, with the exception of comet 81P/Wild 2 where they are represented by error bars. The deviation about each mean is indicated by the shaded areas surrounding the mean data points.

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