COULD CAIS HAVE SURVIVED AS SMALL OBJECTS IN THE SOLAR NEBULA FOR A MILLION YEARS OR MORE?; William R. Skinner, Department of Geology, Oberlin College, Oberlin, OH 44074-1044.

Several recent papers and presentations (e.g., 1, 2, 3, 4) strongly suggest that refractory inclusions, also called CAIs, had a several million year history before they were accreted onto the parent bodies of meteorites such as Allende. It is commonly assumed that this pre-Allende history was a nebular one, but such an assumption should be examined. Our knowledge of the solar nebula is still quite limited, but consideration of accretion disk models (e.g., 5, 6, 7), of estimates of survival times of small objects in space (8), and of experimental impact studies on rock strength (8, 9, 10) leads to the conclusion that centimeter-sized objects such as CAIs probably could not have survived for a million years or more as free objects in the solar nebula. Some alternative, perhaps temporary storage in one or more refractory planetesimals (11), may be required.

A simple model of solid objects in the gaseous solar nebula predicts that a rocky sphere would require a diameter of one kilometer in order to maintain its orbital status for a million years around the protosun (5) . This is so because the gas is partially supported by its internal pressure and orbits slower than the Keplerian velocity of associated solid objects, thus providing a "headwind" that slows these objects and causes them to spiral into the protostar. The effect of the headwind is diminished for larger objects, becoming minimal for those of kilometer or larger size. More complex and probably more realistic models of particle-gas dynamics in accretion disks have recently been developed (6, 7). These models include the effects of momentum transfer in the disk and predict that the boundary layers on either side of an inward-moving, particle-rich midplane layer would be driven radially outward, sweeping small entrained particles along with them. Such outward motion could greatly extend the lifetimes of particles beyond those predicted by the simple accretion model. Thus it would seem that (with the proper adjustment of model parameters) some centimeter-sized objects could survive for a million or more years before being accreted onto a meteorite parent body. However, other things must be considered.

One of these is the survival lifetime of a centimeter-sized object in a turbulent accretion disk. High energy collisions are to be expected (6) and could result in destruction of these small objects by fragmentation. It seems unlikely that CAIs with concentric structure such as type B1s could survive intact for long periods of time. Some quantitative understanding of the problem can be gained by analogy with a study concerned with the destruction of tektites by micrometeoroid impact in the present solar system (8). This study combined impact fragmentation experiments on glassy spheres with estimates of micrometeoroid flux at one AU to arrive at the conclusion that the expected lifetime of a centimeter-sized tektite is only about 1000 years at present in near-earth space. Partial fragmentation and loss of original shape would occur on an even shorter time scale (8). Rupture strengths determined for glass spheres in this study are essentially the same as those determined for basalt, granite, dunite, and granodiorite in other studies (9, 10), so the impact fragmentation arguments of (8) should be applicable to refractory inclusions.

Finally, there is the enormous variation in CAI content from one chondite group to another. The high concentration of refractory material (almost 10%) and the large size of some CAIs in Allende are remarkable in view of the very low concentrations and small sizes found in some other meteorites. It might be possible to account for such differences if CAIs had been preserved in one or more refractory planetesimals (11) which disrupted in the vicinity of the Allende parent body while it was forming. The timing and locations of such disruptions might well account for the low content of CAIs in ordinary and enstatite chondrites and the higher and variable concentrations found in carbonaceous chondrites. Recent observations of some asteroids with CO3/CV3 affinities suggest that there are objects in the asteroid belt with high concentrations of refrctory material (12). Such observations should lead eventually to a better understanding of the distribution of refractory material in meteorite parent bodies as well as to better constraints on the view expressed here that this distribution may result from stochastic collisional events that affected refractory-rich planetesimals that predate the meteorite parent bodies in which CAIs occur.

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