CAIs MADE BY GIANT IMPACT I. S. Sanders, Department of Geology, Trinity College, Dublin 2, Ireland. isanders@tcd.ie

Introduction: Calcium-aluminium-rich inclusions (CAIs) are refractory aggregates of Ca, Al, and Ti-rich oxides and silicates found in most kinds of chondritic meteorites. They are best displayed in the CV chondrites where they have been found to be the oldest objects with solar isotopic abundances. Their age of 4567 Myr has been widely adopted as marking the start of the Solar System. At that time their inferred $^{26}Al/^{27}Al$ was 5×10^{-5}, the so-called canonical value [1]. CAIs were clearly formed as evaporative residues or as condensates in a hot gas, probably of solar composition, though details are poorly understood. They are generally presumed to have formed in a highly energetic setting close to the proto-Sun.

Not all CAIs are like those in CV chondrites. In the metal-rich chondrites of the CB and CH groups, and in the CB/CH-like meteorite, Isheyevo, CAIs have been recognized with barely resolvable initial $^{26}Al/^{27}Al$ [2]. They are associated with unusual cryptocrystalline chondrules, and metal chondrules, that are thought to have condensed from a hot vapour plume generated by a giant impact about 5 Myr after the start of the Solar System [3]. At least some of these CAIs have recently been recognized as having possibly formed in the same impact event that produced the unusual chondrules [4]. In light of this last suggestion, it is not unreasonable to ask whether the more typical CAIs in the CV chondrites might also have a giant impact origin. Five observations lend support to this somewhat unconventional idea.

Brief formation time: If the CV CAIs were produced in an impact plume they would all have the same age. This is exactly what has been inferred from the tight fit of whole-CAI data points to an Al-Mg isochron which is identical to internal isochrons from individual CAIs [1]. The CAIs appear to have crystallized in >20 kyr.

Location: CV CAIs are embedded in the CV parent asteroid. Given the choice, it is easier to argue that they were made in a giant impact several AU from the Sun, where they are now found, than to invoke formation close to the Sun with the added difficulty of explaining how they became transported to their present location in the asteroid belt.

Very early planetary bodies: If CV CAIs formed in a giant impact, then protoplanets must clearly have existed in the disk before the 'beginning'. Evidence that they may well have existed so early is found in the negative ^{182}W anomalies of magmatic iron meteorites. The $\varepsilon^{182}W$ values of these irons, after correction for cosmic ray exposoure effects, are close to –3.47. This is noticably lower than the recently refined value of $\varepsilon^{182}W$ based on an excellent internal isochron for CAIs (-3.28 ± 0.12) by Burkhardt et al. [5] who cautiously suggest that there may be an error in correcting for cosmic ray exposure rather than admit to the possibility that the data might be taken at face value, and that the parent bodies of the iron meteorites had both accreted and melted before the CAIs were formed.

Early giant impacts: While the better documented giant impacts (e.g. formation of the Moon, the impact which preceded reassembly of the Shallowater enstatite achondrite [6], and the putative impact that led to the CB chondrite chondrules) all happened several Myr after the beginning, other giant impacts appear to have been extremely early. One of these, a suggested hit-and-run collision between planetary embryos, apparently left a 300 km diameter sphere of molten iron that cooled to become the IVA parent body [7]. Another has been inferred for the loss of volatile elements in the material that accreted to form the HED parent body [8]. Theoretical modeling suggests the rapid growth of protoplanetary runaways (in 0.1 to 1 Myr) at the start of the Solar System [9].

Energy for vaporization: Planetary embryos that accreted extremely early, before CAIs, would very rapidly (in 200 to 300 kyr) have become heated and melted by the decay of ^{26}Al. Thus, during impact, a huge amount of thermal energy would have augmented the kinetic energy of the collision. Moreover, with, for example, a Moon-sized body, internal pressure would have increased significantly with depth, and the melting point would have been substantially raised. The solidus temperature would rise by about 100 K for each 180 km of depth. Explosive decompression would have ensued on impact, and produced a vapour of solar composition for condensation of CAIs.

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