THE MELTDOWN ERA: A TIME FOR MAKING ANCIENT IRON CORES AND YOUNGER CHONDRULES. I. S. Sanders, Department of Geology, Trinity College, Dublin, Ireland (isanders@tcd.ie).

Introduction: Recent evidence from meteorites challenges the conventional view of the evolving protoplanetary disk [e.g. 1] in which chondrule formation (by the 'flash-melting' of dust clumps) and the accretion of primitive chondritic parent bodies happened first, and the heating and melting of such bodies happened later.

Many iron meteorites have a large negative $\varepsilon^{182}W$ isotope anomaly that is within error of the initial $\varepsilon^{182}W$ in CAIs, and suggests that planetesimal cores were molten within the first 500 kyr [2]. Chondrules, on the other hand, mostly date from some 2 Myr after CAIs, to judge from their initial $^{26}Al/^{27}Al$ and $\delta^{26}Mg$ values [3, 4]. Sintered (planetesimal-derived) dunite fragments recently discovered within chondrules also imply that planetesimals already existed before chondrules were made[5]. As to how chondrules were made, the levels of Na in chondrule olivine imply clouds of droplets far more densely populated than is envisaged in popular models for making chondrules by the 'flash melting' of dust-balls [6].

Interpretation: These disparate observations may be explained by considering the possibility and the likely effects of ^{26}Al-induced planetesimal meltdown in the infant disk.

At the beginning, when CAIs were formed, ^{26}Al (half-life 0.72 Myr) was uniformly dispersed in the disk [e.g. 4, 7]. The initial $^{26}Al/^{27}Al$ ratio was probably close to 5.25×10^{-5} [8], and the decay energy of ^{26}Al is about 3 MeV per atom [9]. Thus, dry primitive dust, with 1.2% Al by weight, would have begun with about 6.5 kilojoules per gram of stored nuclear energy, or roughly four-times the amount needed to heat and melt the insulated interiors of planetesimals made from that dust. On the timescale of heating, the interior below a depth of 5 to 10 km would have been perfectly insulated [10]. The inevitable planetesimal meltdown would explain the early rapid segregation of molten iron cores.

By about 1.5 Myr (roughly 2 half lives of ^{26}Al) after the beginning, the residual ^{26}Al would no longer have stored enough energy to cause total internal melting, so from this time onwards newly accreted planetesimals would have retained their sedimentary features and survived, unmelted, as chondrite parent bodies. Thus, these bodies (unless they were very small), far from being the oldest, would appear to be amongst the youngest to have accreted, consistent with the ages of the chondrules within them.

The dense clouds of cooling droplets inferred from Na in chondrule olivine reinforce the long-standing minority view that chondrules were made, not from dust-balls, but from the disruption and splashing of those molten planetesimals that must have populated the disk at about 2 Myr after CAIs, when chondrules were made [11]. The disruption of molten bodies must have led to enormously dense droplet plumes, at least during the early phase of plume expansion.

This setting also provides a well understood melting mechanism, which is not the case for the widely advocated 'flash-melting' processes. In addition, it would appear to account for many long-established features of chondrules and chondrites, as reviewed by [11], including centimeter-sized chondrules, chondrules occupied by a single huge phenocryst, compound chondrules, and an apparently narrow range of near-liquidus initial temperatures. Finally, the hot insulating crusts of the molten bodies may, upon disruption, have yielded the sintered dunite rock fragments found trapped within some chondrules by [5].

Molten planetesimals must have been a dominant feature of the disk during its first two or three million years. This initial period might appropriately be termed the Meltdown Era of early solar system evolution. The moment when ^{26}Al first dropped below the threshold level needed to melt initially cold planetesimals would have marked a major watershed within the Meltdown Era. This moment was about 1.5 Myr after the beginning. It was only after this stage that chondrules had a reasonable chance of surviving destruction by the melting of their host bodies.

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