PROTOPLANETARY PYROTECHNICS: LIGHTING UP THE CONUNDRUM OF CHONDRULE CHRONOLOGY.

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Introduction: If chondrules and CAIs were formed in the solar nebula, as is widely supposed, then why do they differ in age? Why are chondrules generally between 1.5 and 2.5 Myr younger than CAIs [1]? The age difference is a conundrum that frustrates efforts to reconstruct the first few 'dark years' of the circum-solar disk [1,2]. Here I explore the idea that during these early years planetesimals suffered rapid meltdown, and periodically burst on collision into cascades of molten droplets (chondrules) that were lofted into the nebula.

Meltdown: An excellent correlation exists between the Al-Mg ages and the Pb-Pb ages of CAIs, chondrules, mineral grains in Ste Marguerite, and mineral grains in Forest Vale [3]. The correlation not only shows that the Al-Mg system works as a chronometer but also confirms that $^{26}Al/^{27}Al$ was equal to 5×10^{-5} widely throughout the primitive dust of the solar nebula when CAIs were formed. At this time each gram of dry primitive dust contained about 9 kJ of radioactive energy due to its ^{26}Al. ^{60}Fe possibly contributed a further 1.5 kJ per gram of dust [4]. With over 10 kJ/g available, and with only 1.6 kJ/g needed to heat cold (250K) dust to melting, it follows that the insulated interiors of planetesimals that formed from dry dust during the first 1.5 to 2 Myr after CAIs had no choice but to melt. 'Melting' is taken here as the change from a rigid to cohesionless partial melt at about 1725K. The interior of a planetesimal that accreted at the time of CAI formation would have melted by 0.3 Myr and the molten centre would probably have expanded outwards due to excess radiogenic heat as a turbulently convecting slurry of molten silicate, metal and olivine crystals for a further 2 Myr. Planetesimals that accreted at about 2 Myr after CAIs would eventually have melted at about 5 Myr. The inevitable collisions between molten planetesimals during the first 2 or 3 Myr must have yielded chondrules in abundance!

Chondrules and CAIs: Where are the chondrules that formed before 1.5 Myr? They presumably accreted to new generations of planetesimals and, with ^{26}Al still very active, were destroyed by meltdown. Why were chondrules produced only rarely after 3 Myr? Perhaps by this time, with radioactivity now very weak, planetesimals were becoming thickly coated by chondritic debris which could no longer melt: it merely became reworked by impact. In this light chondritic parent bodies are not first generation planetesimals; they must have accreted after 2 Myr, i.e. after magmatic parent bodies accreted.

How did CAIs survive? According to [5] CAIs with excess ^{26}Mg never got hotter than about 650°C, yet they were resident in planetesimals from the outset. Perhaps their host planetesimals were over endowed with grains of water ice. A massive 3.2 kJ/g is consumed in changing ice at 250K to water vapour at 400K. A planetesimal with 5 parts ice to 2 parts dry dust could never melt. On this basis, chondrules as old as 0.3 Myr should survive too. Perhaps they do, but have not yet been identified. Two 0.7 Myr chondrules have been found so far [1]. Who knows, CAIs may also be a product of overheated planetesimals [6], particularly if lunar sized runaways existed 200 kyr. *before* CAI formation?

References: [1] Huss G. R. et al. 2001. M&PS 36, 975-997. [2] Kita N. K. et al. 2000, *GCA* 64, 3913-3922 [3] Zinner E. et al. 2002, *LPS* 33 # 1204 [4] Mostefaoui S. et al. 2003. *LPS* 34 # 1585. [5] LaTourrette T. and Wasserburg G. J. 1998. *EPSL* 158, 91-108 [6] Hsu W. et al. 2000. *EPSL* 182, 15-29.