THE DISSIPATION OF THE SOLAR NEBULA CONSTRAINED BY IMPACTS AND CORE COOLING IN PLANETESIMALS.

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Introduction: Iron meteorites originated on some of the earliest-formed bodies in our Solar System and represent the cores of differentiated planetesimals [1, 2]. They have survived the processes that shaped Solar System architecture, including giant planet migrations and gas disk dissipation [e.g., 3]. Metallographic cooling rates imply rapid cooling of many planetesimal cores, including the IIAB, IIIAB and IVA parent bodies [4]. This was attributed to the impact removal of their mantles. Dating core crystallisation can therefore elucidate the timing of impacts. The ^{107}Pd-^{107}Ag decay system ($t_{1/2}$ ~6.5 Myr) provides a tool for this. However, early studies of iron meteorites did not fully account for galactic cosmic ray (GCR) exposure, which causes disturbances via secondary neutron capture reactions [5]. Here, we present GCR-corrected parent body initial ^{107}Pd/^{108}Pd ratios for the IAB, IIAB and IIIAB asteroids to date core cooling of planetesimals and constrain dynamic processes occurring in the early Solar System.

Results and Discussion: We determined Pd-Ag and Pt isotope compositions for IIAB and IIIAB irons and Pt isotope data for IAB samples where Pd-Ag data were available [1, 6]. Corrections for GCR were applied following [5] and parent-body isochrons were calculated. Corrected data define one IAB isochron with an initial ^{107}Pd/^{108}Pd ratio of ~1.51 x10^{-5}. The IIABs and IIIABs yield isochrons with initial ^{107}Pd/^{108}Pd ratios of ~1.70 x10^{-5} and ~2.21 x10^{-5}, respectively. The initials of these 3 asteroids are within uncertainty of each other, and the IVAs yield a similar value [7]. This indicates the Pd-Ag system closed in a similar time-frame on these bodies and suggests an energetic inner Solar System at this time. The Pd-Ag cooling ages depend on the Solar System initial (SSI) ^{107}Pd/^{108}Pd. Two SSIs were determined based on the IVA iron Muonionalusta (~3.5 x10^{-5} [7]) and carbonaceous chondrites (CC) (~5.9 x10^{-5} [8]). Together, these cover the range of all determined SSI values and we calculated Pd-Ag ages relative to both.

Cooling ages for the IIAB, IIIAB and IVA bodies calculated using the IVA iron SSI suggest a highly energetic environment between ~2.9-6.8 Myr after CAI. This corresponds with the suggested outward migration of Jupiter in the Grand Tack model [e.g., 9]. However, this SSI cannot be reconciled with thermal events on the IAB parent body [1]. Closure times relative to CC equate to later cooling between ~7.8-11.7 Myr. This may date the dissipation the gas disk, after which the damping effect of gas drag ceases and energetic collisions are predicted [10]. A giant planet instability ('Nice' model) could also perturb the inner Solar System. Although the precise timing of the instability is difficult to determine, models that predict the size of Mars advocate an instability ~5–14 Myr after CAI [e.g., 11]. Impacts on the iron parent bodies between ~7.8-11.7 Myr agree well with this. Gas dissipation may trigger an early giant planet instability [12] and hence these two mechanisms likely acted together to create an energetic, collision-rich Solar System between ~7.8-11.7 Myr after CAI.

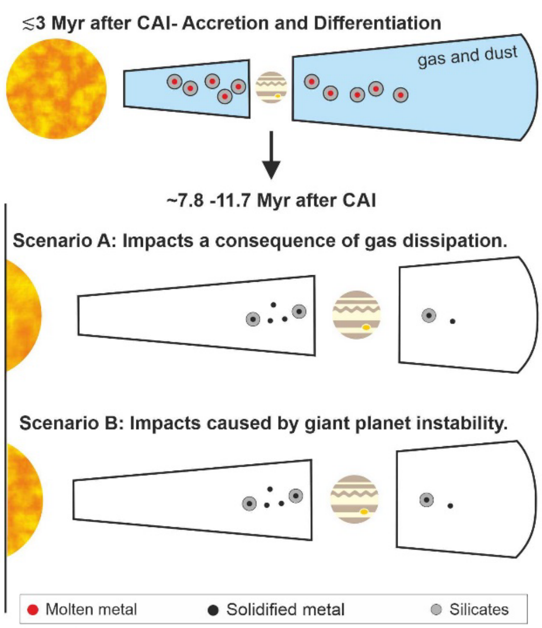

Figure 1.

Figure 1. *Cartoon showing the evolution of iron meteorite bodies. Top: Parent bodies differentiate before ~3 Myr after CAI [2]. The disk is truncated in the region of Jupiter. Later, the cores of the IIAB, IIIAB and IVA bodies were exposed by impacts, causing closure of the Pd-Ag system between ~7.8 - 11.7 Myr. Two mechanisms, alone or in combination, generated an energetic inner Solar System at this time. Scenario A: When the gas disk dissipates, planetesimals are gradually excited until they begin to undergo high velocity impacts [10]. Scenario B: An early giant planet instability is triggered, leading to reorganisation of the inner Solar System and impacts [11].*

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