THE EFFECT OF EARLY IMPACTS ON IRON METEORITE COOLING RATES

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Introduction: The original sizes and structures of iron meteorite parent bodies have been inferred by comparing the cooling rates they record to models for the thermal evolution of differentiated planetesimals [1,2]. Most thermal evolution models treat these bodies as isolated objects that did not experience any impacts during cooling, a period of time that likely lasted hundreds of millions of years. However, recent dynamical models show that impacts in the asteroid belt should have been frequent and energetic during this time period, with asteroidal bodies experiencing hundreds to thousands of such impacts over the first ~100 Myr [3]. While the details of the frequency and velocities of collisions depend on the dynamical situation (giant planet orbits and possibility of migration) assumed for the early Solar System, the expectation for significant collisional evolution at this time should be robust. This is when the number of small bodies is greatest (the epoch of planetary accretion; the number of planetesimals and impactors would decline over time), and energetic collisions (a few to many kilometers per second) were the norm as bodies were excited by the massive planets as they formed and migrated into a dynamically stable regime. Here we examine the effect that impacts would have on the cooling rates of the cores of differentiated planetesimals.

Methodology: We follow the method of Ciesla et al [4] by calculating the thermal evolution of an undisturbed planetesimal, then model an impact into that planetesimal at various times during its evolution. The thermal evolution is calculated as in Haack et al [1], using the same model parameters to facilitate comparison between the models and identify the effects of the impact. We then use the iSALE hydrocode to simulate the impact of a body of various sizes and velocities into the target with the temperature profile as determined by the thermal model. For our initial study, we are focusing on head-on collisions to reduce the computational cost of these calculations (2D instead of 3D) and to take advantage of the self-gravity capabilities of the 2D code. After the planetesimal relaxes back to a static structure, we follow its subsequent cooling with a 2D thermal model [4,5] as the impact would cause structures that can no be accounted for in a 1D, spherically symmetric model.

Preliminary Results and Discussion: As found for chondritic planetesimals in Ciesla et al [4], the time at which a differentiated body is impacted will have a significant effect on its subsequent thermal evolution. Early impacts into bodies where much of the target is at T>1200 K (expected for the frist 10-50 Ma of Solar System history) will lead to large scale excavation of heated materials due to the low strength of the component rock. The mobilization of heated materials will lead to much more rapid cooling of the body as a whole as discussed in [4]. Because of its higher density, the core largely remains in the center of the body. In low energy collisions, this leads to minimal changes in the core cooling rates compared to unimpacted bodies. However, in more energetic collisions, where significant portions of the silicate (insulating) mantle are removed, the cooling rates of the core will be accelerated [e.g. 6]. We are now performing an extensive exploration of model parameter space to determine the amount of silicate mantle removed as a function of target size, impactor size, collision velocity, and time of impact. For each collision, we will calculate the cooling rates recorded by the iron cores of the bodies and compare to those predicted for unimpacted bodies. We use our results to evaluate whether the effects of such collisions may be seen in or inferred from the iron meteorite record.

References: [1] Haack H. et al. 1990. *Journal of Geophysical Research: Solid Earth* 95:5111-5124 [2] Goldstein J. I. and Short J. M. 1967. *Geochimica et Cosmochimica Acta* 31:1001-1023 [3] Davison T. M. et al. 2013. *Meteoritics & Planetary Science* 48:1894-1918 [4] Ciesla F. J. et al. 2013. *Meteoritics & Planetary Science* 48:2559-2576 [5] Davison T. M. et al. 2012. *Geochimica et Cosmochimica Acta* 95:252-269. [6] Yang J et al. 2007. *Nature* 446:888-891.