Stop hitting yourself: Did most terrestrial impactors originate from the terrestrial planets? Alan P. Jackson[1], Erik Asphaug[1], Linda T. Elkins-Tanton[1], David A. Minton[2], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, [2]Department of Earth, Atmospheric & Planetary Sciences, Purdue University, West Lafayette, IN 47907

Introduction: Giant impacts are a key component of planet formation. In our own inner solar system giant impacts have been proposed to explain Mercury's large core fraction [1], the formation of the Moon [2], and the Martian hemispheric dichotomy (MHD)/Borealis basin impact [3].

Giant impacts release substantial quantities of debris. Formation of a planet like Earth results in the release of ~0.15M_E [4] – a mass greater than Mars. By comparison the Asteroid belt, including possible ancient extensions, is unlikely to have exceeded 0.01M_E since the dissipation of the solar nebula [5].

Once released into the solar system this debris will interact with the planets, primarily through re-accretion, and from the masses alone it is clear that the effects of this on the forming planets will not be insignificant.

Cratering: A principal role of giant impact debris is as a source of impactors onto the terrestrial planets. On worlds with old surfaces, such as the Moon, Mars and Mercury, this can leave populations of impact craters that will still be visible today. Indeed in light of the quantities of debris released giant impact debris may have been the dominant source of impactors in the early solar system.

Magma oceans: A consideration for re-impacting giant impact debris is that a body that has recently undergone a giant impact will be at least partially covered by a magma ocean. Debris re-impacts will only be recorded if they strike a solid surface, so if we want to investigate cratering records we must account for the magma ocean solidification time on the progenitor body. Impacts can also influence the solidification process, both through the input of accretion energy as an additional heat source, and on smaller bodies like the Moon and Mercury, by disrupting the forming crust allowing the magma ocean to cool faster.

Moon-formation and the MHD impact: The two most well constrained giant impacts in the inner solar system are the formation of the Moon and the MHD/Borealis impact. A wide range of evidence suggests that Moon-formation occurred relatively late, around 50-150Myr after the first solids [e.g. 6, 7], such that we can expect other bodies to have had solid surfaces at this time. The timing of the MHD impact is less certain, however it only melted the northern hemisphere [3], and the hemispheric dichotomy would have been erased if Mars suffered another giant impact later.

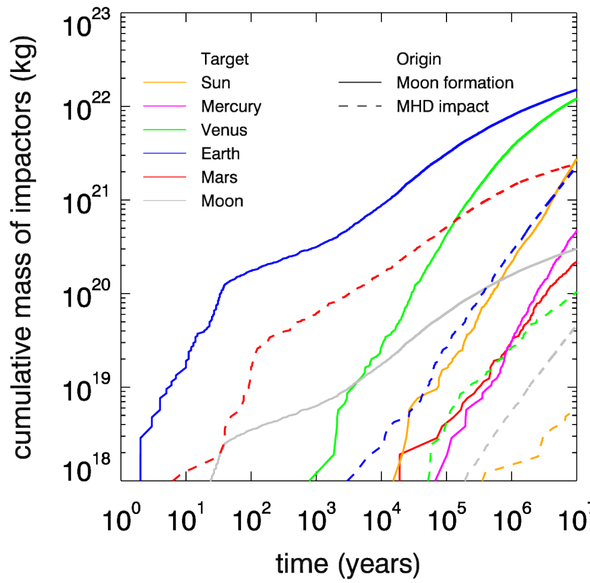

Fig. 1: Cumulative mass of impactors received from the Moon-forming and MHD impacts. Moon-formation releases 10^{23} kg of debris while the MHD impact release 2.2x10^{22} kg. A simple size distribution with $n(D)\propto D^{-3.5}$ and maximum size 500km is assumed. The Earth-Moon accretion ratio is set to be 50 for illustrative purposes.

We thus focus on these two impacts as the best candidates to have left cratering signatures in the inner solar system that can be seen today, particularly on the Moon and Mars. We suggest that many of the earliest craters on these two bodies may be the result of re-impacting debris from their respective giant impacts. Fig. 1 shows the masses of impactors received by various solar system bodies from the Moon-forming and MHD impacts as a function of time after the initial impact. Collisional evolution of the debris is neglected here.

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