The Dynamical Evolution of Asteroids Constrained From Sample Analysis

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Detailed studies of chondrites have provided clear evidence that some of these rocks have experienced geological processing (e.g., thermal metamorphism, hydration, etc.) within their parent asteroids. In addition, certain chondrites are regolith breccias recording geological processes at or near the surface of their parent asteroid. However, from the study of chondrites, with one exception, science does not have a clear understanding of which asteroids have experienced any given geological processes. Constraining the dynamical evolution of asteroids, especially Near Earth Asteroids (NEAs), from research on chondrites has also proven a significant challenge. A more comprehensive view of the dynamical evolution of one NEA is provided by the results from the study of samples returned by the Hayabusa mission from asteroid 25132 Itokawa.

We argue that two findings from analysis of the returned samples provide a key constraint on the dynamical history of Itokawa. Cosmic-ray exposure dating for samples returned by Hayabusa show a lower age of ~1 Mya, with an upper limit of ~8 Mya [1,2]. Furthermore, there are two grain morphologies, angular and rounded [3]. Rounded grains require high-energy geological environments in which to weather and erode. We hypothesize that the young age of Itokawa regolith (and possibly the young ages of some chondrites) combined with the rounded nature of grains indicate that Itokawa experienced grain mobilization on its surface. Leading mechanisms for such transport is the Yarkovsky-O'Keefe-Radziebskii-Paddack (YORP) effect or tidal disruption [4,5]. We argue that the young ages and the rounding of grains may be caused by YORP thermal torques, and/or tidal disruptions which cause small asteroids to spin up or down and can drive particle mobilization to geopotential lows.

[1] Meier et al. (2013) HAYABUSA 2013: Symposium of Solar System Materials [2] Nagao et al. (2011) *Science* **333**, 1128. [3] Tsuchiyama et al., (2011) *Science* **333**, 1125. [4] Walsh et al. (2008) *Nature* **454**, 188. [5] Richardson et al. (1998) *Icarus*, **134**, 47.