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Introduction: Recent spacecraft encounters with five asteroids have led to the inference that at least two distinct outcomes of catastrophic disruption are possible. Namely these events can produce intact, collisional shards which are nevertheless severely fractured, but the result of catastrophic disruption can also be completely disrupted, gravitationally reaccumulated rubble piles. The poster child for the former case is Eros studied by NEAR, while that for the latter case is Itokawa studied by Hayabusa [1,2]. For both asteroids, there are in situ measurements of bulk density and high resolution measurements of surface morphology obtained from spacecraft rendezvous. What can be inferred about internal structure and physical properties?

Collisional Histories: The key evidence comes first, from density and second, from surface morphology. The density of Eros is significantly higher than that of Itokawa, although their mineralogy and their elemental compositions are similar to each other and to ordinary chondrites. Hence the higher density implies a smaller void fraction and supports the inference that Eros is an intact shard, whereas the lower density of Itokawa suggests a rubble pile structure. Another key piece of evidence comes in the form of a global lineation fabric [1], consisting of ridges and grooves covering the surface, at sizes ranging from global (over 10 km) down to tens of meters. These are interpreted as the surface expressions of fractures in a consolidated substrate beneath an unconsolidated, mobile regolith, where the absence of lineations smaller than some size scale is an indication of the depth of regolith cover.

The high resolution observations of surface geology at Itokawa provided evidence of a collisional history qualitatively different from that which produced Eros. Notable differences are that Itokawa has no global lineation fabric, much higher areal densities of large blocks (including many that are too large to have formed on an object the size of Itokawa) and lower densities of craters. In contrast to Itokawa, the blocks and regolith on Eros could have formed there and are consistent with the observed large craters [3]. The profusion of large blocks on Itokawa is best explained [2] by collisional disruption of a parent body followed by gravitational reaccumulation.

Implications and Outstanding Issues: An unexpected result of high resolution imaging was that the regoliths of Eros and Itokawa are qualitatively different. Regolith particles smaller than cm-sized gravel are absent at Itokawa, but a much finer-grained regolith is present on Eros (although sufficiently high resolution images to make this inference were obtained only close to the NEAR landing site). Not only particle size, but evidently mechanical properties are different. The Itokawa gravel, at the Hayabusa landing site, actually forced the spacecraft to bounce off the surface of the asteroid, indicating compressive strength. The NEAR spacecraft, however, landed at oblique incidence and dragged itself many meters along the surface, but did not lose rf contact with Earth, indicating a soft surface.

The different regolith properties are plausibly understood within the context of the different collisional histories of Eros and Itokawa. Eros has at least a billion-year collisional lifetime [4], even within the main belt, and a fine-grained regolith may have formed via comminution by impacts. Itokawa apparently reaccumulated without an initial inventory of fines (either because of high impact ejection velocities such that fines escaped, or because of non-gravitational forces), and subsequently could not produce or retain significant fines within its much shorter collisional and dynamical lifetimes.

It is puzzling that abundant evidence of downslope mass motion is found on both objects. On Eros, there are both slides and ponded deposits (thought to form after seismic shaking). On Itokawa, not only is there similar evidence of localized mass motion, but there is a striking global segregation into blocky and smooth areas, indicating a global-scale migration of gravel.

This is puzzling because of the inferred typical strength of surface material on Eros. Based on the observations of strength-controlled (“square”) craters in particular size ranges on Eros, a typical strength on the order of at least a few kPa is inferred., roughly similar to that for lunar soils. The problem is that such a level of cohesion might be expected to abolish downslope mass motion, given the low surface gravity of Eros (and even lower gravity of Itokawa). Perhaps regolith can be mobile on these bodies only when activated by strong vibrations, sufficient to overcome not only the gravity but more importantly the cohesion.

Another intriguing question is whether there are any true rocks (meaning lithified materials, like for instance the ordinary chondrites) on these bodies. Could the gravel on Itokawa be dirt clods, and if so, could they have caused the spacecraft to bounce?

References: [1] Thomas, P. C., et al. (2002), *Geophys. Res. Lett.*, L014599. [2] Cheng A. F. et al. (2007) *Geophys. Res. Lett.*, 34, L09201. [3] Thomas, P. C., et al. (2001), *Nature*, 413, 394. [4] Cheng, A. F. (2004), *Icarus*, 169, 357– 372.