SECONDARIES AND SELF-SECONDARIES ON ICY AND SMALL ROCKY BODIES. P. Schenk[1], T. Hoogenboom[1] and K. Johnson[2], Lunar and Planetary Institute, Houston, TX (schenk@lpi.usra.edu), [2]Rice University, Houston TX .

Introduction: Secondary cratering is a known phenomenon and highly relevant to the interpretation of observed cratering records [1]. The contribution of secondaries on low-gravity bodies, and indeed their existence, has also been a matter of speculation and inquiry [2]. Here we examine the contribution of secondaries on icy bodies (both moons and dwarf planets) and on small rocky targets, namely Vesta.

Mid-size Icy Satellites: It has been stated (informally) that secondary craters are unlikely on the midsize icy satellites of Saturn and Uranus, although predictions are that they can form [3]. Due to the small size of such craters, the infrequency of intact fresh craters, and the ruggedness of their surfaces, such craters are not easily identified. The required resolutions of <200 m/pixel are also spatially limited. Despite this, several sites for secondary craters have been identified on these satellites.

The large basin Odysseus (D~420 km) on Tethys is surrounded on the east size by a dense zone of similar sized craters. Circumstantial evidence suggests that numerous craters and the tectonic zone Ithaca Chasma are peppered by Odysseus secondaries. On Dione, a well expressed zone of hundreds of small secondaries surrounds the fresh 53-km-wide Sagaris crater.

On Rhea, the similar-size 49-km-wide Inktomi crater (Figs. 1, 2) has two well-defined zones of secondaries. The first is a classic zone of hundreds of irregular shaped craters located roughly 1 diameter from the crater rim and beyond. These have a narrow SFD consistent with expectations. The second zone is roughly oval in shape and occurs near the eastern rim and across the southeast quadrant. More than 1000 craters are found within this zone and they are roughly equidimensional. No craters are found in other quadrants of the floor. There are no other fresh craters on Rhea capable of producing so many secondaries of this size. We therefore interpret these craters as self-secondaries that returned to the floor of the crater shortly after being launched.

Large Icy Satellites: Previous efforts have focused on Europa [4]. Here we report on new measurements of more than 5000 secondary craters on Ganymede [5]. Mapping is severely restricted but secondary crater distributions and SFDs for 10 primary craters between 40 and 220 km have been cataloged (and for Gilgamesh; D~600 km). Focus was on craters in bright terrain, where secondaries can be easily identified from the background. Secondary crater sizes are broadly consistent with expectations in terms of sizes.

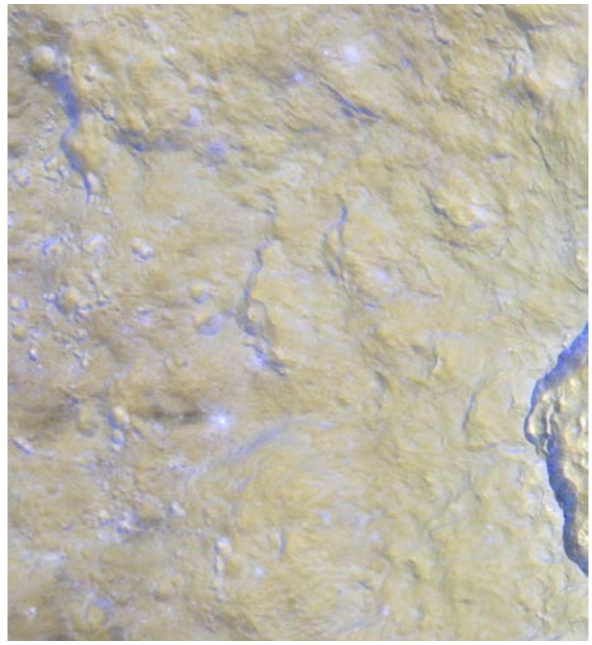

Figure 1. Secondary craters (left) associated with 50-km-wide bright ray crater Inktomi, Rhea (right).

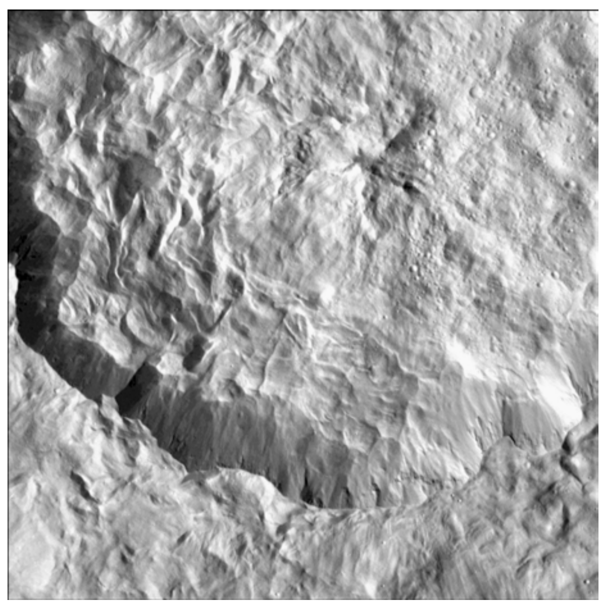

Figure 2. Self-secondary craters associated with 50-km-wide Inktomi, Rhea. Hundreds of small craters are found in right center quadrant, none in other quadrants.

The numbers of such craters, and the identification of distant rays with mappable craters indicates that secondary craters can be a significant contribution to the overall crater populations below ~20 km diameters.

Distant secondary counts and crater shape measurements are under way.

Vesta (and Ceres): Vesta's surface gravity is 5 times lower than on the Moon but comparable to that on the midsize icy satellites. Bierhaus and Dones [2] predict that secondaries could form on Vesta. Despite this, the record as observed by Dawn at 20-m resolutions is mixed.

Incipient secondaries are found as clustered irregular depressions at Fabia crater (D~12.5 km). True secondaries are found at Arruntia crater (D~10.6 km) (Fig. 3). These are found on the west, north and south perimeter approximately 1 crater diameter from the rim. They are absent from the eastern quadrant. Irregularly distributed clustered secondaries are found to the north of Marcia crater (D~62 km), but are otherwise difficult to distinguish from background. The degree to which distal secondaries are significant generally is difficult to extract from the background population.

Figure 3. Secondary craters associated with 10.6-km Arruntia crater, Vesta. Note tight clustering of similar-sized craters ~1 diamter from crater rim.

A few highly-elongate clusters featuring hundreds of craters are also found on Vesta but these are of uncertain origin. They cross crater rims suggesting a possible secondary origin, but other than these examples, densely spaced secondary craters are the exception rather than the rule on Vesta. Several large recent craters are conspicuous for their lack of obvious secondaries. This suggests that either the fast rotation of Vesta smears them out or special circumstances are required to produce well-formed secondary populations on low-gravity rocky bodies.

Secondary craters were widely anticipated for the giant 505-km-wide south polar impact basin Rheasilvia. Sorting out such a population from the background SFD has proved nettlesome, however. One possible indicator of such a population may be the variable density of superposed craters on the floor and proximal ejecta deposits of Rheasilvia. The density of these craters varies spatially by a factor of 4 or more, mostly in the smaller (D<10 km) size ranges. If verified, this would be consistent with the expected sizes of secondaries, the self-secondaries seen on Rhea (Fig. 2), and the self-secondaries inferred within the proximal ejecta of large lunar craters [5].

Ceres may provide a test of some of these observations, given its inferred icy shell and a surface gravity similar to rocky Vesta and icy Dione. If its shell is icy as expected, than craters may look like those on the Saturnian satellites. Secondaries may be more abundant on Ceres than on Vesta.

References: [1] McEwen, A. and B. Bierhaus. (2006) *Ann. Rev. Earth Planet. Sci., 35,* 535–567. [2] Bierhaus, B. and L. Dones (2012) *LPSc 44*, abst. 2451. [3] Bierhaus, B., and 3 others. (2012) *Icarus*, 218, 602-622. [4] Bierhaus (2009) in *Europa,* Univ Arizona Press. [5] Hoogenboom, T., K. Johnson, and P. Schenk, *LPSC* 46, abstr. 2530. [5] Zanetti, M., and 6 others, *LPSc.* 46, abstr. 1209.