MISSING CRATERS ON EROS, PHOBOS, AND THE MOON - CRATER ERASURE IN A THICK REGOLITH?
M.S. Robinson[1], P.C. Thomas[2], J. Veverka[2], [1]Northwestern University, Center for Planetary Sciences, 1850 Campus Drive, Evanston IL 60208, robinson@earth.northwestern.edu, [2]Cornell University, Space Sciences Bldg., Ithaca, NY, 14853.

The NEAR Shoemaker images provided the first reliable observations of sub-100 m craters on an asteroid. Veverka et al. [1] and Chapman *et al*. [2] found that much of the surface approached "empirical saturation", but at sizes below about 100 - 200 m the crater density was progressively lower than predicted for nearly saturated surfaces and did not have a slope expected of production populations. We have subsequently made additional small crater density measurements on Eros and use these data to compare to other bodies, for which comparable resolution data exist. From MOC images crater densities were measured for Phobos by [3,4], including a global data set (>700 m diameter), and local data at good viewing down to pixel scales of ~ 4 m. The Phobos and Eros crater densities between 30 and 200 m are similar except for the region of steep topography (slopes ~20°) within Stickney crater, which has a substantially lower crater density. The similarity of the maximum crater densities on the two objects, and the presence on both objects of decreasing relative densities between crater sizes of ~150 m to 30 m, suggests that the decrease in relative density in this size range is due to a mechanism that is not unique to Eros. Furthermore, on both objects the decrease is observed for areas having different crater densities: these are not saturation curves, nor are they consistent with usual expectations of production populations [2]. Additionally, we note that from moderate resolution Galileo images of Gaspra (~60 m/pixel) Carr *et al.* [5] postulated a drop off in crater densities below 200 m and attributed this to preferential degradation of smaller craters formed in a thick regolith (>20 m).

We speculate that the explanation of the decreased R plot slope at small diameters on Eros and Phobos is primarily due to the destruction of small craters by processes in addition to those predicted whereby new craters remove some fraction of pre-existing craters. Mutual obliteration by craters is the process apparently responsible for producing “saturation” slopes (-2 on cumulative plots, -3 on differential plots, horizontal on standard R-plots). Veverka et al. [1] proposed the idea that seismic shaking of a loose regolith on Eros causes preferential erasure of these smaller craters on Eros. Seismic effects [6] might be able to efficiently result in crater erasure, although the specific model presented by [6] would not predict a substantive change in the slope of part of an R-plot. To form a crater distribution such as those in (Fig. 1) the effects of shaking need to be more effective on the smaller craters. Such a situation might derive from shallower material being looser than deeper material, such that for larger craters the efficacy of seismic jolting decreases not only due to crater size but also by smaller response to similar stresses imposed by seismic accelerations. Since crater morphologies on Eros do not indicate sharp discontinuities in the regolith with depth, stronger material may have to gradually grade into the upper, less consolidated, materials.

To better understand the small crater densities we examined a region on the Moon imaged at high resolution (~7 m/pixel) by Lunar Orbiter III where the mare and highlands should have received the same cratering history (both primary and secondary) subsequent to mare emplacement [7]. The lunar orbiter image was chosen because it has similar spatial resolutions and lighting geometry as the MSI global images. Here the lunar mare has substantially greater crater densities than the older highlands, and both areas show a fall-off from an equilibrium slope at sizes less than ~100 m [see also 8]. The highland data in this example happen to approximate closely the Shoemaker Regio crater counts. The density of small craters on the mare can vary considerably, and in some places, as measured by other workers [8,9,10,11], can show some fall off at sizes less than 200 m. Because the younger mare surface supports a higher density of craters (<100 m) than the highlands, the latter area must undergo rapid degradation and erasure of small craters [8]. This enhanced removal is most likely due to thicker regolith and steeper slopes in the highlands relative to the younger, nearly horizontal, mare deposits. We note that the highland unit comprises a portion of the Flamsteed ring (crater rim) and may thus represent unusually steep and fractured highland topography, thus representing an extreme case of small crater erasure. Similar crater count data for several average highland areas are presented in [12] showing that highlands are depleted (relative to mare areas) in craters over the size range 50-200 m by a factor of 1.5 (from images with incidence range of 65-80° and resolution range of ~1 m/pixel). The lunar example suggests that asteroids with a substantial regolith will have a depletion of craters at sizes smaller than 100-200 m.

Most terrain on Eros is not horizontal; average slopes relative to gravity are about 8° to 10° [13], and 18% of the surface slopes are greater than 15°, a condition favoring gravity driven slides, slumps, or creep. Note that much of the inter-crater area on Eros has slopes in the range of 5-10° [Figs. 2, 3 of 14]. Evidence of downslope motion of material is common on Eros [1,7,14], and may contribute to erasure of craters at a rate greater than expected on horizontal areas similar to that of the lunar highlands.

Chapman *et al*. [2] favored the idea that the relative decrease in crater density below 200 m diameter may be due to an impactor population deficiency at small sizes. If so, this must also apply to the martian satellites which have a similar paucity of smaller impact craters. Since the impactor population most likely differs from the asteroid belt to Mars, the fact that the Phobos data indicate a similar population of smaller craters may be inconsistent with the small impactor deficiency hypothesis. Whatever the role of impactor population, the Phobos and lunar highland data indicate that the similarity of the shapes of relative crater density curves may derive at least in part, if not entirely, from common factors such as slopes and the presence of a substantial regolith contributing to enhanced crater erasure at sizes below ~200 m on all three bodies [7].

References: [1] Veverka, J., et al. (2001a) *Science*, 292, 484-488. [2] Chapman, C.R. (2002) *Icarus*, 155, 104-118. [3] Thomas, P. C. (1998), Ejecta emplacement on the martian satellites, *Icarus* 131, 78-106. [4] Thomas, P.C., et al (2000) *Jour. Geophys. Res*., 105, 15091-15106. [5] Carr, M.H. et al (1994) *Icarus*, 107, 61-71. [6] Greenberg,R. et al (1996) *Icarus*, 120, 106-118. [7] Robinson, M.S. et al (2002) *Met. And Planet. Sci*., 37, 1651-1684. [8] Trask, N.J. and L.C. Rowan (1967) *Science*, 158, 1529-1535. [9] Moore, H.J. (1964) *Astrogeologic studies annual progress report*, August 1962-July 1963, Part D., pp. 34-51, USGS, Washington CD. [10] Shoemaker, E.M. (1965) *The nature of the lunar surface*, Johns Hopkins Press, Baltimore, pp. 23-78. [11] Soderblom, L.A. (1970) *Jour. of Geophys. Res*., 75, 2655-2661. [12] Wilcox, B. (2002) *Workshop on Moon Beyond 2002*, Abstract #3048, LPI, Houston (CD-ROM). [13] Zuber, M.T. et al (2000) *Science*, 289, 2097-2101. [14] Thomas, P.C., et al (2002) *Icarus* 155, 18-37.

Fig. 1. A) R-plot of crater densities within the three largest craters on Eros and intercrater terrain. Data for Psyche, Shoemaker Regio (Sh), and Himeros are at 3-5 m/pixel. The intercrater terrain data are at 2-3 m/pixel in areas at 5°S, 205°W and 10°S, 242°W, with 1 m data at 3°S, 28°W. **B)** Eros and Phobos crater densities. **C)** Comparison of Eros and the Moon. Eros data are from Shoemaker Regio and the intercrater terrain data also shown in a and b. Both sets of data show fall off in relative density below 100-200 m diameters, and both Eros and lunar data show the difficulty of age comparisons if crater erasure mechanisms are different in various terrains [7].