IMPACT CRATERING ON A MID-SIZED PLANETARY BODY: INSIGHTS FROM MORPHOLOGY AS SEEN BY DAWN AT VESTA.

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Introduction: Asteroid 4 Vesta is the first rocky body visited by spacecraft with a surface gravity intermediate between the Moon and the smaller non-ellipsoidal asteroids mapped to date (e.g., Eros, Lutetia). As such, it represents a unique natural laboratory in impact cratering mechanics on lower-gravity planetary bodies. Dawn global mapping has revealed a rich variety of impact crater morphologies, some of which were not anticipated prior to arrival. Here we summarize some of the initial observations and preliminary interpretations regarding impact cratering processes on this transitional planetary body.

Crater Morphologies: Inverse-gravity scaling of the simple-to-complex crater transition for silicate bodies [1, 2] predicts a transition at Vesta of 60-80 km. The largest crater by far is the giant 500-km-wide Rheasilvia basin near the south pole [3], the effects of which may dominate Vesta's geology globally [4]. Rheasilvia has a large central complex, but the next largest fresh crater, Marcia (Fig. 1; 10°N, 10°W), is only 55 by 70 km-wide and is bowl-shaped. Marcia features a large terrace-like feature on the southern edge and what appears to be a small nascent central peak complex. It may be transitional between simple and complex, consistent with g^{-1} scaling of transition diameters. Flat floors and irregular central floor mounds appear in some craters between 30 and 50-km-diameter but none are true complex craters, indicating that the transition must be ~50 km or larger.

Slumping and Rim Failure: Except for large slumps at Rheasilvia and the partial "terrace" at Marcia, rim failure by coherent sliding on Vesta is rare. Very narrow bright lobate deposits are commonly observed originating along rim crests of fresh craters on Vesta (Fig. 1) but these are volumetrically minor. High-resolution images of Marcia [see also 5] reveal a variety of additional features, including debris slides along the rim, dark exposures just below the rim, and extensive striated material on the inner rim flank. Smooth dark floor material (probably ponded impact melt) is pockmarked by round rimless depressions [6]. While many of the rimwall features appear to be simple debris flows, the relative importance of impact melt flow and downslope debris movement is not yet clear.

Melt and Ejecta: Ejecta deposits have been mapped at several other fresh craters, including Marcia. Thick mantling deposits flank crater rims. At one 12-km crater (38N, 216E; Fig. 2), a clear transition from highly scoured continuous ejecta to densely spaced overlapping secondary craters can be discerned (Fig. 2), about 9-km from the rim. This is narrower than observed on the Moon and icy satellites [8] and might indicate that ejecta scales differently on Vesta than on other bodies [9]. Even by this scaling, ejecta should cover large areas outside the Rheasilvia basin [see 4]. The largest apparent secondaries (Fig, 2) are only ~0.3 km, somewhat smaller than expected from comparison to lunar craters [10].

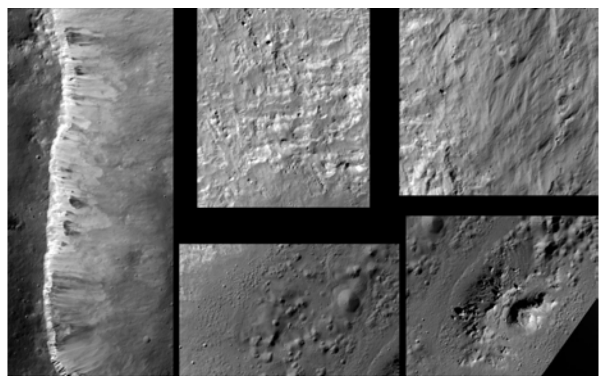

Figure 1: Landforms observed within Marcia, one of the largest and most recently formed impacts on Vesta. Clockwise from upper left: Bright debris slides and dark material exposures along rim scarp, rocky outcrops and smooth dark material, sinuous dark material, irregular central hills (putative central peak?) and dark pitted floor material. Tiles are ~6 km wide.

Lower impact velocities suggest that impact melt volumes might be low on Vesta [7]. "Ponded" and (in the case of Marcia, dramatic) flow-like features are observed flanking large and recently formed crater rims and on their floors (Fig. 1). Many of these are likely impact melt, although some could be down-slope regolith creep and ponding of the type seen on Eros [e.g., 8]. Despite this, the volume of melt filling crater floors may indeed be relatively low in contrast to the Moon.

Bright and dark rays are also common on Vesta and are the subject of ongoing investigations [e.g., 11]. While many rays are a result of impact related regolith processes, some rays appear to be excavation through surface layers of different albedos, others may be contaminated by dark projectiles. In addition, numerous isolated crater chains and short linear grooves have been observed across Vesta not radial to the Rheasilvia basin (Fig. 3). Whether any of these are secondary chains related to specific impact events or to another mechanism is not yet clear.

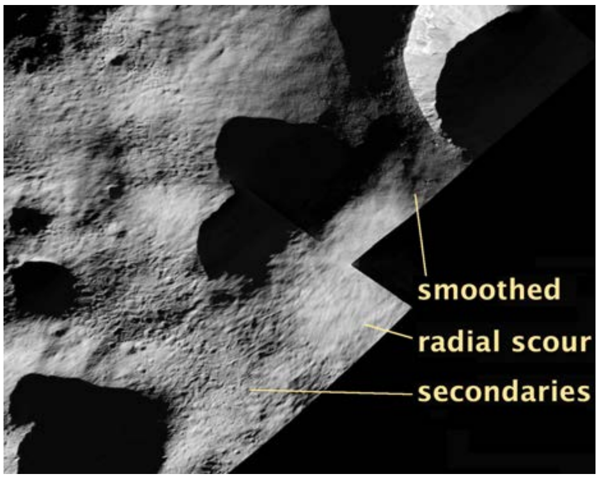

Figure 2: Ejecta morphologies surrounding 12-km-crater (38 N, 216 E).

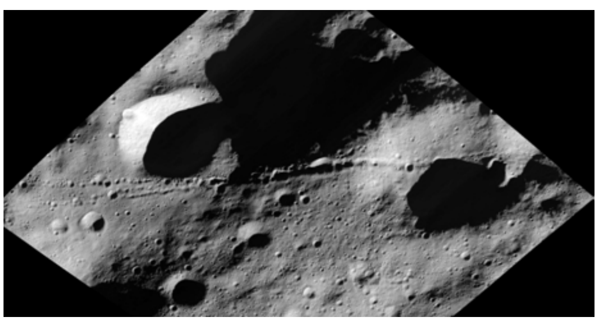
Figure 3. A 20-km-long crater chain near 35 N, 147 E. Chain is bifurcated and may be secondary craters from unknown crater or a manifestation of tectonism within Vesta. Large degraded crater is 6 km across.

Cratering and Slope Effects: A peculiar class of craters observed on Lutetia [12] is unusually common on Vesta. These craters typically form on steeper slopes and have an asymmetric appearance (Fig. 4), with sharp rim scarps on the high upslope side and an (often darker) rounded boulder-strewn rim on the low side. This may be the result of overflowing landslide material or probably the lack of slumping and rim scarp formation on the less steeply sloping lower half of the crater. The rubble strewn rim may simply be an unmodified original ejecta deposit and overturned flap. If so, then it will be possible to estimate the critical slope necessary to initiate rim slumping in simple craters using Vesta examples. In addition, anomalous sinuous ridges resembling deceleration dunes in ejecta deposits the Moon are seen on some Vesta slopes. Impact into steep slopes [13] are common and likely to be a very important phenomenon on Vesta [14].

Discussion: Although broadly similar to lunar and other simple craters, craters on Vesta are distinct and may have important physical differences to those on other bodies. The roles of target properties and the lower surface gravity (including the transition from strength to gravity regimes [15]) are potentially important factors and are currently under investigation by Dawn as global mapping continues.

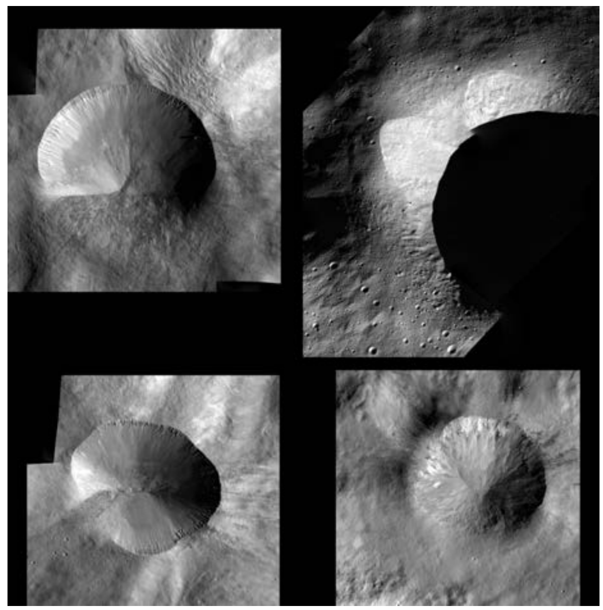
Figure 4. Unusual asymmetric craters observed on local slopes on Vesta, featuring rim crests on upslope side and rubble-strewn rims on down-slope side. Craters range from 18 to ~12 km in size.

References: [1] Pike, R., LPS Conf. 11, 2159 (1980). [2] Schenk et al., in *Jupiter*, (2004). [3] Thomas, P. et al. 277, 1492 (1997). [4] Schenk et al. this conf. (2012). [5] Denevi, B., et al., this conf. (2012). [6] Keil, et al., 32, 349, MAPS (1997); Marchi, S., et al., this conf. (2012) [7] Matz, A., et al., Icarus, 167, 197 (2003). [8] Schenk and Ridolfi, GRL, 29, 31 (2002). [9] Housen, K., and Holsapple, Icarus, 11, 856, (2011). [10] Allen, C., GRL, 6, 51, (1979). [11] McCord, T., et al., this conf. (2012). [12] Vincent, J.-B., PSS, in press (2012). [13] Elbeshausen, D and K. Wunnemann, LPSC 42, 1778, (2011). [14] Jaumann, R., et al., this conf. (2012). [15] Vincent, J.-B., this conf., (2012).