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Impact crater morphologies on Vesta

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Abstract

Impact craters on Vesta share some similarities and differences with other silicate bodies. Fresh craters are bowl-shaped though incipient complex features occur at D>40 km. Flow-like features are observed in crater ejecta but inferred volumes of impact melt are low compared to lunar craters. Local slopes also strongly influence crater shape and ejecta formation.

1. Introduction

Vesta is the first asteroid visited large enough to examine impact craters with potential complex crater morphologies. It also is a relatively low gravity world (only ~14% that of the Moon) but significantly larger than Lutetia, the next largest visited asteroid. The Dawn mission to Vesta [1] has produced global morphology, compositional and topographic mapping down to 20-100 m resolutions. Here we report on observed crater morphologies and how they compare with expectations and with craters on other silicate bodies.

2. Crater Morphologies and Shapes

With the exception of the large south polar basin Rheasilvia (which has a "complex" morphology including a prominent central massif) [2] most intact post-Rheasilvia impact craters on Vesta are simple (bowl-shaped). The largest fresh crater on Vesta, Marcia, is only ~60-km across. The lack of *pristine* large complex craters on Vesta is due in part to the inferred global effects of ejecta mantling and/or seismic disruption of much of Vesta's surface during basin formation and to the relatively young age of this event [2]. Extensive erosion and/or burial is also reflected in the wide range of shallow crater depths of all ages [3], especially in the northern hemisphere.

When only post-Rheasilvia craters are considered, then a well-defined d/D curve emerges in which most craters have d/D ratios of 0.18 to 0.22, roughly consistent with the established lunar d/D curve for simple craters. Fresh craters between ~40 and 60 km, however are shallower than this trend, corresponding also to the formation of irregular floor mounds in these craters and a putative central peaks and a partial terrace in these larger craters (Fig. 1). These changes are interpreted as incipient or incomplete complex crater development, which likely becomes complete only at diameters >60 km. The intersection of the two d/D trends occurs at 25 km, indicating that the simple-complex transition diameter on Vesta may be significantly smaller than predicted from g^{-1} scaling from the terrestrial planets. This is consistent with newly revised Cassini findings for the icy satellites, all of which now suggest that $g^{-0.7}$ may be more appropriate.

3. Ejecta and Impact Melt

The freshest impact craters on Vesta retain original ejecta morphologies. Examples include Marcia (D~62 km) and Cornelia (D~15 km). Both craters are characterized by extensive deposits of mantling material extending ~ one crater diameter from the rim. This material is interpreted as ejecta, which may be hundreds of meters thick in some locations. Both craters feature ponded dark material and flow-like morphologies interpreted as mobilized ejecta, possibly impact melt or ballistic surge deposition, or a combination thereof. At least one crater shows evidence for secondary cratering indicating it is possible on lower gravity targets.

Overall, Dawn has observed only very minor volumes of impact melt/suevite deposits on the floors of these fresh craters (Fig. 1) and melt production appears to be significantly less than observed for similar sized craters on the Moon. Volume estimates will be reported, but are consistent with predictions of low melt production on asteroids [4]. In addition, irregular pits are common within these deposits, suggesting volatile release within or beneath the crater floor deposits [5].

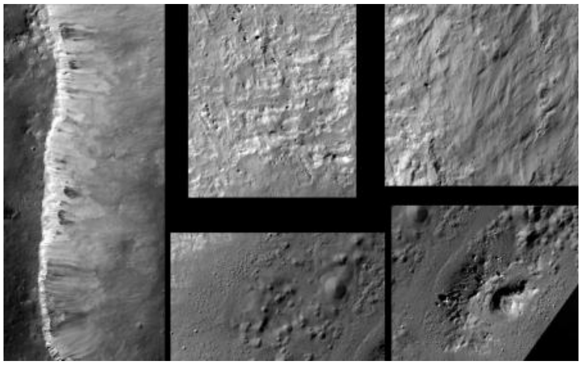

Figure 1: Impact morphologies within Marcia crater (D~62 km). Clockwise from left: rimwall slides, rimwall fracturing, rimwall "melt", central mound and floor, floor deposit and pits.

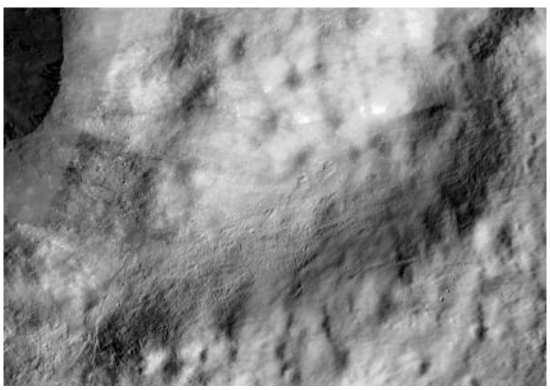

Figure 2: Morphologies within ejecta deposit of Cornelia crater (D~15 km). Mantling of older craters is evident everywhere and flow-like features are visible at base of a topographic low (center). Rim scarp is at upper left. Scene is ~10 km across.

4. Local Slope Effects

An unusual percentage of Vestan craters have asymmetric development of rimwall scarps, wherein a proportion of the rim is defined by a scarp but the rest is rounded and rubble-strewn [6]. Some examples are observed on Lutetia [7] and the Moon. Interpretations based on the steep slopes of Vesta include partial ejecta throw-back in craters [6] and incomplete rim failure. The wide range of this rubble-strewn rim (from <10° to >180° of rim circumference) suggests that low rimwall slopes on the down slope sides of tilted craters may result in incomplete rimwall failure on those sides. If so, then these exposed rim flanks may show what simple craters look like in the absence of rim failure. Other slope effects include asymmetric ejecta and block distribution and swirl patterns within ejecta deposits.

5. Summary and Conclusions

Vesta crater morphologies provide key insights into impact crater processes on silicate worlds intermediate between the smaller lumpy asteroids and the Moon. While the giant Rheasilvia impact reset much of this record, the craters formed since then reveal that while extensive ejecta (and even some secondaries) do form on Vesta, inferred impact melt production is generally low and volatiles may be involved. The transition to complex crater formation may be only partly controlled by surface gravity. Local slope also significantly affects crater development.

Acknowledgements

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