COMPARISON OF IMPACT CRATER MORPHOLOGIES ON MARS AND GANYMEDE.

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Introduction: Layered ejecta morphologies are common around fresh martian impact craters larger than about 3-5 km in diameter. Central pits also are common in martian impact craters. Both of these features have been argued to be a consequence of impact into volatile-rich target material, although the atmosphere may also play a role in the ejecta emplacement. Ganymede provides an important end-member case for the role of volatile-rich target materials. Layered ejecta morphologies have been identified around some Ganymede craters and central pits are common. We are conducting a comparison study of layered ejecta morphology and central pit characteristics on Ganymede and Mars to better constrain the role of target volatiles on the formation of these features.

Background: Martian impact craters display a range of ejecta morphologies, including three major layered morphologies: single layer ejecta (SLE), double layer ejecta (DLE), and multiple layer ejecta (MLE). These layered ejecta morphologies have been the center of a debate regarding the processes involved in their formation. One model suggests that the layered ejecta morphologies result from vaporization of target volatiles during crater formation [1, 2]. The other model suggests that the ejecta curtain interacts with the atmosphere to produce the layered ejecta patterns. [3, 4].

For several years, we have been conducting studies of the distribution and quantitative characteristics of SLE, DLE, and MLE craters on Mars. We find regional variations in the distributions of DLE and MlE craters whereas SLE craters are found essentially global-wide [5, 6]. We find MLE craters tend to be larger than the SLE and DLE craters, indicating a greater depth of excavation [5, 6]. The onset diameters of these different morphologies vary regionally [7] and sinuosities and ejecta extents similarly show variations with ejecta type and location [8].

Martian impact craters also commonly display central pits, unlike craters on the Moon. Central pits can occur either on the floor of the crater ("floor pit") or atop a central peak ("summit pit"). Central pits have been proposed to result either from release of subsurface volatiles during crater formation [9] or due to volatiles released during a comet impact [10]. Recent numerical modeling has shown that both asteroidal and cometary impact into a soil/ice mixed target produces temperatures high enough to vaporize target ice in the center of the crater [11]—this may be the source of the escaping vapor which produces the central pit. Using MOC and THEMIS data, we have identified over 2000 craters displaying a central pit. Regional variations are seen and many of these central pit craters are surrounded by a MLE morphology [12]. However, there are a large number of central pit craters where the ejecta blanket has been destroyed, indicating that the target volatiles probably responsible for central pit formation have been in place for much of martian history.

Voyager and Galileo observations of Ganymede have revealed impact craters with many similarities to what is seen on Mars. A number of craters on Ganymede are surrounded by one ejecta layer (called "pedestals" in the literature) which is qualitatively similar in many respects to the SLE morphology on Mars [13, 14] (Figure 1). A few DLE-type morphologies are also seen around Ganymede craters. Central pits are also quite common on this icy world [15] (Figure 2). Since Ganymede has an icy surface with very little atmosphere, the identification of layered ejecta and central pits supports the idea that subsurface volatiles play a role in the creation of these features on Mars.

Current Study: In addition to our ongoing project to revise the *Catalog of Large Martian Impact Craters*, we have recently received OPRP funding to develop a GIS-based database of impact craters on Ganymede using primarily Galileo data. As with the Mars crater database, the Ganymede catalog will include information on crater location, size, preservational state, geologic unit, ejecta morphology (if applicable), and interior morphology (if applicable). For the layered ejecta morphologies, we will measure ejecta extent, perimeter, and area to allow calculation of ejecta mobility ratios (EM) [e.g., 16]:

EM = (maximum extent of ejecta)/(crater radius)

and a measure of ejecta sinuosity called lobateness (Γ) [e.g., 8]:

$$\Gamma = (\text{ejecta perimeter})/[4\pi(\text{ejecta area})]^{1/2}$$

For central pits, we will classify the pit as a floor pit or summit pit and determine the pit diameter to crater diameter ratio.

We will look for latitudinal and regional variations in the distribution of the craters displaying layered ejecta morphologies and central pits. We will compare the EM and Γ values for craters in different regions of Ganymede to determine how local environment may affect these values. We will search for any regional variations in the distribution of central pits and in the pit/crater diameter ratio. The results of this analysis will help to determine how environmental factors affect the formation of layered ejecta morphologies and central pits on Ganymede.

With the above information for Ganymede, we can do a direct comparison between the characteristics of layered ejecta morphology and central pit craters on Ganymede with their martian analogs. The results of this comparison should provide important insights into the role of target ices in the production of the martian ejecta and interior features.

Preliminary Results: Although our study is in the early stages, a few intriguing results have already been obtained [17]. We have identified 71 Ganymede craters displaying layered ejecta morphologies. 68 (96%) of these craters display a single layer ejecta morphology. The other 3 (4%) show a double layer ejecta morphology. To date, we have not identified any craters displaying a multiple layer ejecta morphology. We find no strong correlation between presence of a layered ejecta morphology and geologic unit.

Martian DLE craters typically have outer ejecta layer with higher Γ than the inner ejecta layer. Thus far our analysis reveals the opposite trend for the few DLE craters identified on Ganymede: Their outer ejecta layers display lower Γ than the inner ejecta layers. The EM values for both SLE and DLE craters on Ganymede are lower than their martian analogs. These preliminary results might be explained by the colder, more viscous nature of the ejecta/volatile curtain during ejecta formation on Ganymede, or they may show that the martian atmosphere contributes to both the sinuosity and ejecta extent for craters on Mars. Our ongoing work will help determine if these initial findings are valid.

Archival Plans: The Ganymede crater database will be produced in GIS format and provided to the USGS for inclusion in their PIGWAD system. Data will also be provided in tabular format to the PDS for archiving.

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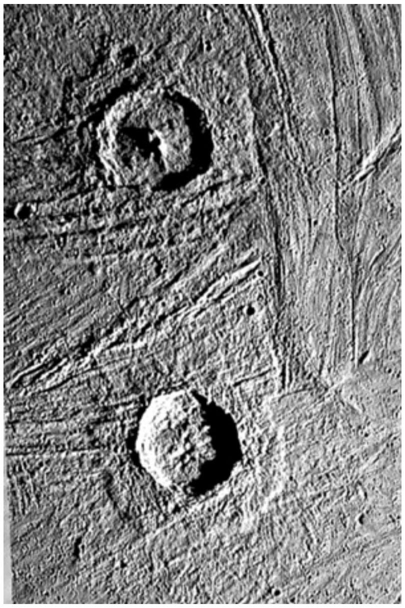

Figure 1: Layered ejecta deposits surrounding 40-km Gula crater and 35-km Achelous crater on Ganymede.

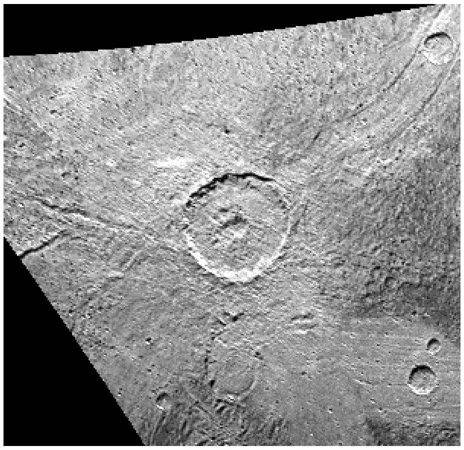

Figure 2: 73-km-diameter Isis crater on Ganymede displays a floor pit.