CRATER MORPHOLOGY AND MODIFICATION ON GANYMEDE, CALLISTO, AND TETHYS; Paul M. Schenk, Jet Propulsion Lab., 4800 Oak Grove Dr., Pasadena, CA 91109

Previous study of crater morphology on the middle-sized icy satellites of Uranus and Saturn revealed unexpected differences in crater morphology in icy and rocky crusts, related to differences in the mechanical properties of ice and rock [1]. New measurements of crater depths, rim and peak heights and widths, and morphological transition diameters have been obtained for the Galilean satellites Ganymede and Callisto, using both shadow measurements and photoclinometry.

On Ganymede, simple, bowl-shaped craters are ≈60% shallower than simple craters on terrestrial planets [2], but similar to simple craters on other icy satellites [1]. The depth/diameter (d/D) curves for complex craters (those with central peaks or wall terraces) on Ganymede and Callisto (Fig. 1) have slopes of 0.3-0.4 and resemble those of the Moon and terrestrial planets [2]. This is in contrast to the steep complex crater d/D slopes of the Uranian and Saturnian satellites [1]. Complex crater depths on Ganymede and Callisto are 60-70% shallower on these satellites than on the Moon, despite similar surface gravities (confirming the original work of [3]). This is due to the enhanced degree of floor rebound, as indicated by the very low central peak onset diameter (5±1 km) on Ganymede, and not to viscous relaxation. Central peaks are roughly conical in shape and in craters on the middle-sized Uranian and Saturnian satellites have large width-to-crater diameter ratios (w/D) of ≈0.3. Central peaks in Ganymede craters larger than 15 km diameter have smaller w/D ratios of ≈0.18, however, similar to lunar central peak w/D ratios [4]. The transition to narrow central peaks on Ganymede also corresponds to the observed transition diameters for the observance of flat floors and rim slumping (both 15±5 km), a change in central peak heights from values 2-3 times higher than lunar to values equivalent to lunar peak heights (≈15 km; Fig. 2), and an inflection in the rim height (h)/D curve at ≈14 km (Fig. 3). Similar but more weakly defined correlations are apparent on Rhea, Titania and Ariel. All of these transitions are substantially higher than the central peak onset and crater d/D transition diameters on the respective satellites. (Note that crater depth and rim height relations for central pit craters on Ganymede (Figs. 1, 3) differ from 'normal' complex craters, and central pit origins are discussed elsewhere [5]).

On Ganymede and the icy satellites, the transition diameters for the occurrence of central peaks is significantly lower than the transition diameters for rim slumping. The similarity of the rim slumping and rim height transition diameters on Ganymede to the diameters for the occurrence of central peak dimensions (relative to crater diameter) suggests that slumping of material from the rim to the floor is partially burying central peaks on Ganymede. This is consistent with the prominence of central peaks in most craters on the smaller icy satellites of Uranus and Saturn, where flat floors and significant rimwall terraces are lacking except in the largest craters. This is exemplified by large central peaks (w/D≈0.35) and a lack of a break in slope in the crater rim h/D curve for Dione.

d/D CURVES ON ICY SATELITES AND THE IMPORTANCE OF VISCOUS RELAXATION. The separation of central peaks and terrace transition diameters on the icy satellites can vary from 5-10 km on Ganymede and Callisto to 50 km or more on satellites like Rhea and Dione. Prompt crater floor rebound and central peak formation reduce crater depth but do not substantially change crater diameter. Rim slumping and terrace formation decrease crater depth but also increase crater diameter, resulting in highly flattened crater shapes, much more so than floor rebound alone (Fig. 4). This suggests that if these two processes begin to occur at greatly different crater diameters for true complex craters, and the third at large diameters for simple craters, the second at intermediate diameters for central peak craters, the third at large diameters for true complex craters with both central peaks and terraces and nearly constant depths (Fig. 4).

For example, the d/D curve for Rhea (Fig. 5) [1] can be reinterpreted as having three segments. This would be consistent with limited rim slumping in 50-80-km craters, indicating a shallowly sloping d/D curve starting at these larger diameters. This implies that the 375-km basin Tirawa has not undergone any viscous relaxation. If depths and diameters of the relatively large impact craters on the Uranian and Saturnian satellites (e.g., Odysseus on Tethys, Gertrude on Titania, Tirawa on Rhea) are scaled to Ganymede gravity (i.e., g_satellite/g_Ganymede), they all plot on the d/D curve for complex craters on Ganymede (Fig. 6). This indicates that they are all true complex craters that owe their observed shapes to floor rebound and wall collapse (i.e., peak and terrace formation) and not to viscous relaxation.

ORIGIN OF ITHACA CHASMA. Morphological evidence suggests the great-circle lineament Ithaca Chasma on Tethys is genetically related to the large (425-km) crater Odysseus [e.g., 6,7]. Models have been constructed assuming that viscous relaxation of the crater has triggered flow in the interior which fractured the lithosphere [7,8]. If Odysseus has not undergone relaxation, as suggested above, a new mechanism is required. The transient, bowl-shaped crater of Odysseus was probably on the order of 325-km-diameter and 45-km-depth. Collapse of this transient bowl, rim slumping and especially floor rebound, could easily account for the shape of Odysseus and would produce a large amount of stress over a very short period of time. Thus Odysseus-Ithaca Chasma could be the only true multi-ring basin on an icy satellite, other than on Ganymede and Callisto [9].

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Fig. 1 (left). Crater depth/diameter (d/D) curves for Ganymede. Solid line is lunar crater depths [10]. Thin lines are best fits to the data. Fig. 2 (right). Central peak heights on Rhea and Ganymede. Solid line is lunar peak heights [4].

Fig. 3 (left). Crater rim heights on Ganymede. Heavy line is rim heights from moon [10]. Thin lines are best fits to the data for craters with central peaks (1), with peaks and terraces (2), and central pits (3). Fig. 4 (right). Schematic diagram of the effects of floor rebound and rim slumping on d/D curves [1].

Fig. 5 (left). Crater d/D curve for Rhea [1], reinterpreted according to discussion. Thin line is lunar curve [10]. Fig. 6 (right). Complex crater d/D curve for Ganymede (Fig. 1), with depths and diameters of large basins on the Uranian and Saturnian satellites scaled to Ganymede gravity (squares).