THE EFFECT OF TARGET PROPERTIES ON IMPACT CRATER MORPHOLOGY – COMPARISON OF CRATERS ON ICY AND SILICATE BODIES. V. J. Bray[1] , G. S. Collins[1], J. V. Morgan[1] and P. M. Schenk[2], [1]Earth Science and Engineering Department, Imperial College London, Exhibition Road, London, SW7 2BP, UK, veronica.bray@imperial.ac.uk, [2]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, Texas, 77058.

Introduction: The icy Galilean moons of Europa, Ganymede and Callisto display exotic crater morphologies with no obvious analogue to craters on silicate bodies. As the Moon and Galilean satellites have similar gravity, differences in crater morphology are likely due to icy lithospheres being mechanically distinct from rocky bodies. The presence of subsurface liquid layers is also thought to affect crater morphology [1]. As the cratering process is affected by target properties, the study of crater morphology on the icy satellites provides a means for investigating the upper-crustal structure of these bodies.

To understand the effects of layering on crater morphology, the underlying impact process in ice must first be understood. To understand crater formation requires two major elements: sufficient observational data, to inspire formation theories and provide ground truth data, and a means to test these proposed formation processes—numerical models. Craters on Europa are likely to be heavily affected by its sub-surface ocean as it is relatively close to the surface [2]. As Ganymede's ocean is at a greater depth, craters on Ganymede provide better observational data for the investigation of impact into unlayered ice. We present scaling trends of complex crater dimensions drawn from topographic profiles of craters on Ganymede. We compare these trends with those of analogous features in craters on the Moon, and investigate the relationship between these morphological trends and target strength using dynamic modeling.

We collected topographic profiles of 48 craters on both dark and bright terrains of Ganymede from *Galileo* data. Most craters profiled were relatively young so that good comparison could be made with fresh impact craters on the moon and final craters produced by our computer models. Several cross-sectional profiles were taken of each impact crater so that any artifacts introduced as a result of the profiling technique, or features superimposed after impact, could be identified and removed. We then collected measurements from each crater, including crater depths and diameters, heights and widths of central features, and slope angles. When a variance in (e.g.) central peak width between each of the topographic profiles of the same crater was evident, the maximum value was adopted. The variety of scaling trends presented here represent the variation in maximum values.

Comparison of craters on Ganymede and the moon

Rim Slope Angle and Material Strength: The rim slopes of craters on Ganymede are consistently shallower than for lunar craters (Fig. 1a). As the slope angle is a proxy for the effective coefficient of friction of the target, this difference is indicative of the Ganymede surface ice being weaker than the lunar surface. The rim-slope of lunar craters decreases as crater diameter increases from ~29° for craters 10km in diameter to ~14° for 60 km craters [3]; this decrease in slope angle demonstrates an effective weakening of the target material as crater size increases. A similar decrease in slope angle with increasing crater size is evident in Ganymede craters where rim slope decreases from ~24° for a 10 km crater to 17° for 60 km craters. This suggests that the relative amount of material weakening during impact is similar in icy targets.

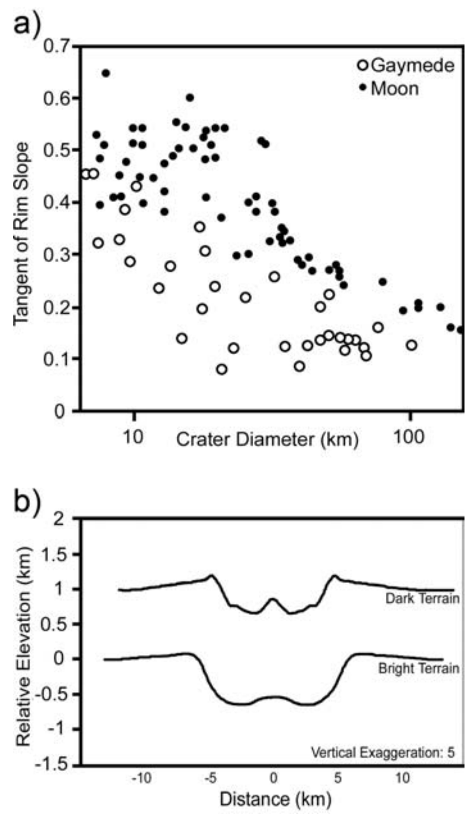

Figure 1:a) Relationship between the tangent of the rim slope for craters on the Moon [3] and Ganymede. b) Topographic profiles across typical central peak craters on Ganymede bright (39N 193W) and dark terrain (13N 200W). The relatively angular peak of the crater in dark terrain is evident. These profiles are averaged about their central point to produce an axially symmetric profile.

Central peak width and slope

Central peak craters on Ganymede have previously been reported up to diameters of 35 km [4]. We have measured 17 central peak craters between 5 and 31 km in diameter and one with a diameter of 50 km. We recorded central peak widths of 1.5 to 17.5 km and found that peak width, W, increased linearly with increasing crater diameter, D: W ≈ 0.30D. This trend is similar to that of lunar central peaks craters (W ≈ 0.22D [5]). Central peaks on the bright terrain of Ganymede appear more rounded than those on dark terrain (Fig. 1b). The slopes of central peaks in dark terrain craters are on average ~4° steeper than those in bright terrain craters. This is consistent with the dark terrain material comprising an ice-rock mix, where the rock component increases the angle of repose relative to that in the pure-ice bright terrain.

Central Pit Craters

On silicate bodies, the morphological class of crater next in size after central peak craters is the peak ring crater. No peak ring craters have yet been observed on Ganymede [6]. Instead, central pit craters replace the peak-ring morphology expected for similar diameter craters on rocky bodies. Pit craters are characterized by terraced rims and flattened floors with a rimmed pit at or near the center (Fig. 2). Although there is no consensus on the formation mechanism for central pits, it as been suggested that they form by a similar mechanism to peak rings in silicate targets, involving the downward and outward collapse of a large central peak [4]. However, it is not clear why such collapse in ice would cause a pit rather than centralized broken massifs as in the lunar crater Copernicus. An alternative, but similar idea is the multiple peak oscillation theory [7] which supposes that the target acts as a Bingham fluid during impact and has the summit pit form by repeated oscillations of the central region of the crater.

The majority of profiles that we collected across craters with summit pits also contained an extra topographic ring feature (Fig. 3) which increases in diameter, Wr, proportionally with increasing crater size: Wr ≈ 0.4D.This value lies between the predicted diameter of central peaks (W ≈ 0.3D) and of peak-rings on the Moon (Wpr ≈ 0.5D [8]). This feature could be caused by oscillations of the crater floor following collapse of the transient cavity, or by collapse and run out of an overheightened central uplift. In either case, it suggests that the central pit crater morphology forms during the impact event, which provides useful constraints for ongoing models of crater collapse in ice targets.

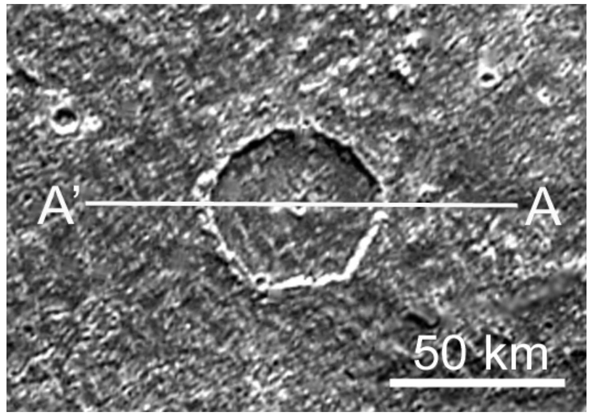

Figure 2: Image of a summit pit crater on dark terrain at 38N 140W (North is right). A possible ring between the summit pit and the crater rim is visible in the southern section of the crater and appears clearly in profile (figure 3).

To investigate the observed differences between central peak crater morphology on the Moon and icy satellites, and the possible formation mechanisms of central pits, we are simulating complex crater collapse in ice using numerical models. We are running suites of models with variable strengths, to determine which sets of parameters produce the best match to central peak craters on Ganymede. Once our strength model is well constrained, we will investigate the progression of larger craters and the effect of fluid layers.

References: [1]Schenk, P. M. (1993), JGR 98, 7475-7498. [2]Schenk, P. M.(2002), Nature, Vol. 417, 419-421. [3]Pike, R. (1977), 489-509 of Impact and Explosion Cratering, Pergamon Press. [4]Passey,Q. and E.Shoemaker (1982), 340–378 of Satellites of Jupiter, UofA Press. [5]Hale,W. and R.Grieve (1982), JGR 87, Suppl.:A65-A76. [6]Croft, S.(1983), LPS XIV, JGR, 88, B71-B89. [7]Melosh, H. J. (1982), JGR 87, 371-380. [8] Wood,C.A. and J.W.Head (1976), Proc. LPS VII, 3629-3651.

Figure 3 (below): Topographic profile of the crater in Fig.2. R marks the crater rims, S denotes the summit surrounding the central pit and black arrows show the intermediate uplift. These uplifted regions were visible in all 4 cross-sectional profiles of the crater indicating that the feature marked with arrows is part of a ring structure. The diameter of the ring in this example is ~24 km, 0.4 times the crater diameter.