Crater Distributions of the Galilean Satellites. N. Schmedemann[1], R. J. Wagner[2], T. Roatsch[2] and H. Hiesinger[1], [1]Institut für Planetologie, Westfälische Wilhelms Universität, Münster, Germany (nico.schmedemann@uni-muenster.de), [2]Institute for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany.

Introduction: The Analysis of the crater size-frequency distributions (SFD) of planetary bodies is a powerful and extensively used tool in order to estimate surface ages where no sample data is available. This approach requires the knowledge of the crater SFD undisturbed from any geological processes. The crater SFD can be approximated by a production function (PF) and a chronology function (CF) which converts the observed, over time accumulated crater frequency, into an absolute model age. Here we focus only on the crater PF for the chronology systems of Ganymede and Callisto. The crater PF can be modelled based on a good understanding of the shape of the underlying projectile SFD, impact velocities as well as certain properties of the target material/-body in order to convert the projectile SFD into a crater SFD. The well-known lunar crater SFD has been derived from numerous measurements [1] and could be converted to other planetary bodies of the inner Solar System [2]. Most of these bodies are rocky in nature. Thus, most gravity related scaling parameters could be estimated by a simple 1/g ratio equation (g - surface gravity). In the outer Solar System however, most bodies are characterized by an icy crust of variable thickness. It is well known, that icy bodies show a different 1/g relationship for e.g. simple to complex crater transitions than rocky bodies [2]. Especially the tidally heated Jovian satellites may feature a relatively thin crust and relatively warm ice that require special treatment for scaling crater SFDs. E.g. [3,4] argued for high similarities between the lunar crater SFD and the crater SFD of the Galilean Satellites, implying a similarly collisionally evolved projectile distribution.

Methods and Data: In Fig.1 we plot the crater frequency of Galileo Regio on Ganymede, together with a heavily cratered area on Callisto as well as the lunar derived crater SFD for Ganymede and Callisto. Table 1 list the used scaling parameters. The scaling procedure follows the one used in [2,5] for the LDM chronology system. The two measurements show high absolute similarities to each other with a local maximum around 25 km crater diameter. Also, the scaled lunar-like crater SFDs show high relative similarities in the range of their local maximum with the measured crater SFDs but are offset by a factor of ~4 towards larger crater diameters. Comparing the scaling parameters between Ganymede, Callisto and the Moon, there is a similarity in impact velocities and surface gravity but the major difference is the target material.

Table 1: Scaling parameters used for scaling the lunar crater SFD to Ganymede and Callisto.

Parameter	Moon	Ganymede	Callisto
target density	2.3 g/cm³	0.9 g/cm³	0.9 g/cm³
projectile density	2.7 g/cm³	2.7 g/cm³	2.7 g/cm³
impact Velocity	17.5 km/s	19 km/s	14.4 km/s
impact angle	45°	45°	45°
surface gravity	1.62 m/s²	1.42 m/s²	1.24 m/s²
strength to gravity transition	0.5 km	0.34 km	0.39 km
simple to complex transition	15 km	3.5 km	4 km
porosity scaling	no	no	no

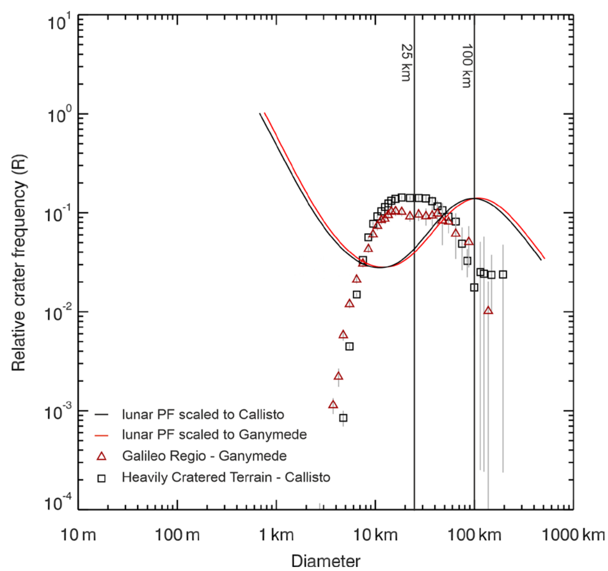

Fig.1: Relative crater plot of heavily cratered terrains on Ganymede (red triangles) and Callisto (black squares) with lunar-like crater production functions (PF) scaled to impact conditions on Ganymede (red line) and Callisto (black line).

Impact velocities have a great influence on the resulting scaled PFs. They are directly related to the orbital dynamics of the projectile population. We estimated the impact velocities for Ganymede and Callisto by assuming a projectile population that has its origin in the realm of the Jovian irregular satellites, which small bodies that have been captured early on in the Solar System history and underwent a very early collisional evolution outside the Jovian system before being captured and a late collisional evolution after being captured within the Jovian system [6]. We estimated the impact velocities from Eq(1), where v_{imp} is the impact velocity, v_{escJ} is the escape velocity of Jupiter at the orbit of the satellite, v_{orb} is the orbital velocity of the satellite around Jupiter and v_{escS} is the escape velocity of the satellite at the satellites surface.

Eq(1) $$v_{imp} = \sqrt{v_{escJ}^2 + v_{orb}^2 + v_{escS}^2}$$

In this setting we assume zero velocity of the projectiles at the distance of the Hill sphere. Since the irregular satellites are a little bit deeper in the gravity well of Jupiter the actual impact velocities should be slightly lower.

Results: Scaling the lunar PF to the assumed impact conditions on Ganymede or Callisto does not result in a good agreement with the observed crater distributions on these bodies with an offset by a factor of about 4. This implies that either the projectile SFD has a different shape than the one that impacted the Moon or that assumptions made for scaling the lunar PF to the Jovian satellites are not correct.

Discussion: For the case that the projectile distribution for the Jovian satellites is different from the one that impacted the Moon, we can try to understand the orbital mechanics of potential projectiles inside and outside giant planet systems. This has already been discussed extensively in literature e.g. [7]. From this discussion irregular satellites emerged as promising contender for the main projectile source of the giant planet satellite systems [6,7]. An analysis of the intrinsic collisional probabilities [8] of 59 irregular Jovian satellites (Fig. 2) reveals more frequent (~8×10^{-16} vs. ~3×10^{-18} km^{-2}a^{-1}/kms^{-1}) collisions but on average lower (1.2 km/s vs. 5 km/s) velocities than inside the asteroid main belt. This may influence the shape of the particle size distribution resulting from a collisional cascade [9] and thus the crater SFDs on the giant planet satellite systems.

On the other hand, impacts in warm ice may not be handled well by the classic crater scaling equations that we used. For instance, it may be possible that specifically large craters are smaller than expected, because the respective large projectiles could punch through a potentially thin layer of ice with less conversion of their impact energy in crater formation than expected. Extensive high-resolution imaging of the Jovian satellites by the upcoming Juice [10] and Europa Clipper [11] missions may help solving this issue. But even though we now failed to scale the lunar PF to the Jovian satellites, the observed crater distributions can be approximated by a PF as it has been done for the Moon [1]. This approach still allows for the determination of relative crater retention ages.

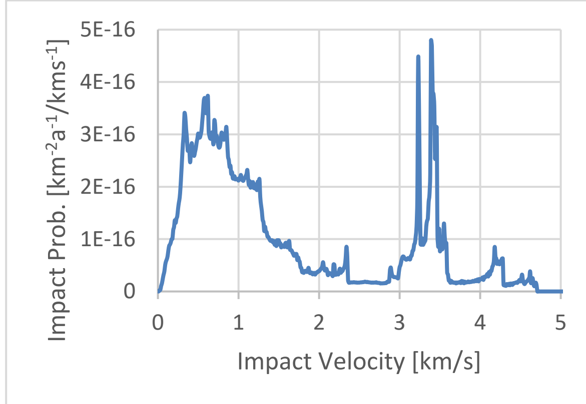

Fig. 2: Averaged intrinsic collision probabilities vs. respective impact velocities of 59 Jovian irregular satellites.

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