EPSC Abstracts
Vol. 11, EPSC2017-470, 2017
European Planetary Science Congress 2017

The Cratering Record of Ganymede and the Origin of Potential Impactors: Open Issues

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Abstract

The origin of impactors on the Galilean satellites of Jupiter is an open question. Observations and dynamical modeling of potential impactor families and impact rates suggests a prevalence of bodies from the outer solar system, especially the ecliptic or Jupiter-family comets [1]. However, our previous investigations of crater size distributions on the densely cratered Galilean satellites Ganymede and Callisto in specific localities imply an impactor size distribution of bodies derived from a collisionally evolved family, such as, e.g., Main Belt asteroids [2][3]. For detailed scrutiny of crater size-frequency distributions (henceforth termed CSFDs) on Ganymede, we began a mapping campaign based on reprocessed Voyager and Galileo SSI [4] images and on an updated global geologic map [5] in order to derive a thourough data base of Ganymede's crater distribution. This data base is used to infer the size distribution and most likely origin of potential impactors.

1. Introduction and Motivation

Investigating the crater size-frequency distribution of Jupiters largest satellite Ganymede is hampered by the fact that a global coverage with images at regional spatial resolution (i.e., an average of at least ~1 km/pxl) has not been fully accomplished by Voyager and Galileo and varies between ~700 m/pxl (Voyager-2) and ~ 4 km/pxl (trailing hemisphere, imaged by Galileo SSI). In this study, we use these data and an updated geologic map of Ganymede [5] to derive a crater size-frequency distribution data base of Ganymede.

2. Procedure

Voyager images from the two flybys in 1979 and Galileo SSI images [4], especially those filling the two gaps left by Voyager, are reprocessed in order to preserve their respective highest possible spatial resolution, instead of applying an average (lower) map scale for a global basemap. In a second step, spatial (highpass) filtering is applied to enhance small-scale details. These data are used to obtain a global data set of crater size-frequency measurements in the size range larger than ~4-5 km. Locally, we use higher-resolution Galileo SSI images from selected target areas for detailed studies of crater distributions at smaller diameters. Geologic units based on the global geologic map by [5] are mapped with the software package *ArcGIS* by a crater tool plugin to create a crater statistics set from each crater distribution measurement [6]. The software tool *craterstats* [7] is then used to obtain relative and absolute ages.

3. Results

In *Figs. 1 & 2*, CSFDs measured on two of Ganymede's major geologic units in the subjovian hemisphere are shown in relative crater size-frequency diagrams (R-plot) [8]. One set of CSFDs depicted in *Fig. 1* is from older ***dark cratered material (dc)*** [5] in Nicholson and Barnard Regio, measured in Voyager-1 data (spatial resolution: 2 km/pxl; red symbols) and two Galileo SSI target areas (28GSNICHOL01, 127 m/pxl, blue; 28GSNICHOL01, 27 m/pxl, green). *Fig. 2* shows a set of CSFDs from younger ***light smooth material (ls)*** [5] in Harpagia Sulcus, measured in Voyager-1 data (2 km/pxl; violet symbols), and two Galileo SSI target areas (28GSMOOTH02, 120 m/pxl, blue; and 28GSSMOOTH01, 16 m/pxl, dark yellow). The horizontal line represents an equilibrium distribution for small lunar craters [9] (labeled as EF in *Figs. 1 & 2*). The curve shown in *Fig. 1* (red) and *2* (blue) is an 11th-degree polynomial derived from the lunar production function [9] which has been transferred to Ganymede's impact conditions based on crater scaling [10] (labeled as PF in *Figs. 1 & 2*).

Despite the high degree of scattering apparent in the R-plot, both crater data sets broadly render a "dip-and-hill" shape which is highlighted by the curve fitted to the data. The best approximation to the measured CSFDs is achieved by assuming preferentially rocky bodies impacting at comparably low velocities (order of ~5 km/pxl [11]) from planetocentric orbits for the crater scaling law. The shapes of the CSFDs which represent production functions shown by the fitted curve are strongly indicative of impactors from a collisionally evolved projectile family, such as, e.g., Main Belt asteroids, or possibly bodies from a now extinct mixed asteroid-comet family of impacting objects. The size distribution of, e.g., Jupiter-family comets (ecliptic comets) which preferentially impact the Jovian satellites at present time [1] is not rendered in the measured CSFDs, however. The deviation of the CSFDs from the curve at smaller crater sizes (i.e., shallower slope than the curve) may be either caused by (1) geologic processes, such as erosion of small craters, or (2) by saturation equilibrium of small craters. Future imaging data by the Janus camera aboard ESA's JUICE mission [12] will help to extend the still insufficient data base at small crater sizes towards craters < ~100 m in specific localities.

4. Summary and Outlook

Our results from crater counts in the densely and moderately cratered units on Ganymede (dark and light materials) favor impactors from a collisionally evolved projectile family which (1) could originate from Main Belt asteroids or (2) from an extinct family of impactors. Applying the chronology model by [2] (labeled as CF, *Figs. 1 & 2*), light and dark materials are order of ~3.8 Ga and ~4.1 Ga old, respectively. Our ongoing studies incorporate global crater counts on reprocessed Voyager and Galileo SSI data, studies of selected Galileo SSI target areas at higher resolution, and a comparison with CSFDs from Ganymede's neighbour Callisto.

References

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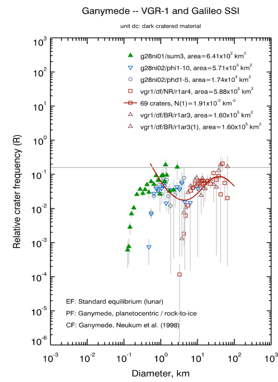

Figure 1: Example of a relative crater-size frequency diagram of measurements from dark cratered materials [5] in Nicholson Regio. Combined measurements from Voyager-1 (red) and Galileo SSI (blue, green) images. Explanation given in text.

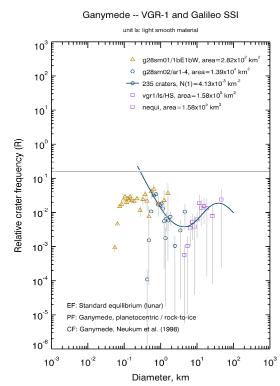

Figure 2: Example of a relative crater-size frequency diagram of measurements from light smooth materials [5] in Harpagia Sulcus. Combined measurements in Voyager-1 (violet) and Galileo SSI (blue, dark yellow) data. Explanation given in text.