EVALUATION OF IMPACT CRATER DISTRIBUTIONS FOR GEOLOGICAL TERRAINS ON ENCELADUS.

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Introduction: Compared with other satellites of the Saturnian system, the geological history of Enceladus is remarkably complex. Images returned by the Voyager and Cassini spacecraft [1,2] have provided evidence of tectonic activity and episodic partial resurfacing that have affected the surface, raising questions about the distribution of morphologically distinct terrains and impact crater areal densities. A fundamental method for deciphering these complex geological relationships is through mapping the distribution of craters across the surface of the satellite, under the assumption that the more densely cratered a given portion of the surface, the older it is. Gaining an understanding of the global distribution of impact craters therefore provides insight into the age and geological history of the surface of Enceladus, which can lead to a better understanding of the mechanical and thermal history of its ice shell. Compiling a global database of impact craters on Enceladus' surface will therefore provide valuable data that will be used, for example, as part of a separate effort to create a global geological map of Enceladus.

Background: The variation of impact crater distributions on Enceladus indicates a wide range of surface ages [3–6], suggesting a long history of geological activity. Crater size-frequency distributions (SFDs) for portions of the trailing hemisphere indicate variations in crater areal density with latitude, as well as a relative deficiency of craters of diameters ≤2 km and ≥6 km for cratered plains, compared with other icy Saturnian satellites [7]. These observations were attributed to a combination of viscous relaxation and subsequent burial of large craters, and burial of small craters, by south polar plume and E ring material.

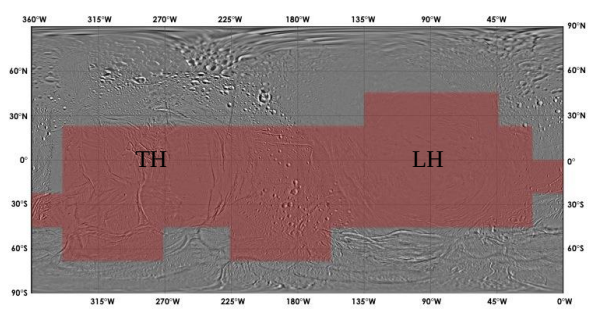

Figure 1. Preliminary coverage (red) of crater counts from 40°N to 60°S. The northern heavily cratered region was not studied due to lack of high resolution coverage. Recent ISS images of this area will be incorporated into future work.

Characterizing crater distributions and morphologies across Enceladus provides a global context for the identification of geological units, and can help determine when portions of the ice shell were resurfaced, as well as what kind of deformation those units subsequently experienced. Several studies have sought to understand the geological history of Enceladus by mapping terrains on the basis of morphology and/or impact crater distributions observed in early image mosaics derived from Cassini ISS image data [7,8]. However, these previous mapping efforts lacked the most recent Cassini image data, thus limiting global assessment of crater distributions. The availability of the final Cassini images of Enceladus incorporated into a completed global control network and basemap allows us to reevaluate these proposed units, and to integrate these data into a USGS-published geological map of the satellite [9,10].

Methods: Crater distributions were mapped and analyzed with a 100 m/pixel global controlled image mosaic of Enceladus, complemented with ancillary observation mosaics with varying viewing and illumination geometries. These datasets were produced by the USGS as part of an effort to map the global geology of the satellite at a scale of 1:2M [9,10]. Terrains located along the equatorial region between 40°N and 60°S were selected for preliminary analysis (**Figure 1**). This region includes both ancient cratered plains and younger, heavily tectonized leading and trailing hemisphere terrains. Due to the very recent availability of new Cassini images of the north polar region, the first phase of this analysis does not consider the heavily cratered northern regions.

All craters ≥0.5 km in diameter were counted to ensure full coverage at >1 km in diameter; the crater SFDs shown in **Figure 2** are for craters >1 km in diameter. To adequately compare our crater measurements with previous studies, we used similar counting methods: we exclude non-impact-related craters (e.g., pit craters) and applied image stretching to accentuate crater depressions in regions where illumination conditions are not ideal for crater identification [7].

Results: Crater areal density maps using $N(D)$ measurements, where N is the number of craters of diameter D (herein 1, 3, and 5 km), were used to compare the distribution of craters at a variety of sizes. Similar to a previous crater areal density study [7], we observed a dearth of large craters near the equator, with the number

of craters increasing at progressively higher latitudes. This observation was noted in both the *N*(3) and *N*(5) density maps, and may be accounted for by the previously proposed explanation of burial and viscous relaxation of craters of these diameters in general [7]. However, these processes do not fully address the latitudinal dependence of the SFDs of large craters that we find. Further crater measurements in the northern heavily cratered regions, for which counts do not currently exist, may provide clarity for this issue.

We also compared our crater counts with a published proposed stratigraphic column for Enceladus [8] (**Figure 2**), by producing cumulative crater SFDs for geological units delineated in that study. This stratigraphy was based primarily on observed tectonic landforms but did not fully incorporate global crater areal density measurements. With our measurements, we find that the proposed "Transitional terrain" [8] (labeled "*t*" and colored light green in **Figure 2**) may be older than the leading hemisphere terrain ("*clh*"; blue), not younger, as had been proposed. This finding may argue for the redefinition of geological terrains on the basis of both structural/morphological features and crater areal density measurements.

We also note that the measured crater distributions of the leading and trailing hemisphere (the red "*r*" unit in **Figure 2**) terrains differ substantially for all measured crater diameters. The relative scarcity of craters in the leading hemisphere terrain, compared with the trailing hemisphere, may reflect a resurfacing event that affected the region. However, a bias arising from sub-optimal illumination geometries for images of the leading hemisphere may also play a role in this apparent lack of craters.

Future Work: The overall goal of this work is to develop a comprehensive crater catalog with the most recent Cassini ISS image data and global control network [10]. The final product will primarily assist in identifying how crater areal densities and morphologies can be used to define geological terrains. The crater catalog, along with the final geological map of Enceladus, will assist in answering questions such as the reason for the latitudinal dependence of crater areal densities on the surface and whether cumulative crater SFD calculations afford us a better understanding of the nature of plume fall out and/or E ring particle deposition on Enceladus.

References: [1] Spence, J. R. et al. (2009) *Saturn from Cassini-Huygens*, 683–724. [2] Squyres, S. W. et al. (1983) *Icarus, 53*, 319–331. [3] Plescia, J. B. and Boyce, J. M. (1983) *Nature, 301*, 666–670. [4] Lissauer, J. J. et al. (1988) *JGR, 93*, 13776–13804. [5] Kargel, J. S. and Pozio, S. (1996) *Icarus, 119*, 385–404. [6] Porco, C. C. et al. (2006) *Science, 311*, 1393–1401. [7] Kirchoff, M. R. and Schenk, P. M. (2009) *Icarus, 202*, 656–668. [8] Crow-Willard, E. N. and Pappalardo, R. T. (2015) *JGR, 120*, 928–950. [9] Bland, M. T. et al. (2015). *LPS, 46*, Abstract #2303. [10] Becker, T. L. et al. (2016) *LPS 47*, Abstract #2342.

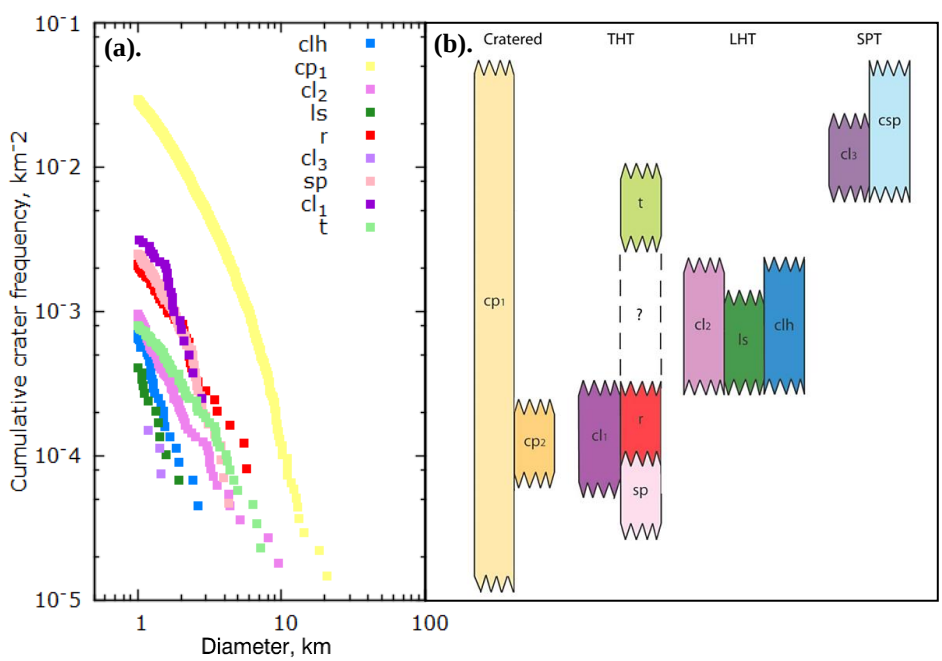

Figure 2. (a). Cumulative SFDs for geological terrains on Enceladus (colors and symbols reflect those in the stratigraphic column). (b). Proposed stratigraphic column for Enceladus from [8].