INVESTIGATING THE MORPHOLOGY OF THE IAPETUS EQUATORIAL RIDGE.

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Introduction: One of Saturn's large icy moons, the 1,469 km-diameter Iapetus, has an enigmatic equatorial ridge that encircles much of the body and has up to twenty kilometers of relief in places. The only other bodies in the Solar System that appear to have a comparable equatorial feature are the moonlets Pan and Atlas, which also orbit Saturn. Current hypotheses for the origin of Iapetus's equatorial ridge generally fall into either endogenic or exogenic categories [e.g., 1, 2].

Proposed endogenic formation mechanisms for the equatorial ridge include formation arising from a two-cell interior convection pattern [e.g., 3], from rapid tidal despinning [e.g., 4], or from Iapetus spinning at a near-critical spin rate early on that then fossilized the spin-induced shape into a ridge as the lithosphere cooled [e.g., 5]. Conversely, the hypothesis that most closely matches observations of Iapetus and its ridge is that the moon had an ancient ring system that accreted onto the surface over time [e.g., 1]. This hypothesis has been bolstered by previous studies of crater areal density, which showed that the ridge is younger than the rest of the moon, consistent with an exogenic origin [2]. Here, with a combination of image and topographic data for Iapetus, we characterized the morphology of the equatorial ridge and conducted additional crater areal density analyses, to search for further evidence of an exogenic origin for this enigmatic feature.

Ridge Morphology: We used a global image mosaic of Iapetus, produced from Cassini Imaging Science Subsystem data with a resolution of 756 m/px, to map the spatial extent of the equatorial ridge. We find that the landform is non-continuous and encircles about 74% of Iapetus's equatorial region (**Figure 1**), consistent with previous studies [6]. We next used a

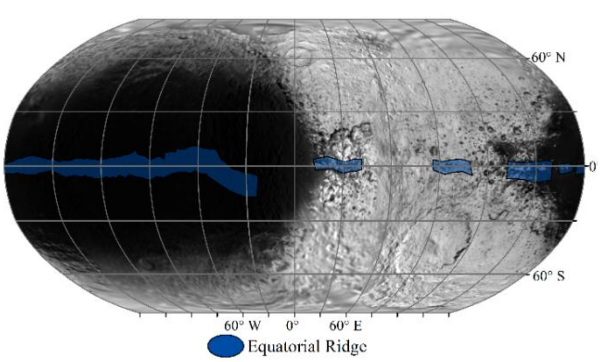

Figure 1. *A map of Iapetus, showing the equatorial ridge in blue. The map is in a Robinson projection, centered at 0°E.*

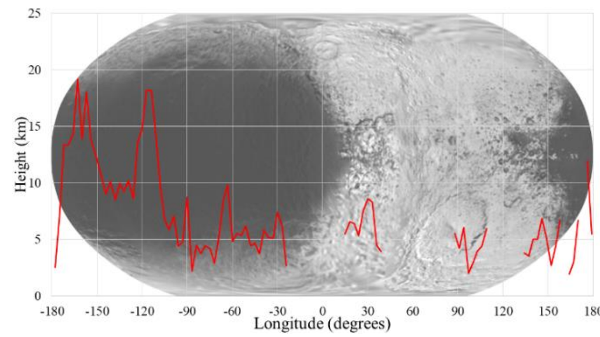

Figure 2. *The relief of the equatorial ridge as a function of longitude. The map is as that in Figure 1.*

global digital elevation model (DEM) to take cross-sectional profiles of the ridge at 300-km increments. Our results indicate that there is a distinct difference in ridge morphology between the leading versus trailing hemisphere. On the leading hemisphere, the ridge not only has greater maximum relief (i.e., 19 km versus 8 km in the trailing hemisphere), but also has steeper slopes (i.e., average slope angle of 11° versus 8° in the trailing hemisphere). When the relief of the ridge with respect to longitude is plotted (**Figure 2**), we find that the ridge is substantially taller on the leading hemisphere than it is on the trailing hemisphere.

Crater Size–Frequency Distributions: To estimate the relative ages of multiple regions across Iapetus, we performed crater areal distribution analyses of eleven sites (**Figure 3**), deriving $N(D)$ values for each (where N is the number of craters of diameter D or greater per unit area, in this case, 1×10^6 km^2) (**Table 1**). Under the assumption that a greater areal crater density value corresponds to an older age, an exogenic ridge that formed some time after the moon should have lower $N(D)$ values than the surrounding terrain. Conversely, similar $N(D)$ values between the ridge and the rest of the moon would support either an endogenic origin for the landform or that accretion of a ring occurred very early.

We find that, for some sites adjacent to the ridge (i.e., Sites 5, 6, and 9), areal crater density values are greater for craters 20 km in diameter and above than corresponding values for the ridge itself. Site 3 has a greater $N(20)$ value than the ridge but a lower $N(30)$ measure, and corresponding values for Site 4 are very close to those of the ridge. Of note, Sites 1 and 8 are both statistically more cratered than the ridge, and are among the more distal locations we considered. And, although Site 7 is also far from the ridge, its relatively low $N(20)$ and $N(30)$ values may be explained by topography: this part of Iapetus constitutes the floor of a 455 km-diameter basin that is less cratered than much of the rest of the moon, and so is presumably younger than other portions of Iapetus's surface including the ridge (**Figure 3**).

Equatorial Sites with no Ridge. Since the ridge is discontinuous along the equator, we calculated $N(D)$ values for some of these portions where the ridge is "missing." We did this with a view to determine whether the ridge simply did not form in these areas, or whether it did form but was not preserved there. We find that areas where the ridge is not present are less heavily cratered than the ridge itself. The areas where the ridge is not present are also generally topographic lows, and although locally higher terrain may have shielded these lows from deposition of incoming ring material, it is also possible that subsequent impacts destroyed any ridge portions that might have originally been present in these areas.

Conclusions: We find that the morphology of the Iapetus equatorial ridge changes considerably between the leading and trailing hemispheres, with the feature possessing steeper slopes and much greater topographic relief on the leading hemisphere. Crater size–frequency measurements indicate that the ridge is less heavily cratered, and is thus presumably younger, than the majority of Iapetus, consistent with a recent crater areal density analysis of the moon [2]. Together, these findings provide support for the conclusion that the ridge is likely exogenic, with the accretion of a former ring primarily onto the leading hemisphere some geological time after moon formation consistent with our morphological and crater areal density results.

Site	N*(10)*	N*(20)*	N*(30)*	*Area (km²)*
Site 1	709 ± 69	211 ± 38	95 ± 25	146,760
Site 2	177 ± 28	53 ± 15	35 ± 12	226,490
Site 3	895 ± 86	173 ± 38	33 ± 16	121,720
Site 4	497 ± 47	111 ± 22	53 ± 15	225,400
Site 5	575 ± 107	198 ± 63	99 ± 44	50,430
Site 6	342 ± 88	137 ± 56	91 ± 46	43,920
Site 7	130 ± 39	24 ± 17	n/a	84,650
Site 8	1176 ± 19	360 ± 66	156 ± 43	83,320
Site 9	887 ± 77	253 ± 41	167 ± 33	149,920
Ridge	519 ± 35	113 ± 16	50 ± 11	416,540
Missing Ridge	316 ± 50	79 ± 25	39 ± 18	126,700

Table 1. *Crater size–frequency data for this study.*

References: [1] Dombard A. J. et al. (2012) *JGR Planets, 117,* 2156–2202. [2] Damptz A. L. et al. (2017) *Icarus*, *302*, 134–144. [3] Czechowski L. and Leliwa-Kopystynski J. (2008) *Adv. Space Res.*, *42*, 61–69. [4] Kuchta M. et al. (2015) *Icarus*, *252*, 454-465. [5] Kreslavsky M. A. and Nimmo F. (2010) B*ull. Am. Astron. Soc.*, *42*, 941. [6] Singer K. N. and McKinnon W. B. (2011) *Icarus, 216,* 198-211. [7] Schenk P. M. et al. (2018) Univ. Ariz. Press, in press.

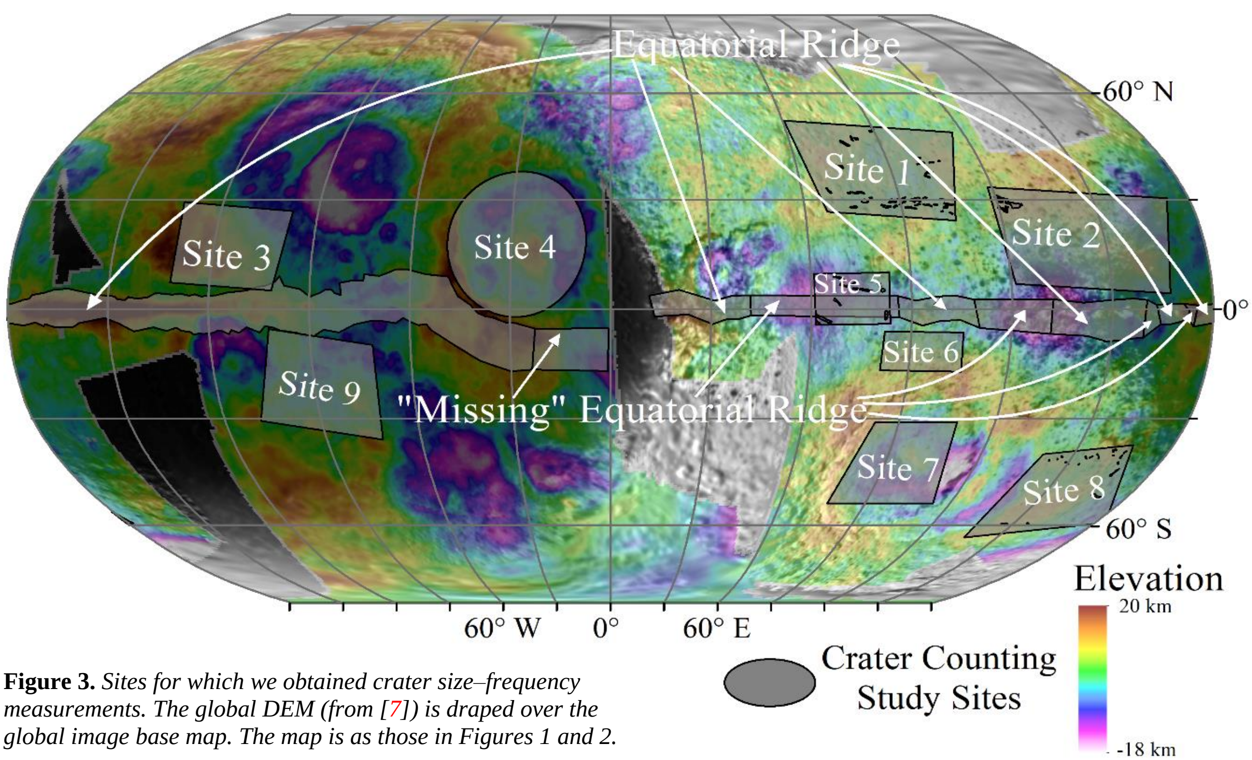

Figure 3. *Sites for which we obtained crater size–frequency measurements. The global DEM (from [7]) is draped over the global image base map. The map is as those in Figures 1 and 2.*