GEOLOGICAL CONSTRAINTS ON OUTER SYSTEM PLANETESIMAL DISK MASS FROM RIDGE SURVIVAL ON IAPETUS. E. G. Rivera-Valentin[1], E. J. Lopez Garcia[1], A. C. Barr[1], [1] 324 Brook St, Box 1846, Dept. of Geological Sciences, Brown University, Providence, RI.

Introduction: The equatorial ridge of Iapetus may be one of its oldest features because of its degraded state [1]. The ridge, which reaches heights of ~20 km and widths of ~100 km, may be formed by either endogenic processes arising during early despinning [2, 3] or debris infall from a primordial ring [4, 5]. Recent morphological investigations found that 33% of Iapetus' ridge retained an unmodified triangular shape with some slopes reaching 40° [6], indicating little to no impact modification. If the ridge is indeed primordial, then it had to survive impacts from planetesimals scattered into Saturn crossing orbits during the dynamical sculpting of the outer planets [7, 8]. This brought $\sim 1.2 \times 10^{19}$ kg of primarily cometary material to Iapetus during the first billion years of its history [7, 9, 10]. Here we use our Monte Carlo model of impact cratering [11] to constrain the planetesimal disk mass based on limits of impact-induced erosion on the ridge.

Impactor Population: We use Monte Carlo methods to select a population of impactors with a total mass and Size-Frequency Distribution (SFD) as the Kuiper Belt, which may be left over from the scattering event (see e.g. [10]). Our SFD contains one slope break at $D = 60$ km and follows a differential power law in mass (m) of the form $dN/dm \propto m^{-1.63}$ for $D \le 60$ km and $dN/dm \propto m^{-2.6}$ for $D \ge 60$ km, assuming impactor density $\rho_i = 1.1$ g cm^{-3} [12, 13]. Given these slopes and the location of the slope break, we find that most of the mass is delivered by objects with $r_i \sim 30$ km.

Analytic Model: The likelihood the ridge survives can be approximated by finding the average number of times an area on Iapetus is excavated. A conservative assumption is that the ridge morphology is affected if a transient crater impinges upon it. An impactor forms a crater of [14]

$$D_{tc} = 1.16 \left(\frac{\rho_i}{\rho_m}\right)^{\frac{1}{3}} D^{0.78} \left(v_i \sin\Omega\right)^{0.43} g^{-0.22}, \quad (1)$$

where $\rho_m = 1.1$ g cm^{-3} is Iapetus' surface density, v_i is velocity, $g = 0.22$ m s^{-2} is Iapetus' gravity, and Ω is impact angle. The characteristic impact velocity at Iapetus is 6.1 km s^{-1} [9]. For $r_i \sim 30$ km and $\Omega = 45°$, D_{tc}~337 km. An estimate of the number of times a given region is excavated, $N_{crat} \approx n \times \left(\frac{1}{4}\pi D_{tc}^2\right) / \left(4\pi R_p^2\right)$, where $n = (R_p/r_i)^3 \left(M_{Nice}/M_p\right)$ is the number of impactors, M_{Nice} is the total mass of material delivered to Iapetus during the first billion years of its history, and M_p and R_p are Iapetus' mass and radius respectively. The total mass of objects hitting Iapetus, $M_{Nice} \sim 1.2 \times 10^{19}$ kg, which includes objects scattered into Saturn crossing orbits in the 800 Myr before the 2:1 MMR crossing, plus the material that hits during the LHB [7, 9, 10]. We find that $N_{crat} \sim 1.3$ for a full *Nice* model bombardment, which would disrupt the ridge to an extent greater than observed.

Monte Carlo Model: Iapetus is modeled as a Cartesian sphere of radius 735 km. We consider the ridge to be centered at 0° latitude and to extend to ±2° latitude. Impact locations are chosen randomly in longitude and latitude following $d\varphi = \sin(2\varphi)$ [10]. To account for the lack of topographic data within the light terrain, we analyze the fate of the ridge in only one hemisphere, which is randomly selected for each Monte Carlo run.

Not only does 33% of the ridge survive major impact-modification, but triangular peaks compose 31%±11% of a 12° longitude bin [6]. This implies that there are significant continuous segments of the ridge that avoid major impact-modification. Thus, the studied hemisphere is divided into 12° longitude bins; latitudinal slices are then taken at the model resolution (5 km). If a crater is incident on a slice, the ridge is assumed to no longer have a triangular shape. For every bin, the percent of non-impact damaged slices is found. If this value falls within the observed (31% ± 11%), that bin is successful. We find the percent of successful bins for each Monte Carlo run to determine the total bombardment mass Iapetus can experience and preserve ridge segments that are 31% pristine.

Results: Figure 1 shows an example post-bombardment map of the number of times an element is impacted following a *Nice* Model bombardment. In this single bombardment history, the maximum number of times an area is excavated is 11 times with a global average of 2 times. For this bombardment history, none of the 12° bins contained an undisturbed region due to the high cratering rate.

We performed a suite of Monte Carlo simulations for a range of bombardment masses, M_x. In Figure 2A, we plot the percent of the post-bombardment ridge that remains unmodified by impacts. In Figure 2B, we plot the percent of 12° bins considered successful (i.e., bins where 31%±11% of slices were unaffected by impacts) averaged over 200 Monte Carlo realizations for each M_x. Error bars are the standard error of the means to a 95% confidence. Supporting our preliminary results from our analytic approach, a *Nice* model bombardment does not allow the ridge to survive because there are on average 2% successful bins. Indeed, on average, only 1.7%±0.4% of the ridge remains unmodified by impacts. For mass ratios >0.34, too much of

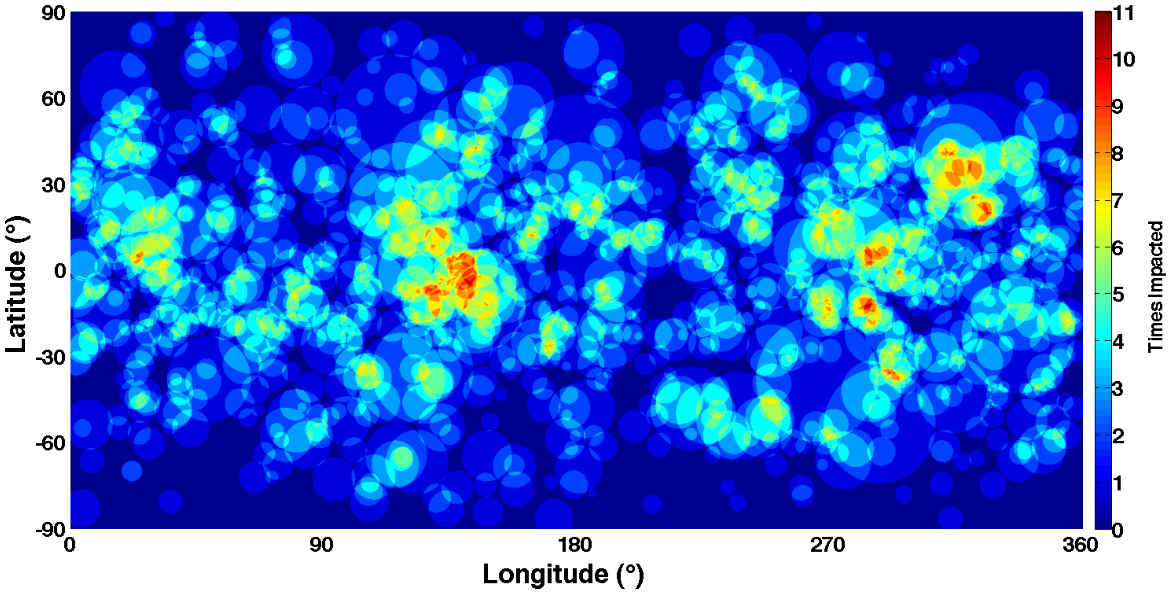

Figure 1: Post-bombardment results for a single impact history onto an model Iapetus following a *Nice* Model bombardment. Colors indicate the number of times an area is excavated by an impactor.

the ridge is affected by impacts and so it does not retain its primordial triangular shape while for <0.17 too much of the ridge survives with its primordial shape. The best successful cases occur for $M_x \approx 3 \times 10^{18}$ kg (i.e., $M_x/M_{Nice} = 0.23$).

Conclusions: We find that a *Nice* Model outer system bombardment would significantly modify Iapetus' ridge to a greater extent than observed. These results may imply: 1) the ridge is young, which may be excluded by the crater density on the ridge itself [1], 2) the surface of the young Iapetus was warm and it did not begin recording craters until sometime during the LHB, much like its interior siblings [15], or 3) Iapetus itself is young, 4) the outer system disk mass is smaller [16] than suggested by prior work [8, 7, 17] or 5) none of Saturn's regular satellites are primordial and the present-day system is not the same that was present during the first billion years of solar system history.

Acknowledgements: This work was supported by NASA through PG&G NNX12AI76G.

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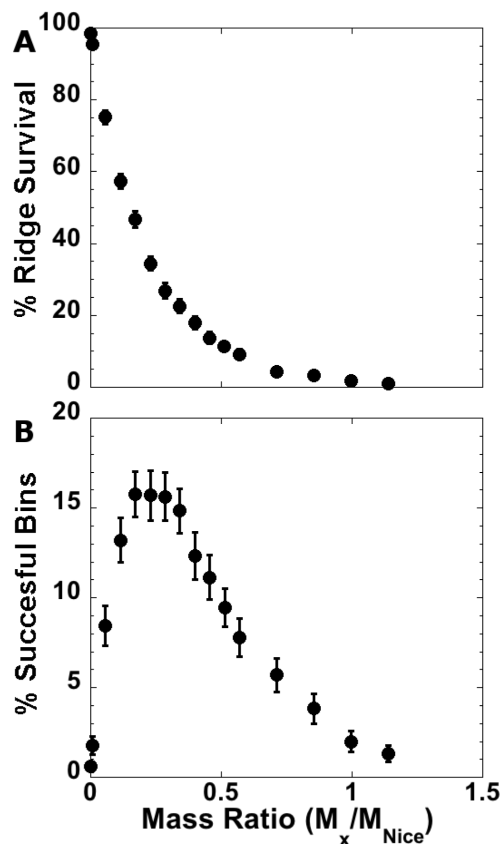

Figure 2: A) Percent of post-bombardment ridge that is unmodified by impacts. The observed global 33% ridge survival correlates with a mass ratio of 0.23. B) Percent of 12° bins that fulfill the pristine criterion of 31%±11%. The most successful cases are for mass ratios between 0.17 and 0.34. Filled circles are Monte Carlo results with error to 95% confidence.