EVIDENCE OF REGIONAL VARIATIONS IN HEAT FLOW ON SATURN'S MOON TETHYS. A.W. Bellagamba[1], A.M. Grimm[1], A. J. Dombard[1], O.L. White[2], Dept. of Earth and Environmental Sciences, [1]University of Illinois at Chicago, Chicago, IL 60607 (adombard@uic.edu), [2]NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: Study of topographic relaxation of large impact basins has proven to be a powerful tool in understanding the evolution of mid-sized satellites of Saturn [1]. Simulation of relaxation can provide an estimate of the heat flow escaping out of satellite, yet just the simulation alone does not carry the temporal information needed to tie this value into an evolutionary pathway. For that, the age of the large crater must be constrained. Here, we turn our attention to Tethys.

Methods: The candidates for this study are Penelope, Melanthius, and an unnamed crater centered at 51°N, 18°W, which will be referred to as Crater X (Fig. 1). Notably, Penelope and Crater X are comparably sized at 180-200 km in diameter, while Melanthius is larger at ~270 km. The diameter of each crater is measured as an average of multiple profiles. We determine the relative age of each basin through the use of standard crater counting techniques [2]. Each crater within the basin is counted using a Cassini derived global basemap imported into Google Earth (a simple scaling is applied to account for Earth's larger diameter). Relative Size-Frequency Distributions as a function of crater size (i.e., R-plots) are shown in Fig. 2.

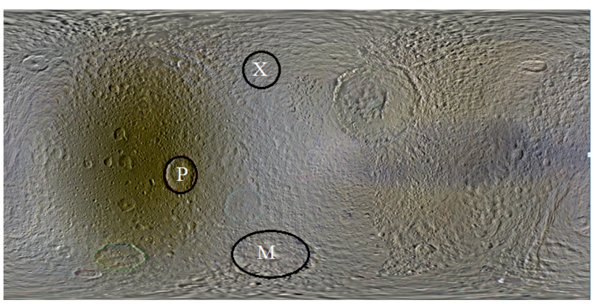

Figure 1: Cassini image mosaic of Tethys with locations of Penelope (P), Melanthius (M), and Crater X (X).

Elevation profiles for each basin are extracted from a Digital Elevation Model (DEM) derived from stereophotogrammetry [1]. Scaling of depth-diameter relationships [3] suggest that Penelope is as deep as would be expected, suggesting that any relaxation has been negligible. In contrast, Melanthius and Crater X are much shallower than Penelope, implicating relaxation (Figs. 3 and 4). Thus, we can use Penelope's shape as a starting point for simulations of the other two.

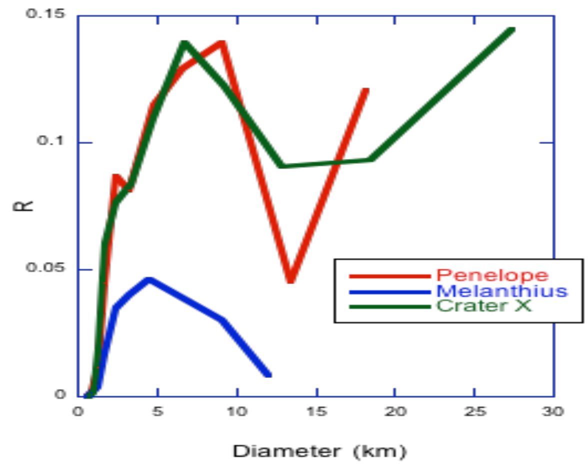

Figure 2: Relative Size-Frequency Distributions as a function of crater size. The data suggest that Melanthius is younger than the others, and suggest Penelope and Crater X are inconclusive.

For these topographic relaxation simulations, we follow our previous work and use the MSC.Marc finite element package [1, 4]. We use a simplified shape with the dimensions of Penelope and simulate 1 radial plane in an icy half-space beneath the crater. Melanthius and Crater X do possess diameters different than Penelope, so their profiles are stretched to match Penelope. The bottom and far boundaries are placed sufficiently far to not affect the results. Material parameters for water ice are applied, including a grain size sensitive viscous rheology [5]. The system is loaded with Tethys gravity (0.147 m/s^2), and a surface temperature of 90 K is applied. We first run a thermal simulation to find the equilibrium between this surface temperature and an applied basal heat flow. The results of this thermal simulation are then piped into a mechanical simulation in which we determine if this heat flow is sufficient to explain the observed topographic profile.

Results and Discussion: Crater counts (Fig. 2) suggest that Melanthius is the youngest of the three. Penelope and Crater X have nearly identical crater counts, suggesting that they are contemporaneous. Their crater counts, however, both peak at R values of ~0.15, which indicates that they may have reached saturation. In which case, either one may be older than the other, in addition to possibly being the same age.

The relaxation simulations indicate that the regional heat flow around Penelope never exceeded 10 mW/m^2 (and was likely even less), otherwise we would predict that Penelope would be significantly shallower than it is. On the other hand, the regional heat flows around Melanthius and Crater X were significantly higher. Melanthius's current depth is best explained by a heat flow of 30 mW/m^2 (Fig. 3). Simulations using an unstretched Melanthius profile indicate a slightly lower heat flow of 20 mW/m^2. Most relaxation happens early (within the first 10 Myr) with lesser though progressive amounts at larger times, a finding consistent with past work [1, 4]. Remarkably, Crater X would have needed heat flows in excess of 100 mW/m^2 (Fig. 4)! Shedding of the crater depth again occurs early; however at such high heat flows, the central uplift begins to collapse at larger times.

Given the relative ages of the basins, these heat flow values are problematic if they are global. Melanthius relaxed under a higher heat flow than Penelope experienced, yet Penelope is clearly older. Had the heat flow that Melanthius relaxed under been a global value, Penelope should be relaxed to a similar degree. A likely resolution to this dilemma is that there existed regional variations in the heat coming out of Tethys. Our inferred heat flow values are well in excess of what radiogenic heating can provide, which suggests tidal dissipation as an extra heat source [cf. 1]. Tidal heating, in turn, can produce regional variations in the surface heat flux with maxima/minima ratios of a factor of several [6]. The pattern of how heat flow varies across the surface depends on the conditions within the moon.

Crater X is even more problematic. If it is younger or contemporaneous to Penelope, then the difference between its apparent extreme heat flow (> 100 mW/m^2) and Penelope's (< 10 mW/m^2) is larger than the regional variations in tidal heating predicted by models [6]. A more likely resolution is that Crater X is the oldest of the three and existed during a time when heat flows on Tethys were very high. In turn, Penelope and Melanthius, being younger, never experienced such high heat flows.

Conclusion: Relative age dating reveals that Melanthius is younger than both Penelope and Crater X, and the relative age ranking of these latter two cannot be determined because of saturation in the crater counts. Unexpectedly, Penelope's topography is deeper and less relaxed than Melanthius (and Crater X). This finding suggests higher localized heat flows in the regions around Melanthius (and Crater X), consistent with predictions of tidal heating. Further study of additional basins on Tethys might be able to constrain better this spatial variation in heat flow, which could then conceivably constrain the conditions within Tethys as it was dissipating orbital energy.

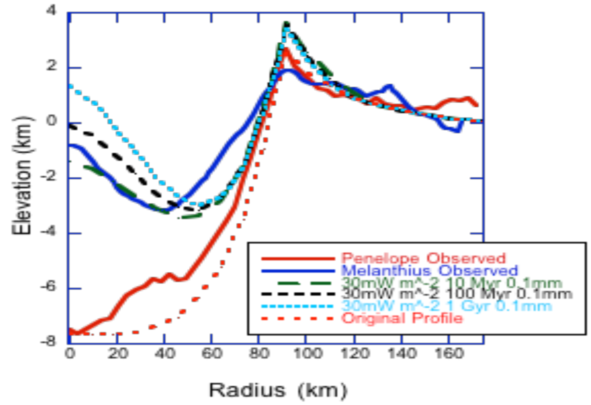

Figure 3: Radial topographic profiles of Penelope and a stretched Melanthius. The solid lines are the averaged topographic profiles of Penelope and Melanthius, while the dotted lines represent simulated profiles for different combinations of heat flow duration, heat flow magnitude, and ice grain size.

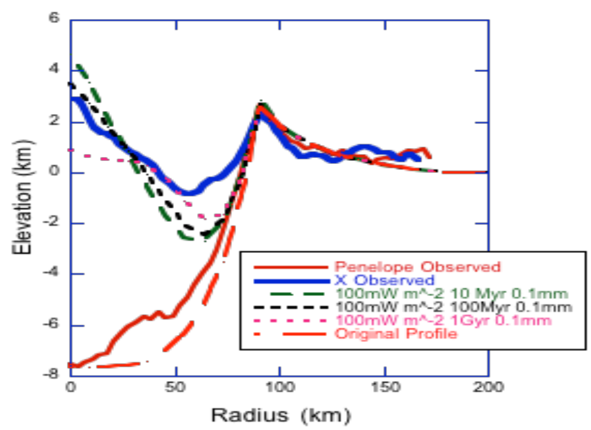

Figure 4: Radial topographic profiles of Penelope and Crater X. The solid lines are the averaged topographic profiles of Penelope and Crater X, while the dotted lines represent simulated profiles for different combinations of heat flow duration, heat flow magnitude, and ice grain size.

References: [1] White O. L et al. (2013) *Icarus 223,* 699-709. [2] Arvidson R. et al. (1979) *Icarus, 37,* 467-474. [3] White O. L. et al. (2014) *AGU Fall Meeting,* Abstract P43B-3990. [4] Dombard A. J. & McKinnon W. B. (2006) *JGR, 111,* doi:10.1029/2005JE002445. [5] Goldsby D. L. and Kohlstedt D. L. (2001) *JGR, 106*, 11,017-11,030. [6] Hamilton C. W. et al. (2013) *EPSL, 361*, 272-286.