THE TICKING CLOCK OF IMPACT CRATERS IN THE SATURNIAN SYSTEM. E. B. Bierhaus[1], L. Dones[2], and S. J. Robbins[2], [1]Lockheed Martin (edward.b.bierhaus@lmco.com), [2]Southwest Research Institute.

Brief Summary: We describe two results from our current research on the saturnian satellites: (1) the varying effect of secondary craters on crater size-frequency distributions (SFDs), and (2) the age uncertainties caused by the presence of secondary craters in the crater populations.

Introduction: The Saturnian system is rich with chronological mysteries. Are Saturn's rings young or old [1]? The giant Herschel crater on Mimas seems young, but generally the largest craters are the oldest craters. What is the distribution of surface ages on Enceladus, and what are the consequences for the subsurface ocean? Are Tethys, Dione and Rhea an original triad of Saturnian satellites, part of the primordial structure of the Saturnian system, or the result of a much more recent set of collisions and restructuring of satellite progenitors [2]? Is Titan's atmosphere recent or primordial [3]? How did the Iapetus ridge form, and how old is the ridge? Depending on the "when" and the rates associated with these events, the answers to some of these questions may provide fundamental constraints on the other questions.

How can we determine the time, and perhaps a rate, associated with these events? Because sample return from the Saturnian satellites remains in the future, we use the proxy of crater populations. Similar to the concept of radioisotopes – in which any particular decay is stochastic but the ensemble behavior over a large population of atoms leads to a reliable relationship between isotopic ratios and an age – any individual primary impact on the surface is a random event, but a population of craters is correlated with a particular surface age. Complicating factors include the effect of secondary craters [4,5], and how well we know the rate at which impactors strike the surfaces of the saturnian satellites.

Making craters: We developed a model that combines the production of primary craters according to [6], ejecta mass-velocity distributions [7], and ejecta-fragment sizes [8] into actual secondary craters. In brief, the first step is to generate impactors according to Case A in [6], which provides the accumulation of primary craters in time. For each primary crater above a threshold size, we create 1000 ejecta fragments. These fragments have realistic size, mass, and velocity distributions. We use SWIFT [9] to integrate the trajectories of the fragments, and record the impact locations and speeds, using crater-scaling laws to translate the fragments into secondary craters. The result is a record of the primary and secondary craters as a function of time. The results allow us to investigate the effect of secondary craters on the SFD, as well as the effect on the derived surface age.

Results: [10] showed that variation of just a few parameters between worlds and satellites results in different masses available for the secondary population on a given surface. The current results refine that conclusion.

Effect on Crater SFDs. The top plot of Figure 1 shows the resulting crater SFD for Dione, including the primary-crater population, the secondary-crater population, and the combined population. There are some secondaries as large as nearly 10 km, made by the very largest primary craters. Because there are only a few of these largest secondaries, they do not substantively change the overall crater SFD at this size. However, at progressively smaller diameters, the steep SFD of secondaries causes them to approach, and then exceed, the population of small primary craters, causing an "uptick" in the overall crater SFD. The sudden decrease at the smallest diameters for both secondary and primary craters is due to the artificial truncation of the populations at those sizes. (Computational limitations constrain the number of secondary fragments to 1000 per primary. A more complete treatment would extend the secondaries to smaller diameters.)

The lower plot in Figure 1 shows the combined primary-plus-secondary crater populations for several saturnian icy satellites. (The Dione curve is the same as in the top plot.) The first feature to note is that for crater diameters that are exclusively primary, the relative "vertical stacking" of the crater SFDs generally matches the observations [11]. Several features of the combined population are different, including the steepness of the upturn due to secondaries, and the diameter at which the upturn occurs. (In this simulation, Mimas does not have secondaries, see [10].) This illustrates that the secondary population will vary between surfaces.

Effect on Age Determination. Figure 2 shows the evolution of crater density in time for three of the satellites, with significantly different outcomes. The spread in ages for a given crater density defines the best-case uncertainty in surface age, ignoring other factors. In the case of Enceladus, secondaries quickly dominate the crater density, but with small differences between the minimum and maximum curves, implying a deterministic relationship between surface age and crater density. Dione shows very large differences between the maximum and minimum crater densities, implying significant uncertainties when deriving surface age from crater density. Iapetus is intermediate between

Enceladus and Dione. These results indicate that just a modest secondary population has a variable and potentially significant impact on the derived surface ages of the saturnian satellites. Larger craters, which are mostly or entirely primary craters, provide meaningful constraints on surface ages.

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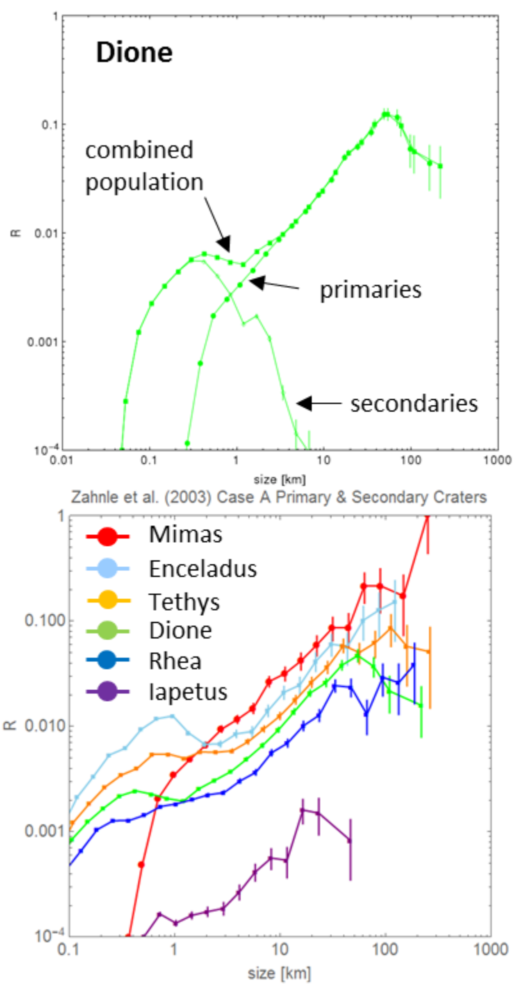

Figure 1. The top plot shows the individual primary and secondary populations, and combined crater population, from our simulation of Dione. The bottom plot shows the combined crater populations for several saturnian satellites.

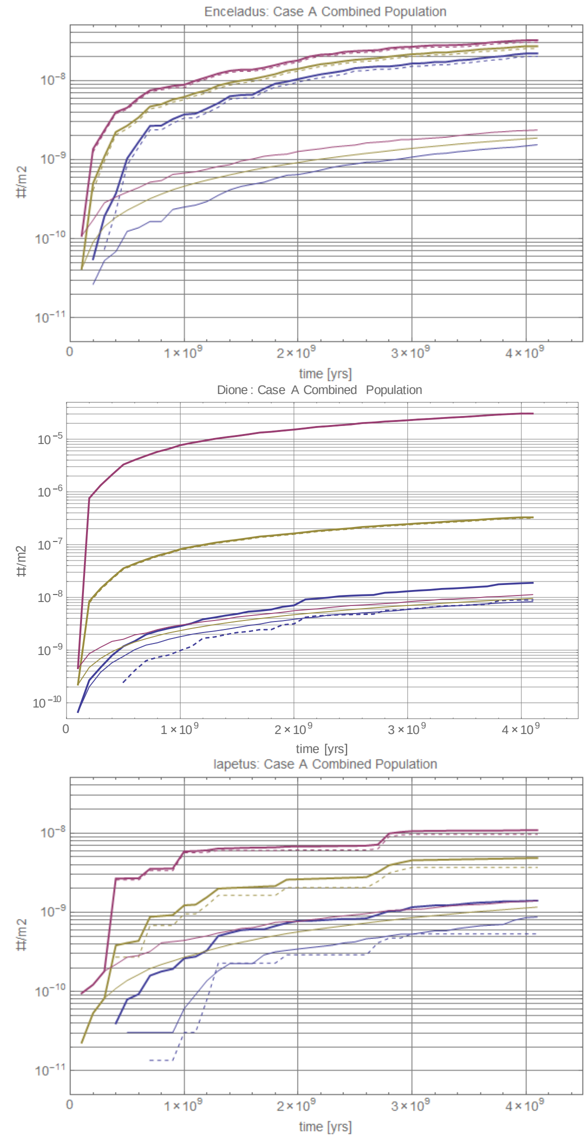

Figure 2. These three plots (top: Enceladus, middle: Dione, bottom: Iapetus) show the minimum, mean, and maximum number density in time for primaries (thin solid lines), secondaries (dashed lines), and combined populations (thick solid lines). Larger differences between the minimum and maximum curves for the combined population correlate with increased error in the derived surface age.