IMPACTOR POPULATIONS IN THE SATURNIAN SYSTEM: CONSTRAINTS FROM THE CRATERING RECORDS. M. R. Kirchoff and P. Schenk, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, USA (kirchoff@lpi.usra.edu & schenk@lpi.usra.edu).

Introduction: When using a planetary surface's impact cratering record to investigate the object's geologic history, it is important to understand the sources of impactors generating the unmodified record. For Saturn's satellites, this implies that impactor populations pertinent to the Saturn system should be characterized in order to acceptably interpret cratering records modified by geologic activity [1-8]. Here, as a first step, we compile and analyze the crater distributions of apparently *unmodified*, heavily cratered terrains on Mimas, Tethys, Dione, Rhea, and Iapetus to place constraints on characteristics of impactor population(s) in the Saturn system (see also [9]). This work provides a preliminary survey of these impactor populations. Numerical modeling, along with this analysis of the cratering records, will be required for further insight into properties of these populations.

Previous Work: Imaging from *Voyagers 1* and *2* provided the first opportunity to characterize the impactor population(s) relevant to the Saturn system from cratering records of the satellites. Generally, the data seemed to imply that cratering of the satellites was dominated by two populations [7, 8, 10-15]. One was characterized by a greater number of large craters (Saturn Population I in *Voyager* literature) and the other by a relative deficiency of large craters (Saturn Population II). Furthermore, Population I was indicated on older terrains, such as Rhea and Iapetus, while Population II appeared to only be found on young terrains of Mimas, Enceladus, Tethys and Dione. Characteristics of Population I seemed to be most compatible with heliocentric comets. Meanwhile, characteristics of Population II seemed to be most compatible with smaller planetocentric impactors created by escaped secondaries from large basins and disrupted satellites. Imaging by *Cassini*, which improves the spatial and resolution coverage over that obtained by *Voyager*, allows us to compile new, expanded crater distributions for the satellites to analyze in an attempt to support or refute this hypothesis.

Methods: Impact crater distributions are compiled from controlled global mosaics of Mimas, Tethys, Dione, Rhea and Iapetus, and high-resolution images of Tethys, Dione, Rhea, and Iapetus all derived from *Cassini ISS* images. From these images the diameter and position of the crater is recorded. Results of our crater counts are presented in the relative (R) size-frequency distribution plot format [16] (Fig. 1). The R-plot is the ratio of our distributions to a distribution with differential slope equal to 3, plotted against crater diameter in log-log space with $\pm \sqrt{N}$ error bars (N is the number of craters counted in that bin). Both averaged (Fig. 1A) and raw (Fig. 1B) R-values are plotted for completeness. R-values are averaged to simplify the plot and make comparisons more straightforward. The raw data points for each terrain shown have been averaged where data overlap from different source images and plotted as a connected line without error bars (the line is dashed when it goes through a diameter bin with no data). Where data is averaged the raw R-values are weighted by their errors (similar to the method of [17, p.45]), so that raw values computed using a large number of measurements, which are more reliable, are given more importance in the calculation of the average.

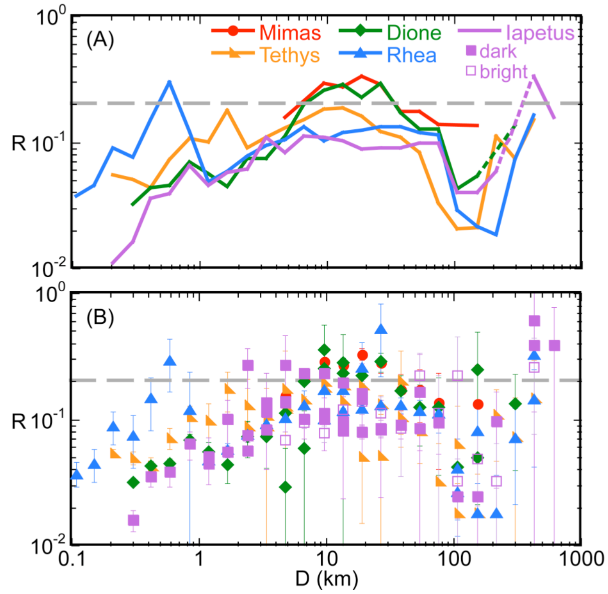

Figure 1. Relative (R) size-frequency impact crater distributions for Mimas, Tethys, Dione, Rhea and Iapetus. (A) Averaged R-values. These lines represent averages of the raw R-values in (B). Dashed line for satellites indicates that data is missing. (B) Raw R-values with error bars. Dashed gray line indicates the suggested saturation equilibrium level [20].

Results: The heavily cratered plains of Mimas, Dione, and Tethys all have very similar impact crater distributions for D < 80 km (Fig. 1). The slope for D < 10 km is generally very shallow (increasing R-values). After D ≈ 10 km the slope steepens slightly (R-values remain flat), but is still relatively shallow until D ≈ 20 km. At D ≈ 20 km the slope then increases (decreasing R-values) implying that large craters are less abundant on these satellites. The impact crater distributions of

Rhea and Iapetus' heavily cratered plains also appear to be very comparable to each other (Fig. 1). For D < 10 km, the distributions are increasing in R-value and have a shallow slope. The distributions are then rather flat on the R-plot for 10 ≤ D ≤ 80 km.

When the distributions of Mimas, Tethys and Dione are compared to Rhea and Iapetus (Fig. 1), both similarities and differences are observed. For D < 10 km, all the distributions have slowly increasing R-values and shallow cumulative slopes. Above D = 10 km, all the distributions have relatively flat R-values until D ~ 20 km. This is where the two groups' distributions begin to diverge. The R-values for Mimas, Tethys and Dione begin to decrease, while Rhea and Iapetus' R-values remain flat and do not start decreasing until D ~ 80 km. Therefore, Mimas, Tethys and Dione appear to be deficient in large craters compared to Rhea and Iapetus.

Discussion: The similarities and differences between our crater distributions are overall similar to those found with *Voyager* imaging [7, 8, 10-15]. One exception is that our data indicate old terrains on Dione and Tethys are similar to Mimas in displaying a deficiency of large craters. This exception, however, may only be due to poor imaging by *Voyager* of heavily cratered terrains on Dione and Tethys. Therefore, the overall similarity of our results to those from to *Voyager* analyses, suggests that the hypothesis of the two different impactor populations may still be plausible. In addition, the similarity of the characteristics implied by the cratering records support the hypothesis that one population is heliocentric comets and the other planetocentric debris.

Can the differences of the distributions for Mimas, Dione and Tethys versus Rhea and Iapetus (Fig. 1) instead be explained solely by alteration due to geologic activity? If we assume that the distributions of Rhea and Iapetus, which show little evidence of geologic activity, represent the unaltered distribution, then viscous relaxation could be a candidate to "remove" large craters from the records of Mimas, Dione and Tethys. Modeling of viscous relaxation has demonstrated that craters with 20 ≤ D ≤ 80 km could be considerably relaxed in a reasonable time frame for a plausibly higher heat flow [e.g., 18]. Viscous relaxation, however, has a couple of challenges. First, no strong evidence has been found to support Mimas having a high enough heat flow to considerably relax craters, even early in its history [e.g., 19]. Second, viscous relaxation of a crater generally leaves remnant topography, as evidenced the many relaxed craters observed on the Saturnian satellites (except Mimas) [e.g., 8]. Therefore, viscous relaxation is not likely responsible for the difference between the size-frequency distributions of Mimas, Dione and Tethys versus Rhea and Iapetus.

Conclusions: While the impact crater distributions of *unmodified* terrains on Mimas, Dione, Tethys, Rhea and Iapetus are similar over most of the diameter range examined, differences are found between 20 ≤ D ≤ 80 km. Primarily, Mimas, Tethys and Dione have steep slopes (decreasing R-values), whereas Rhea and Iapetus remain shallow (flat R-values; Fig. 1). In other words, distributions on Mimas, Tethys and Dione appear to be "missing" large craters (D ~ 70 km) relative to Rhea and Iapetus. This difference is similar to the one found in Voyager analyses and is likely due to two different sources of impactors [8, 10-15]. One population has a shallow slope (Saturn Population I from *Voyager* literature), is likely heliocentric and is best expressed on Rhea and Iapetus. The other distribution has a steeper slope and lack of larger craters (Saturn Population II from *Voyager* literature), consistent with being planetocentric debris, and is primarily expressed on terrains on Mimas, Tethys and Dione.

References: [1] Kirchoff, M.R. and P. Schenk (2007). *Eos Trans. AGU 88(52), Fall Meet. Suppl.*, abst. #P12B-0545. [2] Kirchoff, M.R. and P. Schenk (2008). *Lunar Planet. Sci. XXXIX*, abst. #2234. [3] Kirchoff, M.R. and P. Schenk (2008). *Saturn after Cassini-Huygens Symposium*, abst. #147. [4] Kirchoff, M.R. and P. Schenk (submitted) Crater modification and geologic activity in Enceladus' heavily cratered plains, *Icarus*. [5] Kargel, J.S. and S. Pozio (1996) *Icarus* **119**, 385-404. [6] Neukum, G., et al. (2006). *European Planet. Sci. Cong.*, abst. #610 [7] Lissauer, J.J., et al. (1988) *J Geophys. Res.* **93**, 13776-13804. [8] Plescia, J.B. and J.M. Boyce (1985) *J Geophys. Res.* **90**, 2029-2037. [9] Kirchoff, M.R. and P. Schenk (submitted) Impact cratering records of the mid-sized, icy Saturnian satellites, *Icarus*. [10] Horedt, G.P. and G. Neukum (1984) *J Geophys. Res.* **89**, 10405-10410. [11] Shoemaker, E.M. and R.F. Wolfe (1981) *Abstracts 12th Lunar Planet. Sci.* **Suppl. A**, 1-3. [12] Smith, B.A., et al. (1982) *Science* **215**, 504-537. [13] Smith, B.A., et al. (1981) *Science* **212**, 163-191. [14] Strom, R.G. and A. Woronow (1982) *Abstracts 13th Lunar Planet. Sci.* **Suppl. B**, 782-783. [15] Chapman, C.R. and W.B. McKinnon (1986) in: *Satellites*, University of Arizona Press, Tucson, AZ, pp. 492-580. [16] Crater Analysis Techniques Working Group (1979) *Icarus* **37**, 467-474. [17] Wall, J.V. and C.R. Jenkins (2003) *Practical Statistics for Astronomers*. Cambridge Univ. Press, Cambridge, UK, p. 277. [18] Dombard, A.J. and W.B. McKinnon (2006) *J Geophys. Res.* **111**, E01001, doi:01010.01029/02005JE002445. [19] Schubert, G., et al. (1986) in: *Satellites*, Univ. Arizona Press, Tucson, AZ, pp. 224-292. [20] Melosh, H.J. (1989) *Impact Cratering*, Oxford Univ. Press, NY, p.245.