BOMBARDMENT HISTORY OF THE SATURNIAN SATELLITES. M. R. Kirchoff and P.M. Schenk. Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (kirchoff@lpi.usra.edu & schenk@lpi.usra.edu)

Introduction: A few possible hypothesis implicating that dynamic and orbital changes in the outer solar system generated the Late Heavy Bombardment ~3.9 Ga [1-9] have been described in the literature [10-15]. The basic premise of these models is that formation and/or orbital migration of the gas giants triggered scattering of large reservoir(s) of icy planetesimals throughout the solar system. These icy planetesimals, or more likely asteroids also scattered by the perturbations [9], then could have produced the basins associated with the Late Heavy Bombardment on the Moon. These hypotheses might also predict a signature of the Late Heavy Bombardment on the outer solar system satellites produced by the scattered icy planetesimals. Therefore, we will generate impact crater databases through crater counting for relatively older surfaces of Mimas, Dione, Tethys, Rhea and Iapetus to determine the bombardment history of the Saturnian satellites. Once this history is known we can compare it to hypotheses of outer solar system impactor populations including a possible heavy bombardment.

The work here will focus on determining the distribution of the basins and their ages along with comparing the size-frequency distribution between the satellites and different terrains on the satellites. For determining ages of terrain units and basins, we do not have access to samples that we can date by radioactive elements, but we can estimate the age of basins on various satellites using crater counts and estimated impact rates [16]. While dating using crater counts is not as well constrained as radiometric dating, crater counts are all that is available and will give an impression of basin ages and bombardment history.

Data: Most crater counting is performed on controlled global mosaics generated from *Cassini* ISS images with higher resolution *Voyager* images to fill in remaining gaps. The Mimas mosaic ranges from 400 to 1000 m/pxl. Dione and Tethys mosaics are about 500-700 m/pxl. Rhea and Iapetus mosaics are about 1 km/pxl. We also will get data from a selection of high-resolution images for all the satellites except Mimas that range in resolution from 20 to 200 m/pxl.

To determine the crater density within large basins, we will use the highest resolution image available for that basin from either the high-resolution images or global mosaics. Most of the basins are visually determined from the global mosaics, but some of them have been determined through digital elevation maps [17].

Preliminary Results: Fig. 1 shows relative (R) size-frequency distributions of the impact craters for a couple of impact basins and a few different terrains on Mimas, Tethys, Dione and Rhea in raw (A) and averaged (B) data format. These plots allow us to compare the relative densities and pattern (or shape) of the distributions as a function of diameter. We also give the ages of these basins and terrains examined so far in Table 1. Ages are given for both cases A and B in Zahnle et al. [16], where case A is for a small impactor population similar to that seen at Jupiter and case B for a larger small impactor population as seen for Triton's distribution. These preliminary results indicate that the distributions in the oldest terrains on Mimas, Tethys, Dione and Rhea all show a similar distribution both in density and shape. This implies that these oldest terrains on these satellites were impacted by the same impactor population that was likely heliocentric.

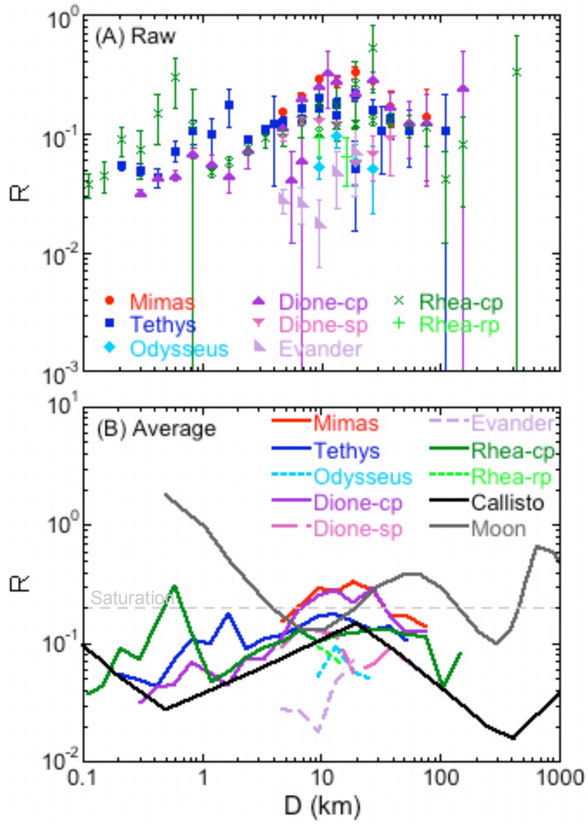

Figure 1. Relative (R) size-frequency distributions. The relative plot (R-plot) shows the ratio of the actual distribution to a distribution with a differential slope of -3. Part (A) shows the raw data for the Saturnian satellites. Counts are shown for Odysseus, a basin on Tethys, and Evander, a basin on Dione. *cp* – cratered plains; *sp* – smooth plains; *rp* – ridged plains. Part (B) shows averaged data for the Saturnian satellites to compare to published data for Callisto [19] and the lunar highlands (Moon) [18].

Also shown in Fig. 1 are the published curves for the lunar highlands [18] and Callisto [19]. When the curves we have derived for the Saturnian satellites are compared to Callisto we find that the shape of the distributions are fairly similar. This further supports the idea that there was one primary, heliocentric impactor population in the outer solar system that bombarded at least the Jovian and Saturnian satellites early in their history. When both Callisto and the Saturn satellite distributions are compared to the lunar highlands, however, the data imply that terrains in the inner and outer solar system were not impacted by the same primary population.

Table 1. Terrain Ages in Gyr

	D ≥ 5 km		D ≥ 10 km	
	A	B	A	B
Mimas	4.39	0.75	4.35	1.33
Tethys	4.56	1.66	4.44	2.10
Odysseus	--	--	3.76	1.06
Dione-cp	4.56	2.60	4.56	3.22
Dione-sp	4.55	1.97	4.43	1.96
Evander	3.62	0.60	3.61	1.00
Rhea-cp	4.56	3.05	4.56	3.67
Rhea-rp	--	--	4.48	2.47

Another important preliminary result of this work is that the impact crater distribution of Dione's smooth plains and, possibly, Rhea's ridged plains, which could be up to ~2 Gyr younger than Dione's and Rhea' cratered plains (Table 1), have a similar shape to the cratered plains (Fig. 1). This implies that the size-frequency distribution of the impactor population striking Dione and Rhea did not change over the time period represented.

Finally, we have computed the ages for two basins in the Saturnian system (Table 1): Odysseus on Tethys and Evander on Dione. Odysseus appears to be 3.8 Gyr or younger and Evander 3.6 Gyr or younger. Given that the error associated the ages is at least 20% (based upon the error for the crater counts), these basins could have been formed around the same time as the Late Heavy Bombardment on the Moon. The caveat is that the small impact population must be similar to that at Jupiter, which our data seems to imply.

Conclusions: The impact crater distribution on the cratered plains of Dione, Rhea, Mimas and Tethys are old surfaces (Table 1) that have likely experienced the same population of impactors according to the similarities of the distributions (Fig. 1). We also conclude that the similarity of the distribution of Dione's smooth plains and, possibly, Rhea's ridged plains to the Dione's and Rhea's cratered plains (Fig. 1) indicates that the impactor population did not change over the first ~2 Gyr (Table 1). When these results are combined with the implication that Saturn's crater distributions appear similar to Callisto's distribution, we can conclude that there possibly was one primary impactor population for the outer solar system that did not change for at least ~2 Gyr. Meanwhile, the distribution for older terrains in the Jupiter and Saturn systems does not appear to be the same as the lunar highlands. The implication, assuming these terrains are representative, is that at least the older terrains of the inner and outer solar systems were bombarded by different impactor populations. The most likely scenario to explain this discrepancy is that the inner solar system cratering record is dominated by asteroids [e.g., 9, 15] and the outer solar system by ecliptic comets from the Kuiper Belt [e.g., 16]. This is an interesting and important conclusion for understanding and comparing bombardment histories of the inner and outer solar systems, and might possibly imply that the signature of the Late Heavy Bombardment in the outer solar system may look different from the one found on the Moon.

The preliminary results for the ages of basins in the Saturnian system have shown that at least two large Saturnian basins could have been formed during the period of Late Heavy Bombardment on the Moon [5-9]. The results here, however, are by no means comprehensive and there are many more basins to explore in the Saturnian system. We will show results for these other basins and discuss implications for recording a late heavy bombardment in the Saturnian system. Other future work will include compiling and comparing Iapetus' impact crater distribution and continuing to generate counts for the relatively younger terrains on Dione, Tethys and Rhea.

References: [1] Turner, G. et al. (1973) *Proc. 4th Lunar Sci. Conf. GCA* **2** Suppl 4, 1889-1914. [2] Tera, F. et al. (1974) *EPSL* **22**, 1- 21. [3] Ryder, G (1990) *Eos* **71**, 313. [4] Dalrymple, G.B. and G. Ryder (1996) *JGR* **101**, 26069-26084. [5] Cohen, B.A. et al. (2000) *Science* **290**, 1754-1756. [6] Cohen, B.A. et al. (2005) *MPS* **40**, 755-777. [8] Cohen, B. (2007) *DPS #39*, abst. #46.03. [9] Kring, D.A. and B.A. Cohen (2002) *JGR* **107**, doi:10.1029/2001JE001529. [10] Liou, J. and R. Malhotra (1997) *Science* **275**, 375-377. [11] Levison, H.F. et al. (2001) *Icarus* **151**, 286-306. [12] Tsiganis, K. et al. (2005) *Nature* **435**, 459-461. [13] Gomes, R. et al. (2005) *Nature* **435**, 466-469. [14] Morbidelli, A. et al. (2005) *Nature* **435**, 462-465. [15] Strom, R.G. et al. (2005) *Science* **309**, 1847-1850. [16] Zahnle, K. et al. (2003) *Icarus* **163**, 263-289. [17] Schenk P.M. and J.M. Moore (2007) *LPSC XXXVIII*, abst. #2305. [18] Ivanov, B.A. et al. (2002) in Asteroids III, pp. 89-101. [19] Schenk, P.M. et al. (2004) in Jupiter: The Planet Satellites and Magnetosphere, pp. 427-456.