Bombardment History of the Saturn System

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We analyze crater distributions on Voyager images of Saturn's satellites and develop models of relative cratering rates on these bodies based on orbital dynamics. Our goal is to construct a history of satellite bombardment, disruption, and resurfacing in the Saturn system. Our observations concentrate on Rhea, the largest and best-imaged of Saturn's airless moons. We divide the portion of Rhea imaged at high resolution into 44 latitude-longitude quadrats for counting purposes. Detailed analysis of the spatial distribution of craters shows no statistically significant evidence for local endogenic resurfacing on Rhea. The apparent spatial variability in the distribution of small craters is strongly correlated with lighting geometry and hence unlikely to have resulted from geologic processes. Also, we find that the spatial distribution of craters on Rhea with diameters $D \geq 32$ km is in fact more uniform than a majority of random distribution produced by Monte Carlo simulations. We interpret this observation as possible evidence that the surface has approached (but not necessarily reached) saturation equilibrium at some diameters up to 32 km. (Impacts on a heavily cratered surface will tend to preferentially obliterate craters in areas of randomly produced crater clustering, leading to an increase in spatial uniformity.) Craters with $D \geq 64$ km on Rhea have densitites significantly below any proposed saturation equilibrium density; therefore they probably represent a production function. The size-frequency relationship of these large craters on Rhea is well fit by the curve $\log_{10} N_L = -2.73 \log_{10} D - 0.064$, where N_L is the number of craters larger than D km per km^2. The analogous relationship for Iapetus is $\log_{10} N_L = -2.70 \log_{10} D + 0.109$. Iapetus is also clearly not saturated at large crater diameters. On Mimas, as on Rhea, the spatial distribution of craters shows no statistically significant evidence for spatial variability, and large craters appear to be present at densities below those expected for saturation equilibrium.

We compute relative cratering rates and collision energies for heliocentric projectiles impacting Saturn's moons, taking into account gravitational focussing by the planet. Using crater scaling laws, we project the large crater distributions seen on Rhea and Iapetus to expected integrated impact fluxes on other moons. Disruption probabilities of Saturn's inner moons estimated by this method vary by a factor of $\sim$2 depending on what crater scaling law we use and whether the impactors are predominantly Saturn-family comets or long period comets. Computed disruption probabilities are 3–8 times higher when scaled to Iapetus' cratering record than to Rhea's. This could be due to Iapetus' surface being older than Rhea's, in which case the Iapetus scaling is correct; alternatively, Iapetus may have been cratered by a long-lived population of Saturn-orbiting debris which did not penetrate inside the orbit of Titan, in which case Rhea's record should be used. These uncertainties not withstanding, we calculate disruption probabilities significantly smaller than those of Smith *et al.* [*Science* **215**, 504 (1982)]. Our results are consistent with Mimas and larger moons being original aggregates and the smaller irregularly-shaped bodies being collisional fragments. Our results also constrain theories advocating recent formation of Saturn's rings from satellite disruption.

We conclude that *(a)* there is no evidence for local geologic resurfacing on Rhea or Mimas; *(b)* Rhea, Mimas, and Iapetus are not saturated with craters at large crater diameters, so that observed densities of large craters may be used to evaluate satellite disruption probabilities; *(c)* Saturn's classical satellites are probably original aggregates dating from about the period of Saturn's formation, as opposed to products of repeated disruption and reaccretion during more recent history; and *(d)* it is very unlikely that Saturn's rings were formed within the last 10^9 years by the disruption of a single moon.