CRATERING HISTORIES IN THE SATURNIAN SYSTEM.

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Introduction: A vital tool to constraining the evolution of the mid-sized saturnian satellites is their impact cratering histories. Images from the *Cassini* Imaging Science Subsystem (ISS) have resulted in a great leap in our knowledge of these histories. It has provided new insights into the crater populations, impact rates, and surface ages. We review the progress on each of these and discuss remaining issues.

Crater Populations: Four broad populations may form craters on Saturn's moons [e.g., 1]: (1) outer Solar System small bodies ("comets"); (2) planetocentric impactors from satellite collisions and primary crater ejecta that escape the moon; (3) secondary impactors from primary crater ejecta; and (4) captured inner Solar System small bodies ("asteroids"). Analyses of crater size-frequency distributions (SFDs), along with dynamical models and astronomical observations of small body populations, have helped to improve constraints on the contributions of these populations.

Comets are likely the main source for craters with diameter, (D) ≳20 km. This is suggested by the shallow crater SFDs [e.g., 2], apex-antapex asymmetries [e.g., 3] (although reduced compared to predictions [4]), and the great extent of crater rays [e.g., 5].

Meanwhile, craters D≲20 km may be partially composed by planetocentric impactors in addition to heliocentric impactors to potentially explain that no significant apex-antapex asymmetry has been observed so far [e.g., 3]. Some small craters on Dione, Tethys, and Rhea are also likely secondaries implied by steeper crater SFDs and model predictions [e.g., 6, 7].

Neukum et al. [e.g., 8] argue the similarity of satellite crater SFDs to the lunar production function supports asteroids captured by Saturn as the main source for all craters. However, dynamical corroboration has not been presented.

Remaining Issues: Does crater degradation or saturation possibly obscure the apex-antapex asymmetry for small craters? What is the contribution of sesquinaries [e.g., 6] and captured asteroids? How can Pluto/Charon data help further constrain the contribution of all populations [e.g., 9]?

Impact Rates: The first rates for cometary fluxes were computed by Shoemaker and Wolfe [10] extrapolating from rates observed at Earth. After *Voyager*, Zahnle et al. [11] determined current (since ~4 Ga) impact rates using crater SFDs, along with astronomical observations and dynamical models of small body populations. These rates were updated using *Cassini* data in [1]. Di Sisto and Zanardi [12] also computed current impact rates using a dynamical model of Centaurs constrained by *Cassini* data. Even though uncertainties are still large on these impact rates, *Cassini* data have helped to considerably improve our estimates.

Remaining Issues: How can outer Solar System impact rates be further improved? How do we incorporate the Late Heavy Bombardment into the rates [e.g., 13]?

Surface Ages: *Cassini* ISS imaging has vastly increased the surface area and diameter range over which crater SFDs can be observed on the mid-sized saturnian satellites. This, along with the improved knowledge of crater populations and impact rates, has provided significant new constraints on the surface ages.

The densely cratered plains on all satellites appear to be old with crater retention *model* ages of >3.5 Ga [e.g., 2, 14]. The only satellites that seem to have large areas of younger terrains (excluding basins) are Dione and Enceladus [e.g., 15–18]. The ridge terrains of Enceladus are suggested to vary in age from 0.7-2.0 Ga. For Dione, a ridged terrain is observed on the trailing hemisphere and is likely at least 2.5 Ga old, while a smooth terrain is found on the leading hemisphere that could be as young as ~1.7 Ga.

Studying the viscous relaxation of impact craters also plays an important role in understanding the surface ages of Saturn's moons. It can alter interpretation of crater SFDs [e.g., 16], help constrain ages of large basins [e.g., 19], and provide clues on surface modifications and defining different terrains [e.g., 20].

Remaining Issues: Have subtle resurfacing events been missed? What sources of error are not accounted for in computing crater retention model ages? How do crater SFDs compare among different researchers and what do similarities and differences mean?

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