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The asymmetric cratering history of the terrestrial planets: latitudinal effect.

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Introduction: By measuring the size-frequency distribution of impact craters on a planetary surface, it is possible to estimate its age *(e.g., Hartmann and Neukum, 2001)*. One fundamental assumption used in such analyses is that the cratering rate, while perhaps not uniform in time, is independent of position on a given planet. However, as the population of asteroids and comets that strike a planet is not isotropic in space, a latitudinal dependency of the cratering rate is to be expected. The impact density on the terrestrial planets has been found to be larger at the equator than at high latitudes.

Velocity and inclination distribution of colliding bodies: For each planet, the probability of an impact and its corresponding encounter velocity have been calculated as a function of the orbital elements (a, e, i) using a modification of Kessler's method as detailed in *(Milani et al., 1990)*. The impact probability of each orbital element bin was then weighted by the relative number of asteroids or comets in that bin as estimated by *(Bottke et al., 2002)*.

Impact density variations in latitude as a function of $N_g = GM/Ru^2$: If the effects of true polar wander can be ignored, the crater density of a planet should depend only upon latitude as a result of its rotation. For the case where the bolides are initially at an infinite distance from the planet, the impact density distribution is found to depend only upon the nondimension factor $N_g = GM/Ru^2$ (*M* the mass of the planet, *R* its radius and *u* the encounter velocity) and the bolide's inclination. When the gravitational contribution to the governing equations is small with respect to the bodies kinetic energy, the distribution tends towards a cosine law, as the paths of the projectiles tend to be straight lines, and the area of the impact zone varies with cos(λ). In contrast, a small encounter velocity will deflect more asteroids towards the poles, leading to a more homogeneous distribution.

Impact densities on the terrestrial planets: By combining the probability distribution for an encounter with a planet's gravitational cross section with the above semi-analytic method for determining the latitudinal impact density, the net impact density as a function of latitude has been calculated. The magnitude of the latitudinal variations ranges from 60% for a small body like the Moon to 30% for the Earth, passing through 40% for Mercury and 35% for Venus. For the special case of Mars, whose obliquity variations are large, the time spent at a given obliquity over the last Ga *(Laskar et al., 2004)* has been used. Even taking into account this strong homogenizing effect, it has been found that a latitudinal variation of 20% is still predicted to exist.

Implications for planetary chronology: Previously, we have shown that the Moon possesses an asymmetric cratering history as a result of its synchronous rotation. Our results here confirm the independent latitudinal effect found, and show that the planets should also possess a moderate variation in impact density with latitude. As the cratering rate has been relatively constant over the past 3 Ga, a X% variation in crater production simply translates to a bias in age of X% when this effect is not taken under consideration.