A STOCHASTIC CRATERING MODEL FOR ASTEROID SURFACES. J. E. Richardson[1], H. J. Melosh[1], and R. J. Greenberg[1], [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721. Email: jrich@lpl.arizona.edu.

Introduction: The observed cratering records on asteroid surfaces (four so far: Gaspra, Ida, Mathilde, and Eros [1-4]) provide us with important clues to their past bombardment histories. Previous efforts toward interpreting these records have led to two basic modeling styles for reproducing the statistics of the observed crater populations. The first, and most direct, method is to use Monte Carlo techniques [5] to stochastically populate a matrix-model test surface with craters as a function of time [6,7]. The second method is to use a more general, parameterized approach to duplicate the statistics of the observed crater population [8, 9]. In both methods, several factors must be included beyond the simple superposing of circular features: (1) crater erosion by subsequent impacts, (2) infilling of craters by impact ejecta, and (3) crater degradation and erasure due to the seismic effects of subsequent impacts. Here we present an updated Monte Carlo (stochastic) modeling approach, designed specifically with small- to medium-sized asteroids in mind.

Basic model description: The model consists of six 1700 x 1700 matrix layers, which form a pseudo three-dimensional model of an asteroid surface. Two layers are used to store crater diameter values, two are used to store ejecta coverage values, and two are used to store crater seismic damage values. The purpose for having two sets of information for each parameter is to permit the superposition of small craters on top of large craters, while preserving the large crater information below. Each matrix element represents a small unit of area on the model surface. For example, in modeling the surface of 433 Eros (1125 km^2 [10]), each element represents a 400 m^2 (20 m by 20 m) area, for a total model surface area of 1156 km^2. The model surface possesses periodic boundary conditions, to produce a continuous cratering surface. This feature permits the entire surface area of an asteroid to be modeled with no effective boundaries or break points.

Impactors and resulting craters: The impactor population used in the model represents the average population of asteroids present in the Main Belt. For sizes below that which has been directly observed, the population comes from the asteroid collisional and dynamical modeling described in [11]. Impactor sizes range from the size needed to produce a crater equal in diameter to the matrix element size, up to the size of impactor capable of completely disrupting the asteroid being modeled [12, 13]. Impactor sizes are then mapped to final crater sizes by multiplying the impactor diameter by 30, employing a simple, cubed-root, crater size scaling-law [14]. The resulting crater sizes fall into the transition region between strength- and gravity-dominated cratering [15].

Crater erosion by superposing impacts: New craters frequently superpose themselves on preexisting craters, with the underlying, older craters eventually eroded and erased by this process. In the model, a size constraint is adopted such that for a small crater to erase a portion of a larger crater via superposition, the smaller crater must be at least 1/10 the size of the larger one. Otherwise, the small crater simply rests on top of the larger one without affecting it. This erasure-by-superposition method is based upon the principle of impact gardening [12] and the crater erosion work described in [16] -- in which each new crater will only affect and turn over a depth of rock and regolith, which is about 1/8-1/12 of its diameter. That is, it takes a new impact on the same size scale as the old one to erase a portion of an older, larger crater.

Crater Erasure by Ejecta Infilling: Whenever a new crater is formed, the area within about five crater radii of the new crater's rim is covered by a layer of impact ejecta, which can accumulate, fill in, and eventually erase impact craters. In this model, an approximate ejecta blanket thickness, as a function of distance from the new crater's rim, is calculated, and added to the cumulative ejecta thickness recorded in each matrix element (unit area). If enough ejecta has accumulated since the formation of a particular crater, such that the crater would be completely filled, the crater is considered filled or erased.

Crater Erasure by Seismic Shaking: If a new crater's impactor is large enough--generally a few meters in diameter--to cause 'global' seismic effects on the asteroid (enough to destabilize all slopes on the surface), then all other craters on the surfaces will suffer some amount seismic damage in accordance, as described in [17]. That is, the crater is slowly eroded and in-filled through the downslope flow of regolith. If the total amount of seismic damage to a particular crater exceeds the amount that the crater can withstand and remain visible (a depth/diameter ratio of > 0.041), then the crater is considered filled or erased.

Model Results: Two examples of the model display screen are shown in Fig. 1, showing a color representation of the cratered surface and a cumulative crater size-frequency distribution plot. Beyond taking advantage of modern computing technology to improve upon previous, similar methods, the most important contribution from this work lies in the adaptation of a more sophisticated model (as compared to [8, 9]) of how crater erosion from seismic reverberation will affect the overall cratering record. This is particularly important on asteroids in the size range of 433 Eros, on which seismic shaking effects can noticeably lower the equilibrium numbers of small craters (< 100 m diameter), well below normal "empirical saturation" values..

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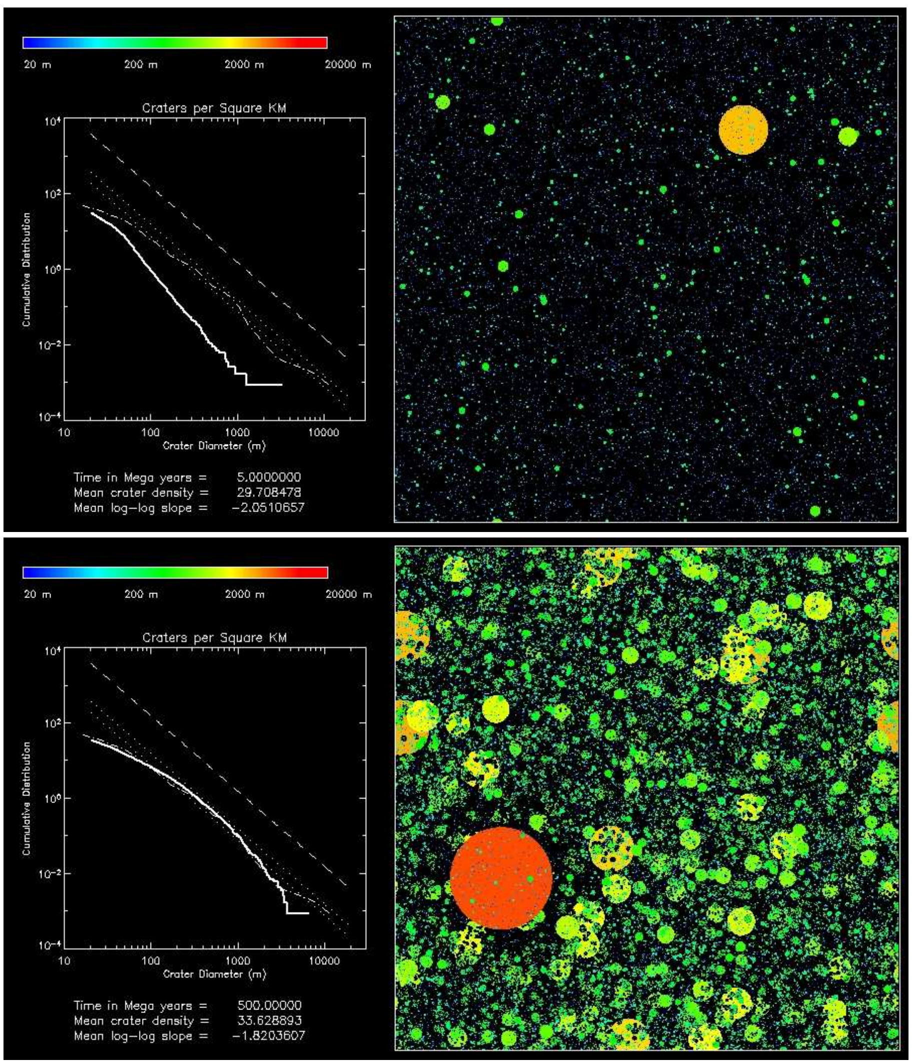

Figure 1: Two examples of the stochastic cratering model output, showing a color-coded view of the cratered asteroid surface on the right, and a cumulative size-frequency distribution plot of crater sizes on the left. The top image shows a production population of craters after only 5 Myr, while the bottom image shows primarily saturation levels after 500 Myr. Note the general lack of very small craters in the bottom image, due to seismic erasure.