

**A 3-D MODEL OF ASTEROID SURFACE EVOLUTION: CRATER CREATION AND EROSION, REGOLITH GENERATION, AND HILLSLOPE PROCESSES.** J. E. Richardson, Center for Radiophysics and Space Research, 310 Space Sciences Building, Cornell University, Ithaca, NY 14853, richardson@astro.cornell.edu.

**Introduction:** Monte-Carlo cratering models have long been a mainstay in the study of cratered terrains. The majority of these models have been geometric in nature, with crater rims represented by circles in a 2D matrix, and employing mathematical functions to determine the effects of ejecta blanket coverage and the erosion of large craters by smaller ones [1,2,3]. The advantage of these simple models has been speed, with the ability to automatically compile crater-count statistics at each time step. Hartmann *et al.* [4] extended these techniques into three-dimensions to produce realistic-looking topography, but required manual crater-counting of the synthetic images produced to obtain useful cratering statistics.

In this work, we present a new Cratered Terrain Evolution Model (CTEM) which utilizes recent advances in the impact cratering scaling-laws [5,6] and our understanding of seismically-induced crater degradation [3] to produce a fully 3D model of crater production and erosion on a given (airless) target surface, which includes regolith generation, downslope regolith migration, and automatic crater counting.

**Impact Cratering Scaling-Laws:** Previously, most applications of these relationships have dealt strictly with either the gravity- or strength-dominated cratering regime. However, cratering on a small target body falls into neither regime: gravity and target strength are both important to the size of the final crater. We therefore adopt the general solution to the crater volume scaling-law developed by Holsapple [5], which includes both gravity and strength terms. The application of this general crater volume scaling-law permitted us to develop a general solution to the ejecta velocity scaling relationships [6]. These new ejecta velocity scaling-laws allow us to compute ejecta blanket thickness as a function of distance from a given impact site, as well as compute the total mass and fraction of ejecta retained for a given impact.

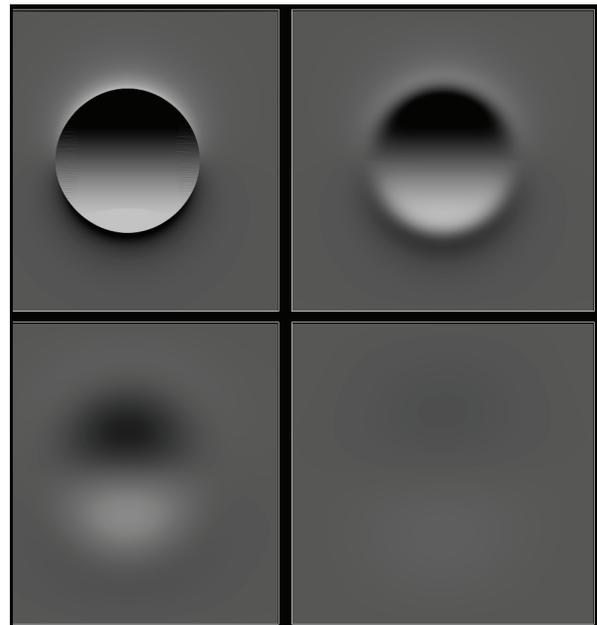
**Downslope Regolith Migration:** A key feature of the CTEM is the inclusion of downslope regolith migration, triggered either by slope instability or by the seismic motion generated by nearby impacts. Following each impact event, the resulting regolith motion is computed in Eulerian fashion, using the slope degradation theory described in [3]. See Fig. 1.

**Crater Superpositioning and Erasure:** In general, impact craters on airless bodies are erased by three mechanisms: subsequent impacts, which erode and modify the underlying crater; coverage by the ejecta thrown up by other, nearby impacts; and the

downslope movement of regolith due to slope instabilities and impact-induced seismic shaking. The CTEM includes 12 layers which track a vertical "stratigraphic column" at each point around the rim of each crater produced. If the crater's rim is either excavated by a subsequent impact or eroded by downslope regolith motion to less than half of its original height, or if the crater's rim is covered over by regolith to a depth equal to its current height, than that portion of the crater's rim is considered to be "erased."

**Model Application:** The primary purpose of this model is to determine the local seismic effects of an impact on nearby crater morphology, particularly for the well-studied asteroid 433 Eros, and to refine the more generic, "global" seismic effects described in [3]. The model is well suited for other problems as well, such as asteroid regolith generation and impact history studies (cratering record modeling).

**References:** [1] Woronow, A. (1978). *Icarus*, **34**, 76-88. [2] Chapman, C.R. & McKinnon, W.B. (1986). *Satellites*, Univ. Arizona Press, 492-580. [3] Richardson, J.E., *et al.* (2005), *Icarus*, **179**, 325-349. [4] Hartmann, W.K. & Gaskell, R.W. (1997). *Meteoritics and Plan. Sci.*, **32**, 109-121. [5] Holsapple, K.A. (1993). *Ann. Rev. Earth & Plan. Sci.*, **21**, 333-373. [6] Richardson, J.E., *et al.* (2007). *Icarus*, **190**, 357-390.



**Figure 1:** A demonstration of the downslope motion module, showing gradual crater degradation due to impact-induced seismic shaking.