CONSTRAINING SOURCE CRATER REGIONS FOR BOULDER TRACKS AND ELONGATED SECONDARY CRATERS ON EROS.
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Introduction: Crater ejecta launched from the surface of small, rapidly-rotating, and highly-elongated and irregularly-shaped bodies are subjected to a complex dynamical process. Dynamical models [1,2] of reaccretion of impact ejecta on asteroids provide important tools for a detailed investigation of the distribution of blocks and finer regolith across Eros' surface as revealed by the NEAR MSI instrument.

In particular, ejecta blocks and/or other ejecta-blanket units might be linked back to specific source craters, yielding valuable information on physical properties of Eros (*e.g.*, regolith structure and target strength) and constraining various aspects of impact cratering in low-gravity environments (*e.g.*, ejecta mass/speed distributions and amount of retained ejecta).

A few good examples of boulders with tracks (Fig. 1) can be found on Eros [3]. None of these appear to be the result of simple downslope rolling, suggesting that the boulders were emplaced directly at the termination of their sub-orbital, impact-induced trajectories. There are also several examples of small, oblong craters. Although some of these craters do not display obvious terminal boulders, their morphologies and small sizes are suggestive of an origin by oblique, secondary impact. If these are indeed secondary craters, their parent impactors may: (1) have skipped far enough downrange so that their association with the secondary crater is not readily apparent; (2) be below the limit of image resolution; (3) be buried below the terminus of the oblong crater; or (4) have been composed of a clod of ejecta too weak to survive reimpact onto Eros' surface.

These boulder tracks and possible secondary craters contain clues to the terminal trajectories of their parent impactors. In the case of boulders with tracks, the back-azimuth of the boulder's terminal trajectory relative to Eros's surface is unambiguous. For elongated secondaries lacking grossly asymmetric crater rims or not obviously blocked by high terrain or obstacles to one side or another, the incoming trajectory is at least constrained to two azimuths 180º apart. Without detailed knowledge of the state of compaction or cohesive strength of the regolith, track or secondary crater morphology alone is unlikely to be particularly diagnostic of the terminal trajectory elevation angle or impact speed.

However, knowledge of only the terminal trajectory azimuth may allow some constraints to be placed on candidate source-crater regions for terminal boulders or secondary impactors. This in turn can be used to study the process of primary impact-crater excavation and to place additional constraints on regolith and subsurface material properties by providing 'ground truth' on boulder size/ejection speed relationships.

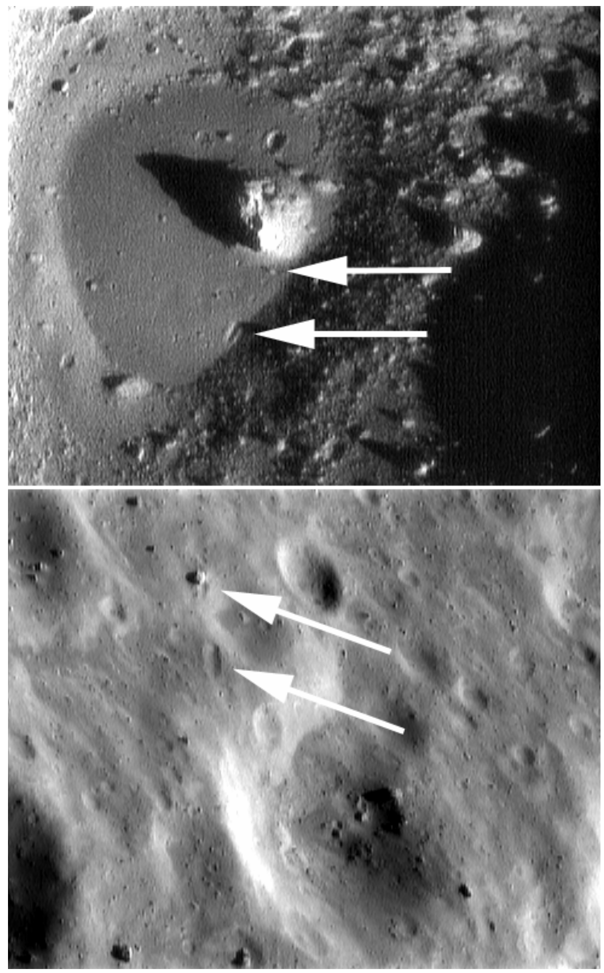

Figure 1. Examples of boulder tracks and oblong secondary craters on Eros. Top: an oblong secondary crater, with an associated track and terminal boulder, in a ponded deposit (image 156087851). Bottom: a boulder track with associated terminal boulder and an oblong secondary crater (image 138525395).

Description of Dynamical Model: The dynamical model is that used in [1], with modifications and improvements described in [2], and here further modified to 'back track' the derived landing trajectories of selected boulders.

To briefly summarize the basic dynamical model, the shape model for the asteroid (Eros, in this case) is filled with a uniform grid of point masses such that the total mass equals the mass of the asteroid. The accelerations of crater ejecta particles are computed as the vector sum of the accelerations due to each of the point masses, and the positions of the ejecta particles and the (rotating) asteroid shape model are updated at each time step. The initial conditions for ejecta particle launch locations and velocities are determined from specified crater latitude/longitude and diameter. Ejecta velocity vectors are determined relative to the local surface normal vector at the center of the crater location. The volume of ejecta (i.e., the number of ejected particles) with speed greater than a given value is determined by the crater ejecta scaling laws of [4], with the assumption of gravity scaling for Eros craters larger than 1 km in diameter. Ejecta speeds are assigned between 1 and 20 m/s (the range of escape speeds on Eros is 3.1 to 17.2 m/s [5]), according to the appropriate crater scaling relation. The constants in the ejecta scaling laws are best fits to the experimental data of [6]. Ejecta launch locations within the crater footprint are set by the (randomly distributed) launch azimuth and with the radial location distributed from the center to the rim according to the launch speed [4,6].

Since for this application we are 'back tracking' the landing trajectories of ejecta blocks, we have to modify the basic dynamical model to: (1) reverse the direction of rotation of Eros; (2) limit the launch azimuths of particles to a small range of angles around the nominal terminal trajectory back-azimuth of the boulder track or oblong secondary crater; and (3) adjust the launch elevation above the local surface of the asteroid to a range of somewhat more oblique angles than the usual ~45° ejection angle for impact craters (since the morphologies of the boulder tracks and oblong secondary craters suggest a somewhat oblique impact angle).

Example Results: To illustrate the results of these simulations we examine the two boulder track examples shown in Fig. 1. The oblong secondary crater and associated boulder track shown in the top panel is located near -2° lat 178° long and is oriented ~1.5° north of east; the apparent small terminal boulder indicates that the boulder landed from the west. The potential source regions are shown in the top panel of Fig. 2. Due to ejecta dynamics near the elongated end of Eros the source region is very tightly constrained.

The boulder track shown in the bottom panel of Fig. 1 is located near -1° lat 215° long and is oriented ~15° east of north; with a large, well-defined terminal boulder it is clear that the boulder landed from the south. Potential source regions are shown in the middle panel of Fig. 2. Here, although the source regions are still relatively well defined, they are somewhat less tightly constrained than in the first example.

The potential source regions (compare to the Eros map of [7], shown in the bottom panel of Fig. 2) are being examined to identify candidate source craters.

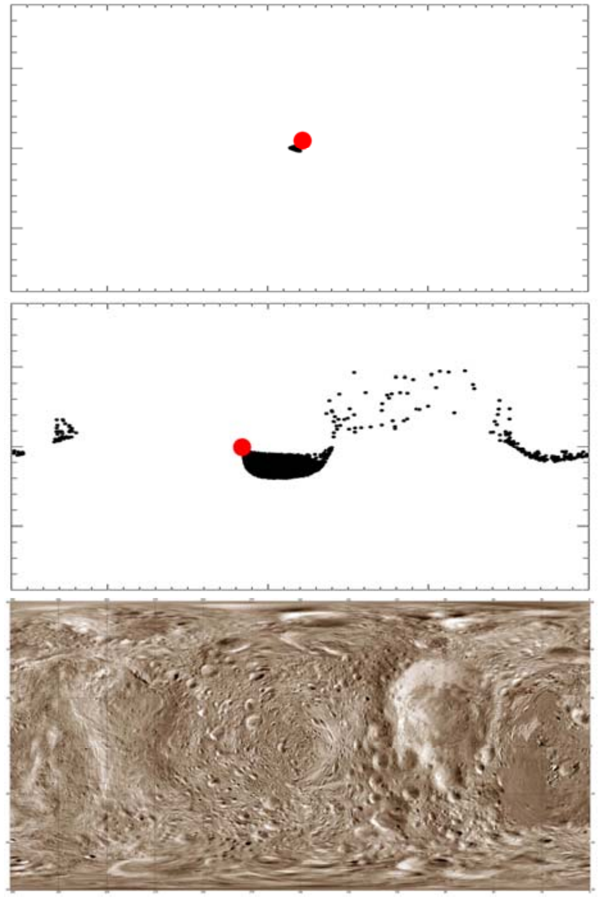

Figure 2. Source crater regions for the boulder tracks and oblong secondary craters shown in Fig. 1. Small black dots represent test particle landing locations from the dynamical model that 'back tracks' the landing trajectories of ejecta blocks. Large red dots are the locations of the features shown in the corresponding panel in Fig. 1. The bottom panel is a simple cylindrical projection map of Eros [7] to the same scale.

References: [1] Geissler P. et al. (1996) *Icarus 120*, 140–157. [2] Durda D. D. (2004) *LPS XXXV*, Abstract #1096. [3] Sullivan R. J. et al. (2002) in *Asteroids III*, (W. F. Bottke, A. Cellino, P. Paolicchi, and R. P. Binzel, Eds.), pp. 331–350. [4] Housen K. R. et al. (1983) *J. Geophys. Res. 88*, 2485–2499. [5] Yeomans D. K. et al. (2000) *Science 289*, 2085–2088. [6] Cintala M. J. et al. (1999) *Meteoritics and Planetary Science 34*, 605–623. [7] Stooke P. J. (2008) *LPS XXXIX*, Abstract #1218.