SIMULATING THREE-DIMENSIONAL REGOLITH TRANSPORT WITH THE CRATERED TERRAIN EVOLUTION MODEL.

Y. Huang[1], D. A. Minton[1], J. Richardson[2], B. Cohen[3], C. Fassett[4], and N. Zellner[5]. [1]Earth, Atmospheric, and Planetary Sciences (huang474@purdue.edu). [2]Arecibo Observatory, Arecibo, PR 00612, [3]NASA Marshall Space Flight Center, Huntsville, AL 35808, [4]Mount Holyoke College, South Hadley, MA 01075, [5]Department of Physics, Albion College, Albion, MI 49224.

Introduction: The density of impact craters has been used as a tool to tell us about the age of planetary surfaces. Crater counting studies give us a relationship between a crater density in a given area of a planetary surface and its surface exposure age. Combined with absolute radiometric dating of returned lunar samples [1], a lunar cratering chronology for the inner solar system has been established [2]. Degradation states of craters, especially in a crater profile influenced by impacts [3], is the degradation time for a given crater to reach. Recently, a correlation between rock abundance near the rims of impact craters and age has been formulated, and used to suggest that the impact rate of the Moon has increased since the start of the Copernican period [4].

Here we describe how we have modified a Monte Carlo cratering code called the Cratered Terrain Evolution Model (CTEM) to model the horizontal transport of materials on the lunar surface by impacts. CTEM is a Monte-Carlo code that simulates the evolution of a planetary surface subject to different impact fluxes [5,6]. Our computational model is able to simulate the excavation of ejecta from within each transient crater volume, including the mixing of pre-existing components present at the site of excavation. In this study, we focus on the transportation process of impact craters on the Moon with a constraint of diffusion phenomenon across mare and highlands contacts [7].

Motivation: Because of ability of craters to mix and transport materials, impacts could potentially change the spatial and temporal distribution of impact-related products generated by an impact over time. Li and Mustard studied mare and highlands components on both sides of mare/highland boundaries by using their reflectance difference and an analytical model called anomalous diffusion [7]. They found out that the amount of highlands and mare materials are equally transported after mare emplacement about 3 billion years ago, creating a symmetric compositional profile across the contact. Since the emplacement of the mare deposits ~3.5 billion years ago, they presumed that the impact flux has remained nearly constant. In their model, they also assumed that small craters could not penetrate to the bottom of the mare deposit and excavate the highland material underneath the mare. Therefore, the highland component on mare is more likely to have been transported from the highland side, and vice versa. This indicates that the vertical excavation process is less important than the lateral transport of impacts.

Li and Mustard modeled this diffusion phenomenon by an anomalous diffusion model. The finding in their diffusion model [8] is that energetic ejecta blankets are accounted for the diffusion phenomenon with larger diffusion coefficient than was expected. Instead of parameterized ejecta blanket, CTEM is based on Maxwell Z-model of excavation flow and ballistic transportation, in which ballistic flight is allowed. Although CTEM is able to generate a realistic crater shape, a lack of ability of tracking ejecta over generations of impacts would not address this diffusion phenomenon correctly. An ejecta blanket generated by an impact carries with it any previous impact products exiting under its surface. In order to track impact ejecta over time in CTEM, there are two main topics that we must consider: a linked list data structure for storing information of generations of impacts dynamically and an approximation of a stream tube that is responsible for the excavation flow and emplacement of ejecta blanket.

Method: A linked list data structure has been implemented in each pixel in CTEM. When a crater forms, CTEM will emplace ejecta blanket at its corresponding location, and the information of ejecta blanket including composition, thickness, and melt fraction is stored in a First-In-and-Last-Out (FILO) linked list. The formation of the crater cavity will be carried out by popping the information out of its corresponding linked list. An important feature of our code is that it can exhume previously-existing layers and incorporate them into each new ejecta blanket.

An ejecta blanket originates in a transient crater and can be described as a streamline based on Maxwell Z-model [9,10]. We approximate stream tubes as a circular tube. The shape of this circular tube is defined by streamline model in poor coordinates: $r(\theta) = r(1\text{-}\cos\theta)$ shown in Figure 1. We also demonstrate an implementation of linked list data structure and transportation model in CTEM (Figure 2). The background of Figure 2 shown in dark blue color is bedrock. The simulated Copernicus crater with light blue color rays is centered at the figure, and it represents mostly the two layers inducing bedrock and Copernicus crater ejecta blanket layer. The yellow and red color represents more than 2 layer, which is accounted for subsequent impacts occurring.

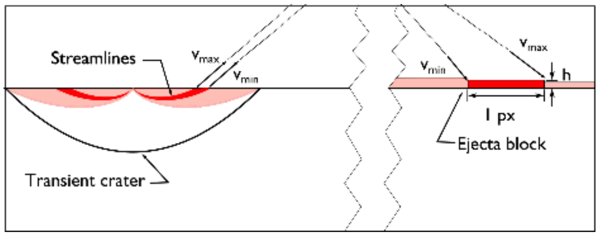

Figure 1. Ejecta blanket schematic diagram. The stream tube with dark red color represents the bound material in a transient crater accounted for ejecta block in the right side of the figure.

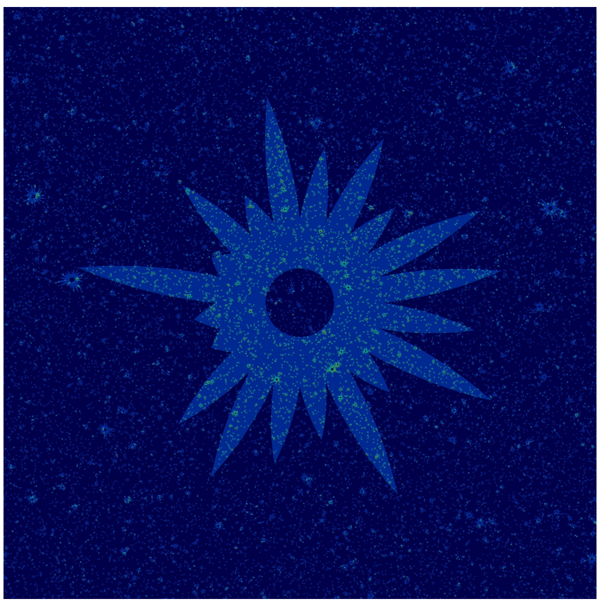

Figure 2. Example of layering system in CTEM. The colors represent the number of ejecta layers present at each pixel. A simulated surface, 800 km × 800 km area, bombarded by small craters after simulated Copernicus crater formed about 800 Ma ago.

Future work: For the next step, the contribution of the underlying ejecta blanket layers that are contained in a stream tube will be estimated. A stream tube will contain a specific ratio of mare and highland components as a whole. In the mare and highland diffusional contact problem, our approach not only considers the depth history of ejecta blanket layers over time, but also can be used to constrain the thickness of mare.

References: [1] Stoffler, D. and G. Ryder (2001) *Space Sci. Rev.*, 96, 9-54. [2] Neukum, G. et al. (2001) *Space Sci. Rev.*, 96, 55-86. [3] Fassett, C. I. and B. J. Thomson (2014) *J. Geophys. Res.*, 119, 2255-71. [4] Mazrouei, S. et al. (2015) *Early Solar System Impact Bombardment III* #3032. [5] Minton et al. (2015) *Icarus* 247, 172-190. [6] Richardson (2009) Icarus 204, 697-715. [7] Li, L and J. F. Mustard (2000) *J. Geophys. Res.*, 105, 20,431-450. [8] Li, L. et al. (1997) LPSC 28th #2206. [9] Maxwell et al. (1974) *Tech. Rep., Defense Nuclear Agency, Washington, D.C.* [10] Maxwell (1977) *Impact and explosion cratering: Planetary and terrestrial implications*, 1003-1008.