Modeling lateral and vertical mixing by impact cratering with applications for the Moon. A. Agrawal[1] and O.S. Barnouin-Jha.[2], [1]Mount Hebron High School, 9440 Route 99, Ellicott Ccity, MD 21042, meeshersnj@hotmail.com, [2]The Johns Hopkins University Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20723-6099, olivier.barnouin-jha@jhuapl.edu.

Introduction: On planets such as the Moon, where no liquid water and atmosphere are present, the formation of craters are one of the main processes by which planetary surfaces change over time. These craters are the primary contributors to mixing among different geological units. During the cratering process, excavated ejecta comprised of material from one geological unit can be thrown laterally to obscure a contact between a neighboring unit. In addition, a geological unit present at depth, but obscured by the thin surface unit could be transported vertical by this same impact to further complicate the relationship between the surface units observed. A better understanding of how such lateral and vertical mixing occurs on the Moon could be useful in further deciphering the history of the surface of this planet [e.g., 1]. We have begun a simple numerical modeling effort to investigate how lateral and vertical mixing via cratering might operate, in order to re-evaluate how factors such as crater size, pre-exiting thickness of geological units, and the efficiency of secondary cratering might influence the evolution of boundaries between geological units.

Background: A variety of techniques have been used to investigating the lateral versus vertical transport of material by cratering on the Moon. These investigations can be split into two categories. The first are theoretical cratering assessments [e.g., 2, 3, 4]. The second involves detailed analysis of the surface regolith and include studies of particle size evolution, [5], geochemical gradient analysis [e.g., 6] and petrographic studies of lunar samples and cores [e.g., 6, 7,8 9]. All these studies argue that vertical transport is more efficient than lateral transport. Lateral transport is thought to be efficient only at a few 100m to a km scales.

New studies [1, 10, 11, 12] using Clementine data reveal, however, a complex array of mixing at contacts between highland units on the Moon. This is well exemplified, for example, in recently processed FeO occurrence maps [13] (Figure 1). In some instances very abrupt changes in units are visible at some geological contacts, while in others a more gradual change is observed. These observations could argue for more extensive lateral mixing.

Use of spectral analysis techniques [11,12,13] indicate that at some contacts lateral mixing is important. Indeed the diffusive nature of contacts in some regions of Grimaldi, Orientale and Fecunditatis basins, and Tsiolkovsky craters are well explained by lateral transport of ejecta derived from smaller craters, with ejecta from beyond the continuous ejecta being an important contributor [11]. Studies which focus on larger scale contacts indicate that large craters are significantly contributors to lateral transport of surface materials [12, 13].

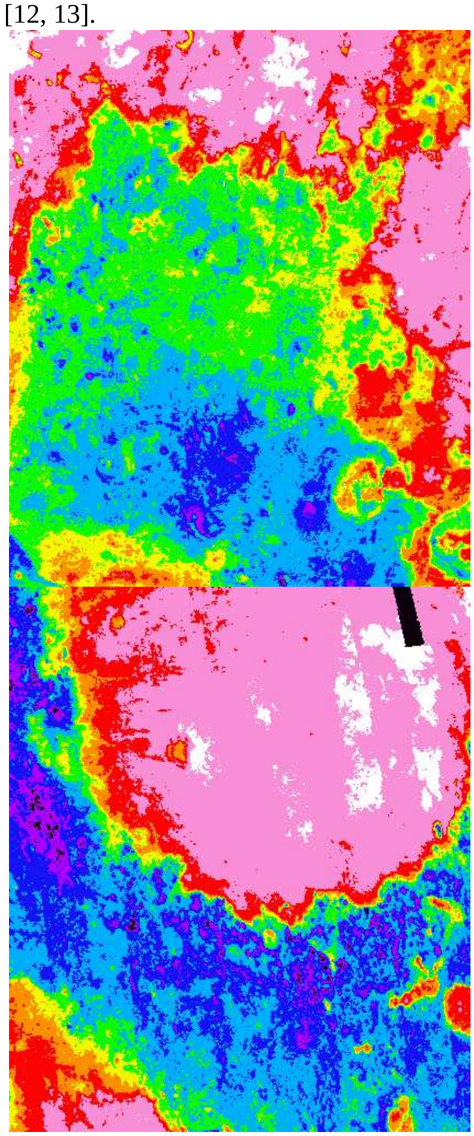

Figure 1. FeO maps derived from Clementine [6] for region near Mare Tranquilitatis (top) and Mare Crisium illustrating both a diffuse (left) geological contact (left) and a very sharp one. The height of each image corresponds to ~500km. Redder colors correspond to greater FeO content.

Methodology and Preliminary Results: In this study, we build on the work of [2, 3, 4, 14] and use a theoretical approach to further understand how lateral versus vertical mixing might govern the evolution of the Moon. We use a Monte Carlo approach to investigate how craters may transport material and modify a geological contact. We begin splitting a 10 by 10km box into two halves: a teal and a pink one. In each half, we use a random number generator to place craters with their ejecta.

In the current version of our model, we have made several simplifying assumptions. First, we assume that only ejecta within one crater radius are important to lateral mixing. Second, we assume that craters from 0 to 10 km are all equally likely to occur. Third, we assume that ejecta excavated on the surface is thin: craters will always excavate primary unit comprising the side of the box in which they occur even if they initial impact on a different color ejecta. Fourth, the thickness of each unit on the two sides of the box are infinitely thick.

Lateral transport across a contact occurs when craters impact either on or near the boundary. In the case that they occur directly on the boundary, we assume that the material from one side of the boundary passes over the contact only when more than 50% of this material is present in the piece of pie delineated by the contact boundary and the crater center (Figure 2). An example of results obtained using such assumptions are shown in Figure 3 As would be expected, little lateral mixing is observed.

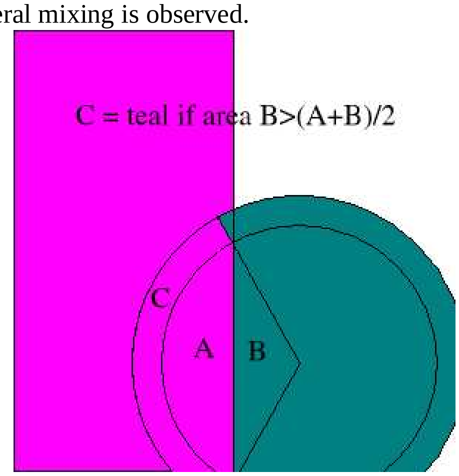

Figure 2. Criteria for when lateral transport occurs in region C.

Future study: We will consider more realistic assumptions for our model. These include use of a realistic crater production function and ejecta model, and consideration of layering effects. We also consider changing the amount of material required to define lateral transport for impacts that occur on the boundary.

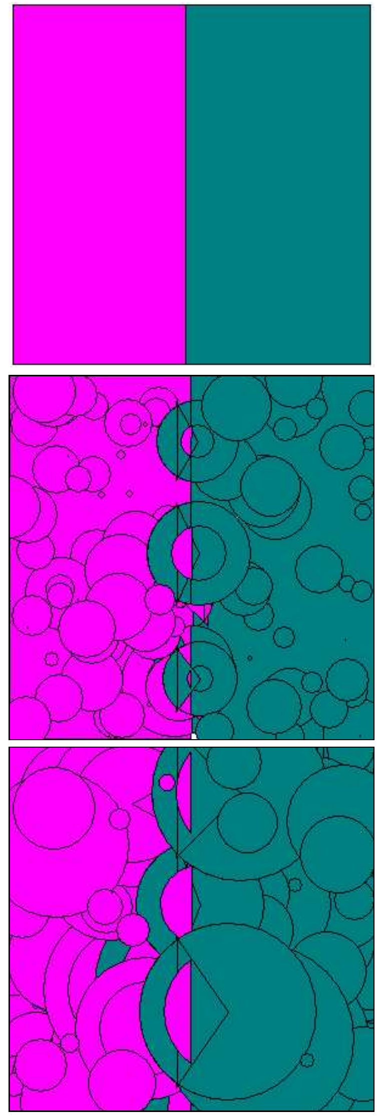

Figure 3. Example of results obtained by Monte Carlo simulation. Top figure shows starting condition; middle shows results after a few tens of craters; and bottom after a 100 or so craters. Box is 10 by 10 km.

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