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2D Models for the evolving distribution of impact melt at the lunar near-surface

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1. Introduction

Impact events have been the primary mechanism for modification of the lunar surface since the formation of the lunar crust [1]. Impacts produce varying amounts of melt, which may be identified and radiometrically dated in surface samples. Existing melt can be redistributed by the ejection process of subsequent impacts.

It is possible to evaluate the amount of the impact melts, but the cumulative effect of the impact gardening process (i.e. excavating, burying, and re-excavating) has not been systematically studied. Michael et al. 2014 simulated such long-term process by using the Monte Carlo method [2]. Nevertheless, the corresponding results are in an average sense, where the impact melt is considered to be evenly distributed over the entire lunar surface.

The purpose of this work is to refine the average model into two-dimension (2D) where the lateral distribution of impact melt is recorded, and the age of melts within the evolving mixture is tracked.

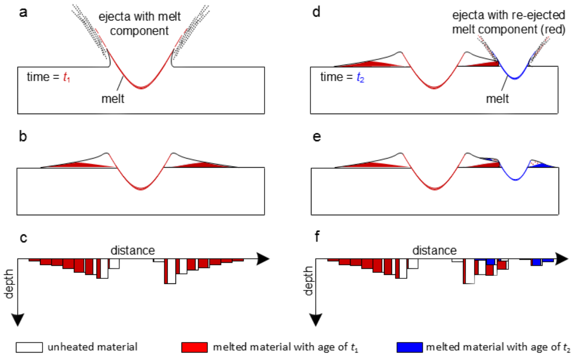

Figure 1. Schematic of the simulations. (a) Impact event causing ejecta of both unheated and melted material when time is t_1. (b) The deposition of ejecta with a mixed layer of unheated (white) and melted (red) material. (c) The expected lateral distribution of (b) in this model tracking the percent of unheated and melted material, the age of impact melt and the thickness of ejecta. (d) A subsequent impact event when time is t_2, penetrating the previous ejecta blanket, excavating material from both the previous layer and beneath, and melting a fraction of both (blue). (e) The deposition of a new layer containing both new melt and a component of re-excavated melt from the previous event. A fraction of ejecta materials overlay the previous deposition. (f) The expected lateral distribution of (e) in this model tracking the percent of unheated, melted material, the age of each fraction and the thickness of ejecta.

2. Method

The essence of the model is the following:

1. The minimum crater diameter considered, $D_{\min}$, is chosen as 5 km based on the performance of computers.
2. By using the Monte Carlo method, the diameter of the formed craters is generated to conform to the production function larger than $D_{\min}$ [3].
3. The impact rate is calculated for the current model time, t, on the basis of the lunar chronology function, which describes the cumulative number of craters larger than 1 km in diameter at age t [3]. Using the production function the formation rate of craters larger than $D_{\min}$ is found.
4. The average time to the next impact event can be obtained based on the impact rate.
5. For each crater, the excavation depth is taken as $D/10$ [4], where D is the corresponding crater diameter.
6. The ejecta blanket thickness is related to the distance from crater center, r: $\delta = aR^b(r/R)^c$ for $r>R$, where R is the crater radius, and a, b, and c are taken as 0.14, 0.74 and -3.0, respectively [4].
7. The distribution of impact melt both inside and outside the crater has not been fully understood limited by the laboratory conditions or/and computer performance in the previous researches [5]. Such issue is under study in collaboration with the group guided by Kai Wünnemann. In this model, the power law normalization is performed for the melt in the ejecta, and assume

that 75% volume of the total melt would remain inside the crater.

The expected results after the lunar surface experiencing two impact events in this model are shown in Figure 1.

3. Results

A band of width 110 km passing along the great circle through the late-forming Imbrium basins, Serenitatis basin, and Crisium basin is chosen for modelling. Based on the crater statistics results, N(20), the ages of three basins are taken to be 3.88, 4.13, and 4.09 Ga, respectively [3, 6]. As the preliminary 2D model, only 1550 impact events on the great circle are considered, assuming the age of Serenitatis crater as the starting time.

Figure 2 shows the present day distribution of the impact melt at the lunar near-surface (~3.5 m). It can be seen that the melt of relatively young Imbrium basin and Crisium basin is dominant, comparing with that of Serenitatis basin. The melt of Imbrium basin is widespread. The melt younger than ~3.5 Ga locally distribute and is much less than the older one.

4. Conclusions and Future Work

The lateral distribution of the melt with diverse ages is traced in this model. Using the observed distribution of melt age in lunar samples and meteorites, the possible scenarios of the lunar impact history can be discriminated [2]. The record is also helpful for the future lunar sampling, guiding the choice of site to obtain samples from different impact basins, and to understand the mixture of melt ages observed at any one site.

There has long been a dispute over the cause of the high percent of lunar samples with age of ~3.9 Ga [7]. Some believe that it results from the impact cataclysm [8]. Others argue that it might be due to the origin of the collected samples, most of which might be the ejecta materials from Imbrium crater [7]. Our model shows that the melt of Imbrium basin is widespread. Is it possible that the melt is globally distributed? To find the possible distribution of the melt of Imbrium basin, the model need to be refined in the future work.

Acknowledgements

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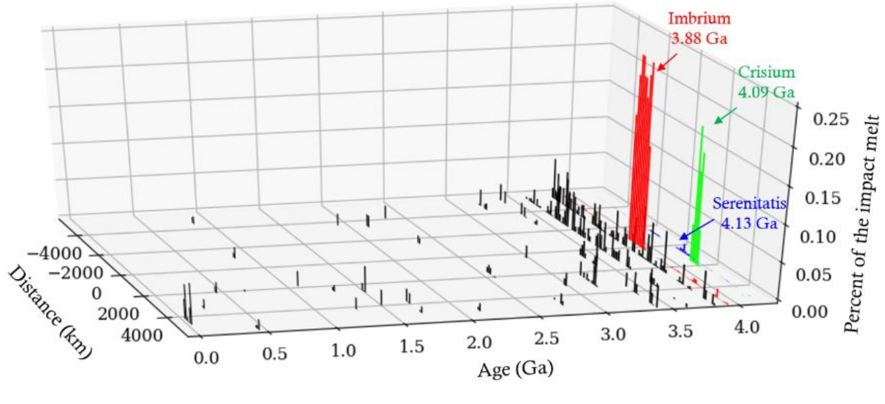

Figure 2. The present day distribution of the impact melt on the lunar near-surface