FOREIGN MATERIAL IN THE LUNAR REGOLITH: LATERAL TRANSPORT BY POST-BASIN CRATERING. N. E. Petro and C. M. Pieters, Box 1846, Department of Geological Sciences, Brown University, Providence, RI, 02912, USA. (email: Noah_Petro@brown.edu).

Introduction: The lunar regolith, a layer of fine-grained material that covers the entire Moon, contains a mixture of foreign and locally derived material. Regolith samples from all Apollo and Luna landing sites contain a portion of material derived from tens to thousands of kilometers away [1]. This foreign component is introduced to the regolith as ejecta from distal impact craters. A portion of the foreign component in the regolith, such as the KREEP-rich component at Apollo 16 [2,3], is introduced by basins, while smaller, post-basin craters have also introduced a foreign component [2,4-6]. Recently, crater ejecta models have been used to estimate the amount of material transported laterally by basins during the first ~600 Myr of lunar history [4,7]. During this period, basins distributed a significant amount of material and introduced foreign material to the regolith [8]. But how has cratering since the end of basin formation contributed foreign material to the regolith, and at what scale?

While the effects of post-basin cratering have been considered statistically using crater production functions [e.g., 9], such an approach does not illustrate important spatial variations in the degree and amount of lateral transport across the lunar surface. Here we assess key components of post-basin lateral transport using identified craters. We first assess the cumulative post-basin contribution to the regolith by craters 30-300 km in diameter. In assessing post-basin craters, we do not account for ejecta mixing; we consider only the total accumulation of ejecta in the last ~3.85 Gyr. Second, we estimate the source regions of the foreign component in the regolith at five locations. Third, we map the percentage of the cumulative post-basin crater contribution derived from greater than 500 km across the entire Moon. These assessments of post-basin lateral transport reveal that the foreign component in the lunar regolith likely originated from within 1000 km of any location.

Post-Basin Craters: In order to assess the amount of lateral transport caused by post-basin craters, we must first identify a minimum crater size threshold for the model. The minimum crater size should represent the transition where craters contribute more to lateral transport rather than to vertical mixing. To identify this value, we determine the percentage of ejecta from craters 10, 20, and 30 km in diameter introduced within multiple ranges. These values are given in Table 1. For any 10 and 20 km diameter crater, 92 and 83% (respectively) of the crater’s ejecta is emplaced within 40 km of the crater rim. In the case of a 30 km diameter crater, only 75% of its ejecta is located within 40 km of the rim, and it contributes more material to the regolith at larger distances. Thus, we use 30 km as a minimum crater size in our assessment of post-basin lateral transport.

Wilhelms [10] identifies post-Imbrian aged craters larger than 30 km in diameter. Subsequently, McEwen et al. [11], Grier et al. [12], and Li [13] identified additional Copernican and Eratosthenian aged craters. Because there is a more complete database of recent craters, the minimum diameter of Eratosthenian and Copernican aged craters was decreased to 25 km. In total, 411 craters were identified that satisfied the above constraints.

Table 1. Distribution of a crater’s ejecta (in %) within a given distance from the crater rim.

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<th>Crater Diam. (km)</th>
<th>Distance from Crater Rim (km)</th>
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<td>10</td>
<td>67</td>
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<td>20</td>
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Distribution of Post-basin Contribution: The cumulative post-basin contribution is estimated using the Housen et al. [14] ejecta scaling equation. We assume that crater ejecta is distributed continuously and symmetrically around the center of each crater, and that the transient crater size is best approximated using Equation 17 of Li and Mustard [9]. Additionally, a spherical correction is applied to the estimate of each crater’s ejecta distribution in order to account for the curvature of the Moon. In order to highlight the cumulative amount of material transported laterally by each crater, ejecta emplaced within 50 km from the rim of each crater are masked. The cumulative, lunar-wide distribution of post-basin crater ejecta is illustrated in Figure 1. These values represent the amount of material that would have accumulated at the lunar surface over the last ~3.85 Gyr.

Figure 1. Nearside centered, simple-cylindrical projection of the cumulative post-basin crater ejecta distributed across the Moon. The area inside and within 50 km of each crater is masked. Five example locations are identified by stars. On average, the lunar surface is predicted to have accumulated less than 10 m of post-basin crater ejecta. The areas with cumulative ejecta greater than 10 m are confined to regions surrounding the largest of the 411 craters. The minimum accumulation of post-basin crater ejecta (1.2 m) is in the Schiller-Schickard region.
Source Regions of Foreign Component: Utilizing the lunar-wide post-basin contribution described above, we constrain the source areas for the material distributed at five example locations. The example locations (identified in Figure 1) are the South Pole (SP), Schiller-Schickard (SS), an area near Moscoviense (Mos), the interior of the South Pole-Aitken Basin (SPA), and the Apollo 16 site (Ap16). We describe the post-basin contribution as a function of distance to the source of the foreign component at these example locations and consider, for the entire Moon, the percentage of the cumulative amount of post-basin crater ejecta derived from greater than 500 km.

Cumulative Amount of Post-Basin Contribution: In considering the source regions for the foreign component in the regolith, we first examine the amount of material contributed to the example locations by craters located outside discrete distance intervals. The relationship between the cumulative amount of material introduced to the example locations and minimum distance the material traveled is illustrated in Figure 2. In general, for most of the foreign material, variation in the source region occurs within 500 km of the example locations. Beyond 1000 km, all five example locations received similar, small amounts of material. The more uniform small accumulations of material from large distances are likely a consequence of the assumption that ejecta from all craters is continuous across the entire lunar surface.

Figure 2. Amount of cumulative ejecta contributed by craters located greater than a given distance from the example locations.

If we assume that a well-mixed ~10 m deep regolith formed across the Moon in the last 3.85 Gyr, then the percentage of foreign material in the regolith derived from certain distances can be estimated. Based on the values shown in Figure 2, we estimate that for any given location on the Moon, between 1 and 2 m of the post-basin contribution is derived from greater than 500 km. These values suggest that ~10 to 20% of the well-mixed regolith is foreign material derived from greater than 500 km. For example, at Apollo 16, 1.1 m of ejecta accumulated from greater than 500 km in the post-basin era. If this entire post-basin regolith is 10 m deep, 11% of the Apollo 16 regolith would be derived from greater than 500 km, a value supported by the abundance of mare basalt sampled at Apollo 16 [2,4,5].

Regolith Component From Greater than 500 km: Figure 2 illustrates that there is variation in the amount and proportion of foreign material derived from large distances at different locations. A map of the proportion of cumulative post-basin contribution that is from greater than 500 km is illustrated in Figure 3. There are areas of the lunar surface where the foreign component is shown to be almost completely dominated by material derived from greater than 500 km. Additionally, regions surrounding larger craters tend to be dominated by almost entirely local material. This proximal material can be derived either from a single large crater or from several smaller craters.

Figure 3. Percent of post-basin contribution to the regolith that is derived from greater than 500 km. Map projection is the same as in Fig. 1. The example locations are identified by stars.

Conclusions: Post-basin cratering is predicted to have distributed small amounts of material over the entire lunar surface. It is therefore likely that across the Moon, the foreign component of the post-basin contribution to the regolith is derived mostly from within 1000 km. This result is supported by the statistical analysis of Li and Mustard [9]. Because local events dominate the near-field, no single expression can describe the variation in the amount of foreign material in the regolith from one location to another. The scale of lateral transport described here suggests that measured geochemical anomalies observed in lunar feldspathic meteorites [15] can indeed be a result of a foreign component being introduced by post-basin lateral transport.

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