THE LUNAR-WIDE EFFECTS OF THE FORMATION OF BASINS ON THE MEGAREGOLITH.

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Introduction: The surface of the Moon underwent an intense bombardment during the first ~700 my of it's history (e.g. [1]). During this time at least 43 basins [1,2] and countless smaller craters were formed across the entire surface [1,3]. A quantitative assessment of the regolith as formed and modified by basins is discussed here.

The formation of the basins (craters >300km in diameter) caused a significant amount of material to be excavated and redistributed across the surface of the Moon [4,5,6,7]. The material excavated by each individual basin was deposited and laterally mixed with the surrounding surface. This resulted in the development of a lunar-wide mixed zone of fragmented material, several kilometers thick [5,8,9]. This mixed zone was developed further by subsequent impacts resulting in a fragmental zone 1-2km thick called the megaregolith [10].

The initial zone of mixed material formed by the basins is not expected to be uniform across the surface of the Moon because of the varied size and random distribution of the basins. The main topographic ring of the 43 basins discussed by Wilhelms and Spudis [1,2] are illustrated in Figure 1.

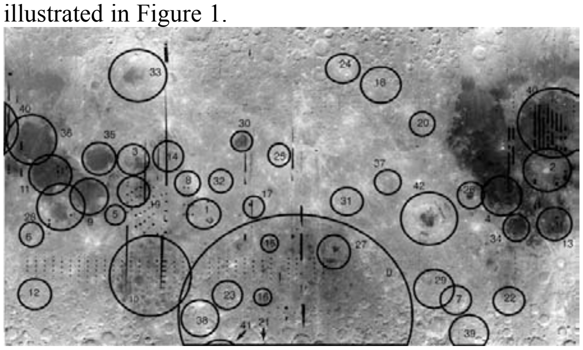

Figure 1. Clementine 750nm albedo map in Mercator projection from 70ºN-70ºS. Basins are identified by number in stratigraphic order [1, 7]. After Petro and Pieters [7].

Recent models of regolith development resulting from the formation of basins have been used to predict the character of the regolith at a location inside the South Pole-Aitken Basin (SPA) [6,7]. Here we extend these analyses and examine the effects of the formation of all basins on the evolution of the zone of mixed material across the entire globe utilizing the parameters defined earlier [7]. This analysis will include, a) examination of the thickness of ejected material from 42 basins (excluding SPA) in a 1ºx1º grid across the lunar globe, b) investigation of the global depth of the resulting regolith at every location, and c) a discussion of the implications for the evolution of the megaregolith.

Cumulative Thickness of Primary Basin Ejecta: The amount of ejecta from basins on the lunar surface contributes to lunar topography [11] and surface chemistry [12,13] at some level. Estimating the total amount of basin material distributed across the surface will aid in determining which geologic features are directly related to basin ejecta. Our primary objective is to estimate the amount of material that has been redistributed across the lunar surface by basins and to model how this material contributed to the formation of the megaregolith.

Estimating the amount of material introduced to a location by any given basin is dependant on many parameters (e.g., size of the transient crater, distance from the center of the basin). For our analyses we do not include any effects due to rotation of the Moon and we also assume that the basin ejecta deposits are both continuous and symmetrical. Transient crater (TC) sizes for all basins are derived from data of Wieczorek and Phillips [14]. Example data presented here use the mean* TC estimate that uses TC sizes determined for 10 basins [14] and the mean derived TC size for the 32 other basins [7].

Two models for the amount of ejecta from basins are compared, that of Pike [15] and Housen [16]. The only difference between the results is in the total amount of ejected material at each location; the Pike model predicts a 2-3 times greater cumulative amount than Housen. The resulting spatial distribution, however, is almost identical for the two models. Illustrated in Figure 2 is the cumulative thickness of material from all 42 basins across the moon as calculated using the Housen model, corrected to account for the curvature of the Moon.

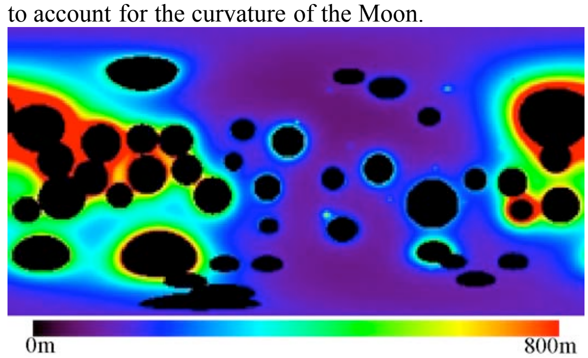

Figure 2. Map of cumulative thickness of primary ejecta from 42 basins in Cylindrical Equal Area projection from 90ºN-90ºS, centered on 0ºN, 180ºW. Black represents area inside the main topographic ring of the basins.

Major differences are seen between the nearside and the farside in the amount of basin ejecta. Local variations also exist in each of these hemispheres. These patterns are illustrated in Figure 2. Note that the north and south farside regions contain the smallest amount of cumulative ejecta. In contrast, in the area surrounding the northern nearside basins, the amount of ejecta is ~10 times that predicted to be on the farside, while the amount at the Apollo 16 site is ~4-5 times that of the farside.

The contribution of ejecta from the SPA basin event is not included in this example of the cumulative thickness of primary ejecta. Had the contribution from SPA been included in Figure 2, the entire lunar surface would be dominated by its ejecta.

Total Depth of the Zone of Mixed Material Due to Basin Ejecta: The total amount of basin ejecta is only part of the effects of basins on the megaregolith. In order to model the global depth of the mixed zone due to basins, the process of mixing between the ejected material and local material must accurately modeled. The model Oberbeck [9] mixing ratio (μ), defined as the ratio of local to foreign material resulting from the emplacement of ejecta, provides a basis to estimate the depth of the mixed zone due to the emplacement of basin ejecta. The product of the ejecta thickness estimate and a mixing ratio at any location results in an estimate of this depth of the zone of mixed material.

However, the mixing parameter is not well constrained. The Oberbeck model mixing ratio has been validated up to a μ value of 5.00 [17,18,19]; values of μ greater than 5.00 have not been validated. Schultz and Gault [20] examined the morphology of and ejecta from a large variety of experimental craters and found a greater amount of primary material at the surface than is predicted by Oberbeck. The effect of lower mixing ratio values on the evolution of the regolith has been explored in earlier studies [7]. For the global analysis presented here values of the mixing ratio greater than 5.00 are systematically decreased by a factor of 2. A mixing ratio lower than the Oberbeck model μ predicts a greater amount of primary material to be at the surface.

We have modeled the depth of the zone of mixed material across the surface of the Moon for each of the 42 basins in sequence. In this example, we again use the Housen model for ejecta thickness. At any given site, we evaluate the depth of the mixed zone from all 42 basins. The upper portion of the mixed zone has been involved in several events while the deepest mixed zone has been involved in only one event. An example of depths involved in multiple basin events is illustrated in Figure 3 for the Apollo 16 landing site. Utilizing the Housen model of basin thickness at the Apollo 16 site, the deepest mixing event penetrates to a depth of 2000m. However, only the upper ~100m has been involved in more than 4 events.

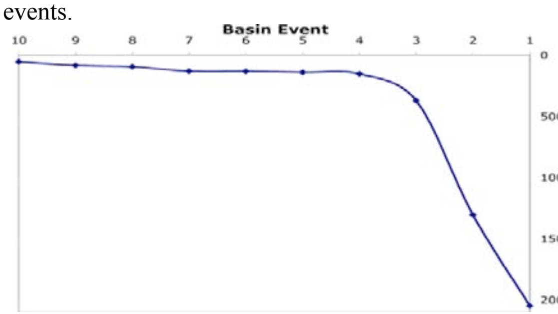

Figure 3. Depth profile of the 10 deepest basin mixing events (after SPA) at the Apollo 16 site.

Illustrated in Figure 4 is a global map of the depth of the crustal zone that has been mixed by 5 basin events. As with the cumulative thickness of basin ejecta (Figure 2) a distinct difference between the nearside and farside is apparent for the depth of mixing. The highest values of the mixed zone are located near the nearside basins and are ~5 times the values observed on the farside. The greater thickness of ejecta predicted by the Pike model would result in a greater depth of mixing were it to be used. Again we have not included the effects of the SPA basin here as that event set the maximum depth of mixing across the entire surface.

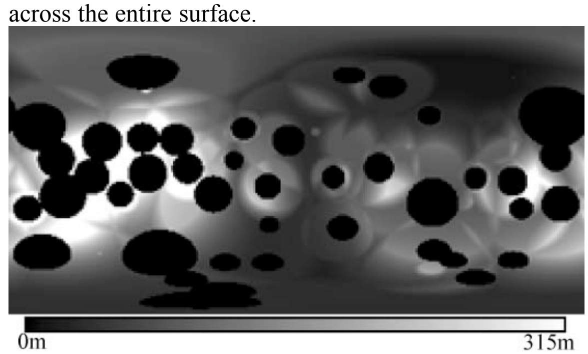

Figure 4. Map of depth of mixed zone affected by 5 basin events using the Housen ejecta model. Map is in Cylindrical Equal Area projection from 90ºN-90ºS, centered on 0ºN, 180ºW.

Conclusions: The basin contribution to the megaregolith created a very non-uniform distribution of both basin ejecta and depths of mixing across the entire lunar globe. The farside Feldspathic Highlands Terrane identified by Jolliff et al. [13] coincides with an area that has a distinctive regolith evolution. Our results show that for this area in the northern farside the small amount of basin material incorporated into the regolith coupled with the shallow zone of mixed material resulted in a vast exposure of early crustal material on the Moon. Similarly, our results indicate that the contribution of basin material to the regolith of the interior of SPA is inherently small [6,7]. The interior of SPA is also one of the least re-worked areas on the Moon. During and after crater formation, small craters have saturated the lunar surface and ultimately set the final depth of the megaregolith. However, the global effects of the lateral transport and mixing of material by basins as discussed above remain unchanged by the smaller more localized cratering events.

References: [1] Wilhelms, D.E. (1987) *USGS Prof. Paper 1348*. [2] Spudis, P.D. (1993) *Cambridge U. Press*, 263pp. [3] Hartmann, W.K., (1966) *Icarus*, *5*,406. [4] Hartmann, W.K. (1980) *Lunar Highlands Crust*, 155. [5] Short, N.M. and Foreman, M.L. (1972) *Mod. Geol.*, *3*, 69. [6] Haskin, L.A. et al. (2003) *MAPS*, *38*, 13. [7] Petro, N.E. and Pieters, C.M. (2004) *JGR*, *109(E6)*. [8] Hartmann, W.K. (1973) *Icarus*, *18*, 634. [9] Oberbeck, V.R. et al. (1975) *The Moon, 12*, 19. [10] Hörz, F. et al. (1991) in *Cambridge U. Press,* 736pp. [11] Zuber, M.A. et al. (1994) *Science*, *266*, 1839. [12] Haskin, L.A. (1998) *JGR, 103,* 1679. [13] Jolliff, B.L. et al. (2000) *JGR, 105*, 4197. [14] Wieczorek, M.A. and Phillips, R.J. (1999) *Icarus, 139*, 246. [15] Pike, R.J. (1974) *Earth Planet Sci., 23*, 265. [16] Housen K.R. et al. (1983) *JGR, 88*, 2485. [17] Pieters, C.M. et al. (1985) *JGR, 90*, 12393 [18] Head, J.M. et al. (1993) *JGR, 98*, 17149. [19] Blewett, D.T. et al. (1995) *JGR, 100*, 16595. [20] Schultz, P.H. and Gault, D.E. (1985) *JGR, 90*, 3701.

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