THE COMPOSITION OF THE LUNAR MEGAREGOLITH: SOME INITIAL RESULTS FROM GLOBAL MAPPING

P. D. Spudis[1] (paul.spudis@jhuapl.edu), N. Jackson[2], S. Baloga[3], B. Bussey[1], L. Glaze[3] 1. MP3-E128, APL, Laurel MD 20723 2. Univ. S. Queensland, Toowoomba, Australia 3. Proxemy Research, 14300 Gallant Fox Lane, Suite 225, Bowie, MD 20715

The megaregolith is the name given to the kilometers-thick debris layer that covers the lunar highland crust [1]. This debris is generated by the large-scale impact bombardment that produced the observed craters and basins in the highlands. As such, it consists of complex breccias and crushed plutonic rocks derived from an originally igneous crust and its composition should reflect the rocks from which it is derived [1]. As the highlands megaregolith shows clear lateral heterogeneity [2], the implication is that the crust of the Moon is laterally heterogeneous.

Exactly how the megaregolith varies in composition from place to place and what this might imply about sub-regolith highlands crustal "bedrock" has not been systematically studied. Pieters [3] summarized knowledge of the highlands crust as it then stood and noted that while Earth-based spectral data showed diversity at depth, globally, the highlands megaregolith appeared everywhere dominated by feldspar and low-Ca orthopyroxene. New Clementine data show that globally, the megaregolith does vary and its composition and variance may serve as a proxy to understanding the variation of the crust as a whole [4].

Craters excavate to depth proportional to their diameters so that, in principle, it is possible to map variations in megaregolith composition around the Moon using the ejecta of impact craters. We have assembled Fe and Ti compositional data for over 2000 impact craters between 5 and 50 km in diameter. Our purpose is to analyze these data statistically to understand (1) how the megaregolith varies in composition with position and depth around the Moon; (2) whether the megaregolith reflects the composition of the underlying highland crustal basement or reflects other processes, such as volcanism; and (3) what the implications of these relations are for the origin and evolution of the impact processed debris layer that covers the outer few kilometers of the Moon.

Ejecta for randomly selected craters were analyzed for Fe and Ti concentrations using the method of Lucey et al. [5], which utilizes the Clementine UVVIS images. Our data collection technique is described in a companion abstract [4]; for each crater, 12 points around the crater rim, within a crater radius, were analyzed for Fe and Ti content. These measurements were then averaged. Initial examination of the entire population of craters shows that both the Fe and Ti contents of the ejecta follow a classical lognormal distribution, as often occurs in natural settings (Figure 1; [6-8]). Such distributions usually arise from mixtures of relatively small numbers of subpopulations or random effects that depend on proportions. A preliminary statistical exploration of the data set shows that the populations are well-behaved and subpopulations might reflect statistically significant differences in Fe or Ti as a function of location on the Moon, different Fe versus crater diameter trends, and correlations within and between the subpopulations. We will be able to validate underlying assumptions of statistical hypothesis testing if subpopulations are found [8]. This validation includes analyzing the character of the distribution as well as placing confidence limits on the parameters of the distribution [6, 7]. Often in the analysis of natural geologic data, the sample size is insufficiently large to determine such 'error limits' or derive convincing statements about the character of the statistical distribution. However, the sample size in this case is more than adequate to develop meaningful inferences and intercomparisons about subpopulations.

Our initial examination shows that the megaregolith naturally falls into compositional provinces (Figures 2, 3). Compositions appear to cluster by virtue of inferred underlying crustal "bedrock" composition, such as the compositional "terranes" of Jolliff et al. [2] or the petrological provinces determined by our own mapping techniques [9, 10]. We can infer the make-up of the underlying crustal "bedrock" through the use of basins that excavate beneath the highlands megaregolith [11, 12].

As a preliminary attempt at analyzing the statistical differences in the data and determining which populations are different, we have subsampled the population from five different, arbitrarily selected regions on the Moon (near and far side highlands, eastern and western mare, and SPA) and have performed a so-called, "Analysis of Variance" (ANOVA). The results in Figure 4 show which groups are statistically indistinguishable or distinct by the overlap, or lack thereof, of the 'error bars'. With the one exception, the plots of Fe content for the five provinces form groups that show a range of natural variation and are distinct from each other, in agreement with other data [10]. We plan to determine if these and other clusters show any relationship to position and depth of excavation (inferred by crater diameter; [13]). There are many subtle alternatives to extracting more detailed information from ANOVA analysis [6, 7]. What we have found to be most intriguing from this preliminary exploration is the normality of the Fe wt.% distributions of the subpopulations by region. It is the existence of well-defined normal subpopulations that appears to be the underlying cause of the lognormal distribution in the global data set.

Our new mapping is summarized in Figure 2, which shows the location and average Fe content of the ejecta of 2059 craters. We also show the same data in a gridded version, in which the craters have been classified into a province map (Fig. 3). This map may be compared with the surface Fe map (Fig. 3); to first order, the two maps are quite similar, although the surface map is higher in resolution. The principal conclusion to be drawn from this figure is that the megaregolith closely resembles the composition of the surface. We will continue to analyze the data to determine whether the megaregolith varies in composition with depth and (by using nearby crater central peaks and basin inner rings as indicators of the sub-regolith basement [3, 14, 15]) assess its compositional affinities (or lack thereof) to the underlying crystalline crustal "bedrock" of the Moon.

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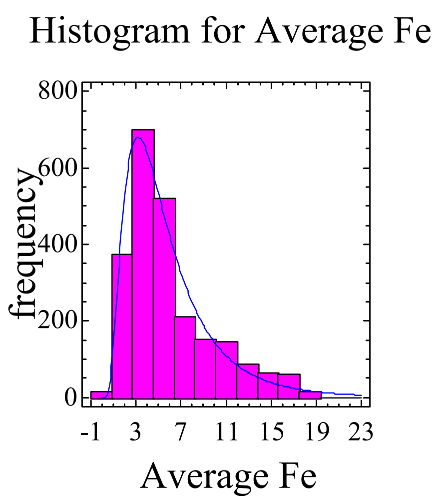

Figure 1. Distribution of Fe content in the ejecta of 2059 craters on the Moon with diameters between 5 and 50 km.

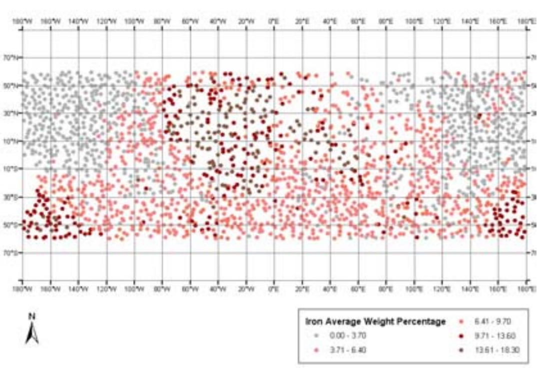

Figure 2. Average Fe values for the ejecta of 2200 craters. Note the central, near side maria (high Fe values between –90 and 90 longitude), with a secondary peak on the far side (centered around 180) that corresponds to the mafic SPA basin floor.

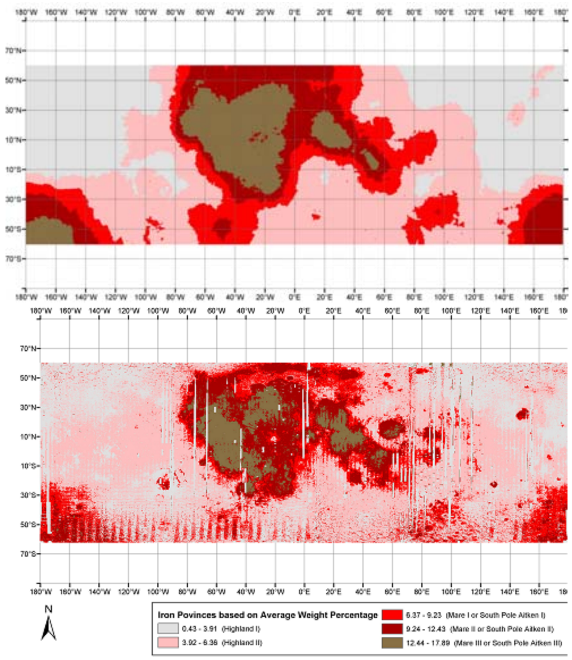

Figure 3. Top – gridded Fe data for megaregolith, based on craters shown in Fig. 2. Several compositional provinces are evident. Bottom – surface Fe content map, gridded to same scale as megaregolith map. Similarity of unit boundaries is evident, suggesting that surface composition maps well with megaregolith composition.

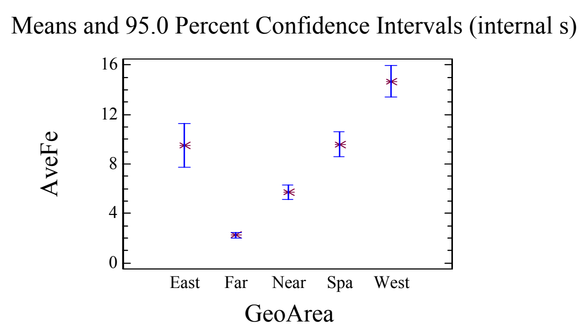

Figure 4. ANOVA chart for the mean values of the Fe wt.% and the standard 95 % confidence intervals on the mean values for the five geographic areas on the Moon. The chart clearly shows that the near and far side highlands, SPA, and the western maria are statistically distinct groups according to Fe wt.% in the ejecta of the craters because the none of the confidence intervals overlap. However, the eastern maria have a mean value that is not statistically distinguishable from SPA. Moreover, the variability of the iron content in this region is significantly higher than all other groups, as reflected by the larger confidence interval on the mean value.