ANALYSIS OF THE GRAIN SIZE FREQUENCY DISTRIBUTIONS OF LUNAR FINES.
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Grain size frequency distributions of a total of 72 samples (3 Apollo 11, 9 Apollo 12, 8 Apollo 14, 12 Apollo 15, 19 Apollo 16 and 21 Apollo 17) of lunar fines have been completed by sieving with an Allen-Bradley sonic sifter and precision sieves. Relative humidity was controlled in the sieving chamber so as to avoid clumping of the less than 30 µm fraction and the "thumping action" was minimized to preserve the delicate agglutinates. Weight of sample retained on each of a total of 14 sieves (841, 420, 250, 177, 149, 125, 105, 74, 53, 44, 37, 30, 20, and 10 µm) and the pan was measured to the nearest 0.0001 g. These data were converted to percentage form, a cumulative curve with a probability ordinate was prepared for each sample and the graphic mean grain size, the graphic standard deviation and graphic skewness were calculated and described as suggested by R. L. Folk (1).

The lunar fines that we have analyzed can be characterized as bimodal, poorly to very poorly sorted and nearly symmetrical. The broad mode in the 1-4Ø (500-62.5 µm) size range is composed primarily of lithic fragments and agglutinates, the 4-5Ø (62.5-31.3 µm) size range is relatively depleted in weight fraction in many of the samples and the greater than 5Ø size range constitutes a second mode composed of mineral grains and glass. Although we have observed a considerable variation in size frequency distribution properties, the cumulative frequency plots are nearly linear and sub parallel such that a log normal distribution model is justified.

There appears to be a positive correlation between graphic mean grain size and total sample weight for those samples for which we have received more than one split (2). At our request, five gram splits of 76321,10 and 78221,8 were made available by the LRL for the purpose of ascertaining whether or not a larger sample would possess a greater graphic mean grain size as a result of our sieving procedures. Another purpose of requesting the two five gram splits was to investigate systematic differences in grain size results between different laboratories. Each sample was homogenized by rolling on a sheet of powder paper and two quarter sample splits and four eighth sample splits were prepared from each parent sample. A large (approximately 1.4 g) and a small (approximately 0.6 g) split from each parent sample have been sieved in our laboratory. Differences observed by our laboratory between aliquots of these comparison samples are much less than the differences found between sample aliquots distributed by the LRL. Causes of variations between the LRL distributed aliquots are difficult to specify, although it seems probable that they reflect size sorting of particles during preliminary handling and sieving in the LRL and/or during splitting prior to distribution. If the apparent biasing is widespread, then additional problems arise in comparing the results of size analyses performed by different groups of investigators if the same weights of sample were not used.

Several investigators (3 and 4) have noted a significant negative correlation between graphic mean grain size and graphic standard deviation (a measure of sorting). For our 72 samples the correlation is positive; that is, our finer grained samples are more poorly sorted than our coarser grained samples. Thus, it is presently impossible to develop a model for the genesis of the lunar regolith that make use of all of the grain size information available from all laboratories.

Splits of 76321,10 and 78221,8 were sent to D. McKay at JSC and to J. Lindsay at La Trobe University for grain size analysis using the same techniques that they had used in their recent analyses of the lunar regolith. These investigators have been using a Millipore particle measurement computer system for the analysis of the fine fraction and sieving for the coarse fraction. Millipore results are made compatible with the weight percent data from the coarse fraction by graphical integration assuming spherical particles of uniform density (3 and 4). The cumulative frequency distributions for McKay's and Lindsay's data exhibit marked increases in slope at the ϕ unit corresponding to the change from sieve data to Millipore data. Because Lindsay changes to the Millipore system at 44 μm, the effect is more pronounced for his data than for McKay's, in which the change was made at 20 μm). Recasting the Millipore data to make it compatible with the weight data apparently forces the cumulative percent to equal 100 at the lower limit of resolution of the device. Grain size distributions obtained using the Millipore system terminate at 8.33ϕ for Lindsay's data and 9ϕ for McKay's data. Grain size frequency distributions for our data do not have a fixed end point. Graphic mean, graphic standard deviation and graphic skewness are computed as functions of ϕ_{16}, ϕ_{50} and ϕ_{84} (1) and in the two comparison samples analyzed by all groups, ϕ_{84} occurs at a greater ϕ value than that at which changes in technique were made. Therefore, the value of ϕ_{84} selected from our plot is considerably larger than that selected from the plots of the other investigators with the result that (if ϕ_{16} and ϕ_{50} are the same for all three groups) McKay's and Lindsay's samples would possess lesser graphic mean grain sizes (coarser), lesser graphic standard deviations (better sorted) and a lesser positive (or greater negative) graphic skewness. The effect of change in slope and a fixed end point is most pronounced for those samples that have greater graphic mean grain sizes and it would appear that the coarser samples of McKay and Lindsay must of necessity be poorer sorted than their finer samples. The total effect of mixing together data from two different techniques, however, is quite complex and each sample must be treated independently if comparisons between the size analyses performed by different groups are required.

Q mode factor analysis has been used to examine our weight percent data for relationships between the 72 different samples analyzed. Rotated factor loadings were converted to factor components and plotted on a ternary diagram. Samples 68411,13 from Station 4 on Stone Mountain, 12037,32 from the rim of Bench Crater and 12041,23 from 75 meters from the rim of Bench Crater can be considered as the "end members" for factors I, II, and III, respectively.

By comparing the grain size frequency distributions of these three samples it is possible to speculate as to the importance of these samples in our lunar grain size data. Sample 12037,32 (II) is strongly bimodal, coarse, poorly sorted, and nearly symmetrical. Closely associated on the plot with

12037,32 are samples from Cone, North Ray, Elbow, Head and Surveyor craters. Sample 12041,23 (III) is poorly sorted, of intermediate size and negatively skewed. This sample contains a pronounced mode in the greater than 5Ø size range. Sample 68411,13 (I) is very fine, very poorly sorted, nearly symmetrical and only slightly bimodal. We suggest that the regolith associated with impact craters with fresh characteristics will have a large factor II contribution. With time (an increase in I) the mean grain size is reduced through micrometeoroid comminution and the sample becomes more poorly sorted. This evolutionary scheme may be modified at any time by the influx of fine material (increase in III) and/or the creation of a new impact crater (increase in II). In addition to the concept of lithologic maturity it may be useful to define grain size maturity on the factor I content of the sample. Samples taken from ejecta of fresh impact craters at all sites form a distinct cluster with a large content of component II. For the other samples, those from Apollo 11 and 12 have relatively low grain size maturities. Apollo 14 and 15 (Apennine Front) are more mature and samples from Apollo 16 and 17 exhibit a wide range of maturity values because of the complicated local site geology. Nonlinear mapping of the 72 samples also supports the above conclusions. These results are in agreement with our previous conclusions (2) that there are grain size distribution differences within and between the Apollo sites that can be related to local geology and total time of regolith accumulation.

References

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