SAMPLING PROBLEMS AND THE CHARACTERIZATION OF LUNAR ROCK TYPES.

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Analytical procedures have progressed to the point where results can now be obtained with milligram quantities. However, the dispersion of chemical analyses reported in the literature for a given lunar rock that has been analyzed by different laboratories is often greater than the analytical uncertainty of the various methods used in the analyses. If one assumes that the competency for analysis is equal, then the variations in values reported must represent a variation in composition of the subsample that each group has analyzed, a variation caused by an analysis of a subsample that is too small to be adequately representative of total rock. Allocations for chemical analysis are typically 0.25 to 1.0 gram; amounts are occasionally larger or smaller. However, investigators only rarely report the actual amount used to produce the analysis and the amount used for an analysis may be less than the weight allocated.

Mason et al. (1) briefly discussed the problem of obtaining a significant whole rock analysis from a 0.5 g subsample of the coarser grained rocks; a volume proportional to the cube of the average grain size of the rock was suggested as a representative subsample. Rhodes and Hubbard (2) illustrated the problem by comparing published analyses of 15555 from seven different laboratories (Table 1). Others (e.g. 3, 4) have also commented on the problem of obtaining a representative subsample for analysis.

The density of mare basalts typically ranges from 3.3 to 3.4 g/cm^3. Highland rocks range from 2.75 to 3.0 g/cm^3. The volume of rock represented in a 1.0 g allocation then is about 0.3 cm^3 and for a 0.5 g allocation about 0.15 cm^3. As long as the mineral grain size is small compared to the volume of rock analyzed and the shape, orientation or distribution of the individual minerals do not introduce a bias, the values reported will be representative of the total rock. However, an analysis of a subsample that is less than representative of the total rock will produce numbers applicable only to the unique specimen that was allocated.

A computer program designed to model mineral percentages and grain size to the volume required to contain a representative sample has been developed. The program at present considers only random distributions and orientations and does not include provisions for preferred mineral orientation. The expression for the statistically significant volume V of a subsample s that contains a quantity of mineral species i as determined by this model is:

$$V_{s,i} = \frac{N_i \overline{V}_i}{f_i} \qquad [1]$$

where $\overline{V}$ is the average volume of the grains of mineral type i, f_i is the mineral fraction and N_i is the number of grains of the type i contained within the volume. N_i is dependent on grain shape, grain orientation and the mineral fraction.

The computer program is designed to determine N_i for a given grain size

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distribution and mineral fraction assuming that a two dimensional thin section is representative of the sample volume. Presently, the grain size distribution used for the calculations is flat with grain dimensions ranging from a x a to b x a (b:a is the grain size aspect ratio).

Briefly, the computer program employs a random number generator to determine the size, planar orientation θ_j, and position (x_j, Y_j) of grain j within the modeled thin section. If grain j impinges on any previously placed grain, then the orientation of grain j is redetermined and its center slightly adjusted about (x_j, Y_j). If this procedure fails to eliminate grain impingement then new values for (x_j, Y_j) and θ_j are randomly generated and the process repeated.

To test the statistical significance of area $A_{s,i}$ so determined, the area is divided into halves and the average areal fraction $f^{1/2}_{s,i}$ of the halves is calculated. The average deviation $d_{s,i}$ of the halves from the whole is ascertained by:

$$d_{s,i} = \frac{1}{m}\sum\left|\frac{f_{s,i} - f^{1/2}_{s,i}}{f_{s,i}}\right|$$

where m is the number of thin sections simulated using the same input data.

The criterion for the choice of $A_{s,i}$ for the results presented in this abstract is:

$$0.04 > d_{s,i} > 0.03$$

The statistically significant volume V_s containing a given mineral i is then given by the equation:

$$V_{s,i} = K_{i,j,k}\, a^3 \qquad [2]$$

$K_{i,j,k}$ is a dimensionless constant with index i referring to the mineral type, index j referring to the size aspect ratio and index k referring to the designated sampling error. Variable a, as previously defined, is the minimum dimension of the grain. Some values for $K_{i,j,k}$ are given in Table 2; this brief tabulation is included to illustrate the magnitude of the problem.

The basic source of size and percentage data is from the Lunar Sample Information Catalogs. It is important to emphasize that any errors in mineral percentages and size parameters caused by a nonrepresentative subsample or by investigator error will be carried through the calculation and so bias the results. A comparison of the variations between binocular data and petrographic data for sample 15555 (5) serves to illustrate the significance of the raw data used in the calculations.

Consider, for example, the pyroxene content of a subsample of 15555. The thin section description given in the Lunar Sample Information Catalog shows that the pyroxene phenocrysts comprise 45% of the sample with the size (in mm) given as 1 x 1 x 2. Approximating f_i as 50% and b:a as 1:1 (instead of 2:1)

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SAMPLING PROBLEMS

U. S. Clanton

the value of $K_{i,j,k}$ from Table 2 is equal to 7.2×10^2. From formula [2] $V_{s,i}$ is 0.72 cm^3 and the weight of the subsample should be greater than 2.4 g (density = 3.3 g/cm^3) to obtain a statistical sampling error of less than 4% in the pyroxene content. It is interesting to note that the weights of most of the subsamples used in the analyses given in Table 1 were 0.5 g.

CONCLUSIONS: The amount allocated for an analysis should be sufficient to represent the total rock, otherwise the analysis will represent more the unique subsample that was allocated. Because of the large amount of material required to adequately characterize the coarser grained samples, an alternative suggestion would be for the curator to prepare a volume of homogeneous material that would be representative of the total rock from which smaller subsample allocations could be made (a procedure that was followed for a few rocks from Apollo 11 and 12).

References:

(1) Mason, B., Jarosewich, E., Melson, W. G. and Thompson, G. (1972), Proc. Lunar Sci. Conf. 3rd, p. 785-796.

(2) Rhodes, J. M. and Hubbard, N. J. (1973), Proc. Lunar Sci. Conf. 4th, p. 1127-1148.

(3) Shih, C-Y., Haskin, L. A., Wiesmann, H., Bansal, B. M. and Brannon, J. C. (1975), Proc. Lunar Sci. Conf. 6th, p. 1255-1285.

(4) Korotev, R. L. and Haskin, L. A. (1975), Proc. Origins of Mare Basalts and Their Implications for Lunar Evolutions, p. 86-90.

(5) Butler, P. (1971) Lunar Sample Information Catalog Apollo 15.

TABLE 1: COMPARATIVE ANALYSES OF 15555; (2)

								Mean	Rel. Dev.
SiO_2	44.24	45.0	43.82	44.75	44.75	45.21	44.22	*44.57*	*1.1*
TiO_2	2.26	1.60	2.63	2.05	2.07	1.73	2.36	*2.10*	*17.0*
Al_2O_3	8.48	9.37	7.45	9.01	8.67	10.32	7.54	*8.69*	*11.6*
FeO	22.47	21.18	24.58	21.68	23.40	20.16	24.24	*22.53*	*7.3*
MnO	0.29	0.26	0.32	0.30	0.30	0.25	0.29	*0.29*	*8.4*
MgO	11.19	12.22	10.96	11.39	11.48	11.20	11.11	*11.36*	*3.7*
CaO	9.45	9.25	9.22	9.62	9.14	9.96	9.18	*9.40*	*3.2*
Na_2O	0.24	0.26	0.24	0.27	0.24	0.35	0.29	*0.27*	*14.8*
K_2O	0.03	0.03	0.04	0.04	0.05	0.05	0.04	*0.04*	*20.4*
P_2O_5	0.06	0.07	0.07	0.06	0.05	0.05	0.06	*0.06*	*13.6*
S	0.05	—	0.06	0.04	—	—	0.07	*0.06*	*21.5*
Cr_2O_3	—	0.47	0.59	0.58	0.61	0.66	0.73	*0.61*	*14.2*
Total	99.46	99.71	99.98	99.79	100.76	99.94	100.13	*99.98*	

TABLE 2: $K_{i,j,k}$ VALUES FOR A 3-4% SAMPLING ERROR

		Mineral Grain Aspect Ratio		
	b:a	1:1	5:1	10:1
Mineral Fraction f_i	10%	9.0×10^4	4.7×10^5	1.2×10^6
	30%	1.0×10^4	3.9×10^4	9.7×10^4
	50%	7.2×10^2	1.0×10^4	2.8×10^4

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