A FUTURE MOON MISSION: CURATORIAL STATISTICS ON REGOLITH FRAGMENTS APPLICABLE TO SAMPLE COLLECTION BY RAKING.

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Introduction: Robotic sample return from South Pole-Aitken has the appeal of high science return for low technological risk. A variety of sampling devices (core tubes, drill cores, scoops, rakes) have been honed to work effectively on the lunar surface [1,2]. Due to the global nature of the surface physical processes, we also have confidence in predicting the scientific usefulness, as measured by number of allocations, of various physical sample forms (Fig. 1). The strategy of raking rock fragments from the lunar regolith as a means of acquiring representative samples has wide support due to science return, spacecraft simplicity (reliability) and economy [3, 4, 5]. While there exists widespread agreement that raking or sieving the bulk regolith is good strategy, there is lively discussion about the minimum sample size. Advocates of consortium studies desire fragments large enough to support petrologic and isotopic studies. Fragments from 5 to 10 mm are thought adequate [4, 5]. Yet, Jolliff *et al.* [6] demonstrated use of 2-4 mm fragments as representative of larger rocks. Here we make use of curatorial records and sample catalogs to give a different perspective on minimum sample size for a robotic sample collector.

Assumptions and Plan: We make the assumption that the most desired South Pole-Aitken samples are coherent, crystalline material - specimens less-tainted by regolith processing. Anyone perusing the catalogs of the 2-4 mm fines observes that a large proportion of the fragments are regolith breccias or are coated with impact glass. We attempt to use curatorial database and sample catalog lithologic classifications of fragments to assess the relative proportions of the more desirable non-regolith materials among rock, rake samples, 4-10 mm and 2-4 mm soil fragments.

Examples of lithologic types considered "crystalline" are basalt, impact melt, troctolite, norite. Included with regolith-derived and impact-damaged lithologies are breccia, agglutinate, impact glass and anorthosite. The term anorthosite is used broadly and encompassed highly shocked materials.

Lithologic Classification Caveats: The lithologic classifications in the curatorial database were taken mainly from PET (Preliminary Examination Team) information found in sample catalogs. The early catalogs were written by various petrologists who identified materials inside of a nitrogen glovebox based on binocular observation of frequently dusty fragments. Ryder *et al.* [7] have assessed the ability of an experienced lunar petrologist to correctly identify lithologies of 2-4 mm fragments by binocular observation as very good. However, particles in that study were rinsed with freon. Dust coverings on fragments may result in some crystalline fragments being identified as regolith products. Thus, numbers presented here could be lower limits for expected portions of crystalline fragments. Nevertheless, the quality of the classifications is adequate for this study.

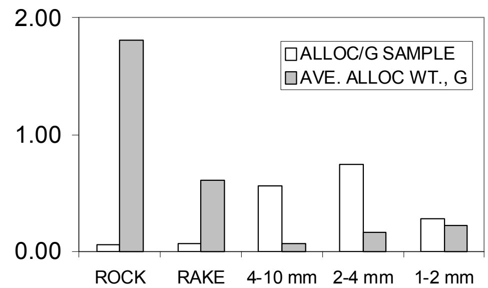

Fig. 1. Allocations per gram of returned sample and average weight of allocations in grams, in order of decreasing size: rocks, rakes, 4-10 mm, 2-4 mm, 1-2 mm.

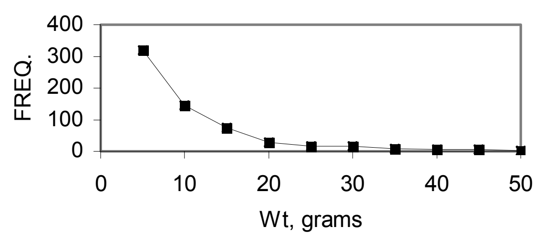

Fig. 2. Size distribution of Apollo rake samples (bin size is 5 g). The 42 specimens greater than 50 g are not shown for clarity in the lower weight region of the distribution [2].

Table 1.

MSN	Ave. wt, g crystalline	Ave. wt, g Regolith-derived
15 rock	768	466
15 rake	**78**	**5.8**
16 rock	350	440
16 rake	**94**	**12**
17 rock	291	360
17 rake	**94**	**19**

Rake Sample Characterization: The rocks gathered by raking with 1-cm tine spacing on Apollo 15, 16 and 17 consist of 665 specimens ranging in weight from 0.2 g to 415.4 g with an average weight of 15.9g. The size distribution is shown in Fig. 2.

Initial compilations of the average weights for crystalline vs regolith-derived specimens for rocks and for rake samples suggested that the regolith-derived materials in rakes were smaller, perhaps due to natural differences or due to mechanical stress of raking (Table 1)[2].

Fragments Sieved from Regolith: Portions of 144 bulk soils were dry sieved inside nitrogen-filled gloveboxes in curation laboratories into the following bin sizes (and wt. percent): <1 mm (90%), 1-2 mm (4%), 2-4 mm (3%), 4-10 mm (3%). These percentages are good broad-base predictors of numbers of fragments to be expected from sieving lunar regolith.

Assessing fraction of crystalline specimens (by count) from 4mm to rock size: Is there a minimum size fraction below which the portion of regolith-derived particles dilutes the advantage of greater numbers of particles? Comparison among these vastly different size specimens is not straightforward using existing records. The classification of rocks and rake samples is more thorough and easier because more characteristic surface is visible for binocular observation. Many 4-10 mm fragments are individually numbered and were examined after dust removal with nitrogen jet. In contrast, most 2-4 mm fragments are handled in groups. We could not correlate 2-4 mm classifications in a meaningful way to the larger size specimens. Apollo 17 specimens of rocks, rakes and 4-10 mm fragments are compared in Table 2.

Jolliff e*t al*. [6] have analyzed an unbiased set of 2-4 mm fragments from Apollo 17 station 6 which should be comparable to station data in Table 2. In contrast to the crystalline fraction of 0.4 to 0.5 shown in Table 2, the Washington University group reports 0.74 weight fraction comprised of impact melt, high titanium mare and other basalts (minus 4-8% abrasion fines, which if added to the total adjusts their value to 0.7). Their work was performed on acetone-washed fragments and consisted of INAA, thin section and electron microprobe analyses. Because the 2-4 mm fragments are small, the difference between count and weight fractions should not be significant. The difference between our catalog compilations and the Washington University study needs explanation. Ryder's results from a similar classification exercise of 2-4 mm fragments from the Apennine Front yielded 0.05 fraction of non-regolith products [7]. Perhaps the portion of crystalline materials is underestimated by binocular classification. There are also sample preparation issues, such as intensity of sieving (to disaggregate friable regolith clods), to consider. Clearly more data are needed.

Conclusions: 1) The best broad-based predictors of numbers of fragments expected from sieving lunar regolith are the results of sieving 144 soil samples: 1-2 mm (4 %), 2-4 mm (3%), 4-10 mm (3 %). **2)** There is no clear indication in Table 2 that the smaller fragments are enriched in regolith materials. **3)** It is apparent in Table 2 that all size ranges are sensitive to compositional differences between sampling stations (5-10 km distances).

Table 2. Apollo 17 data from 216 rocks, 115 rakes, and 1503 (4-10 mm) fragments. 4-10 mm data from [8]

STA	Specimen size	Crystalline fraction, by count
LM	rock	0.85
	4-10 mm	0.68
1	rock	1
	rake	1
	4-10 mm	0.75
2	rock	0.05
	rake	0
	4-10 mm	0.08
3	rock	0.14
	4-10 mm	0.14
4	rock	0.63
	4-10 mm	0.34
5	rock	0.92
	4-10 mm	0.78
6	rock	0.41
	rake	0.5
	4-10 mm	0.43
7	rock	0.24
	4-10 mm	0.24
8	rock	0.63
	rake	0.44
	4-10 mm	0.21
9	rock	0.19
	4-10 mm	0.35

References: [1] Allton J. H. and Dardano C. B. (1987) LPI Tech Rep. 88-07, p.30-31. [2] Allton J. H. and Bevill T. J.(2003) submitted to *Adv. Space Res.* [3] Ryder G. et al (1989) EOS 70, No. 47, p.1495. [4] Warren P. H. et al (1996) EOS 77, No. 5, p. 33. [5] Duke M. B. (2002) LPI Contr. 1128, p. 13. [6] Jolliff B. L. et al (1996) Met. Planet. Sci. 31, 116-145. [7] Ryder G. et al (1988) 18th LPSC, p.219. [8] Meyer C. (1973) Ap 17 Coarse Fines, JSC Curator catalog.