RELIABILITY OF CALCULATING AVERAGE SOIL COMPOSITION OF APOLLO LANDING SITES. A. Basu[1] and S. Riegsecker[1], [1]Department of Geological Sciences, Indiana University, Bloomington, IN 47405, USA (basu@indiana.edu).

Lunar soil, i.e., the fine fraction of the lunar regolith is the ground truth available for calibrating remotely sensed properties of virtually atmosphere-free planetary bodies. Such properties include albedo, IR-VIS-UV spectra, and secondary XRF, which are used to characterize the chemical and mineralogical compositions of planetary crusts [1]. The quality of calibration, however, is dependent on the degree to which ground truth is represented in the remotely sensed properties. The footprints and spatial resolution of orbital and earth-based observations are much larger than the sampling areas at the landing sites. Yet, an average composition of soils at each landing site is our best approximation for testing calibration.

Previously, we have compiled chemical compositions of lunar soils and estimated the best average composition (CC) for each landing site (Table 7.15 in [2]). We have now compiled and estimated the best average mineralogical composition (MC) of soils (90µm-150µm fraction) at each Apollo landing site [3]. In this paper, we examine how these two estimates (Tables 1 & 2) compare and how representative they may be. For the purpose of comparison, we have calculated the normative mineralogy of each site (from Table 1) and recast them on a quartz-apatite-pyrite-free basis, i.e., in terms of feldspar, pyroxene, olivine, and ilmenite + chromite (Table 3).

The modal composition is calculated on a glass-regolith breccia-agglutinate-free basis (GRA-free) on the assumption that they represent the mineralogy of the soils. The chemical composition, however, is that of the bulk. Thus, unless the chemical composition of mineral and rock fragments (MRF) is identical to that of the GRA fraction of the soils, there would be a difference between CC and MC. Regolith breccias and agglutinates consist of mineral and rock fragments cemented together, the populations of which are not likely to be much different from those in the soils. Chemical analyses of agglutinate separates, however, show a distinct shift from the average composition of the soils to its finer size fractions [4]. This shift is small and the composition of agglutinitic glass may be statistically indistinguishable from the composition of the bulk soil [5]. The composition of glass, on the other hand, is very different from bulk soil compositions. Common but specialized glass types (green, orange, black, and colorless) show a wide variation in their chemical compositions. Modal abundance of glass fragments of most lunar soils, however, is less than 5%. Therefore, unless a soil is made up mostly of glass (e.g., 74220), the composition of a soil should not be significantly different from the composition of its MRF.

Yet, normative and modal compositions are different (Table 4). Several factors may be responsible for the observed deviation. First, it is possible that the modal composition of the 90µm-150µm fraction of lunar soils does not represent the bulk, the composition of which is more similar to that of a feldspar-rich finer fraction. Second, the assumption that the composition of GRA of a soil is not significantly different from that of its MRF, is not valid despite the reasons given above. Third, modal proportions of mare and highland rocks (Table 3 in [3]) may be based on insufficient and non-representative data, which may have compromised the modal estimate (Table 2). Finally, CIPW norm calculation is not appropriate to derive standardized mineralogy from lunar soil compositions.

The geographic distribution of soil samples from the landing sites was based on sampling ease, perceived variations in soil types, and location with respect to surface morphology and albedo to maximize representation of diversity. Thus, there is an inherent sampling bias against obtaining an average composition of a site from soil samples. Moreover, lunar soils rarely mimic the composition of lunar rocks (p. 345 in [2]).

We, therefore, conclude that (1) the average composition of Apollo landing sites is still poorly known, and (2) the task of inferring bedrock composition of a pixel of the Moon from remotely sensed properties is complicated. The latter requires filtering many layers of modification of bedrock material imposed by lunar surface processes and accepting the best averages of the time (Tables 1 and 2).

REFERENCES: [1] Lucey et al., 1995, Science, **268**, 1150-1153. [2] Heiken et al., 1991, Lunar Sourcebook, Cambridge, 736p. [3] Riegsecker et al., 1998, This volume. [4] Papike et al., 1982, Rev. Geoph. Space Ph., **20**, 761-826. [5] Hu and Taylor, 1978, View from Mare Crisium, 291-302.

Table 1. Average chemical composition of lunar soils at Apollo Landing Sites

	A 11	A 12	A 14	A 15	A 16	A 17
SiO_2	42.2	46.3	48.1	46.8	45.0	43.2
TiO_2	7.8	3.0	1.7	1.4	0.54	4.2
Al_2O_3	13.6	12.9	17.4	14.6	27.3	17.1
Cr_2O_3	0.3	0.34	0.23	0.36	0.33	0.33
FeO	15.3	15.1	10.4	14.3	5.1	12.2
MnO	0.2	0.22	0.14	0.19	0.3	0.17
MgO	7.8	9.3	9.4	11.5	5.7	10.4
CaO	11.9	10.7	10.7	10.8	15.7	11.8
Na_2O	0.47	0.54	0.70	0.39	0.46	0.40
K_2O	0.16	0.31	0.55	0.21	0.17	0.13
P_2O_5	0.05	0.40	0.51	0.18	0.11	0.12
S	0.12			0.06	0.07	0.09
Total	99.9	99.1	99.8	100.8	100.8	100.1

Table 2. Average mineralogic composition of lunar soils at Apollo Landing Sites

	Feld	Oliv	Pyrx	Opq
A 11	26.7	3.2	53.7	16.3
A 12	23.0	8.7	63.4	4.9
A 14	49.7	1.8	47.0	1.5
A 15	37.9	8.4	52.2	1.5
A 16	69.0	2.6	28.2	0.1
A 17	35.5	5.5	56.3	2.7

Table 3. Normative composition of lunar soils at Apollo landing Sites

	Feld	Oliv	Pyrx	Opq
A 11	39.6	0.0	44.8	15.6
A 12	53.8	0.0	39.8	6.4
A 14	52.9	0.0	43.5	3.6
A 15	41.9	10.1	44.7	3.3
A 16	76.4	7.8	14.1	1.6
A 17	48.7	11.2	31.5	8.6

Table 4. Percent deviation (modal – normative)

	Feld	Oliv	Pyrx	Opaq
A 11	-48	100	17	5
A 12	-134	100	37	-31
A 14	-6	100	7	-141
A 15	-10	-20	14	-114
A 16	-11	-197	50	-1074
A 17	-37	-103	44	-222