THE OPTICAL PROPERTIES OF THE FINEST FRACTION OF LUNAR SOILS: INITIAL RESULTS AND IMPLICATIONS FOR WEATHERING PROCESSES.

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Introduction: The finest fraction of lunar soils are geochemically and petrologically quite different than the larger size fractions. The less than 10µm fraction tends to be more feldspathic in composition than the bulk soil from which it formed [1]. The finest fraction of lunar soils controls the optical properties of the bulk and the optical properties of the finest fraction appears to be due to weathering products rather than simply particle size effects [2]. The finest fraction (<10µm), while composing only about 10 to 20% of the soil by weight, constitutes about two-thirds of the surface area [3]. Many space weathering products have been shown to be surface correlated [4], and are therefore concentrated in the finest fraction. Understanding the character of this fraction is essential to understanding both these weathering effects and the optical properties of the soil as a whole. There are multiple processes involved in creating the unique properties of the finest fraction that need to be investigated in greater detail.

Background: Although the finest fraction dominates the optical properties, it is not known how the many individual components contribute to a bulk mixture. It is necessary to evaluate the optical and compositional properties of the bulk samples as well as various size fractions.

Feldspathic soils: A suite of feldspathic soils with different degrees of maturity but similar composition were selected for study by Fischer et al [5]. These soils were wet sieved using large quantities of freon into several size fractions. The smallest, <10µm, was collected after evaporating the freon. Fischer noted the unique qualities of this finest fraction of the feldspathic soils: a definite flattening at longer wavelengths in contrast to other size fractions. The origin of this effect was not well constrained at the time. One of the soils examined is shown in figure 1.

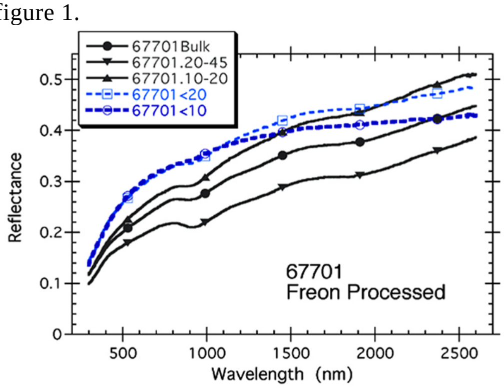

Figure 1. Size fractions from a feldspathic soil [5]. Sample prepared by wet sieving with large amounts of freon.

The origin of the unusual flattening was investigated with a few additional experiments. Measurements of the <10µm fraction were taken with several different viewing geometries to determine whether the flattening was due to photometric effects. No significant difference was observed over phase angles from 30° to 95°, including specular geometry.

Fischer et al further tested for possible effects due to the freon by processing a lunar soil simulant and a bytownite (feldspar) in a similar fashion. He found a slight overall darkening of the material (perhaps due to organics) but no flattening was observed for the <10µm fraction of either test material.

Basaltic soils: The initial study of basaltic soils by Taylor et al [6,7,8] provides the opportunity to compare and contrast soils of different compositions. These various mare soils were dry sieved using a sonic sifter (a relatively harsh mechanical vibration). Figure 2 provides an example of the spectral properties observed for the three finest fractions of a mare soil. The <10µm fraction has more muted features and a much steeper, almost linear, continuum slope than any of the larger size fractions of mare soils.

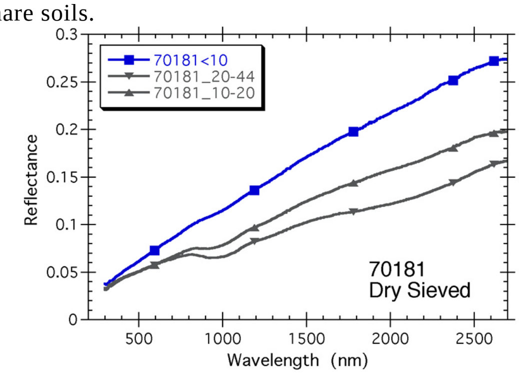

Figure 2. Size fractions from a basaltic soil [6]. Sample prepared by dry sieving with a sonic sifter.

Issues: The finest fraction of the measured highland soils have very different spectral properties than the mare soils when compared to larger size fractions: the feldspathic soils flatten at longer wavelengths, whereas the basaltic soils continue in a steep, almost linear fashion. Although there are significant compositional differences, the two suites were also processed in very different ways. It is necessary to determine how various preparation methods may have affected the results in order to understand the true character of the finest fractions.

Measurements and Tests: In addition to the original tests for geometry and freon processing performed with the highland samples, we also tested general interaction with fluid by exposing mare <10µm samples that had been previously dry sieved (70181) to various amounts of freon. One mare sample was exposed for several days to large amounts of freon, the other for several hours to only small amounts of freon. In the latter case, much of the freon was removed after the sample had settled before the remaining freon was evaporated. We detected virtually no change in the limited exposure sample, but the extended exposure sample displayed some unusual spectral characteristics, particularly an overall darkening, which may be related to some type of contamination in the freon. Nevertheless, no flattening was observed with either of the freon processed mare <10µm samples.

We also independently tested the effects of dry sieving by gently hand dry sieving (i.e. no sonic sifter) a highland sample of mature soil 68501. If indeed, space weathering effects are surface correlated, it is possible that the not-so-gentle process of mechanical dry sieving may cause the material in the outer rims of larger grains to be removed and concentrated in the finest fraction. The resulting <10µm sample of 68501 exhibited some flattening but it was less pronounced than that observed for the freon processed samples.

Initial Results and Conclusions: Preparation methods do indeed have an effect on the spectral characteristics of the finest fraction. Wet sieving appears acceptable, if fluid interaction is kept to a minimum. The samples in the current Taylor et al study have been carefully wet sieved [9].

Coatings, or rims, of optically active weathering products do exist on soil grains and can be disrupted by severe dry sieving. These products are then, presumably, concentrated in the finest fraction. Figure 3 compares the spectral properties of two samples of lunar soil 79221 processed in different ways [6,9]. The dry sieved sample displays a noticeably steeper continuum slope. This reddening may be due to an increase in nanophase iron due to the artificial mechanical concentration of weathering products. [This will be verified by measuring the I_s values of the samples to see if the amount of nanophase iron from the rims has increased in the dry sieved finest fraction vs. the wet sieved.] Gentle dry sieving may minimize this effect.

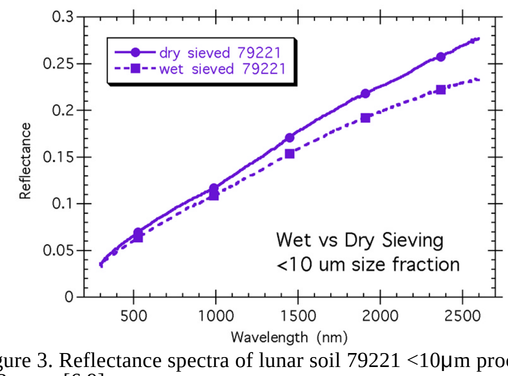

Figure 3. Reflectance spectra of lunar soil 79221 <10µm processed in 2 ways [6,9]

Character of the finest fraction: The following table lists several soil samples with their bulk soil maturity indices [10] and method of processing. A maturity index (I_s/FeO) of 0 to 29 is considered immature, 30-59 is submature and over 60 is mature. The spectral properties of these samples are summarized in figure 4.

Sample #	I_s/FeO [10]	Processed
10084	78	Dry sieved [6]
12030	14	Dry sieved [6]
61221	9	Wet sieved [5]
64801	71	Wet sieved [5]
67701	39	Wet sieved [5]
68501	85	Dry sieved (gentle)
70181	47	Dry sieved [6]
79221	81	Wet sieved [9]
79221	81	Dry sieved [6]

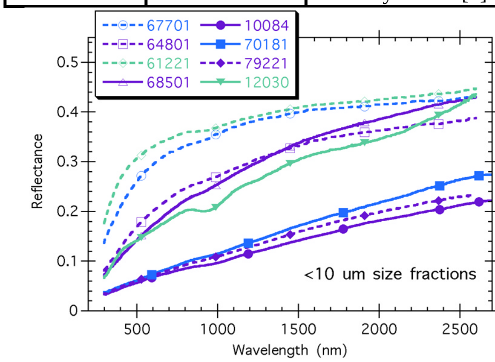

Figure 4. Reflectance spectra of <10µm size fraction of lunar soils (see table). Wet sieved = dotted line, dry = solid. More mature = darker line.

Preliminary results show systematic variations between the <10µm finest fraction of soils of varying exposure ages (maturity). This is expected, as more mature soils have accumulated a larger quantity of weathering products. In general, the more mature the soil, the steeper the continuum slope of its finest fraction.

Additionally, we find variation between the finest fraction of mare and highland soils. Highland soils clearly flatten at longer wavelengths while mare soils maintain a nearly linear slope. Preparation methods do indeed have an effect on the spectral properties of this finest fraction, they cannot, however, account for this dramatic difference. This indicates that the products of space weathering are also a function of initial composition.

These are preliminary optical results for the finest fraction. As more complete data are acquired for the current suite of mare soils [9], spectral information will be combined with chemical and petrological data, as well as I_s data and detailed information on the nanophase coatings. This integrated study will provide a much better understanding of the finest fraction and its role in regolith processes.

References: [1] Papike et al (1981) PLPSC12th p.409-420. [2] Pieters, C.M., E.M. Fischer, O. Rode, A. Basu (1993) *J.G.R.*, **98**, p. 20,817-20,824. [3] Housley, R.M. (1980) *Proc. Conf. Ancient Sun*, p. 401-410. [4] Keller, L., S. Wentworth, D. McKay (1998) LPSC29 ab #1762. [5] Fischer, E.M. (1995) Ph.D., Brown Univ. [6] Taylor, L.A. et al (1998) LPSC29 ab #1140. [7] Pieters, C.M. et al (1998) LPSC29 ab #1827. [8] Pieters C.M., L.A. Taylor (1998) LPSC29 ab #1840. [9] Taylor, L.A. et al. (1999) these volumes. [10] Morris, R.V. (1977) PLPSC 8th, p. 3719-3747.

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